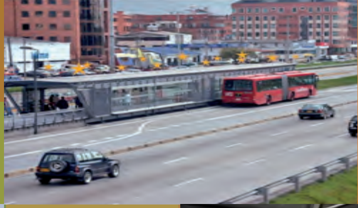



Sustainable energy solutions for South African local government







A practical guide



HEINRICH BÖLL STIFTUNG SOUTHERN AFRICA
SEA SUSTAINABLE ENERGY AFRICA
SAMSET Supporting Sub-Saharan Africa's Municipalities with Sustainable Energy Transitions
USAID | SOUTH AFRICA Low Emissions Development Program
Brot für die Welt Bread for the World – Protestant Development Service

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Contents

Glossary

AFD	Agence de Developpement Francais
AFOLU	agriculture, forestry and land use
AMEU	Association of Municipal Utilities
AMR	Advanced Meter Readers
ASI	Avoid, Shift, Improve
ASIF	Activity, mode Share, Intensity, and Fuel mix
ASP	Accredited Service Provider
BAS	Building Automation System
BAU	Business as Usual
BBP	Bronkhorstspruit Biogas Project
BEV	Battery Electric Vehicles
BIDS	Business Improvement Districts
BMS	Building Management System
BNR	Biological Nutrient Removal
BOOT	Build, Own, Operate and Transfer
BRT	Bus Rapid Transport
BYD	Build Your Dream - Chinese automobile manufacturer
CBD	Central Business District
cCR	Carbonn Climate Registry
CCT	City of Cape Town
CDM	Clean Development Mechanisms
CDP	Carbon Disclosure Project
CFL	Compact Fuorescent Light (bulb)
CHP	Combined Heat and Power
CICLIA	Cities and Climate Change in Africa
CIDS	City Improvement Districts
CIGAR	Covered in Ground Anaerobic Reactor
CLO	Community Liaison Officers
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
COD	Confirmed chemical Oxygen Demand
CoGTA	Department of Cooperative Governance and Traditional Affairs
CoM	Covenant of Mayors
CSIR	Council for Scientific and Industrial Research
CSP	City Support Programme
CSP	Concentrated Solar Power
CTL	Coal To Liquids
DANIDA	Danish International Development Agency
DB	Distribution Board
DBSA	Development Bank of South Africa
DC	Direct Current
DEA	Department of Environmental Affairs
DME	Department of Minerals and Energy
DMWS	Durban Metro Water Services
DO	Dissolved Oxygen
DoE	Department of Energy
DHS	Department of Human Settlements
DMWS	Durban Metro Water Services
DoRA	Division of Revenue Act
DoT	Department of Transport
DST	Department of Science and Technology
EASI	Enable, Avoid, Shift, Improve
ECAP	Energy and Climate Action Plan
EE	Energy efficiency
EEDSM	Energy Efficiency Demand Side Management Programme
EIA	Environmental Impact Assessment
EIPPPP	Renewable Energy Independent Power Producer Procurement Programme
EMT	Energy Management Team
EnMS	Energy Management System
ERA	Electricity Regulation Act
ERC	Energy Research Centre
EREV	Extended Range Electric Vehicles
ESCO	Energy Service Companies
Eskom	South African electricity supply company
ESPC	Energy Service Performance Contract
FBAE	Free Basic Alternative Energy
FBE	Free Basic Electricity
FCV	Fuel Cell Vehicle
GABS	Golden Arrow Bus Service
GBCSA	Greener Building Council South Africa
GDP	Gross Domestic Product
GEEF	Green Energy Efficiency Fund
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GIZ	Gesellschaft für Internationale Zusammenarbeit
GJ	Gigajoule

GJ	Gigajoule
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
Gt	Gigatonne
GWh	Gigawatt hour
HVAC	Heating, Ventilation and Air-Conditioning
IBT	Inclining Block Tariff
ICE	Internal Combustion Engine
ICT	Information Communication Technology
IDC	Industrial Development Corporation
IDP	Integrated Development Plan
IEE	Industrial Energy Efficiency
IEP	Integrated Energy Plan
IIPSA	Infrastructure Investment Programme for South Africa
INCA	Infrastructure Financing Cooperation
INEP	Integrated National Electrification Programme
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IPTN	Integrated Public Transport Network
IRP	Integrated Resource Plan
IRT	Integrated Rapid Transport (system)
IT	Information Technology
ITDP	Institute for Transportation and Development Policy
kg	kilogram
koe	kilogram of oil equivalent
KPA	Key Performance Area
kVA	1000 volt amps
kWh	kilo-watt hour
kWp	kilowatt-peak
ℓ	litre
LCOE	Levelised Cost Of Electricity
LEAP	Long-Range Energy Alternatives Planning
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
LFG	LandFill Gas
LGEERE	Local Government Energy Efficiency and Renewable Energy Strategy
LPG	Liquid Petroleum Gas
LPS	Low Pressure Solar Water Heater
LV	Low Voltage
LVC	Land Value Capture
M&E	Monitoring and Evaluation System
MFMA	Municipal Finance Management Act
MFU	Multiple Fuel Use
MIG	Municipal Infrastructure Programme
MSA	Municipal Systems Act
Mt	Megatonne
MTREF	Medium Term Revenue and Expenditure Framework
MVA	Megavolt Amperes
MW	Megawatt
MWh	Megawatt-hour
MYPD	Multi-Year Price Determination
NATMAP	National Transport Master Plan
NBR	National Building Regulations and Standards Act
NCCRP	National Climate Change Response Policy
NDC	Nationally Determined Contributions
NDP	National Development Plan
NERSA	National Electricity Regulator of South Africa
NGO	Non-Governmental Organisation
NMBMM	Nelson Mandela Bay Metropolitan Municipality
NMT	Non-Motorised Transport
NOx	generic term for the mono-nitrogen oxides NO and NO_2
NRS	National Regulation Standard
NSWH	National Solar Water Heater Programme
NT	National Treasury of South Africa
O&M	Operations and Maintenance
OECD	Organisation for Economic Cooperation and Development
PCF	Prototype Carbon Fund
pkm	passenger kilometres
PM10	Particulate Matter up to 10 micrometres in size
PNT	People Near Rapid Transit
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PRASA	Passenger Rail Agency of South Africa
PV	Photovoltaic
QC	Quality Control
REIPPP	Renewable-Energy Independent Power Producers Programme
RfQ	Request for Quotations
ROI	Return on Investment
RPP	Renewable Power Plant
RSA	Republic of South Africa
RTMC	Road Traffic Management Corporation

SABS	South African Bureau of Standards
SACN	South African Cities Network
SAD	Special Assessment District
SAGEN	South African-German Energy Programme
SA-LED	The USAID South Africa Low Emissions Development
SALGA	South African Local Government Association
SAMSET	Supporting Sub-Saharan Africa's Municipalities with Sustainable Energy Transitions
SANEDI	South African National Energy Development Institute
SANS	South African National Standards
SAPIA	South African Petroleum Industry Association
SAPOA	South African Property Owners Association
SAPVIA	South African Photovoltaic Industry Association
SARPPGC	South African Renewable Power Plants Grid Code
SASGI	South African Smart Grid Initiative
SATC	South African Transport Conference
SCADA	Supervisory control and data acquisition
SCM	Supply Chain Management
SDBIP	Service Delivery and Budget Implementation Plan
SDF	Spatial Development Framework
SDG	Sustainable Development Goals
SEA	Sustainable Energy Africa
SECAP	Sustainable Energy and Climate Action Plans
SESSA	Sustainable Energy Society of Southern Africa
SHS	Solar Home System
SMME	Small, Medium and Micro Entrepreneurs
SMS	Short Message Service
SO_2	Sulphur Dioxide
SOV	Single Occupancy Vehicles
SSB	Stuttgart Public Bus Company Strassenbahnen AG
SSEG	Small-Scale Embedded Generation
Stats SA	Statistics South Africa
SUNREF	Sustainable Use of Natural Resources and Energy Finance
SUV	Sport-Utility Vehicle
SWH	Solar Water Heater
TAZ	Traffic Analysis Zone
tCO_2e	tonnes of CO_2equivalent
TCT	Transport for Cape Town
TDM	Travel Demand Measures
TIF	Tax Increment Financing
tkm	tonne kilometres
TOD	Transit Orientated Development
TOU	time-of-use
UCT	University of Cape Town
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USSD	Unstructured Supplimentary Service Data
vkm	vehicle kilometres
VOC	Volatile Organic Compound
VOC	Vehicle Operating Contractor
VSD	Variable Speed Drive
WCG	Western Cape Government
WRC	South African Water Research Commission
WtE	Waste-to-Energy
WWTW	WasteWater Treatment Works
ZAR	South African Rands

Foreword

10 years ago Sustainable Energy Africa (SEA) developed the first handbook for South African city officials and planners titled "How to implement renewable energy and energy efficiency options: Support for South African local government. The document was produced in partnership with North Energy Associations Ltd and funded by the Renewable Energy & Energy Efficiency Partnership (REEEP). It was 58 pages long and identified four key interventions that would be important and sensible starting points for cities:

- solar water heating;
- energy efficient lighting;
- energy efficient buildings; and
- public transport.

The longest chapter was 16 pages and focussed on solar water heater implementation; the other chapters were roughly 10 pages each. Designed as a practical handbook, readers were able to identify easy-to-achieve energy interventions that would save money, promote local economic development and enhance the sustainable profile of a city.

Due to the practitioners' high interest to access new and practical information, the 2007 handbook was consequently updated in 2009 with the same title and funder. The document doubled in volume to over 120 pages long with updates to the original four technical chapters and five new chapters were included:

- Waste to energy with a primary focus on Landfill Gas
- solar photovoltaics;
- green power purchase;
- concentrated solar power; and
- wind.

At the end of 2016, again due to popular demand, SEA decided to update the handbook, this time supported by USAID's SA-LED programme, SAMSET, HBS and Brot. In almost 8 years, the field of energy efficiency and renewable energy has evolved dramatically and the level at which South African municipalities are now working requires an enormous depth of knowledge and technical detail. The new handbook reflects this not only in the volume of information presented, but in the diversity of topics covered and wealth of case studies available.

As a fair amount of water has passed under the bridge since the 2009 edition, liberty was taken to change the title and modernise the format, however the core of the manual highlights energy related municipal-led initiatives.

The manual is essentially divided into the following three content sections:

- a generic introduction
- governance and legislation;
- municipal initiatives; and
- macro developments.

The governance and legislation section was introduced in light of the growing global, national and local awareness that urban and local management is key to many areas of sustainable energy development and climate change mitigation. There are five chapters within this section that has incorporated an updated version of the 2009 chapter on Green Power Purchase :

- Municipal mandates: planning, regulation, service delivery;
- Institutionalising Sustainable Energy and Climate Change Mitigation;
- Processes and finances for implementing municipal projects;
- Green Public Procurement; and
- Green Power Purchase Agreements (PPA).

The section on municipal initiatives provides updates and new case studies to the 5 chapters of the 2009 guidebook :

- Solar Water Heating;
- EE Lighting;
- EE Building;
- Sustainable Transport; and
- Waste to Energy: Municipal landfill waste methane gas to energy implementation

Since 2009 the field of waste and wastewater has expanded dramatically thus three extra chapters have been added:

- Energy Efficiency in Municipal Water and Wastewater Works;
- Wastewater Biogas to Energy; and
- Waste to Energy: Incineration, gasification and pyrolysis.

In addition the Wind and Solar Photovoltaic (PV) systems chapters from the 2009 guidebook have been added to the municipal initiatives section and updated with practical case studies for municipalities. The PV chapter focusses on Small-Scale Embedded Generation Systems explaining the technology, drivers and standards of relevance, as well as the impact on municipal revenue, and how the challenges can be met in a way that works for the customer and the municipality.

Two important chapters on cutting edge subjects for local government complete the municipal initiatives section: Small-scale and conduit hydropower and household energy access.

The manual is completed via the macro developments section which provides an update and case studies for the concentrated solar chapter from the 2009 guidebook and the following 5 new chapters:

- Sea energy;
- Geothermal Energy for heating/cooling;
- Hybrid systems;
- Smart Cities; and
- Smart grids.

These chapters serve more as information and feasibility updates as implementation is mostly not within the jurisdiction of local government.

SEA August 2017

Acknowledgements

Municipalities need support to build their capacity, to provide them with detailed technical information, and to prioritise from the range of management. Since its inception in 2000, Sustainable Energy Africa (SEA) has provided products such as this practical guide in order to promote the development of an equitable low carbon, clean energy economy throughout Southern Africa.

The production of this guide involved the collaboration of a number of authors supported by SEA, and the following specific projects and organisations that deserve a special mention and thanks:

- Bread for the World (BROT), the globally active development and relief agency of the Protestant Churches in Germany, finances a project managed by SEA called 'Pioneering new urban energy services development models'. This project co-funded the development of the manual in terms of design and layout. In addition, project staff invested considerable time to writing chapters that align with project objectives and activities, and are inspired by the diverse material developed by the project.
- Heinrich Boell Stiftung (HBS) co-funded the development of the manual in terms of design and layout and partial content contributions drawn from the sustainable energy development project currently undertaken by SEA and funded by HBS.
- The USAID South Africa Low Emissions Development Program (SA-LED) funded Dr Susanna Godehart's time to write a significant number of the chapters of this guide. The USAID South Africa Low Emissions Development Program (SA-LED) is working to strengthen the capacity of the public sector to plan, finance, implement, and report on low emissions development projects and to accelerate the adoption of low emissions technologies. The program was developed and is implemented in partnership with the Department of Environmental Affairs (DEA) and the Department of Science and Technology (DST). SA-LED made a commitment, from the beginning, to support the printing of what became a sizeable document which is greatly appreciated.
- The 'Supporting Sub-Saharan Municipalities with Sustainable Energy Transitions' (SAMSET) Project co-funded the development of the manual, with SAMSET project staff giving substantial time to writing many of the chapters, and drawing on other material developed by the SAMSET project. SAMSET is funded by UK aid from the UK Department for International Development (DFID), the Engineering & Physical Science Research Council (EPSRC) and the Department for Energy & Climate Change (DECC), for the benefit of developing countries.

There are a number of other people who contributed to specific chapter content. A big thanks to Marco van Dijk from the Department of Civil Engineering at the University of Pretoria for his contribution to the Small-scale and conduit hydropower chapter. We are very thankful for the cutting edge case studies he provided.

Caroline Huwiler from ENCO Energie-Consulting AG provided information on municipal financing as part of a project with SEA funded by the Swiss State Secretariat for Economic Affairs (SECO). This information was able to bolster the Processes and finances for implementing municipal projects chapter.

A substantial amount of the information drawn on in this manual was sourced from work commissioned by SALGA-GIZ. These are referenced within the document, but special acknowledgement of this very valuable source of information and municipal support work, funded through the GIZ, is warranted.

The editor

Author biographies

Dr Susanna Godehart

(EE Lighting; EE Buildings; Wind; Concentrated Solar; Ocean Energy; Geothermal Energy; Hybrid Systems; Smart Cities; Smart Grids; Municipal mandates: planning, regulation, service delivery; Institutionalising Sustainable Energy and Climate Change Mitigation; Processes and finances for implementing municipal projects; Green Power Purchase Agreements)

Susanna is a consultant for sustainable energy and urban development. Between 2012 and 2016 she worked in the eThekwini Municipality Energy Office on strategic projects. Susanna came to South Africa in 1997 as a manager for the German International Cooperation (GIZ) in the Urban Upgrading and Development Programme. Before moving to South Africa she worked in Germany as an architect on energy efficient construction and co-generation projects. She has a PhD in Town Planning and a professional degree in Architecture. Her primary field of interests are sustainable urban development and decentralised energy supply of buildings and facilities.

Megan Euston-Brown

(Municipal mandates: planning, regulation, service delivery; Institutionalising Sustainable Energy and Climate Change Mitigation; Processes and finances for implementing municipal projects; Green Power Purchase Agreements; Energy Efficiency in Municipal Water and Wastewater Works; Waste to Energy: Municipal landfill waste methane gas to energy implementation; Wastewater Biogas to Energy; Waste to Energy: Incineration, gasification and pyrolysis)

Megan has worked for Sustainable Energy Africa since 2003 with a focus on the areas of energy efficiency, renewable energy, energy services, climate change and greenhouse gas reduction. This work has focused on the local government sphere as a strategic point of delivery, but has involved close partnership also with relevant national departments and organisations.

Megan has contributed to the ongoing development of a national learning network amongst South Africa's leading cities and towns with regard to sustainable energy development. This work has focused on research and documentation of relevant local and international experience; the sharing of relevant information as well as learning exchange in a dynamic learning network of South African municipalities; and more formal training experiences, notably the week-long, masters-level further professional development course run with the University of Cape Town (Eng faculty) on Sustainable Energy in City development.

Experience emerging from this work has been directed to supporting the inclusion of local government perspectives into national policy development. Megan is also involved in the extension of this area of work in Sub Saharan African urban development.

Zanie Cilliers

(Editing; Green Public Procurement; Small-scale and conduit hydropower)

Zanie has worked in the field of environmental management, broadly, and sustainable energy, specifically, since 2008. During this time, she gained experience in issues relating to climate change mitigation and its role in socio-economic development, the roles and responsibilities of different spheres of government relating to climate change and sustainability, local government energy and climate change strategy development, cleaner production in the hospitality industry, energy efficiency in the commercial and residential sectors, and the technical and financial aspects of solar water heating.

Zanie's focus areas include research and materials development, as well as building and city-scale energy modelling.

Mark Borchers

(Solar Photovoltaic systems)

Mark is a founder and director of Sustainable Energy Africa, established in 1992. Since this time he has led numerous projects researching and promoting sustainable energy, ranging from pure research through to renewable energy project implementation (e.g. installation of rural clinic solar PV systems). He has worked with the University of Cape Town extensively, and has served clients from international aid organisations and academic institutions through to national and local government and corporate clients. Most of his work in recent years has been supporting South African cities with sustainable energy transitions, through research, capacity building and technical involvement. His organisation has become the leading institution in the country in this field. Mark has worked in South and Southern Africa, as well as partnering on international programmes, and has significant experience managing large multi-year, multi-partner programmes.

Adrian Stone

(Sustainable Transport)

Adrian has a BSc Mechanical Engineering and an MSc in Energy Studies in Engineering from UCT. He has a broad background in engineering, energy modelling, financial modelling and data analysis. Much of this has been with university based research groups and their private sector spin-offs but also included a 5 year stint as a system developer in the financial services industry. Between 2011 and 2015 he worked at the University of Cape Town's Energy Research Centre (ERC) where in addition to undertaking energy research and modelling projects, he taught topics in modelling, energy systems analysis and financial analysis in the ERC's post-graduate program. In 2016 Adrian moved to Sustainable Energy Africa a not-for-profit company supporting sustainable transitions in municipalities in a technical support and project management role.

His recent work has focussed on transport modelling. The interest in this arose from extensive work in vehicle emissions testing which led to the development of inventory models and later detailed vehicle parc models for the projection of transport sector energy demand.

Hlengiwe Radebe

(Household Energy Access)

Hlengiwe holds a Master of Science in Interdisciplinary Global Change Studies from the University of the Witwatersrand. She started working at SEA in 2015 with a specific focus on tackling urban energy poverty through alternative energy services approaches, including development project implementation of municipal and small businesses energy services partnerships. She is also involved in supporting cities in sub Saharan Africa in their transition to a sustainable energy future through strategy development, implementation and knowledge exchange.

Hlengiwe is very passionate about gender equality and that often comes through in her work as she tries to address the gender inequalities.

Ian Turner

(Editor; Smart Cities)

Ian has a Masters in Environmental Management from Cape Town. He has over 15 years' of environmental project management experience with the last decade specialising in sustainable energy at the local level in Europe.

Having worked in South Africa, the United Kingdom and France, Ian is comfortable leading or participating in multi-lingual, cultural and disciplinary project teams.

For the last decade Ian was working in the east of France for Energy Cities, the European association of local authorities in energy transition. As head of projects and campaigns he oversaw the team responsible for preparing and managing projects or campaigns involving Energy Cities' members and strategic partners throughout Europe. Through his work with this European network, Ian gained a wealth of experience in managing municipal lead initiatives. His specific area of focus is around communication campaigns encouraging public servants, citizens and stakeholders at a local level to play their part in building a sustainable energy future.

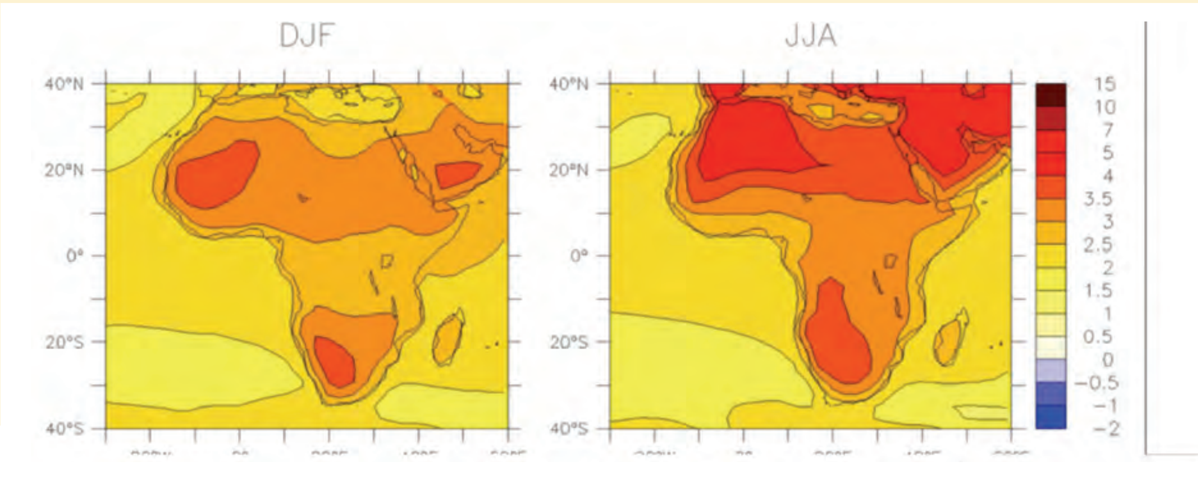
Introduction – Success through sustainability

Current energy use patterns, particularly our dependence on fossil fuels, inefficient use of energy, and lack of adequate energy supply for the poor, cannot continue. A move to more sustainable energy is important for the following reasons:

Global warming impact

Climate change is an accepted reality, the devastating impacts of which are increasingly being felt around the globe. It will place enormous strain on our health sector, agricultural production, plant and animal biodiversity and water resources. Disruptions in agriculture are likely to result in increased urbanisation and pressure on urban resources. Fossil fuel-based energy use is the largest contributor to carbon dioxide emissions – the principle global warming gas. South Africa is still largely dependent on fossil fuels for electricity generation (i.e. coal) and for transport energy (oil products), although national electricity plans are increasingly promoting renewable energy sources.

Figure 1: Temperature increase predictions for Africa for different times of the year (temperature increases on right-hand legend)

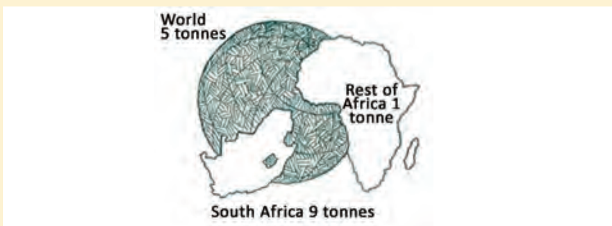


Source: Engelbrecht et al. (2015) Projections of rapidly rising surface temperatures over Africa under low mitigation. Environmental Research Letters, Volume 10, Number 8

Lºocal air quality

Pollution from burning fossil fuels in power stations as well as from exhaust emissions leads to poor air quality. In poor households, the use of coal, paraffin or wood results in a high incidence of respiratory illnesses in poor households. Research indicates that air pollution kills 20 000 people in South Africa every year, costing the economy nearly R300-million[1].

Figure 2: Tonnes CO_2 per capita – South Africa is a relatively high global warming gas emitter, and will increasingly be obliged to reduce such emissions as global warming takes place.



Source: SEA (2012). How to implement renewable energy and energy efficiency options – Support for South African local government

1 Air Pollution: Strengthening the Economic Case for Action, 2016. The World Bank and Institute for Health Metrics and Evaluation, University of Washington, Seattle.

Figure 3: Local air pollution

Source: Wikimedia Commons

Figure 4: Poor households are forced to use inconvenient, unhealthy and unsafe fuels, with consequences such as frequent fires in informal settlements.

Source: Wikimedia Commons

Household welfare

Poor households often have limited access to modern, safe, clean energy sources such as electricity, or cannot afford them even when they are available. This leads to continued dependence on polluting and unsafe fuels such as paraffin, coal or wood. Largely because of this, devastating fires in South African informal settlements are common occurrences.

Economic inefficiency

In spite of some energy efficiency gains over the past 5 years, the South African economy is still generally inefficient in its use of energy, leading to higher production costs per economic output. This leads to reduced economic competitiveness.

The financial and social costs of our sprawling cities

Urban layout has a large impact on sustainable energy. Because our cities are based on apartheid spatial legacies and have also been allowed to develop in a sprawling manner, travel distances for many residents are far and it is very difficult to provide adequate, affordable public transport. As a result fuel consumption is high, pollution levels are worrying, and residents spend long hours and much money moving to urban amenities and economic opportunities. Current urban layout exacts a high social and economic cost.

Energy security

A continued dependence on unsustainable fuels is inherently insecure because of the problems associated with their use, as notes in other parts of this chapter. Sustainable energy is by definition the fuel of the future, and cities and countries need to ensure that they invest in this direction rather than be left with outdated, unacceptable, unsustainable energy systems.

Figure 5: Energy is essential for almost every activity and function in our urban areas

The Green Economy and Sustainable Energy

There is increasing recognition that future economic prosperity is linked to proactively promoting a more sustainable economy. For this reason national government and local authorities are developing Green Economy strategies and action plans. A significant component of the 'green economy' is sustainable energy adoption, with benefits in local employment creation and manufacturing sectors, as well as being resilient and competitive in a carbon-constrained future.

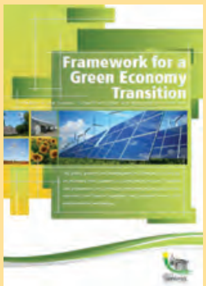
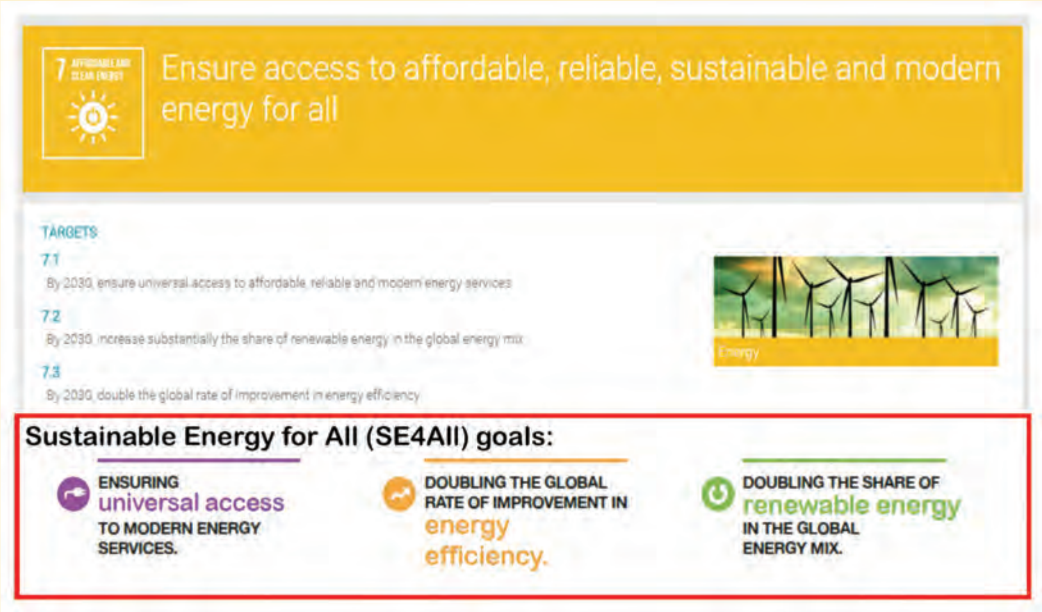


Figure 7: The globally endorsed Sustainable Development Goals (SDGs) include action on Sustainable Energy, Cities and Climate Change.

Figure 8: SDG 7 (Sustainable Energy) has ambitious targets for Access to Modern Energy, Energy Efficiency and Renewable Energy



Cities as sustainable energy leaders

Urban centres in South Africa are huge contributors to the national economy and thus represent energy intensive nodes of activity. The seventeen cities covered in the third State of Energy in South African Cities[2] report are home to half (52%) of South Africa's population, but occupy only 4.5% of the country's land area. They account for over a third (37%) of national energy consumption and nearly half (46%) of national electricity consumption. They also consume half (52%) of the country's petrol and diesel and produce approximately 70% of the country's economic wealth. These dense urban centres therefore have a fundamental role to play in the development of South Africa, and the city energy picture is crucial for the development and implementation of any national and local energy and climate strategies.

Modelling projections show us that unsustainable increases (a tripling of energy consumption by 2050) in city energy use are expected under the 'Business-as-usual' scenario. The projection in figure 11 is for 17 cities around the country, including all the large metros[3]. The expense and emissions associated with these increases comprise burdens which will not be tolerable in the future.

City authorities have a much greater influence over energy use patterns within their boundaries than is often realized. Amongst others, this is through:

- Building regulations
- Urban layout (spatial planning)
- Transport planning
- By-laws
- Standards & codes
- Air quality control measures
- Electrification

2 Sustainable Energy Africa (2015) State of Energy in South African, Cape Town. Available at www.cityenergy.org.za

3 Sustainable Energy Africa (2015) City Wide Mitigation Potential for South Africa, Cape Town. Available on www.cityenergy.org.za

Figure 9: South African cities are key to national economic and social welfare, and are energy intensive nodes of activity.

Source: Sustainable Energy Africa (2015) State of energy in South African cities.

Figure 10: Urban authorities have a big influence over energy use patterns – all of the above urban functions affect urban energy use.

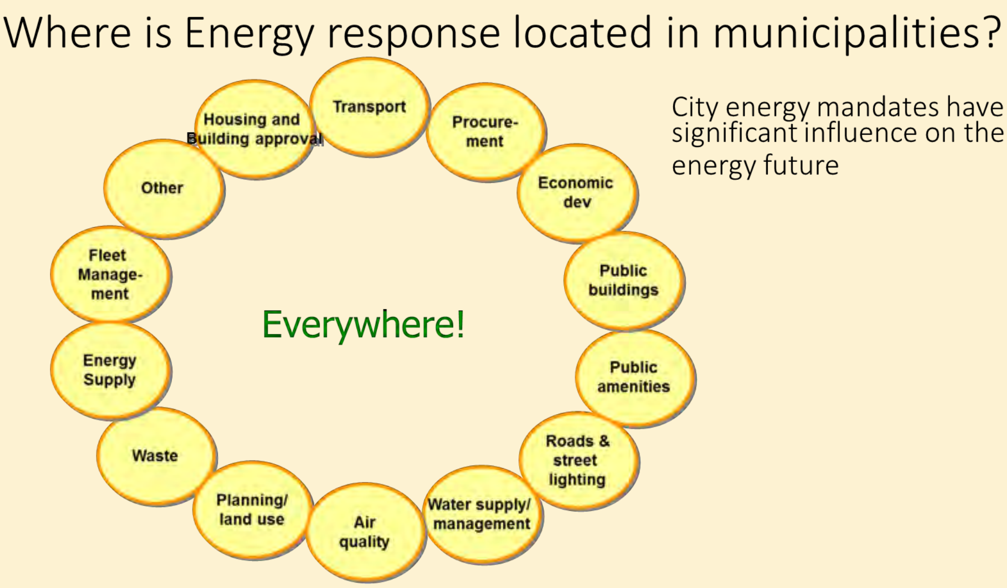


Figure 11: Urban energy consumption is expected to escalate unacceptably under Business-as-Usual conditions (27 case study cities)

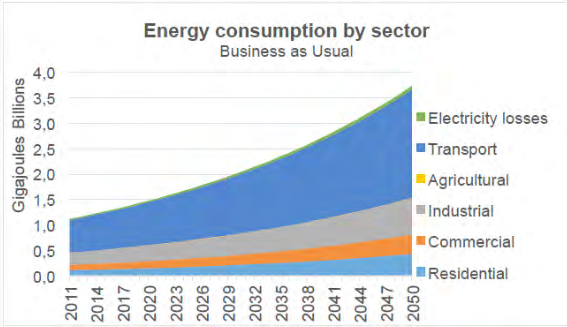


Figure 12: The data picture in South African cities is represented in the third State of Energy in South African Cities report (available at www.cityenergy.org.za)

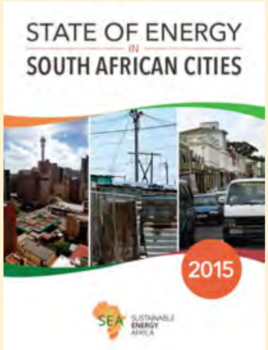
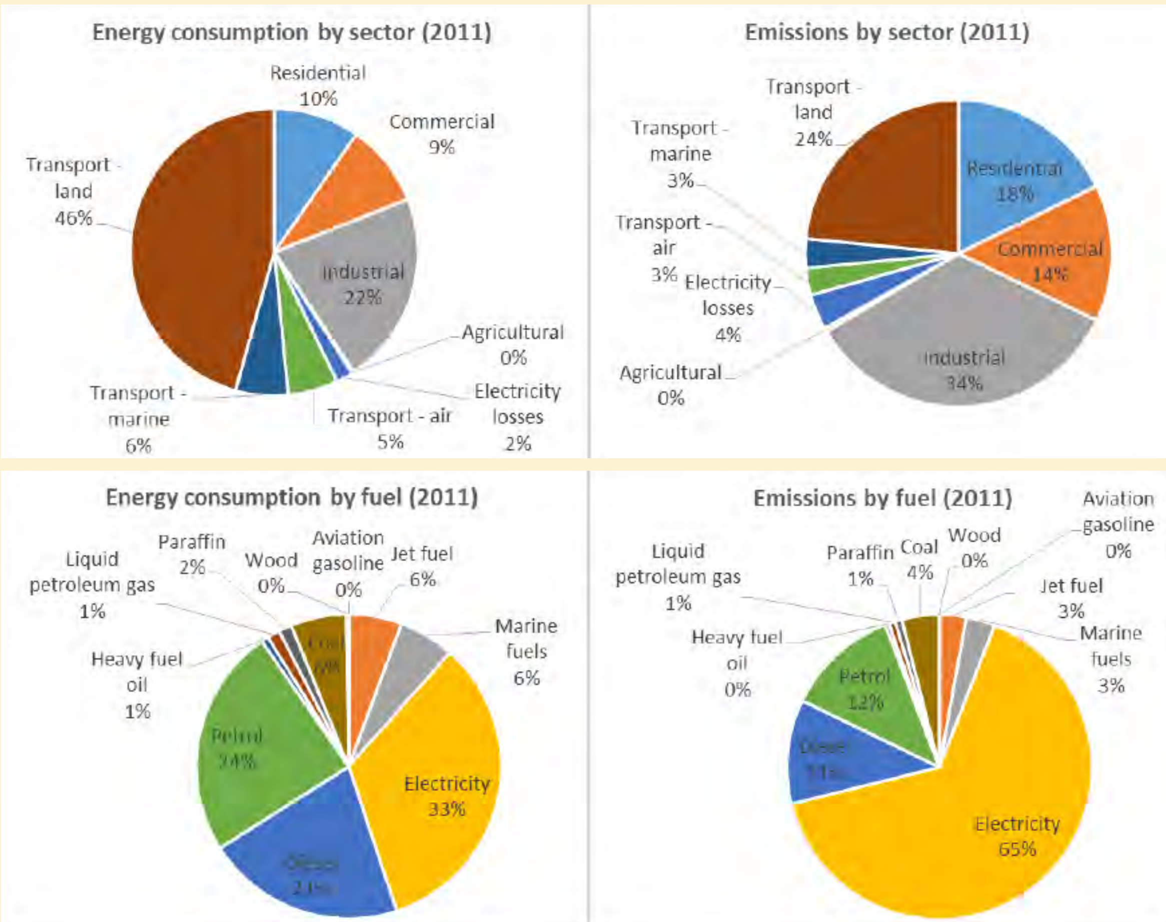


Figure 13: Energy consumption by fuel and sector for 27 South African urban areas



Source: SEA (2015). City-wide mitigation potential for South Africa.

If the country is to move towards more sustainable energy paths, cities will be essential partners in this process. Achieving the targets set by national government, for example around energy efficiency, will be largely reliant on the actions of cities.

Municipal initiatives


Photo: Bablu Virinder-Singh

Solar Water Heating

Overview

Heating water is extremely energy intensive. Solar thermal heating of water can substitute the electricity typically used in heating water with an electrical resistance element. In terms of the new, energy efficient building regulations, 50% of all hot water in new buildings needs to be produced by methods other than electrical element heating.

Solar water heating is a key technology to meet this new building requirement. Retrofitting of existing electrical element water heating also offers important energy and financial savings for residential and commercial applications. For low-income households who do not have an electrical geyser, the technology offers important health and quality of life benefits.

What is a solar water heater?

A solar water heater (SWH) uses energy from the sun to heat water. It works on two basic principles. Firstly, when water gets hot it rises due to density differences between hot and cold water (thermosiphon effect). Secondly, black objects absorb heat. A solar water heater collects heat from sunlight and irradiation through the solar collector and transfer that heat to water, which is then stored in a geyser or tank. Systems comprise of three main parts: the collector, an energy transfer fluid and the storage tank.

1. Collector: The solar collector absorbs solar radiation and transfers the energy, in the form of heat, to the fluid within it. The solar collector is generally a flat plat collector or an evacuated tube collector. More basic systems may be a coil of black pipe within a box or similar.
2. Transfer fluid: This is the heat transfer medium. In a direct system, the transfer medium is the potable water from the storage container. In an indirect system, the transfer fluid is generally a mix of water and glycol, which passes the energy to the storage container via an isolating heat exchanger. In areas in South Africa where temperatures drop below freezing, an indirect system is the best system to use.
3. Storage tank: As with a conventional geyser, the hot water storage container is thermally insulated to retain heat. Solar geysers are usually larger than electric geysers and better insulated. This allows for the maximisation of the solar gains. Solar water heaters are classified as either active or passive systems. An active system uses a pump to circulate the fluid/water between the collector and the storage tank. A passive system uses natural convection (thermosiphon) to circulate the fluid/water between the collector and the storage tank.

At least 50 % (volume fraction) volume of the annual average hot water heating requirement shall be provided by means other than electrical resistance heating, including but not limited to solar heating, heat pumps, and heat recovery from other systems or processes.

SANS 204 and Building Regulation 10400-XA

Figure 1: Heat transfer fluid and heat exchangers

heat transfer fluid

photos: Solar Heat Exchangers

storage tank

collector

Water pressure will also determine whether a system is a high- or low-pressure system. Some of these system differences are discussed in more detail below.

Direct vs indirect

Direct systems (also called open-circuit systems) circulate water directly between the storage container and the collector(s), so that the water you use in your shower is the same water that has been heated in the collector. A direct system can only be used in areas that are frost free (never drops below freezing) and the quality of the water supply is suitable. The water should not be hard (water is classified as hard when it has a high calcium/lime or mineral content – traces of scale on the element or inside of a kettle are indicators of calcium/lime in the water supply).

Indirect systems (also called closed-circuit systems) have a heat transfer fluid that circulates through the collectors via a heat exchanger (like a jacket that surrounds the tank) that transfers heat from the collector circuit to the water in the storage container. Closed-circuit systems are essential in areas that are exposed to frost or freezing, because they are resistant to the cold. They are also used where the water is hard, as the system avoids lime scale build-up in the collectors. Indirect systems can require additional maintenance, as the heat transfer fluid must be checked and might need to be topped up.

Flat-plate vs evacuated tube

Flat-plate collectors: The main components of a flat-plate collector are a transparent front cover, collector housing, and an absorber. This technology has been used for over 50 years by manufacturers and has a well-established track record of reliable performance. The type of glass used in flat-plate collectors is almost always low-iron, tempered glass. Being tempered, the glass can withstand significant hail without breaking, which is one of the reasons that flat-plate collectors are considered the most durable collector type.

Evacuated-tube collectors: This comprises two concentric tubes of glass with a vacuum in between, inside which is a metal absorber sheet or thermal absorbent coating with a heat pipe in the middle containing the heat transfer fluid. The vacuum tube admits heat from the sun (to heat the pipe) but limits heat loss back to the environment due to convection heat not being able to pass through the vacuum. The heat transfer fluid flows through the absorber directly in a U-tube or sometimes in a tube-in-tube system. A heat pipe collector contains a special fluid that vaporises at low temperature. The hot vapour rises in the heat pipes and warms the heat transfer medium in the main pipe before condensing and recirculating. The pipes must be at a certain angle to facilitate the process. Too flat or too steep an angle and the system will not work. Several tubes are connected to one another or to a manifold that makes up the solar collector. The rounded edge of the tube enables far greater range of solar collection.

Evacuated tube collectors are a newer technology manufactured mostly in China. Evacuated tubes have not yet had time to establish a track record of reliability. The lifespan of the vacuum varies from collector to collector, anywhere from 5 years to 15 years.

Evacuated tubes generally create more hot water, especially when the sun is weak and the weather is cold, but they have three important disadvantages. One is that they are more likely to break from hail (generally they can withstand up to golf-ball-sized hail) and other environmental conditions. The second is that because they are so efficient, they risk overheating in summer. Finally, because they are largely imported, evacuated-tube panels become more expensive when the Rand weaken

High Pressure vs Low Pressure

Solar water heaters can be designed to function as high- or low-pressure systems. Low-pressure solar water heaters provide gravity-fed hot water pressure only, and typically do not have a backup electrical heating element.

High-pressure solar water heaters provide hot water at pressures commonly found in homes and businesses, and have backup electrical heating elements to provide hot water when solar radiation is too low or at night.

High-pressure systems are generally more expensive than low-pressure systems. This is because the materials used for high-pressure systems must be of high quality and strength in order to withstand the pressures created by the system. Low-pressure systems need to be durable, but do not need to withstand any pressure other than that generated by the weight of water they contain, keeping material costs down.

Low-pressure systems also do not require any additional valves to regulate the internal pressure of the system, further reducing costs. Low pressure systems are 'gravity fed' – therefore the higher the SWH in relation to the outlet, the stronger the water pressure. Mixing water, for example in a shower, is difficult with low-pressure systems, as the cold water supplied by the municipality is at a substantially higher pressure.

In South Africa, high-pressure systems are usually targeted at the mid- to high-income sector, to replace existing geysers, while low-pressure systems are targeted at the low-income sector.

Solar water heating technology is relatively simple and durable and can last 30+ years. They do require some maintenance, in terms of cleaning and removing residues once a year (lime scaling) and parts replacement, though usually simple parts such as valves.

Local manufacturing opportunity

Design of systems can be adapted to local material availability and an implementation programme can result in the establishment of local workshops and not just distribution/installation networks. Creating the capacity for the manufacture of local evacuated tube collectors may be a bit more challenging as these are produced at very low cost in China and the manufacture is more complex than that of the flat plate collectors.

Figure 2: Flat-plate collectors and evacuated tube collectors

Evacuated tube collectors

Source: New Energy

Flat-plate collectors

Source: Solar Heat Exchangers

Installation methods

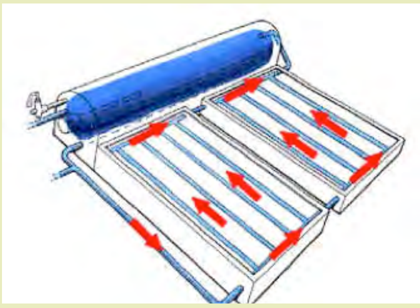
Close-couple system: This is the most energy and cost efficient and most commonly used installation. It consists of a roof-mounted solar collector, combined with a horizontally-mounted storage tank that is located immediately above the collector.

The main advantage of close-coupled solar geysers is that they require no electricity or moving parts to circulate. The glycol or water in the panels rises naturally when it is hot and sinks when it is cooler. This circulation is called the thermosiphon effect. These solar geysers have fewer parts and therefore require less maintenance. They also continue to work when the electricity is off.

Split systems: These refer to systems where the panels are on the roof, but the tank is not. The water storage tank is situated elsewhere – usually within the roof. Split systems are commonly used when the aesthetics of having a visible or exposed tank are a concern.

Where the tank can be installed above (higher than) the collectors, a passive system can usually still be used (using thermosiphon to circulate water). However, systems installed below the collectors will require the use of a small pump (active system) to circulate the heat (water or glycol) from the water storage tank to the panels/collectors. To eliminate the problem of electricity outages or in order to improve energy efficiency, some systems even use a solar-powered pump.

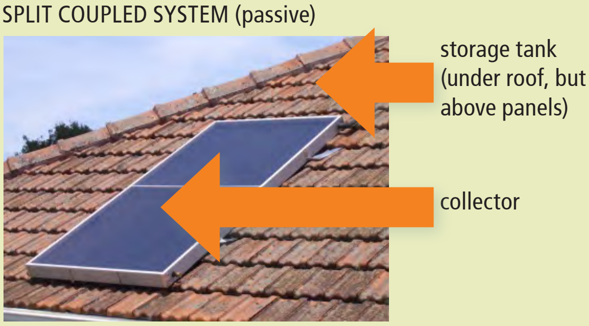
Figure 3: Close couple systems: the collector and the tank are an integrated unit



Source: Solar Heat Exchagers

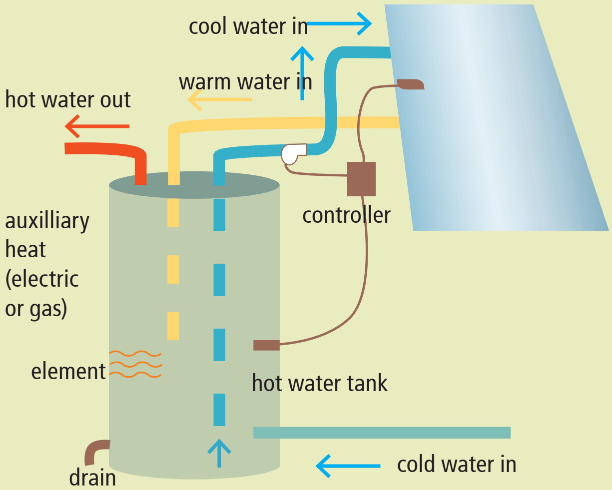
Figure 4: Water is pumped from the storage tank, through the collector and back again. Pump rate is usually controlled electronically.

SPLIT COUPLED SYSTEM (passive)



Source: Sustainable Living Projects

SPLIT COUPLED SYSTEM (active)



Split system installations are more customized and more expensive, but can achieve moderate improvements in efficiency compared to a close-coupled system: a horizontal tank exposed to the outside air will lose more heat at night than a tank indoors, and a vertical tank will retain more heat than a horizontal tank. This is because a horizontal tank has more surface area where the mixing of hot and cold water takes place, so when cold water comes into the geyser, the water in the geyser cools down more quickly than with a vertical geyser.

Electric element water heating backup: this has been found to be too costly for households in low income rollouts. In Kuyasa, Cape Town, where a rollout of solar water heaters was done the experience was that households rapidly switched off the back up element as they couldn't afford the cost of electrically heated hot water (pers. com, Kuyasa 2010; Goldman, UNDP, 2010). However, in mid-income households where a conventional electric element geyser is being replaced, a 'backup' electrical heating is important as the household has an expectation of 24/7 hot water availability and overall costs will still be lower than before the installation.

Product and Installation quality assurance and system optimisation

The performance of a solar water heater is tested by the South African National Standards. SANS 6211 measures the energy collected and stored during a day using 6 representative sample days of solar irradiation typical of the weather in South Africa over a period of a year. The levels of efficiency are determined by quality and size of the collector. This is measured as a "Q factor" which must be provided for every system.

There are many components that go into an installation so it is important that there is a SABS mark (or similar international certification) on all components used. A proper quality installation is also essential. Installations must comply with SANS 10106 (The installation, maintenance, repair and replacement of domestic solar water heating systems) and SANS 10142-1 (The Wiring of Premises. Part 1: low-voltage installations). Certificates of Compliance for the plumbing work and a separate one for the electrical work will provide additional documentation of quality installation. All reputable systems/installments should come with a 5 year warranty on all major components.

Collectors must be orientated and inclined correctly during installation. In South Africa, collectors should face true north or slightly to the west to take advantage of higher irradiance in the afternoon. A deviation of 45° east or west is acceptable, but deviation greater than this will require larger collectors to compensate for solar losses.

Solar collectors should be placed in an area of uninterrupted sunlight. If an area is in shade between 9am and 3pm, another position should be found. Partial shading by obstructions during daylight hours is acceptable, provided the shade does not cover more than 10% of the collector's surface area.

A timer is critical if the SWH is installed with electrical backup. Without a timer a SWH will fail to achieve the promised savings. The key to saving energy is to avoid heating the water with electricity just before the sun gets to work. It is also worth ensuring that SWH electric backup is turned off during national peak demand – saving the municipality costly peak demand rates. In the summer, electrical back-up may not be needed at all, and households should be advised to switch off the electricity to the geyser at the distribution board (DB).

A heat pump uses some electricity to power a small 'pump' that moves the heat, compressing it for greater effect, from the surrounding air into the geyser. A heat pump, like an air conditioning unit, is a vapour compression cycle, and works on the same principles as a refrigeration cycle. Where an air conditioning unit is used to cool air with heat as a by-product, a water heating heat pump can use the heat generated to further improve its heating efficiency.

Figure 5: Solar energy changes for different orientations and tilt angles (this is for a site at latitude 27 degrees South)

Tilt Angle	Heading / Azimuth																		
	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
5*	-8%	-8%	-8%	-7%	-7%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-7%	-7%	-8%	-8%	-9%	-9%
10	-9%	-8%	-7%	-6%	-5%	-5%	-4%	-4%	-4%	-4%	-4%	-4%	-5%	-5%	-6%	-7%	-8%	-9%	-10%
15	-9%	-8%	-6%	-5%	-4%	-3%	-3%	-2%	-2%	-2%	-2%	-3%	-3%	-4%	-5%	-7%	-8%	-9%	-11%
20	-10%	-8%	-7%	-5%	-4%	-3%	-2%	-1%	-1%	-1%	-1%	-2%	-3%	-4%	-5%	-7%	-9%	-10%	-12%
25	-12%	-9%	-7%	-5%	-4%	-2%	-1%	0%	0%	0%	0%	-1%	-2%	-4%	-5%	-7%	-9%	-12%	-14%
30	-13%	-10%	-8%	-6%	-4%	-3%	-1%	0%	0%	0%	-1%	-1%	-3%	-4%	-6%	-8%	-11%	-13%	-16%
35	-15%	-12%	-9%	-7%	-5%	-3%	-2%	-1%	-1%	-1%	-1%	-2%	-3%	-5%	-7%	-10%	-12%	-15%	-18%
40	-17%	-14%	-11%	-8%	-6%	-4%	-3%	-2%	-2%	-2%	-2%	-3%	-5%	-7%	-9%	-11%	-14%	-17%	-20%
45	-19%	-16%	-13%	-10%	-8%	-6%	-5%	-4%	-3%	-3%	-4%	-5%	-7%	-9%	-11%	-14%	-16%	-19%	-23%
50	-22%	-18%	-15%	-12%	-10%	-8%	-7%	-6%	-5%	-6%	-6%	-7%	-9%	-11%	-13%	-16%	-19%	-22%	-25%
55	-24%	-21%	-18%	-15%	-13%	-11%	-10%	-9%	-8%	-8%	-9%	-10%	-12%	-14%	-16%	-18%	-21%	-25%	-28%
60	-27%	-24%	-20%	-18%	-16%	-14%	-13%	-12%	-12%	-12%	-12%	-13%	-15%	-17%	-19%	-21%	-24%	-27%	-31%
65	-30%	-27%	-24%	-21%	-19%	-17%	-16%	-16%	-15%	-16%	-16%	-17%	-18%	-20%	-22%	-25%	-27%	-31%	-34%
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75	-37%	-33%	-31%	-28%	-27%	-26%	-25%	-24%	-25%	-25%	-25%	-26%	-27%	-28%	-30%	-32%	-35%	-38%	-41%
80^	-41%	-37%	-35%	-33%	-31%	-30%	-30%	-30%	-30%	-30%	-31%	-31%	-32%	-33%	-34%	-36%	-38%	-41%	-44%

Other efficient water heating technologies: heat pumps

Heat pumps still rely on electricity, but substantially reduce the amount of power required to achieve the equivalent water heating as when using an electric element. Studies confirm a typical 'performance coefficient' of 4 for heat pumps, i.e. the heating capacity is 4 times the amount of electrical energy that would be required from a normal electrical element (Rankin and van Eldik, 2008[1]). So, if the heat pump is powered by 1 kW of grid power then the heating capacity will be the equivalent of a 4 kW heating element. The saving is therefore up to 70% of water heating bill at times for the consumer, or about 25% of your full monthly electricity usage (similar to solar water heaters). The exact saving is dependent on consumer usage patterns, ambient temperatures and humidity of the area.

A detailed comparative study of the relative cost of a heat pump vs a SWH (200 litres with electrical backup) indicate that heat pumps are a slightly more expensive option for household water heating than SWHs (Janisch, 2008[2]). However, they offer an important option where SWH installation is not possible. It should be noted that the efficiency figures of a heat pump when compared to a standard electric element geyser increase with an increase in the ambient temperature. Relative efficiency will thus depend on location.

Comparative advantages of a heat pump over a SWH:

- A heat pump works during the day and at night, and does not need to switch to an electric element on cloudy days, like a solar water heater does.
- Heat pumps can be the better option for houses with lots of surrounding trees that shade the roof, for flats and sectional title units, for old houses with roofs that might not support the weight of a tank, and for new houses where there's no room for the tank in an attic space and the aesthetics of a roof-top tank is an issue.

1 Rankin & van Eldik (2008) An investigation into the energy savings and economic viability of heat pump water heaters applied in residential and commercial sectors – a comparison with solat water heating systems. M-tech Industrial (Pty) Ltd/North-West University.

2 Janisch (2008) Heat Pump/SWH Comparison SEA. The study, drawing on work done by North West University and SESSA/CEF can be reviewed on: http://www.cityenergy.org.za/uploads/resource_166.pdf

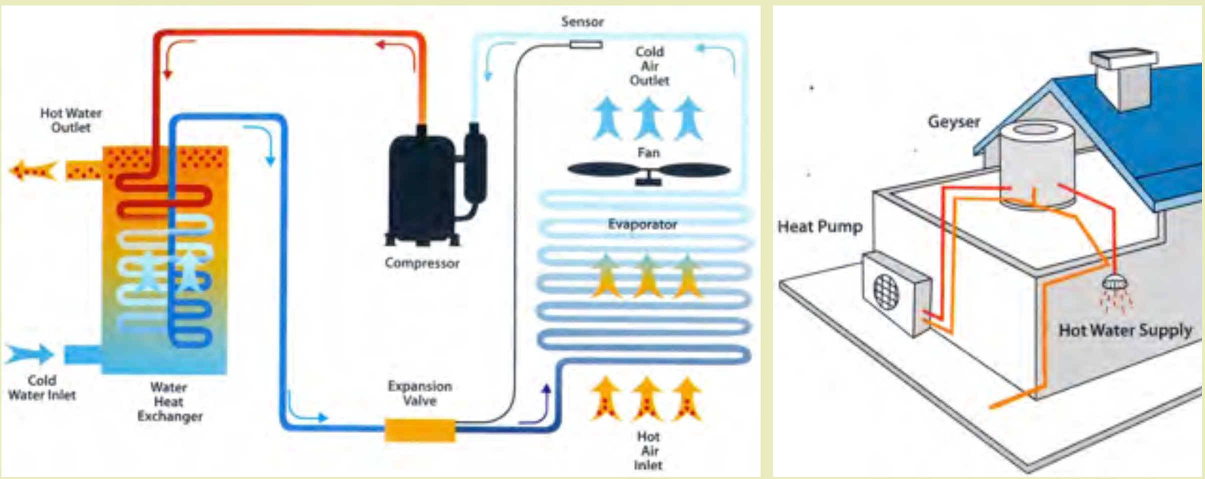
- Heat pumps also perform well in coastal areas where fog and haze can limit the performance of solar water heaters.
- They are easy to install and take up less area than solar panels would to provide the same amount of hot water.
- A heat pump hot water system can be integrated with the HVAC system for further savings.
- It is an important technology for the commercial sector where large quantities of water are being heated and stored – such as in hotels and hospitals – and the energy savings offset the higher capital costs of the pumps.

Disadvantages or barriers:

- The Sustainable Energy Society of Southern Africa (SESSA), based on Eskom and DoE studies, report disappointing results from heat pumps in the Highveld and generally for the residential sector, but also note that it is an important technology for commercial sector heating (www.sessa.org.za).
- Heat pumps require regular annual maintenance (as do some solar water heaters).
- When the heat pump is operating it can be noisy depending on the model, its position and how it is mounted.
- Due to the fact that heat pumps are still dependent on a supply of electricity, they are not a feasible option for households that are not electrified and won't function if the electricity fails.
- There is currently no SABS standard for heat pumps, so judging the quality of any brand or model requires a bit more effort by the consumer. It is important to consider the warranty offered on any heat pump sold, as well as any international certifications of quality, among other factors.

In South Africa the only common type of heat pump is the air-water heat pump that extracts heat from outdoor air and uses it to heat water. The figure below shows how this functions.

Figure 6: Air-water heat pump



Source: eThekwini Energy Office, 2016, Technologies for renewable energy and energy efficiency–How do they work?

The case for mass SWH implementation

Residential solar water heaters

The residential sector in South Africa consumes 18% of the country's electricity; in metro and secondary cities the residential sector accounts for 31% of electricity sold (SEA, 2017[3] drawing on NERSA[4], 2015 and SEA, 2015[5]). Of particular issue is that most of this demand occurs over the 'peak demand' period, which is when electricity is enormously costly to supply – both nationally and for municipalities. The largest electricity consuming appliance in our houses is usually the electric geyser. It makes up typically 30–40% of the total electricity used in many households which translates to around 5% of the country's energy consumption. A solar water heater may reduce this energy consumption figure by more than half. Used carefully, with a timer device, it can also shift this demand to off-peak periods.

The majority of South African houses do not have electric geysers installed. Householders use kettles to heat water for bathing and cooking. The widespread use of such geysers would further add to the national water heating figure for the residential sector, but the current situation represents a significant 'repressed demand' for hot water. Once a household's economic position improves, they may install electric geysers and their energy consumption would rise. This represents an important opportunity to 'leapfrog' directly into more efficient water heating technology.

Solar Water Heaters (SWH's) provide an excellent alternative for heating water. They draw on the sun to heat water in a clean, safe and sustainable manner. As the source of energy being used is the sun, the household is also protected from the inevitable increase and fluctuations in the price of electricity and other fossil fuel sources. Use of kettles to heat water is also a major contributor to peak demand and therefore SWH's are an important solution in reducing the need for expensive new power generation and costly cross subsidy within the municipal distribution business.

Related to this is another important consideration in terms of reticulation infrastructure. Most low-income developments were planned not to have electric geysers and therefore the electricity supply to these areas is not designed to cope with the excessive loads created by electric geysers. As these communities inevitably develop, the distribution system will most likely fail under the new load and any repairs/upgrades will be extremely costly. By installing solar water heaters, the communities can still develop and improve their quality of life without straining the distribution network.

Figure 7: Kuyasa CDM project, Cape Town

Photo: Chris Galliers

3 SEA (2017) Solar Water Heating versus Conventional Geyser Cost Benefit Analysis Spreadsheet Tool.

4 NERSA Consultation Paper, Eskom Cost of Unserved Energy Methodology, Published 25 May 2015.

5 SEA (2015) State of Energy in SA Cities.

Commercial, institutional and industrial use of SWHs

Solar water heaters can be used effectively in several commercial applications (eg hotels), as well as in hospitals, clinics, boarding school hostels and old age homes. In addition to water heating for bathing and cleaning, SWH offers an important opportunity to save on cooking energy as water for food preparation can be pre-heated through the thermal application of the SWH. Although the hot water demands here may be higher than residential, the increased roof area of these buildings allows for more collectors to be installed. Efficiency figures comparable to those of the residential sector can be achieved (see modelling above). As the relative cost of these systems is cheaper/litre than for residential systems, the financial case for these units is even stronger than the residential cases.

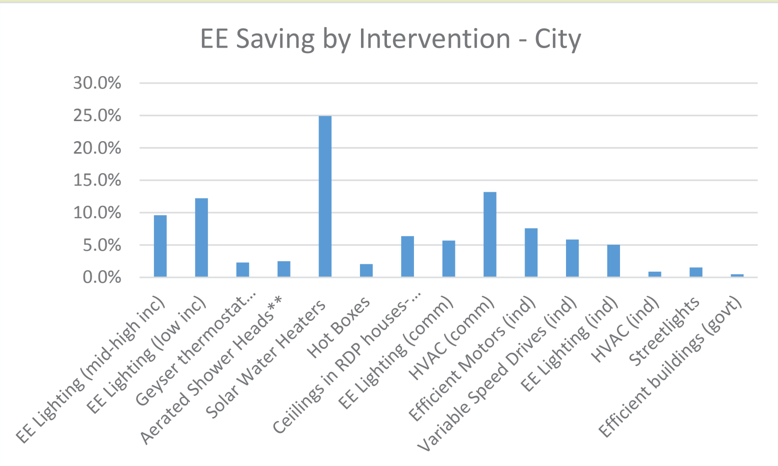
Solar water heaters are not suited to replace boilers and other high temperature water apparatus in industry. However they can be used for preheating purposes, so that at least a percentage of the heating operation draws on solar, rather than carbon-based energy.

Solar water heating remains the technology that offers the most substantial energy savings.

Figure 8: Solar water heaters in the city of Cape Town

Source: Suntank

Figure 9: Comparison of energy savings potential within an average South Africa city by energy efficiency technology.



Source: SEA (2014). Revenue Impact Tool

As the relative cost of these systems is cheaper/ litre than for residential systems, the financial case for these units is even stronger than the residential cases.

Use of this technology can be enormously beneficial to all stakeholders – households, businesses, cities and national government:

- Greater energy security and electricity system cost savings: The one million SWH target set by government should reduce peak demand on the grid by 630 MW, or 1.6%146 (Maia, et al. (2011).[6]
  - Lower peak demand reduces the need for additional and costly power stations to be built – thus keeping electricity prices down.

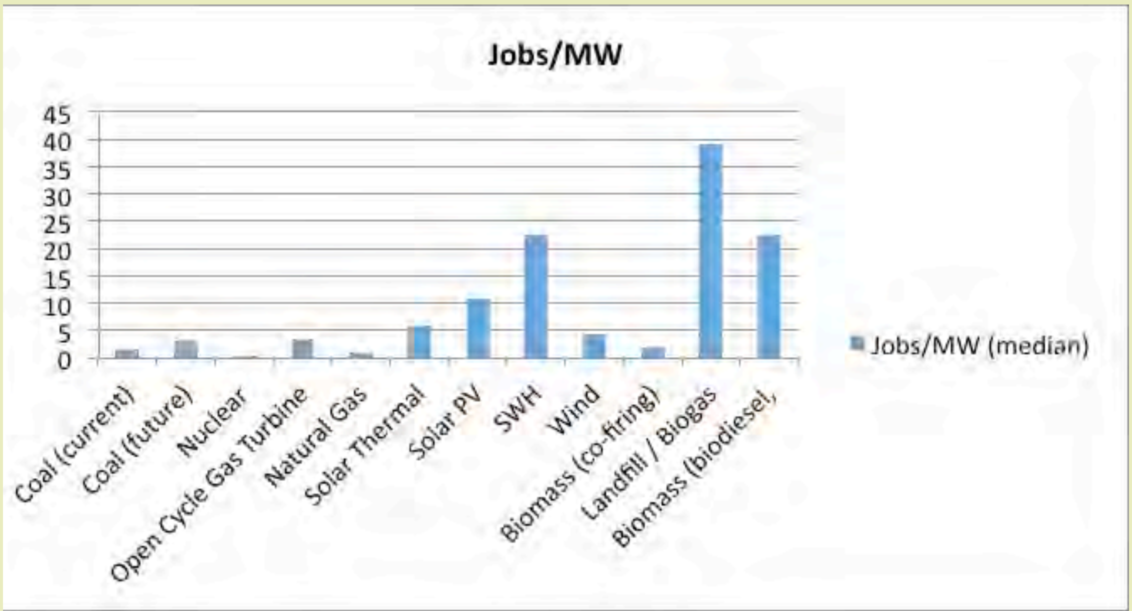
6 Maia et al. (2011) Green Jobs: An Estimate of the Direct Employment Potential of a Greening South African Economy. Industrial Development Corporation, Development Bank of Southern Africa, Trade and Industrial Policy Strategies.

- Lower peak demand reduces costs for municipalities – losses are made on the sale of electricity to the residential sector during costly peak periods as municipal distributors sell into the residential sector at a flat rate usually below the Eskom megaflex peak tariff. Where this is subsidized electricity use it is costing the municipality the full megaflex peak rate.

- Local employment creation: jobs will be created in the solar water heater industry – both in manufacturing and system installation.
- Carbon reduction: as water is heated mostly by the sun, a solar water heater that displaces electric geyser heating will reduce a city's CO_2 emissions by about 2 – 3 tons per household per year (Maia, et al., 2011).
- Household cost savings: water heating costs for a mid to high income household can typically be reduced by 60% with a solar water heater resulting in a 25 – 30% saving on monthly electricity bills. With the price of electricity increasing steadily, the financial case for solar water heaters is very strong. Poor households spend proportionally far more of their income on meeting their energy needs than wealthier households. Solar water heating can substantially reduce the energy burden facing poor households.
- Household quality of life: where a solar water heater is replacing "dirtier" fuels, such as paraffin, for water heating, a solar water heater will provide substantial health and safety benefits.

There is a huge potential in terms of energy and carbon saving, as well as peak demand shifting, in a mass rollout of SWHs. Despite having known this for some time, and despite national and city targets, the country is still nowhere near achieving this potential. South Africa has one of the highest insolation (energy from sunlight) rates in the world, and solar water heaters make financial sense in all scenarios. Despite this, only some 3-5% of households in South Africa have SWHs installed (noting that this has increased from less than 1% in 2009) – as compared with a country such as Israel, which has installed SWH in 60% of houses (GIZ-SAGEN, 2015).[7]

Figure 10: Job creation potential from solar water heaters is significant



Source: SEA.(2010). Renewable Energy Employment figures: A Synthesis of Available Studies

7 GIZ-SAGEN (2015) Review of Best Practice Solar Water Heating Implementation by Local Government Prepared by SEA.

Figure 11: Simple installation and robust technology, along with obvious economic, environmental and social benefits make solar water heaters a viable option for mass rollout

Source: Sustainable living projects

Table 1: Potential peak demand reduction, and energy and emissions savings from large-scale SWH rollout

	10% penetration of SWHs (thousands of systems)	Peak demand reduction (MW)	Energy saving (GWh/yr)	Carbon reduction potential (thousand tons CO_2/yr)	**50% penetration** of SWHs (thousands of systems)	Peak demand reduction (MW)	Energy saving (GWh/yr)	Carbon reduction potential (thousand tons CO_2/yr)	**100% penetration** of SWHs (thousands of systems)	Peak demand reduction (MW)	Energy saving (GWh/yr)	Carbon reduction potential (thousand tons CO_2/yr)
Buffalo City	19	12	42	50	96	60	210	248	191	119	420	497
Cape Town	76	48	167	198	380	238	836	988	760	475	1,672	1,976
Johannesburg	105	66	231	273	525	328	1,155	1,365	1,050	656	2,310	2,730
Tshwane	56	35	124	146	282	176	619	732	563	352	1,239	1,464
Ekurhuleni	75	47	164	194	373	233	820	969	745	466	1,639	1,937
eThekwini	79	49	173	205	394	246	866	1,023	787	492	1,731	2,046
King Sebata	9	6	20	23	45	28	98	116	89	56	196	231
Mangaung	19	12	41	48	93	58	204	241	185	116	407	481
Msunduzi	13	8	29	34	65	41	143	169	130	81	286	338
Nelon Mandela	26	16	57	68	131	82	287	339	261	163	574	679
Potchefstroom	3	2	7	8	16	10	35	42	32	20	70	83
Saldanha Bay	2	1	4	5	9	6	20	23	18	11	40	47
Sedibeng	23	14	50	59	114	71	250	295	227	142	499	590
Sol Plaatje	5	3	10	12	24	15	52	61	47	29	103	122
uMhlatuze	7	4	15	17	34	21	74	87	67	42	147	174
ALL CITIES	**515**	**322**	**1,133**	**1,340**	**2,576**	**1,610**	**5,667**	**6,698**	**5,152**	**3,220**	**11,334**	**13,395**

Assumptions (from Eskom DSM estimates):

Peak demand reduction (after diversity)	0.625	kW/household
Energy savings:	2200	kWh / system / year
Tons CO_2 saved per system:	2.6	tons/yr

Figure 12 – Potential cumulative energy savings from SWH mass rollout in Tshwane

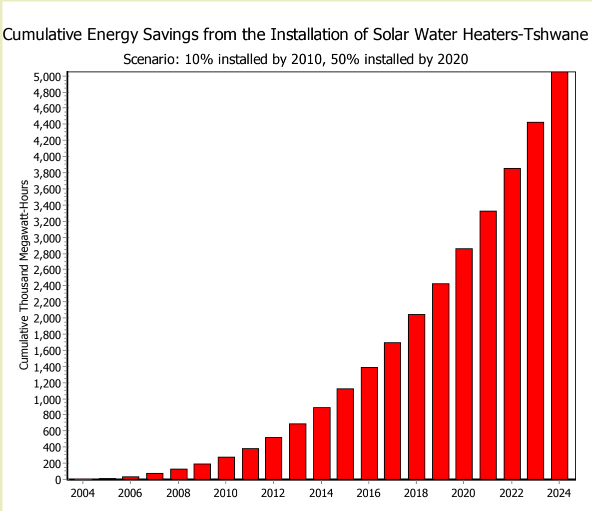
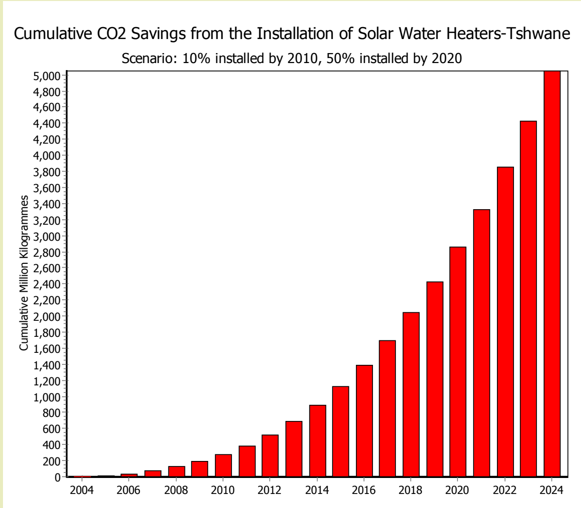


Figure 13 – Potential cumulative emissions savings from SWH mass rollout in Tshwane



Source: SEA. (2006). City of Tswane State of Energy

Implementation

Solar water heaters are a truly sustainable solution to water heating. The benefits for the country and individual users are clear. They are a particularly important way to reduce middle to high income electricity consumption and to provide low income households with a better quality of life. It is important that municipalities start to engage with solar water heating as a core part of household service delivery.

The publication of the new, energy efficient National Building Regulations is a very important development. This ensures that all new buildings will largely be serviced through solar water, or alternative efficient heating systems. The National SWH Programme, drawing on Eskom' Multi-Year Price Determination (MYPD) and Division of Revenue Allocations (DORA) funding to initially subsidise high pressure SWH systems and then moving into the Social Programmeme with low pressure installations in poor communities, has been an important learning-by-doing space. City Power have run the country's most substantial rollout – some 75–80 000 low pressure systems delivered in the areas of Devland, Lawley, Vlakfontein, Eldorado Park, Lenasia, Alexandra and Lehae in Johannesburg (case study below) – and this was achieved largely as a municipal programme.

An overview of the financial viability of the technology and some initial approaches, mechanisms and incentives to facilitate mass implementation and 'kick start' the market are outlined below.

Figure 14: Sol Plaatjie Rollout

Source: Agama Energy

*Financial feasibility of mid-high income residential SWH rollout**

Installation of SWHs in mid-high income households makes excellent financial sense, particularly in a financed, new build scenario. Analysis done indicates that even in the instance of retrofitting a working electric geyser the intervention will pay itself back over the short term (5 years).

Below are the results of the analysis for the following scenarios:

a. Retrofit working geyser: Financed (5-year and 10-year) and Cash Payment (i.e. conventional geyser being replaced is still working);

b. New build or burst geyser replacement: Financed (5-year and 10-year) and Cash Payment

All scenarios indicate financial viability. The financial case for the latter scenario (new build, financed) is most compelling. The detailed, spreadsheet analysis is available from Sustainable Energy Africa.

A standard warranty on SWH (parts and installation) is 5 years. They are anticipated to last a minimum of 7 years and a 15 year lifespan is considered standard. The modelling undertaken is based on a 15 year system lifespan.

The scenarios presented here assume electricity price increase of 8% per annum.

Table 2: Assumptions for SWH Analysis

SWH cost (including installation)	R 22,173.00
SWH size	200 litres
SWH water heating savings (vs. conventional geyser)	60%
Average hot water use per day	150 litres
Conventional electric geyser size	200 litres
Conventional electric geyser cost (including installation)	R 6,500.00 (replacing broken geyser) R 0.00 (replacing working geyser)
Current electricity price	R 1.98 / kWh
Electricity increase p.a.	8%
Geyser / SWH thermostat setting	60°C
Average incoming / cold water temperature	15°C
Efficiency of electric element	95%
Finance rate	11%
Number of years financed	5 or 10
Discount rate	8%

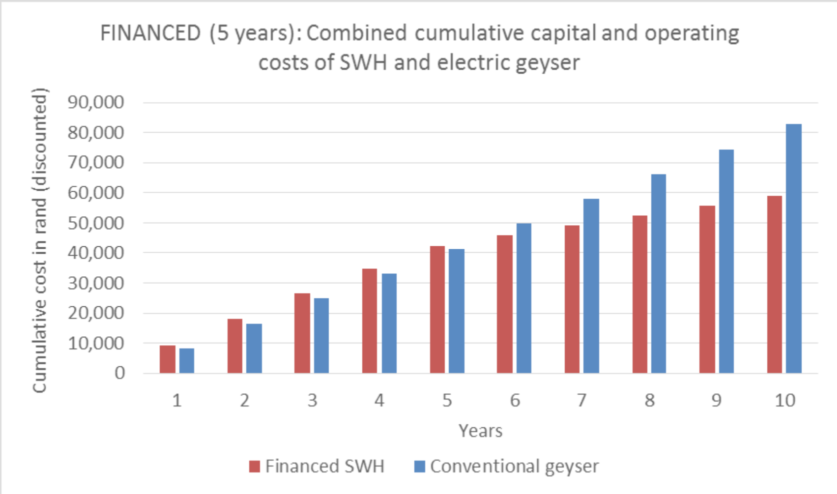
a. Retrofit Working Geyser Analysis: Financed and Cash Payment

This scenario assumes the replacement of a working conventional geyser. If you had to finance or buy a SWH cash INSTEAD of buying a conventional geyser when you need to replace it anyway (i.e. when the conventional geyser breaks), the financial case will be even more compelling.

The combined monthly repayments and electricity costs of a SWH under a 5-year financed payment are slightly higher, though similar enough, to that of a financed electric geyser from year 1 – 5 and thereafter increasingly lower, as indicated in the graph and table below. If the repayment was extended over 10 years, then the SWH repayments and operational costs would be lower than that of the electric geyser from the start.

* This part of the chapter draws extensively from: Sustainable Energy Africa (SEA). (2017) Solar Water Heating versus Conventional Geyser Cost Benefit Analysis Spreadsheet Tool. Unless referenced otherwise the information is sourced from this document.

Figure 15 – Retrofit working geyser: 5 years analysis



Payments in the cash upfront option for a SWH retrofit are slightly higher than for a conventional geyser over year 1 – 4; but by year 5 the cost is equivalent and payback is achieved by year 5; savings are made thereafter. If an end user has access to capital this is an optimal approach.

Table 3: Retrofit working geyser – figures showing combined cumulative capital and operating costs of SWH and electric geyser for 5 years

YEAR	1	2	3	4	5	6	7	8	9	10
Conventional geyser										
Financed payments per month	R0	R0	R0	R0	R0	R0	R0	R0	R0	R0
Electricity bill per month	R690	R690	R690	R690	R690	R690	R690	R690	R690	R690
Cumulative payments p.a.	R8,276	R16,551	R24,827	R33,103	R41,378	R49,654	R57,930	R66,205	R74,481	R82,757
SWH										
Financed payments per month	R500	R463	R429	R397	R367	R0	R0	R0	R0	R0
Electricity bill per month	R276	R276	R276	R276	R276	R276	R276	R276	R276	R276
Cumulative payments p.a.	R9,310	R18,175	R26,629	R34,701	R42,421	R45,732	R49,042	R52,352	R55,662	R58,973

Figure 16 – Retrofit working geyser: 10 years analysis

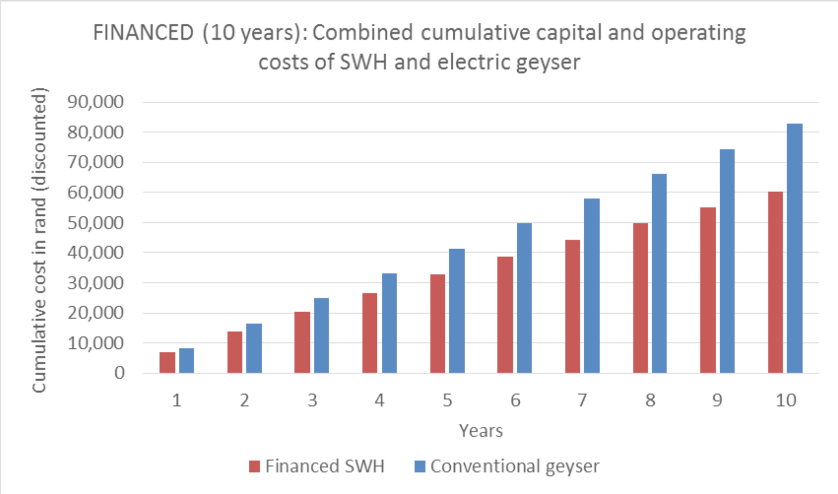


Table 4: Retrofit working geyser – figures showing combined cumulative capital and operating costs of SWH and electric geysers for 10 years

YEAR	1	2	3	4	5	6	7	8	9	10
Conventional geyser										
Financed payments per month	R0	R0	R0	R0	R0	R0	R0	R0	R0	R0
Electricity bill per month	R690	R690	R690	R690	R690	R690	R690	R690	R690	R690
Cumulative payments p.a.	R8,276	R16,551	R24,827	R33,103	R41,378	R49,654	R57,930	R66,205	R74,481	R82,757
SWH										
Financed payments per month	R314	R291	R269	R249	R231	R214	R198	R183	R170	R157
Electricity bill per month	R276	R276	R276	R276	R276	R276	R276	R276	R276	R276
Cumulative payments p.a.	R7,075	R13,872	R20,410	R26,709	R32,787	R38,659	R44,342	R49,849	R55,194	R60,387

Figure 17: Retrofit working geyser

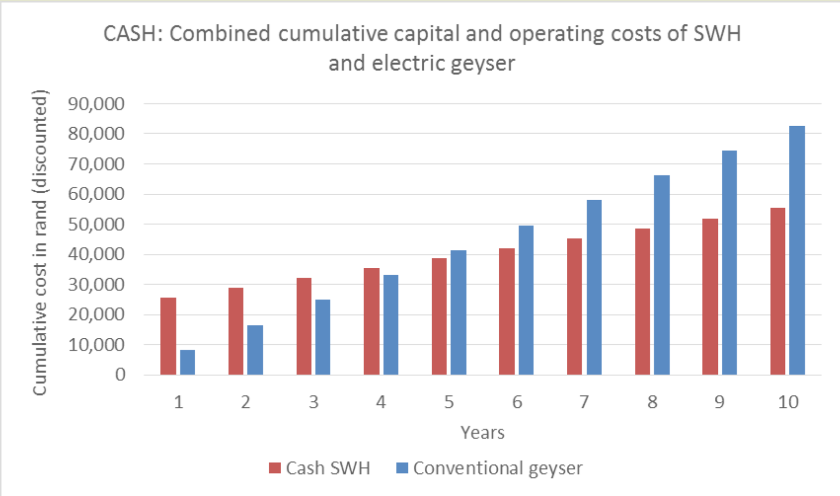


Table 5: Retrofit working geyser – cash figures of the combined cumulative capital and operating costs of SWH and electric geyser

Year	1	2	3	4	5	6	7	8	9	10
Conventional geyser										
Electricity bill per month	R690	R690	R690	R690	R690	R690	R690	R690	R690	R690
Cumulative payments p.a. (capital and elec bill)	R8,276	R16,551	R24,827	R33,103	R41,378	R49,654	R57,930	R66,205	R74,481	R82,757
SWH										
Electricity bill per month	R276	R276	R276	R276	R276	R276	R276	R276	R276	R276
Cumulative payments p.a. (capital and elec bill)	R25,483	R28,794	R32,104	R35,414	R38,724	R42,035	R45,345	R48,655	R51,965	R55,276

b. New build or burst geyser replacement Analysis: Financed (5-year and 10-year) and Cash Payment

Both financed and cash scenarios assume you're installing a new geyser in a new property, or replacing a broken/ burst geyser. In this instance, in a 5-year financed scenario, the costs of the SWH (combined capital and operating) are lower from year 1. The cash upfront scenario breaks even in year 3, with savings achieved thereafter. Given this picture, it would make no sense for a new build or geyser replacement not to fit a SWH.

Figure 18: New build or burst geyser replacement: 5 year analysis

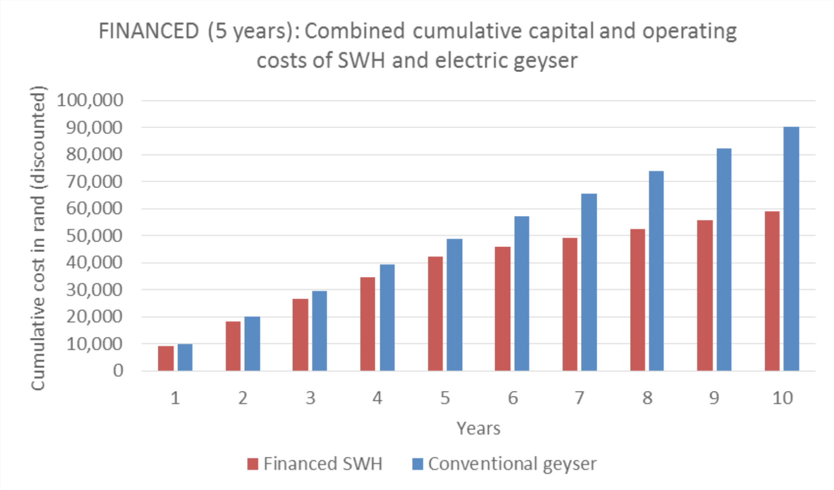


Table 6: New build or burst geyser replacement – figures of the combined cumulative capital and operating costs of SWH and electric geyser for 5 years

Year	1	2	3	4	5	6	7	8	9	10
Conventional geyser										
Financed payments per month	R147	R136	R126	R116	R108	R0	R0	R0	R0	R0
Electricity bill per month	R690	R690	R690	R690	R690	R690	R690	R690	R690	R690
Cumulative payments p.a. (finance payments and elec bill)	R10,034	R19,938	R29,722	R39,394	R48,962	R57,238	R65,514	R73,789	R82,065	R90,341
SWH										
Financed payments per month	R500	R463	R429	R397	R367	R0	R0	R0	R0	R0
Electricity bill per month	R276	R276	R276	R276	R276	R276	R276	R276	R276	R276
Cumulative payments p.a. (finance payments and elec bill)	R9,310	R18,175	R26,629	R34,701	R42,421	R45,732	R49,042	R52,352	R55,662	R58,973

Figure 19: New build or burst geyser replacement: 10 year analysis

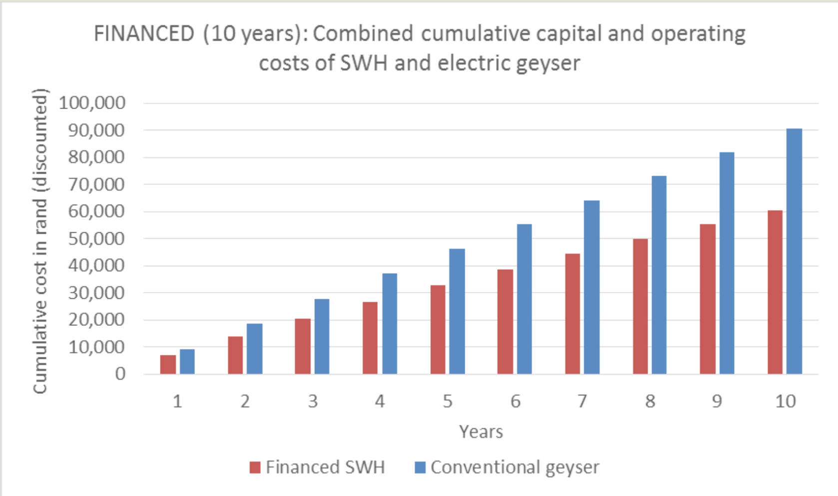


Table 7: New build or burst geyser replacement – figures of the combined cumulative capital and operating costs of SWH and electric geyser for 10 years

Year	1	2	3	4	5	6	7	8	9	10
Conventional geyser										
Financed payments per month	R92	R85	R79	R73	R68	R63	R58	R54	R50	R46
Electricity bill per month	R690	R690	R690	R690	R690	R690	R690	R690	R690	R690
Cumulative payments p.a. (finance payments and elec bill)	R9,379	R18,677	R27,899	R37,051	R46,138	R55,165	R64,136	R73,055	R81,927	R90,755
SWH										
Financed payments per month	R314	R291	R269	R249	R231	R214	R198	R183	R170	R157
Electricity bill per month	R276	R276	R276	R276	R276	R276	R276	R276	R276	R276
Cumulative payments p.a. (finance payments and elec bill)	R7,075	R13,872	R20,410	R26,709	R32,787	R38,659	R44,342	R49,849	R55,194	R60,387

Figure 20: New build or burst geyser replacement: cash analysis

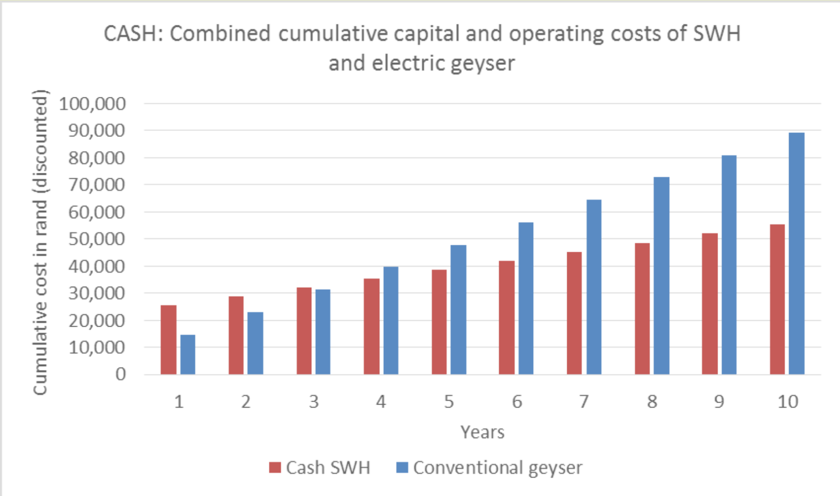


Table 8: New build or burst geyser replacement – cash figures of the combined cumulative capital and operating costs of SWH and electric geyser

Year	1	2	3	4	5	6	7	8	9	10
Conventional geyser										
Electricity bill per month	R690	R690	R690	R690	R690	R690	R690	R690	R690	R690
Cumulative payments p.a. (capital and elec bill)	R14,776	R23,051	R31,327	R39,603	R47,878	R56,154	R64,430	R72,705	R80,981	R89,257
SWH										
Electricity bill per month	R276	R276	R276	R276	R276	R276	R276	R276	R276	R276
Cumulative payments p.a. (capital and elec bill)	R25,483	R28,794	R32,104	R35,414	R38,724	R42,035	R45,345	R48,655	R51,965	R55,276

Financial feasibility of low income residential SWH rollout

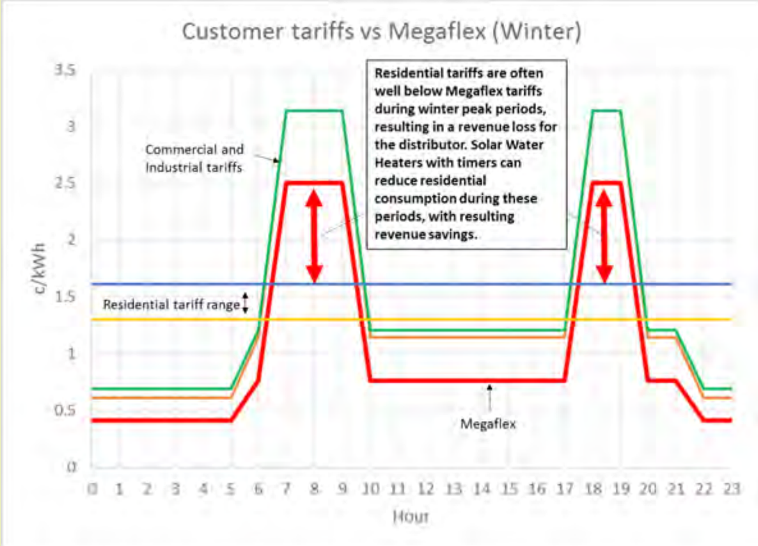
A financial case for solar water heating for low income households has been explored over the years. At one point it looked as if carbon financing might be able to support a financial case for low income SWH rollout and substantial work went into developing the large scale Clean Development Mechanisms (CDM) methodology for 'suppressed water heating demand'. With the collapse of the carbon market this anticipated finance stream has dried up. It may offer opportunities in the future, but experience to date has indicated that this is risky as well as being an enormously lengthy and costly (resource intensive) funding avenue.

A new 'case' currently being pursued is that of offsetting peak demand, which is costly electricity for the municipality to supply. In the residential sector peak electricity is generally purchased at Eskom's Peak Megaflex tariff, but only sold on to the household at the standard domestic tariff as there is no time of use metering and

Figure 22: Low pressure solar water heater.

billing systems in place. The distributor usually makes a loss on kWhs sold into the residential sector during peak (and a 100% loss where this is subsidized electricity). Where thermally heated water could offset kettle or stove usage for water heating during peak, this would make sense.

Figure 21 – Customer tariffs verses megaflex



Source: SEA. (2017). Impact of SSEG on Tswane's Revenue

However, given that the strongest motivation in this market segment has been quality of life improvements and poverty alleviation, government has also allocated grant funding for SWH rollout.

However, given that the strongest motivation in this market segment has been quality of life improvements and poverty alleviation, government has also allocated grant funding for SWH rollout. National government, within its SWH Social Plan, and in terms of its goal to deliver 1 million solar water heaters to low income households, has allocated money through the Division of Revenue Act (DORA) for this purpose. This programme has been halted for redesign, but it is anticipated that a restructured programme will be launched shortly. Grant funding is limited, however, and can only support a limited number of municipalities and households per year.

Municipalities may also consider 'own funding' of such rollout programmes. The major example has been that of City Power of the City of Johannesburg, which has instituted a R0.05 EEDSM levy/kWh within the high end user tariff. This funding stream has been used to subsidise a mass SWH rollout.

It is probably important for municipalities to bear in mind that a survey in Kuyasa, Khayelitsha, found that people were prepared to pay an amount for hot water (R20 – R30 in 2010 terms)(Goldman, 2010[8]). Combining a subsidy to reduce costs with a low monthly fee payment may be an important step for long term sustainability of SWH rollout in low income communities. This may also open up the space for implementing agents to engage in a financially viable rollout model.

A 100 litre, low pressure solar water heater (LPS 100 litre) costs in the region of R3 500 and with full installation included this figure is around R7 000 (incl. VAT).

8 Goldman (2010) Kuyasa CDM Project: Renewable Energy Efficienct Technology for the Poor, UNDP.

Barriers to rollout and attempts to address these

A number of the barriers to SWH rollout have been addressed over the past 5 years.

Regulation has been developed in terms of the new, energy efficient National Building Regulations that ensures solar, or a highly efficient alternative, for water heating in new buildings and within substantial building renovations. The challenge here remains that of ensuring that these regulations are enforced and building inspectors trained to do this.

High upfront capital costs have long been the greatest barrier to SWH implementation and capital costs have not substantially come down despite the growth in the market. This barrier has been substantially resolved through the increase in the cost of electricity over recent years, making the financial case far stronger. Associated positive adjustments to this have included:

- financing packages from banks that have been developed in response to this market opportunity;
- the coming on board of the insurance industry to support the replacement of burst conventional electrical geysers with SWHs (this has been supported also by government engagement with the industry).

A lack of quality assurance relating to parts and installation and associated consumer confidence has deterred adoption of the technology. However, standards for better regulation and quality assurance within the industry have been developed (see Product and Installation quality assurance and system optimization above). Training for plumbers and installers has also been developed. The City of Cape Town has gone further to address these concerns through developing a SWH Programme that provides residents with a list of pre-approved installers.

Other barriers remain challenging:

Financing for low income SWH rollout remains a challenge. National government grant funding through the DORA towards the SWH Social Programme made important strides. Hopefully this programme will be resumed. City Power has used a ring-fenced EEDSM fund, generated from a R0.05 which is levied on the higher tariff bracket, to fund their programme. To date this is the most sustainable funding model in existence in the country.

Implementation challenges to Social Programme rollout, including technical and installation quality, maintenance shortfalls and monitoring and evaluation of projects. Many of these challenges can be addressed and substantial best practice lessons have been derived from the experience of the past 5 years. This will require substantial capacity and resources at the local level. A detailed overview of these challenges and best practice solutions to address them can be found in the GIZ-SAGEN: Review of best practice solar water heating implementation by local government (November 2015).

The absence of a clear and consistent government policy direction has hampered new technology adoption. The stop-start nature of the SWH policy and programmes has hindered technology adoption. Factories have had to be shut down due to the suspension of the programme. To mitigate this municipalities, rather than waiting for national government programmes, should embark on their own programme development, drawing on national programmes or funds when and if they become available. This can also help to rebuild manufacturer confidence in the market.

Local content specifications can be a double-edged sword**.** Local content is seen by all as being a very important component of the programme – particularly where it involves government support – but this needs to be done in a very clear and consultative manner and expedited quickly so that manufacturers can adjust with confidence. There have been concerns that the national requirements inadvertently pushed smaller suppliers and installers out of the market.

Many municipalities still maintain that they should not pursue solar water heating amongst their mid to high income customers as they don't wish to suffer electricity revenue losses**.** This approach is short-sighted as households may pursue this regardless of municipal wishes. It is better for municipalities to manage this opportunity, to reap the benefits (jobs, carbon emissions reduction, quality of life, reduction in costly peak consumption) that the intervention offers.

The most effective revenue loss mitigation strategy (SEA, 2014[9]) is the decoupling of the current electricity tariffs into the following (1) an energy charge (to cover Eskom charges) and (2) a fixed charge (to cover distribution costs). This will secure the municipal business model and even allow municipalities to encourage renewable energy and energy efficiency within their distribution network. Additionally, business processes need to become more efficient and losses need to be either absorbed or minimised.

Major implementation mechanisms to consider

When considering how to go about implementing a solar water heater programme municipalities will need to consider different market segments (or target groups) and whether the intervention addresses new housing stock or existing housing stock (the retrofit market). If the full value of solar water heating is to be gained, all of these different target markets should be considered. The following implementation mechanisms are explored in detail below. These are not prescriptive, or comprehensive, but rather ideas that have been explored and which could be considered independently, or in combination, or variations thereof, etc.

Table 9: Solar water heater rollout mechanisms for municipalities across different housing segments

Implementation mechanism	New build or retrofit	Housing segment
Regulation: Enforce building regulations.	New build	Mid-high income
Regulation: Develop regulation (by-law) for SWHs to be a requirement for sale of house (similar to electricity certificate required – it could be part of this).	Retrofit market	Mid-high income
Government housing delivery: Encourage developers to include SWHs through housing tender process.	New build	Low income/govt subsidy
Municipal service delivery: Develop a SWH delivery programme as part of municipal service delivery and/or facilitate national programme delivery (retrofit market).	Retrofit	Low, mid, high income (variably)
Municipal service delivery: For informal settlements consider simple black tubing on rooftops, or innovations emerging in the market place, such as the Tshisa box.	New build/retrofit	Informal sector
Municipal driven or supported market-led approach: Develop an awareness campaign and support, facilitate and endorse a private sector rollout.	New build (i.e. for houses installing geyser for first time) and Retrofit	Mid to high income

The amended South African National Building 10400–XA Regulations

SANS 10400-XA provides the 'deemed-to-satisfy' requirements for compliance with the new National Building Regulations with regards energy usage, and SANS 204 specifies the design requirements to achieve the required levels of energy efficiency. These essentially require all new buildings to utilize solar thermal heating, or alternative efficiency technology, for water heating.

XA1 – buildings should utilise energy efficiently and reduce greenhouse gas emissions in accordance with a checklist of requirements.

XA2 – not more than 50% of the annual volume of domestic hot water may be heated using electricity. As most mid-income SWHs still partially use electricity, this effectively means that all hot water must be supplied by SWHs, or alternatively a heat pump system.

9 Sustainable Energy Africa (2014) Impact of localised Energy Efficiency (EE) and Renewable Energy (RE) on Municipal Finances over the next 10 years – Summary Report.

REGULATION

It is important that municipalities drive the enforcement of the new building regulations – ensuring all planning approval officials and building inspectorate are trained to approve plans and installations and enforce the law correctly. The requirement for solar water heating (or equivalent efficiency solution) will also help to grow and strengthen the solar water heater industry and market.

Municipalities should be considering what regulatory approaches may work in the retrofit 'market segment'. One intervention would be including solar water heating as a requirement of the sale of a house. This could function similarly to the electricity certification process, and could even be included as an aspect of that certificate. This would require the municipality to pass a local by-law bringing this requirement into local building regulations. The legality of such an action by municipalities has been explored and the conclusion was that this was within the ambit of municipal powers and functions (de Visser, 2007[10]).

Figure 24: A report commissioned by GIZ-SAGEN provides a good overview of lessons learnt through the rollout of the national SWH Social Programme

GOVERNMENT HOUSING DELIVERY

Where municipalities deliver government subsidy housing, they should also work to ensure that solar water heating be included in the housing delivery. Tender documents can indicate that bidders who are able to include SWHs within their proposals would be advantaged.

MUNICIPAL SERVICE DELIVERY

In this approach the municipality installs the SWH units as part of municipal service development (similar to installing an electricity meter). It would involve the appointment of service provider/s and collection of monthly repayments from the user via the rates or electricity billing system (if units are entirely grant funded this would not apply). Maintenance of the units would need to be built into service provider contracts, or into the City's service operations.

The most extensive rollout using this model has been the low income SWH rollout by City Power in Johannesburg (see case study below). While this approach is least risky to business, it is an enormously complex process for municipalities, requiring extensive project management skills and a thorough upfront consideration of issues relating to:

- Ownership of systems and risk. The legal indications are that ownership of the unit must reside with households, but this presents a huge risk in a low income household municipal-funded rollout where households cannot afford insurance, rendering the municipal investment very vulnerable.
- Contracting and quality assurance. The relationship between system suppliers and installers can be complex in terms of who is responsible when systems fail.

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10 De Visser (2007) Legal opinion on whether cities can implement efficient water heating bylaws, for SEA.

The Tshisha Box is a small mobile solar water heating box that heats and disinfects a small amount of water over a number of hours in the sun, providing a lower cost alternative to conventional solar water heaters.

In good sun the Tshisa box can heat 10 litres of water in 4 -5 hours while also using solar ultra-violet to disinfect the water. In winter it can warm to 42 degrees celcius and in summer maximum temperatures of 62 degrees are achieved. It does not need any domestic plumbing system and requires no installation. Boxes cost in the range of R200 – R300.

The product is distributed in a flat-pack form, which reduces transport costs and offers the opportunity to create assembly work (and value-add) in assembly in communities where it is sold.

Figure 26: Example of a hot water box manufactured by Tshisa Box.

Source: Tshisa (www.tshisa.co.za)

- Maintenance of systems. Certainly in low income rollouts, households cannot afford to maintain units beyond a certain amount (R20 –50 is indicated as the maximum a poor household can spend at any one time on maintenance).
- Community engagement. Experience indicates that thorough (pre, during and post installation) engagement should be undertaken with beneficiary communities for optimal results.

Further detail on these challenges and best practice in addressing them can be found in the GIZ-SAGEN: Review of best practise solar water heating implementation by local government November 2015: http://www.cityenergy.org.za/uploads/resource_351.pdf

What about Solar Water Heaters in informal housing?

It is often feasible to provide electricity to informal settlements, but there are no widely available solar water heating solutions for these houses at present. Informal houses have little or no plumbing, which means that conventional solar water heating systems are not applicable. However simple, cost effective ideas such as coiled rubber tubing on the roof or even black water containers could work. New innovations are also emerging in this space, such as the hot water box manufactured by Tshisa. Slightly more elaborate systems, some involving mounting, are under development.

MUNICIPAL DRIVEN OR SUPPORTED MARKET-LED APPROACH

Given that there is a strong business case for financed solar water heater systems, a real opportunity presents itself for entities to provide SWHs to end users at attractive monthly repayments. A number of banks (notably Absa and Nedbank) now offer attractive financing packages for solar water heaters, addressing the long-standing upfront capital barrier.

This rollout model could apply in mid-high as well as low income communities. However, in the latter, the municipality would need to be able to source a secure funding stream to bring down the monthly costs (such as carbon finance streams, EEDSM levy, or government grants). In addition the municipality would need to provide a maintenance service (this approach may overlap strongly with the Municipal Service delivery above).

Key elements of the model include:

- Attractive financing
- Bulk purchase and installation to bring down unit costs
- Effective monthly fee collection mechanisms
- Drawing on potential additional funding – government grants, EEDSM subsidies, carbon finance.

Key elements of municipal involvement in order to catalyse a market-led approach:

- Municipal Awareness and assurance – initiate awareness campaigns to inform households of the benefits and cost savings achievable through

SWH installation and the technology itself; build customer confidence in the industry through pre-approval of 'certified' suppliers;

- Financing arrangements – provide information on banks that offer SWH financing packages; consider inclusion of financing of SWH within the rates or electricity billing system.
- City provides some degree of assurance to the business entities to reduce their risk in terms of the scaling up required.

The municipality would need to decide on its level of involvement. This could either be municipal-driven, or municipal-supported.

The model involves private sector Implementing Agent/s, with strong municipal support and endorsement. This has been the approach of Cape Town and Durban for the mid-high income 'market segment'. Although this approach was explored in the Kuyasa low income delivery model it has not to date been successfully implemented in a sustainable way – largely due to the collapse of the carbon market on which the model's financial viability was based.

This model places the risk on the private sector, but as there are benefits reaped by the municipality in terms of peak load shifting, meeting carbon targets, job and enterprise development, the municipality may choose to encourage the market through mitigating the business risk. This can be done through various means, including:

- Awareness raising: running information campaigns to promote awareness about SWHs and the financial gains that households will reap;
- Assurance and endorsement: many residents are uncertain about what installation companies are reputable and how to select units. City endorsement of pre-approved service providers can go a long way to ensuring quality of supply and creating trust amongst residents.
- Revenue collection: municipalities who have a good record of tariff/rates collection may even consider offering this revenue collection facility to the installation companies in order to support the SWH rollout.

The National Solar Water Heater Programme

The National Solar Water Heater Programme (NSWH) was launched in 2010. Already the country had developed some SWH rollout experience through the 2009 Eskom rebate scheme. This initial rebate scheme was designed to assist with the energy security issues facing the country, and targeted mid-high income users, although it was also used for low income community rollouts. The NSWH Programme was designed to meet a broader range of goals, and the Minister's 1 million SWH campaign target. This has been run by the Department of Energy. The Social Programme component of the programme, building on the Eskom rebate schemes, delivered SWHs into a number of communities, but encountered some challenges.

These included system failures from substandard imported systems and poor installations with untrained installers. The Department is now

Key elements that catalysed mass adoption of SWH technology in Tunisia

1. Stable and clear policy direction from government
2. Installation and systems quality assurance through certification process
3. Allow consumers to buy SWHs cheaply, and pay back over long periods
   - Subsidy to bring down cost
   - Loan mechanisms over a 5-year term
   - Monthly repayment correspond to energy savings
4. Simplified adoption process
   - Repayment of the loan via the utility bill
   - Simplified 'sign up' procedure: consumers contact the SWH supplier and fill a form with ID and last utility bill, and installation is immediate

Source: San Giorgio Group Case Study: Prosol Tunisia, Climate Policy Initiative, 2012 http://climatepolicyinitiative.org/wp-content/uploads/2012/08/Prosol-Tunisia-SGG-Case-Study.pdf.

redesigning the Social Programme with the aim of developing an enhanced model for stakeholder cooperation and SWH installation training with a specific focus on training local people.

A project undertaken as part of the South African-German energy cooperation programme (GIZ-SAGEN) aimed at piloting the DOE's enhanced model, drew the following conclusions for rollout:

- A community-based/driven approach be adopted in all aspects and processes of implementing the pilot solar water heater programme from inception, planning, implementation and project hand over;
- Roles and responsibilities of all stakeholders should be clearly outlined, discussed and agreed upon in advance to avoid confusion and conflicts during project rollout. Preferably, the latter should be documented and communicated to all including the installer/contractor;
- A user and language-friendly installation, operation and maintenance booklet be developed with built-in warrantees and contact details of manufactures and installers for major repairs of the solar water heater equipment;
- Local skilled and unskilled labour as well as emerging contractors/SMMEs be recruited and offered employment and skills transfer opportunities by installers/contractors; and
- Facilitated by the Ward Councillor/Area Committee, Community Leadership Structures, Social Facilitator and Community Liaison Officer, responsibilities of installers and households should be clearly delineated and agreed upon pre- and post-implementation of the solar water heaters.

In addition, based on detailed interviews with municipal officials, the advice is that when engaging with a national programme municipalities need to take the following into account and plan accordingly:

- Local communities do not take well to projects benefitting businesses from outside of the area;
- Any implementer must be held to the critical elements of community engagement;
- Maintenance of the systems post installation must be catered for. Even if the municipality did not deliver the system, the community will turn to the municipality post installation for maintenance help or if any problem arise in relation to the installation.

Master Planning

Experience indicates that a municipal SWH engagement/programme should begin with a detailed Master Planning session that establishes the rationale for bringing solar water heating into the municipal service delivery framework, addresses who should drive the new initiative, how it will be funded and considers in detail some of the complexities and challenges that will arise during rollout.

Municipal SWH / hot water service delivery Master Plan Development

1. Programme goal/ design of service

Establish the rational for bringing solar water heating into municipal service delivery. Consideration needs to be given to different municipal 'customer' segments and how these target groups would link to the service delivery framework. Consideration also needs to be given to 'new build' and 'retrofit' market segments. The nature of service (including life cycle of service, ownership of system and what this means for insurance, maintenance, etc) should be detailed.

2. Lead department

Consider where the programmes will best align with the existing service function of a department: Electricity and Energy, Water, Housing, etc. It is likely to require the coordination amongst departments. SWH projects can require complex project management skills. New programmes always benefit from the drive of a 'champion'.

3. Finance and funding

Financing of a new service framework needs consideration. Possible funding streams include:

- Service delivery charges
- National programme or grant funding
- Internal financing (EEDSM levy)
- Combinations thereof (e.g. national programme for installation of system, but local financing of ongoing maintenance)
- Other sources of finance may emerge through carbon initiatives and/or energy access financing models

4. Community engagement

How will the beneficiary/target communities be identified and, where rollout is sequential, how are beneficiary communities selected? There will be technical and efficiency consideration to bear in mind (water/water quality, roof strength, location of households)

What is the process of engaging with the community (when and how and who) and the information to convey – noting that this will differ depending on different projects/ programmes relating to the different market segments identified. The nature of the service and responsibilities of all parties is vital upfront information that needs to be established. Basic technical information can also assist enormously with down the line system maintenance.

5. Procurement, QC and payment cycles (where the municipality will be delivering SWH systems directly)

This is complex and must consider: supply, installation, maintenance, community engagement, job creation and skills training – one contract or many. Can contracting and payment cycles be structured to ensure enterprise development?

6. Maintenance of systems

It is critical that provision is made for the ongoing maintenance of systems. This is an operational cost that requires municipal resources.

7. Jobs skills and enterprise development

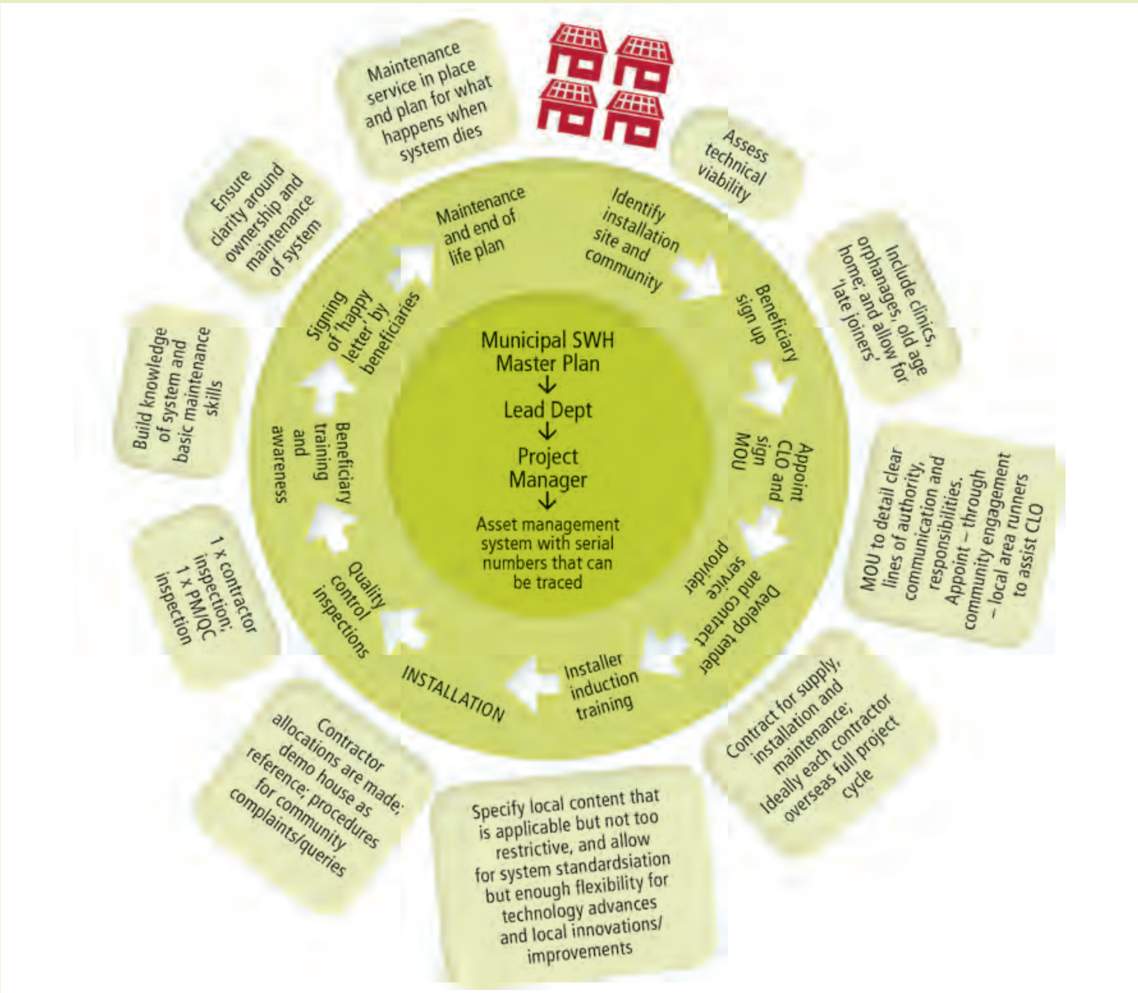
This is likely an important motivator for any municipality and requires thought and capacity/ resources to ensure that it is properly addressed (this is often included as a strategic goal but programmes fail to allocate any resources to this element of the programme). Consider strategic partnerships, such as with the Expanded Public Work Programme (EPWP) programme.

A detailed analysis of best practice for all of these elements of SWH rollout by municipalities can be sourced in the GIZ-SAGEN: Review of best practice solar water heating implementation by local government November 2015: http://www.cityenergy.org.za/uploads/resource_351.pdf

Figure 27: Solar water heaters in Kuyasa

Source: Kuyasa CDM Project

Figure 28: Schematic of a solar water heating rollout project cycle



Source: SEA

Case Study 1: The City of Cape Town's Residential SWH Service Provider Accreditation Programme

The latest GIS count (February 2015) shows that there are over 46 000 SWHs installed in the Cape Town metropolitan area. These have contributed over R830 million into the economy, creating over 1 300 job years. These systems are reducing electricity consumption by more than 128 000 MWh per year, and reducing carbon emissions by more than 132 000 tonnes per year. Households are saving over R270 million per year that can then circulate in the local economy.

This is considered partly the result of the Accredited Solar Water Heater (SWH) Programme of the City. This programme – part of the City's broader "Save electricity" programme – is an intervention to promote installation of SWHs amongst mid-to-high income home owners, as electric geysers are typically responsible for about 40% of their consumption. Market research undertaken by the City indicated:

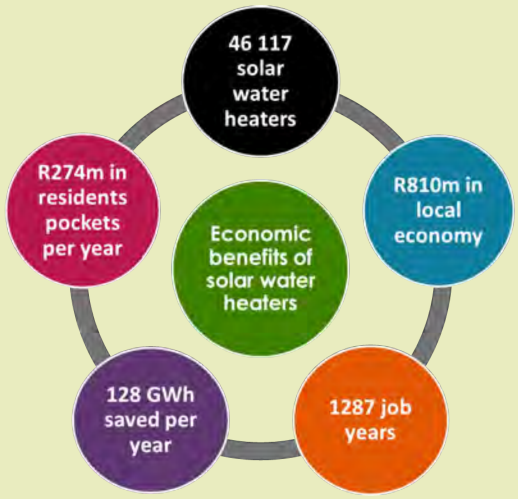
- *A willingness amongst residents to move to acquire energy efficient hot water systems due to rising electricity tariffs;*
- *A lack of public knowledge of the products available and of their effectiveness and reliability;*
- *Lack of trust: concern about the competence and sales ethics of installers in the market; and*
- *Upfront capital sum still an inhibitor in the decision to acquire a SWH.*

In order to address the market situation towards more rapid uptake of SWH technology in mid-high income households in the city the City of Cape Town decided to develop an accreditation programme. Key elements of the programme include:

- *Public awareness, educational, advertising and marketing campaign describing the technology involved and answering customer questions;*
- *Working with local service providers to try and develop public confidence in the industry through vetting and*

The Accredited Solar Water Heater Programmeme is an intervention to promote the installation of SWHs amongst mid-to-high income home owners, as electric geysers are typically responsible for about 40% of their consumption.

Figure 29: Convincing figures from the City of Cape Town



Source: City of Cape Town

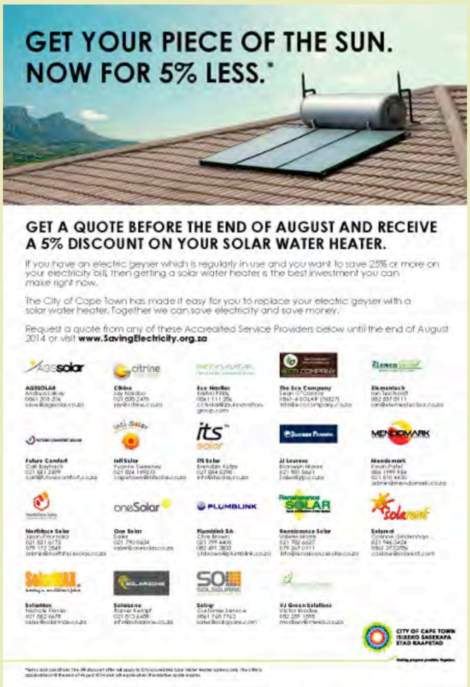
Figure 30: The City's citizen SWH awareness and support campaign website provides useful and accessible information to potential SWH buyers.

Source: City of Cape Town www.savingelectricity.org.za

Figure 31: The City provides endorsement of SWH system suppliers.

Source: City of Cape Town
www.savingelectricity.org.za

Figure 32: Lessons Learnt 08: SWH Programmeme Explanatory Leaflet



Source: City of Cape Town
http://www.cityenergy.org.za/uploads/resource_275.pdf

accrediting a set of reliable service providers who will provide quality SWHs and expert installation and service.

- *Encouraging the growth of local manufacturing capacity in the region for SWH components;*
- *Working with local banks and other lending institutions to facilitate the greater availability of installation finance for financing product sales directly to customers and possibly bulk funding for suitably sized service providers who may wish to act as the lender themselves;*
- *Assisting service providers if needed by offering a billing and collection service for installations done from customers. Note that this last option has not yet been actualised.*

The City has a project management unit specifically dedicated to running the programme. This unit does the screening of applications for accreditation and conduct random inspections on installations to see that a contracted Code of Conduct has been adhered to by the Accredited Service Providers (ASPs). It will endeavour to assist in the resolution of disputes between ASP and their customers.

Accreditation is an extremely rigorous process in which the business applicant must provide detailed confirmation of technical capacities in line with SABS installation requirements and plumbing certification, overview of systems – SABS approved with minimum 5-year warranties, local content guarantees, etc. Detailed documentation on this and the associated ASP contract template can be found on the City's website or via the City Energy website: http://www.cityenergy.org.za/uploads/resource_275.pdf.

Source: City of Cape Town SWH website: http://savingelectricity.org.za/pages/water_heaters.php; and Cape Town SWH Programme Lessons Learnt 08: SWH Programme Explanatory Leaflet: http://www.cityenergy.org.za/uploads/resource_275.pdf.

Case Study 2: Mass rollout of SWHs in low income households Johannesburg, City Power, City of Johannesburg*

Between 2011 and 2014 City Power, the electricity utility of the City of Johannesburg, ran a project that installed 75 – 80 000 solar water heating systems on households in the communities of Devland, Lawley, Vlakfontein, Eldorado Park, Lenasia, Alexandra and Lehae. This is to date the most sizeable installation in the country. Despite many upheavals and challenges, the project achievement is huge and the process has generated enormous and valuable lessons. Although no formal evaluation has taken place, quality control consultants involved noted that beneficiaries felt the intervention was very worthwhile.

A total of R800 million was spent over the 3 year project. Initial project funding came through the Department of Energy's DORA-funded SWH programme, but the majority of the rollout was funded by City Power through a DSM levy on their 500 kWh/month and above electricity tariff. The City reverted to own funding and own management of the programme as the national programme processes made procurement difficult and whether funding would be secured each funding round was uncertain. This meant that the City had limited control over the outcome of the process.

The programme contracted two different suppliers and a number of smaller installation companies. Tensions arose between the system suppliers and the installers as these had not worked together before and when system failures arose responsibility for this was disputed. Due to limited cash flow, smaller installer companies struggled to pay their labour when inspection was either not speedy enough or resulted in systems having to be re-done before sign off.

Quality control and monitoring included two levels of inspection. This first was done by the suppliers and the second by the contracted QC. The second was a random

Despite many upheavals and challenges, the project achievement is huge and the process has generated enormous and valuable lessons

Figure 33: Field visit of municipal officials from Uganda and Ghana to Alexandra SWH rollout in December 2015.

Source: Sustainable Energy Africa. (2015). State of Energy in South African Cities

* This case study draws extensively from the publication GIZ-SAGEN: Review of best practice solar water heating implementation by local government, prepared by Sustainable Energy Africa, November 2015: http://www.cityenergy.org.za/uploads/resource_351.pdf. Unless referenced otherwise, information is sourced from this document.

second by the contracted QC. The second was a random 10% sampling in which an 80% pass rate was required – or installers would be required to fix the whole batch. A strong 'zero tolerance' approach was taken on leaks and south facing orientation of systems.

Warranty on installation was 5 years. However, a major oversight in the project was that although the original plan for the Terms of Reference included a 3 phase approach including supply of systems, installation and maintenance, the maintenance aspect never made it to tender as a formal stage with decent budget allocation and plan. Contracts vaguely said "enable maintenance for 10 years" and ideas about developing local depots and staffing them were essentially unfunded.

One supplier set up one of the trained community installers to become a longer term maintenance person. They helped him to establish a small call centre, donated a vehicle and provided him with computer skills. Although this is working well and the technician has extended his business into basic plumbing services, the feeling from the supplier is that municipalities should be providing this service, or paying for this service, out of their service maintenance budgets as it is not a viable business prospect without some kind of funding support. This approach – of a municipal "on-ground" maintenance officer to manage solar water heater maintenance also has the potential to address the on-going challenge of municipal water leaks.

Learning and innovation on the job is an important element. They established demo houses as reference for each type of installation. These provided an opportunity to test innovation, teach installers and set the standard against which to measure and monitor quality of installation.

A lack of clarity, or piecemeal allocation, of project management roles and lines of communication and accountability added to an already complex contracting situation and community engagement process. The suppliers were responsible for aspects of the project beyond system supply, such as management and payment of the Community Liaison Officers (CLOs) and did some quality inspection.

Those involved believe that a clearer outlining of the process and establishment of clear procedures for the community to follow when things went wrong or they had queries about the process would have benefited the critical process of community engagement. On ground community engagement was found to be enormously challenging: in an identified community of say 2 000, there may be some 500 houses that do not have the correct roof orientation or strength for installation and then the installer or supplier or CLO may have their life threatened. One supplier graphically described being cornered between the QC saying they wouldn't pay for an incorrect orientation installation and the community – "literally holding a revolver to your head, or knife to your throat and saying: 'you must install or we will kill you.'"

Training of installers and labour was very well done. However, a high turnover of staff and installer management meant that valuable skills developed were then lost. Although the project aimed to generate jobs, this was again a neglected area within the tender documentation. Without budget allocation the contractors did not have resources to allocate to ensuring the sustainable development of jobs. The project did go on to engage Jozi@ Work, which helped to provide a more sustained development path for those employed within the project on short term labour contracts.

Case study 3: Kuyasa – exploring a carbon market-led low income housing SWH rollout in Khayelitsha, Cape Town*

The Kuyasa Clean Development Mechanism (CDM) project was the first large-scale attempt to rollout SWH's on a market basis in low income households. Over 2000 RDP households in Kuyasa, Khayelitsha, were fitted with SWHs, insulated ceilings and the supply of 2 CFLs per household. The project, led by NGO SouthSouthNorth and the beneficiary community, produced the project design, which was registered as the world's first Gold Standard (has social upliftment value) Clean Development Mechanism (CDM) project in August 2005. AGAMA Energy was appointed as the implementer.

Benefits included an estimated emission reduction of 2.85 tons of CO_2 per household per year and an energy services cost reduction of over R600 per household per year. Employment opportunities were created through SWH installation, ceiling installation and CFL retrofits. Human capacity was built around project design aspects, including energy efficiency and renewable energy.

Implementation funding was obtained from the Provincial Housing Department research grant, ICLEI (International Association of Local Governments) and through the Poverty Alleviation Grant from the Department of Environmental Affairs and Tourism. A further source of funding was anticipated to come from the sale of Certified Emission Reductions (CERs) at €8 per ton. At the time of project development the Net Present Value of the CERs would cover 30-40% of the project's capital cost. Households were also to pay R30 per month for their hot water service, as on ongoing contribution.

The project ran into seriously difficulties with the collapse of the carbon market. This revenue stream was to have funded the management of the project, including systems maintenance, in the long term. When this revenue failed to materialise the project could no longer employ staff or replace damaged or failing systems. Early stands, made of weaker material, began to collapse and householders became angry at the potential damage to houses. Although the project was not undertaken by the City of Cape Town, the City has had to step in in order to avoid social and political fallout.

Despite challenges important lessons have been learnt in this pioneering project. These include:

- *Demand drives better materials development; only through trial and error can this be achieved;*
- *Projects in low income areas, where households do not have the resources for upkeep and maintenance, should probably best be held by a public institution, such as a municipality, in order to avoid the risks associated with a private sector funded initiative;*
- *Municipalities should be very aware that when things go wrong in SWH rollout projects developed by parties other than the municipality (whether other spheres of government or private or NGO sector), communities will lay the blame at the door of the municipality, or at least expect the municipality to sort out the problems;*
- *The indications were that households were prepared to pay for hot water services.*

Figure 34: Solar water heater in Khayelitsha

Photo: Chris Galliers

* This case study draws extensively from Goldman, M, Kuyasa CDM Project: Renewable energy efficient technology for the poor, UNDP, January 2010, and personal communications with City of Cape Town and Kuyasa project manager (SEA, 2014). Unless referenced otherwise, information is sourced from this document.

Support organisations

Key role-players to support implementation of Solar Water Heater projects:

Department of Energy – EEDSM Programmeme, including SWH Social Programmeme

www.doe.gov.za

Sustainable Energy Society of Southern Africa (SESSA)

www.sessa.org.za

South African Bureau of Standards (SABS)

www.sabs.co.za

Energy Efficient Lighting

Overview

According to the International Energy Agency in 2013 electricity for lighting consumed 20% of the output of the world's power stations.[1] For the USA the share of lighting was 15% in 2016[2]. The use of energy efficient lighting is one of the simplest and most cost effective ways of reducing energy consumption. Efficient lighting programmes can be implemented in several areas within cities by:

- Replacing traditional incandescent bulbs with compact fluorescent light bulbs (CFLs).
- Replacing old fluorescent tubes with efficient fluorescent tubes.
- Replacing old magnetic ballasts with electronic ballasts in fluorescent tube systems.
- Installing lighting control systems (motion and lux level sensors)
- Using light-emitting diode (LED) technology wherever possible. This technology is developing fast and is getting steadily cheaper. LED's are now able to replace most conventional lighting applications, such as traffic lights, down lighters, streetlights, security lights and even strip lighting to replace fluorescent tubes.
- Making streetlights more efficient e.g. by replacing mercury vapour lights with high pressure sodium lights or LEDs that operate on around a third of the power. LED lights have more than double the life span. Decreasing costs makes them financially more viable for street lighting.

Figure 1: CFLs save up to 80% of energy compared to incandescent light bulbs

Photo: Armin Kübelbeck, CC-BY-SA, Wikimedia Commons

It is anticipated that LEDs will be used in most applications in the future.

1 https://www.iea.org/topics/energyefficiency/subtopics/lighting/

2 https://www.eia.gov/tools/faqs/faq.cfm?id=99&t=3

LED: lights of the future

The development of LED lights is moving fast. LED alternatives are now available for nearly all lighting applications. Their advantages include:

- 80 to 90% more energy efficient compared to incandescent lights; on average 20% more efficient than fluorescent lights.
- LEDs have a very long life span of claimed 30000 to 50000 hours.
- LED lights are available in many light colours including the popular warm light of incandescent bulbs.
- LED prices are decreasing fast as this technology becomes more mainstream.

It is anticipated that LEDs will be used in most applications in the future.

Figure 2: Types of LED light bulbs.

Photo: Geoffrey Landis at English Wikipedia

Implementation

Lighting is a significant component of electricity consumption in the residential and commercial sectors that in South Africa together consume around 50% of the country's electricity[3]. The replacement of lights with highly energy efficient ones is one of the simplest and most cost effective measures to reduce electricity consumption and related greenhouse gas emissions.

The replacement of incandescent light bulbs with CFL or LED lights reduces the electricity consumption by around 80% to 90%.

In a domestic and work environment a task light like the pictured desk lamp is far more energy efficient than general lights at the ceiling because it lights only the area that needs to be lit from a very short distance. If task lights are applied the brightness of the general lighting can be strongly reduced resulting in energy savings. A typical desk lamp with CFL bulb needs only 8 to 11W, or with LED bulb only 5W.

Figure 3: Desk lamp brightly illuminating a small area

Source: CC0 Public Domain 12 https://www.usea.org/sites/default/files/event-file/497/South_Africa_Country_Presentation.pdf

Lighting technologies differ strongly in energy efficiency, life span and price. In order to compare cost all three factors must be considered. Below are comparisons of energy efficiency, life span and finally lifecycle cost of four most common technologies. These are:

- Incandescent,
- Halogen (incandescent technology but bulbs filled with halogen),
- CFL, and
- LED.

3 https://www.usea.org/sites/default/files/event-file/497/South_Africa_Country_Presentation.pdf

The brightness of light is measured in lumen. The electricity demand of light bulbs is measured in Watt. The lumen rating allows comparing the electricity consumption of different technology light bulbs providing the same brightness. In the table below lumens and wattage of incandescent, CFL and LED lights are compared. Please note that the figures are estimates. Especially the LED technology is developing fast becoming more energy efficient (see textbox below).

Figure 4: Comparison of brightness (lumens) and power consumption (watt) for different technologies

DIMMER → BRIGHTER

LUMENS	450	800	1100	1600
Standard Incandescents	40W	60W	75W	100W
New Halogen Incandescents Save up to 28%*	29W	43W	53W	72W
CFLs Save up to 75%*	9W	14W	19W	23W
LEDs Save up to 77%*	8W	13W	17W	N/A

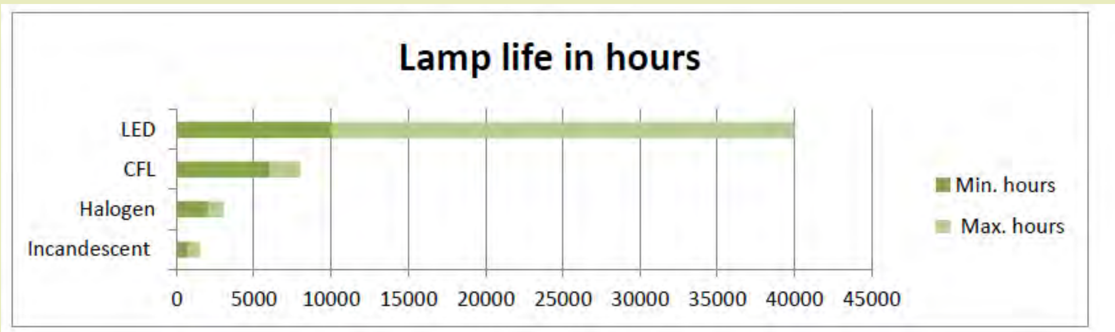
LEAST EFFICIENT → MOST EFFICIENT

*Percentage of energy saved by replacing a standard incandescent light bulb; based on usage of approximately 796 hours annually and average residential electricity rate of $0.15/kWh

Source: IDAVIDMCALLEN, 2015
https://idavidmcallen.wordpress.com/2014/05/05/led-watt-conversion-light-replacement-guide/

The expected minimum and maximum lifespans of the different technologies are indicated in the figure below. It is noted that cheap LED lights tend to have a far lower lifespan than more expensive ones.

Figure 5: Comparison of lamp life of different technologies

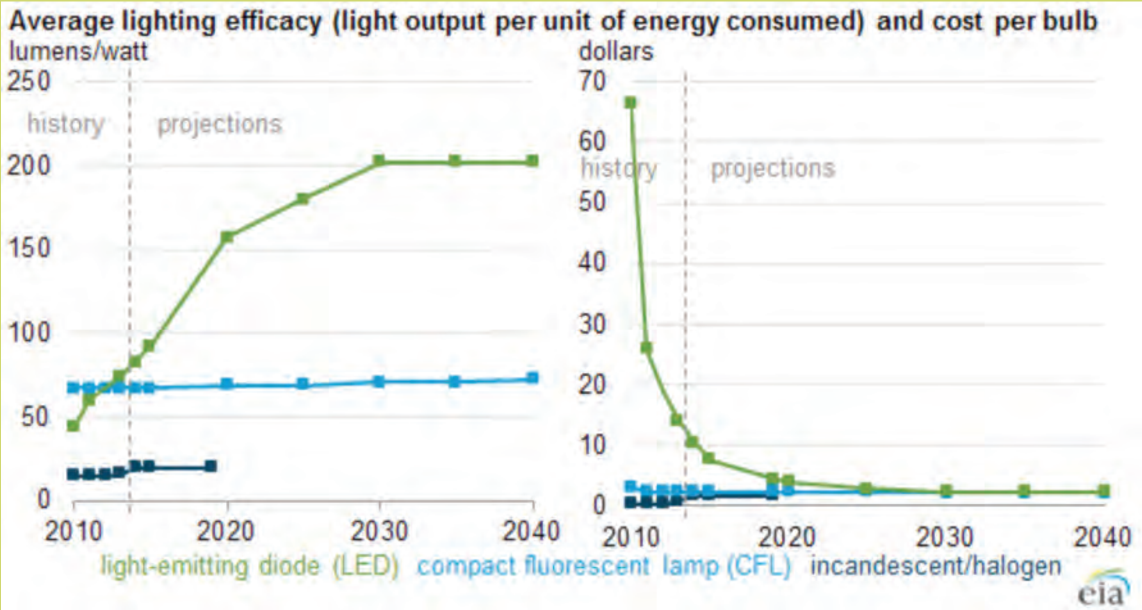


Source: mygreenhome, 2014
http://mygreenhome.org.za/wp-content/uploads/2014/05/Guide-to-Globes-20-May-v3-.pdf

LED bulb efficiency and cost

The US Energy Information Agency expects the energy efficiency of LED bulbs to increase while prices drop.

Figure 6: Average lighting efficacy



Source: U.S. Energy Information Administration, 2014
https://www.eia.gov/todayinenergy/detail.php?id=15471#

From an electricity system's perspective energy efficient lighting has the benefit of reducing electricity demand, including during the evening peak period. It therefore contributes to the security of electricity supply in the municipality and nationwide. Eskom and the DoE have recognized that efficient lighting plays a major role in demand side management (DSM) and have funded programmes for the mass roll-out of CFL lights in the past.

From an electricity consumer's perspective efficient lighting technologies have the following benefits:

- CFL and LED are expected to last several times longer than incandescent bulb and require only one fourth to one fifth of the amount of power. Over their life cycle, these efficiencies more than compensates for the higher purchasing costs of approximately R25 for CFL and R50 for LED.
- From an environmental perspective, approximately 800kg of CO_2 will be saved over the lifetime of one CFL or LED bulb compared to the equivalent incandescent, assuming that the electricity source is a largely coal based power station.
- The cheapest way of reducing electricity demand for lighting is behaviour change. It is estimated that through behavioural changes. Changes to energy efficient technology should be accompanied with campaign for behaviour change.
- The replacement of fluorescent tubes (T12 or T8) with more energy efficient ones (T5) and the installation of electronic ballast will improve energy efficiency by around 25%.
- Installing sensors in buildings which only switch on lights in the presence of a person (movement sensors) or at insufficient lux levels (light sensors) will further reduce power demand for lighting.

WARNING

CFL and fluorescent tubes contain mercury vapour, which makes their safe disposal important. They must not be thrown into the general waste but should be taken to specific recycling facilities or electrical appliance shops for recycling or safe disposal. Some supermarkets also have drop-off containers for CFLs or tubes. The distribution and promotion of CFLs should be accompanied by education about their safe disposal.

This problem does not apply to LED lights.

Municipal buildings and facilities

The business case for energy efficient lighting is so strong that municipalities should implement energy efficient lighting technologies in their own buildings and facilities. This requires them to develop a strategy for the systematic implementation of energy efficient lighting.

In addition, municipalities should promote energy efficient lighting with communities and businesses.

An energy efficient lighting strategy requires:

- Locating responsibility for retrofits of lighting with a specific department. This is typically the department responsible for maintenance of municipal buildings.
- Identification and prioritisation of municipal buildings and facilities; drafting a retrofit programme.
- Identification of funding for lighting retrofit. This may come from the maintenance budget or through making the case for municipal capital budget, arguing that future savings justify higher upfront costs. Additional funding can be sourced through the Energy Efficiency Demand Side Management (EEDSM) programme of the DoE. This programme offers grant funding for energy efficiency measures.
- To ensure long-term implementation the municipality should adjust its standard specifications for lighting so that efficient lighting is routinely procured and installed. This may require a capacity building process amongst staff involved in lighting procurement.
- To implementation of any energy efficiency measures including lighting follows four steps:
- Energy audit of the lighting system and its electricity consumption.
- Design of energy efficiency measures. These can be simple exchanges of light tubes and bulbs with more efficient ones. However the re-design of the whole lighting system may achieve higher savings and rationalisation reducing maintenance costs. This step includes an indication of the expected savings and estimated pay-back period of the capital cost.

Lighting Behaviour Changes

- *If a room is well windowed, use natural light and not electric lighting*
- *Turn of lights in unused rooms*
- *Use task lights instead of ambient lighting wherever possible*

- Implementation of the measures. In most cases this will require a tender process and appointment of a service provider (see Green Public Procurement). However, simple replacements of light bulbs and tubes with more energy efficient ones can be done in-house e.g. as part of maintenance.
- Monitoring and validation of the energy savings and whether or not they correspond to the design estimates.

In South Africa the standard tubes are T8, but T12 tubes can still be found in old buildings. T5 tubes and LED tubes are more energy efficient and will likely become the new standard. T12 tubes can simply be replaced by T8. For the installation of T5 tubes into old fittings a retrofit kit or adapter is required. For the fitting of LED tubes the ballast must be by-passed.

Figure 7: T5 retrofit adapter

Source: http://www.t5fixtures.com/how-to-use-t5-light-bulbs-with-t8-or-t12-light-fixtures/

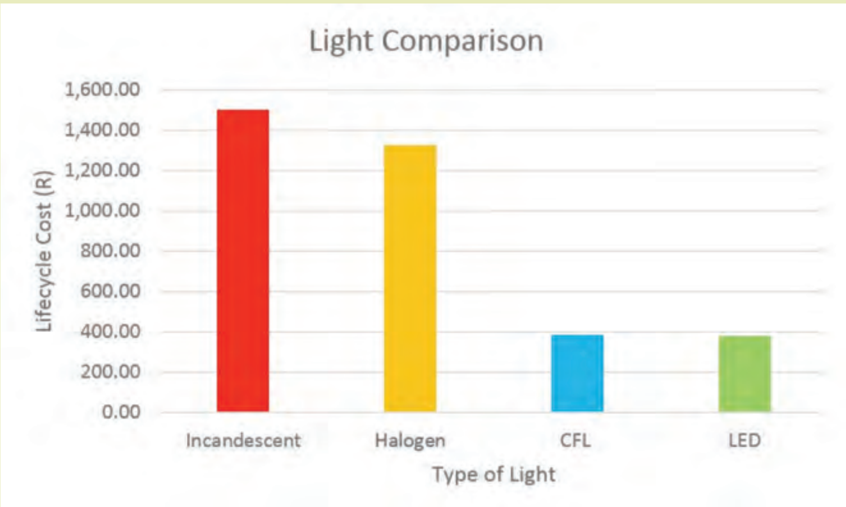
FINANCIAL ASPECT

To date energy efficient lighting interventions have been implemented by many municipalities in their buildings. The experience shows that the electricity savings typically pay for the new technologies in less than 3 years.

Prices of CFLs and particularly of LEDs vary strongly according to the type of light and the quality. In 2017 the prices of CFL were between R25 and R80 if a single bulb is purchased. Prices for LEDs were in the range of R50 to R120.

The University of North West has published a lifecycle costing study for the different technologies for domestic use taking into account cost of electricity consumption, life span and purchasing costs of lights. The figure below that already in 2014 LEDs had the lowest lifecycle costs followed by CFLs.

Figure 8: Life Cycle cost comparison of different lighting technologies



Source: NWU, 2014
http://www.nwu.ac.za/faculty-engineering-energy-saving-home-lighting

The authors of the study state:
"In conclusion, the LED has the lowest lifecycle cost making it the most economical, it uses the least electrical energy and it does not have any mercury in it making it the most environmentally friendly. Thus, when replacing old light bulbs, spend a little more money on a LED and save more than R1100 over the lifecycle of a single LED." [4]

In commercial and industrial environments, around 25% electricity savings can be achieved through the replacement of older fluorescent tubes (T12 or T8) with energy efficient ones (T5)[5] and the installation of electronic ballast and lighting control systems such as sensors. The costs of T5 tubes are only marginally higher than of T8 tubes and retrofit kits are available. Also LED tubes are available that are around 40% more energy efficient than fluorescent T5 tubes. The prices of LED tubes are decreasing fast but they are currently still around 8 times more expensive than fluorescent tubes.

Street Lights

Street lights consume around 20% of electricity used for municipal operations[6]. It is therefore worth focussing on street lights to reduce the electricity consumption and costs of the municipality. There are several technology options for street lights that are explained in detail in the brochure "Efficient Public Lighting Guide". The guide can be downloaded at http://www.cityenergy.org.za/uploads/resource_17.pdf).

The most common ones are listed in the table below and shown in the images on the next page.

Table 1: Comparison of different street lighting technologies

Type	Overview	Colour of light	Life time (hours)	Lumens/ Watt
Mercury Vapour	Pros: inexpensive, medium life span Cons: inefficient, contain mercury, get dimmer with age	white	12000-24000	13-48
High Sodium Pressure	Have replaced Mercury Vapour in many cities Pros: energy efficient, medium life span Cons: yellow colour, contain mercury and lead	Golden yellow	12000-24000	45-130
Compact fluorescent	Only for small street lights Pros: very energy efficient, good colour rendering Cons: limited size; become dimmer with age, contain mercury	Soft white	12000-20000	50-80
LED	Rapidly evolving technology, that is expected to become mainstream Pros: very energy efficient, long life, low maintenance, Cons: high initial costs	white	50000-70000	70-150

Source: SEA, 2012: Energy Efficient Lighting Guide (modified)

Figure 9: Examples of street lighting technologies

Source: SEA. (2012) Sustainable Energy Africa. Energy Efficient Lighting Guide

Figure 10: Solar street light

Photographer: Milton Dawson

Source: https://commons.wikimedia.org/wiki/File:Mammoth_Lakes_CA_Solar_Street_Lights.jpg

SOLAR STREET LIGHTS

Solar street lights do not need a connection to electrical grid and are therefore a solution for areas without grid connections. They are stand-alone units consisting of solar panel, battery, LED light and light sensor that switches it on and off at dusk and down. Suppliers claim a life span of five years. The life span of the battery may be shorter. Theft is being experienced as a problem of solar street lights.

FINANCIAL ASPECT

The replacement of mercury vapour streetlights with high pressure sodium (HPS) streetlights is becoming the norm in cities, due to the energy and financial savings achievable. LED lights are the technology of choice due to their long life and related low maintenance costs. They are still relatively expensive but are being introduced increasingly due to their versatility and quality of lighting. They are already cost competitive with pay-back periods of around seven years when replacing inefficient mercury vapour lights. It is anticipated that the costs of LED street lights will further come down making them fully cost competitive.

The costs of a solar street light depend on its brightness and can be anything between R5000 and R30000. At this cost and considering the risk of theft it is expected that solar street lights will only be used in special circumstances in the near future.

Traffic Lights

Traffic lights are another financially viable field for energy efficiency interventions. The replacement of incandescent or halogen light bulbs with LED ones saves up to 80% of electricity. In addition, LED lights have a much longer life span than incandescent and halogen lights. This reduces the maintenance cost of traffic lights.

Table 2: Comparison of cost and power consumption of traffic light technologies

Cost and energy comparison			
	75W Incandescent	55W Halogen	LED 8-10W
Purchase price for a single traffic signal bulb (R)	14	8	400
Electricity usage (W)	75	55	10
Lumens (lm)	1100	1500	1300
Lumens/watt	15	27	130-160
Lifespan (hours) for single bulb @ 8hours/day	960	960	14400
Bulb cost over 10 years @ 8 hours/day	420	240	800
Energy consumption over 10 years for single bulb (KWh)	2160	1584	288
Energy cost over 10 years @ ave electricity rate of R0.81/KWh (at est 10% increase p.a) (Rands)	1749.6	1283.04	233.28
TOTAL Cost over 10 years for single bulb	2169.6	1523.04	1033.28
TOTAL Cost over 10 years for single aspect (3 lights)	6508.8	4569.12	3099.84
Cost saving with LED retrofit of Incandescent traffic signal (single aspect, 3 lamps) over 10 years			R 3 408.96
Energy consumption over 10 years for single bulb	2160	1584	288
Energy consumption over 10 years for single aspect (3 lights)	6480	4752	864
Energy saving with LED retrofit of Incandescent traffic signal (single aspect, 3 lamps) over 10 years (KWh)			5616 KWh
Carbon emissions reduction (t CO_2e)			5.8 t CO_2e

Method notes:

Life span of incandescent and halogen bulbs based on 4 months; LED based on 5 years.

Average electricity costs estimated as R1.00/kWh.

Reduced maintenance costs excluded from calculation.

Source: SEA. (2012). Energy Efficient Lighting Guide, updated 2017

FINANCIAL ASPECT

There is a very strong case for energy efficient technologies in street lights as LED lights reduce the electricity and maintenance costs strongly. Due to the increased cost of electricity, the payback period of installations made today will be significantly less than 3 years.

Figure 11: eThekwini Municipality, Energy Efficiency Staff Campaign Poster

Source: eThekwini Municipality, Energy Office

Awareness Campaigns

Awareness campaigns should promote energy saving in the workplace and at home includes in lighting. It is important for the success of awareness campaigns that messages are sustained, varied and engage the target group. This can be achieved through information on achieved energy savings, requests for feedback, or competitions.

Awareness of energy efficiency also needs to be built amongst municipal staff involved in the procurement and maintenance of lighting equipment. Energy efficiency must determine the procurement policy of lighting equipment.

The business case for energy efficient lighting is strong and municipalities should raise awareness with other government institutions, businesses and the general public of the benefits of energy efficient lighting. This can be done through environmental education campaigns, and in partnership with organised business and education institutions. The municipalities should participate in national programmes should they be implemented again such as the mass distribution of CFL to households in their areas of jurisdiction. These programmes should particularly target poor households for whom the higher price of CFL is a barrier to realising the savings of electricity costs. Distribution programmes should be repeated to prevent households from reverting to incandescent bulbs once CFL lights are broken.

Municipalities are responsible for waste management and campaigns for energy efficient lighting must raise awareness of the disposal of CFLs and fluorescent tubes that contain mercury vapour. The safe disposal of CFLs is an important environmental issue which needs serious attention. Municipalities should cooperate with the electrical appliances and recycling industries to develop a safe disposal system that is easily accessible for consumers in all parts of the municipality.

Barriers and opportunities

The main barrier to implementing energy efficient lighting is the high initial costs of installing new lights. Due to the decreasing costs of the new technologies this barrier is diminishing. In the short term it can be addressed by

- using grant funding programmes like the EEDSM provided by the Department of Energy;
- establishing a policy to implement energy efficient lighting especially in buildings where the pay-back periods are typically less than 3 years;

Other barriers are limited capacity and knowledge of municipal officials and companies in this field. With the energy efficient technologies fast becoming main stream solutions the competence is growing. Training courses should be provided to municipal staff responsible for maintenance and specialised lighting such as street and traffic lights.

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Case study 1: LED Traffic lights in eThekwini Municipality

LED traffic lights consist of arrays of tiny light emitting diodes that are extremely energy efficient and have a very long life. Each LED is about the size of a pencil eraser, and hundreds of them are used together in an array. The LEDs are replacing the old-style incandescent halogen bulbs rated at between 50 and 75 watts. LED units have three main advantages:

- *LEDs are more visible because the LED array fills the entire surface of the traffic light making them brighter overall.*
- *LED bulbs last for years, while conventional bulbs in traffic lights only last for months. The longer replacement intervals reduce the maintenance costs considerably.*
- *LED bulbs save up to 80% of electricity.*

Between 2009 and 2011 the eThekwini Municipality has installed LED lights in all traffic lights.

- *41 000 lights replaced at 759 intersections;*
- *Project cost: R41m;*
- *80% saving of electricity achieved amounting to around 6MWh/year;*
- *Substantial saving on maintenance costs;*
- *Electricity savings along would have resulted in 10 years pay-back period but the additional savings of costs have resulted in 3 to 4 year payback period; and*
- *Savings of approximately 6000t CO_2e of greenhouse gas emissions per year.*

Figure 44: LED traffic lights in Durban

Source: http://www.durban.gov.za http://www.durban.gov.za/City_Services/energyoffice/Enery%20Office%20Project%20Pictures/LED_traffic_lights_LR_02.jpg

Between 2009 and 2011 eThekwini Municipality installed LED lights in all its traffic lights.

Case study 2: Efficient Lighting in Municipal Buildings in Ekurhuleni Metro

The Ekurhuleni Metropolitan Municipality (EMM) institutionalised a sustainable energy approach through energy efficient practices in its municipal buildings already in 2005. The Germiston Civic Centre and EGSC buildings, serving as EMM's political head office and administration head office respectively, were identified for energy efficiency retrofits in 2005.

Among the energy efficiency measures implemented in both buildings, was the replacement of incandescent lights with CFLs, the replacement of cool-beam down lighters with LEDs, and the replacement of ninety-six, 8-foot double fluorescent light fittings with 5-foot double fluorescent lights with electronic ballasts. In addition lighting timers have been installed. In total 2003 CFLs, 90 LED lights and 2 lighting timers were used for the lighting component of the project. The CFLs were found to be highly efficient. The efficient lighting installations achieved substantial savings:

- *Pre retrofit energy use: 387 718 kWh/year*
- *Post retrofit energy use: 109 894 kWh/year*
- *Energy savings: 277 823 kWh/year*
- *Percentage of energy savings from the use of CFLs and LEDs: 75%*
- *Percentage of energy savings from the use of fluorescent lights with electronic ballasts: 13 %*

The emissions reduction for greenhouse gases represented in CO_2 equivalent and other pollutants such as NOx and SOx were:

CO_2e reduction: 260 tonnes/year

SOx reduction: 2205 Kg/year

NOx reduction: 1 035 Kg/year

This retrofit project of the lighting component alone has resulted in 387 718 kWh of energy saved in one year. In this year it achieved saving in the order of R369 000 and a payback period of less than year. Additional benefits are the GHG emission reduction of around 260 tons of CO_2e, 2.2 tons of SOx and 1.1 tons of NOx per year. It is noted that this project was installed at a time of little experience with the new technologies. Apparently, the users were satisfied with the equipment and lighting quality.

Figure 12: various images of the Ekurhuleni case study

EGSC Building

Germiston Civic Centre

8 foot double fluorescent lights

Lights timer set to switch on at 5h30 and switch off at 19h00

Source: ICLEI. (2005). Improving Energy Efficiency in Ekurhuleni Metropolitan Municipal Buildings

Lessons learned

At the time of this project in Ekurhuleni energy efficiency technology and equipment were new in the South African market and it was difficult to find sufficiently experienced tradespeople. This has changed and the CFL and LED are now mainstream products that are produced in the country. Therefore these technologies must be mainstreamed.

The formulation of the policy on Energy Efficiency in Council Buildings and on Council Premises, the State of Energy Report, the draft Energy Efficiency and Climate Change Strategy of Ekurhuleni and the subsequent retrofit project have been part of the Ekurhuleni municipal strategy that can be replicated in other South African cities.

Case study 3: Efficient Lighting in City Health Building in eThekwini Municipality*

Figure 13: eThekwini Municipality City Health Building

Photo: S. Godehart

The City Health Building has been selected to pilot an energy efficiency programme for municipal office buildings in eThekwini Municipality. The pilot is being carried out in collaboration between the Energy Office, the Architecture Unit and the Health Unit. The purpose is to assess the energy consumption of a building and select, implement and monitor the most effective measures. The project was funded by the EEDSM programme. The assessment was carried out by consultants in 2013. The measures were implemented by a contractor in the same year.

The City Health Building is a 4-storey office building that accommodates 2 labs, an auditorium and large storerooms. The floor area of the building is 11,200m^2. It was built around 1970. Since then the internal uses of the building has changed and the additional light fittings have been added to the system show in the photograph below.

Baseline Assessment

The baseline assessment showed that lighting constituted 32% of the power balance in summer and 39% in winter. It was therefore a large component of the overall electricity demand.

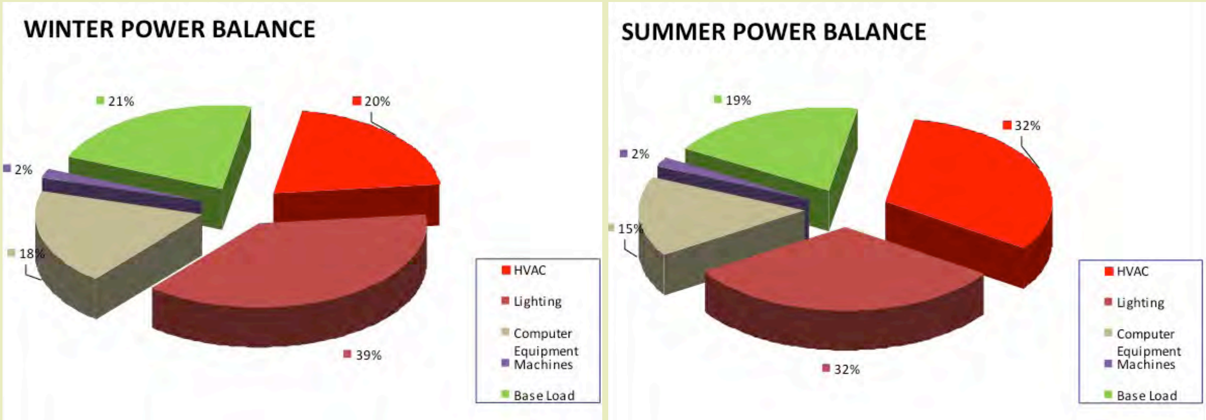
A specific lighting assessment was conducted. The methodology included the compiling of electrical energy balances and noting areas for increased optimisation. The assessment included the following elements:

- *Monitoring of power consumption,*
- *Inspection and measurement of the lighting installation,*
- *Calculation of lighting energy usage, &*
- *Calculation of energy savings.*

The lighting installation comprised almost entirely of fluorescent lamps fitted in a varied range of light fittings. Linear fluorescent lamps made up 96.5% of the light sources in the building and the bulk of these fittings were dated and fitted with magnetic ballasts.

* This case study draws extensiviely from: eThekwini Municipality EEDSM 2013-14, Baseline Report: City Health Building. Unless referenced otherwise, information is sourced from this document.

Figure 14: Winter and summer breakdown of demand for electricity in City Health Building

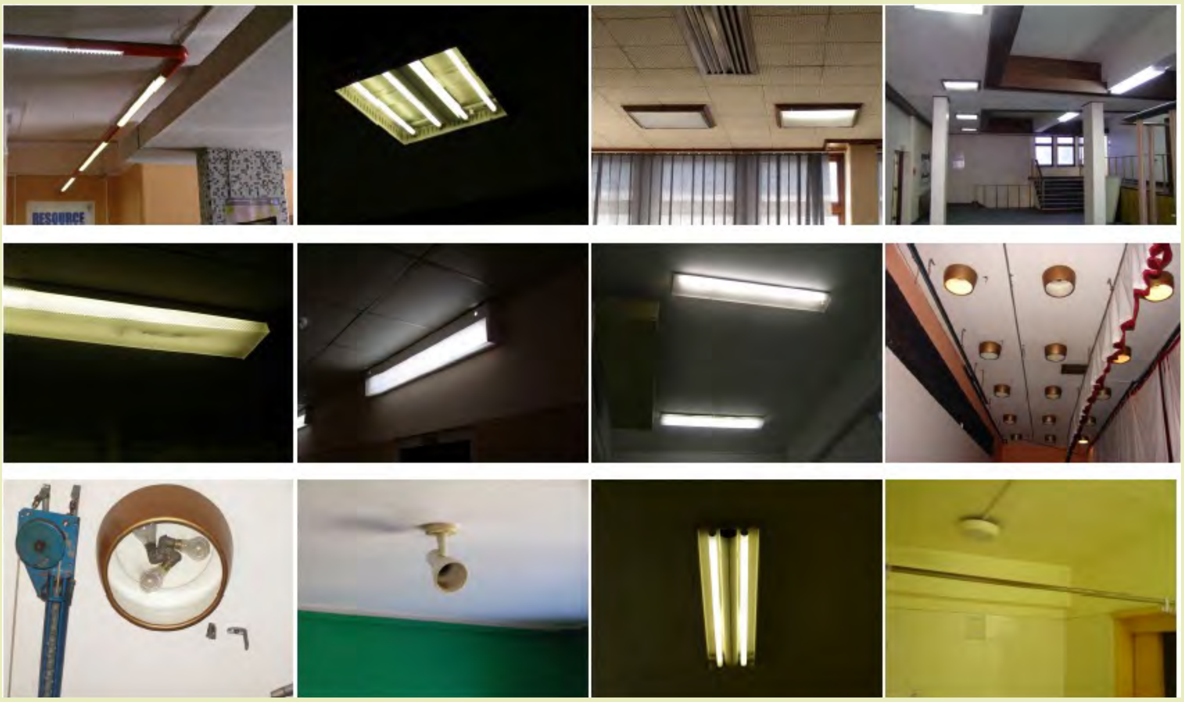


Source: eThekwini Municipality EEDSM, 2013-14

Minimum lighting levels were generally exceeded but the task lighting was, for the most part, not acceptable. Staff discomfort was experienced. A complete redesign of the lighting is suggested to:

- *comply with the latest applicable standards;*
- *make use of new energy efficient light sources;*
- *standardise light sources for simplified maintenance; and*
- *introduce automatic switching and dimming devices.*

Figure 15: Examples of light fittings in City Health Building before redesign



Source: Presentation by SNA Consulting Electrical Engineers, 2013

Lighting Redesign

The entire building was measured and the lighting was modelled using energy efficient, task sensitive light sources. The new design is aimed at reducing energy consumption and annual maintenance costs as follows:

- *Reduction of high loss equipment;*
- *Removal of high energy light sources;*
- *Replacement with modern light sources and reflectors;*
- *Reduction and rationalisation of light sources; and*
- *Compliance with task and safety lighting requirements.*

The lighting redesign would make use of new energy efficient lighting technologies such as:

- *T5 fluorescent to replace the T8 fluorescent lamps (over 80% of lights);*
- *Fluorescent lamps to replace the incandescent lamps;*
- *LED lamps to replace the existing halogen lamps;*
- *Reduction of lamps from 2119 to 1571; and*
- *Rationalisation of types of light fittings from 25 to 6.*

Table 3: Proposed light fittings after redesign

SCHEDULE OF PROPOSED LIGHT FITTINGS				
LIGHT FITTING	**QTY**	**TOTAL LAMPS**	**RATING (W)**	**TOTAL (KW)**
2x49w T5 Low Brightness	353	706	49	34.594
2x49w T5 Prismatic	109	218	49	10.682
Recessed 3x14w T5 Prismatic	165	495	14	6.93
Recessed 18w CFL Downlighter	134	134	18	2.412
Compact Fluorescent Bulkhead	17	17	16	0.272
Compact Fluorescent Bulkhead	1	1	50	0.05
	779	1571		54.94

Source: Presentation by SNA Consulting Electrical Engineers. (2013).

The lighting redesign is expected to have the following costs and benefits:

- *Improved lighting for staff despite a reduction from 2119 to 1571 lights*
- *55KW reduction in connected lighting load;*
- *49KW reduction in operational lighting load;*
- *174MWh reduction in annual energy consumption;*
- *R 8500.00 annual maintenance cost savings;*
- *R 204 000.00 annual savings for electricity;*
- *R 960 000.00 estimated installation cost; and*
- *Estimated pay-back period of 4 years (considering increasing cost of electricity).*

Lessons learned

In this project the lighting system was completely re-designed. Many old fittings were removed or replaced with new ones. The investment was therefore higher than in other energy efficient lighting projects. However the project achieved additional benefits:

- *Energy savings of 174MWh/year;*
- *Reduced number of fittings from 2116 to 1571;*
- *Simplified and cheaper maintenance through rationalsation and reduction of light fittings; and*
- *Improved working conditions for staff through better task lighting.*

Many government buildings have been built in the 1960s to 1970s. Over time most of them had changes to how they were used and related additions to the lighting system. In buildings of this age re-design and rationalisation of the whole lighting systems is often justified.

Support organisations

Financial assistance

The Energy Efficiency Demand Side Management (EEDSM) programme provides grant funding to municipalities for energy efficiency projects in their buildings and facilities. Municipalities must apply to the DoE to benefit from the programme.

Department of Energy

https://www.energy.co.za

GIZ

South African German Energy Programme (SAGEN)

https://www.giz.de/en/worldwide/17790.html

Training

The Energy Training Foundation

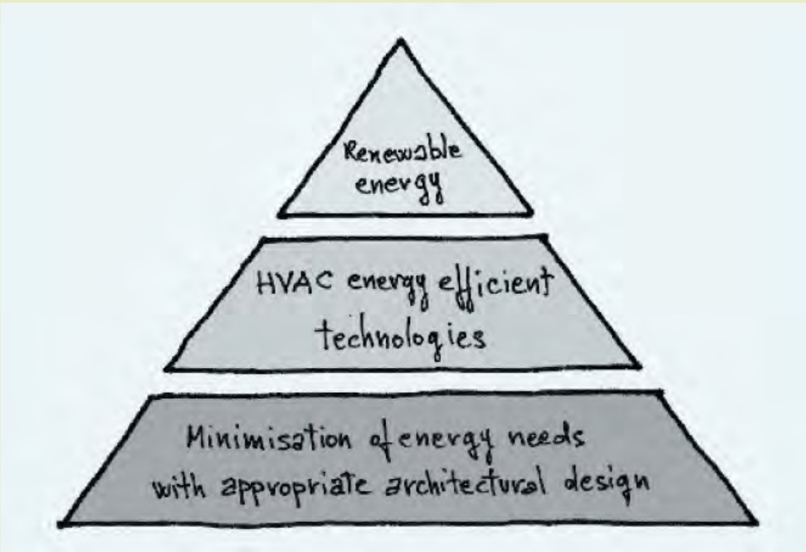
www.energytrainingfoundation.co.za

Energy Efficient Buildings

Overview

Buildings provide protection from the elements, shelter and comfort. Regardless of the weather the indoor temperature during the day and evening should ideally be in a range between 19 and 25°C that is comfortable for the large majority of people. A comfortable indoor climate can be achieved through building design that is appropriate for the local climate. This is also called 'passive solar design'. In addition, technologies for lighting, heating, cooling and ventilation are often needed that consume electricity or other forms of energy. These technologies are called 'active systems'. Energy efficient buildings seek to maximise the effects of passive design and to minimise the use and energy consumption of active systems. If the energy for the active systems is generated from renewable sources the building may become a 'net-zero energy building'.

Figure 1: Components of 'net-zero energy building'



Source: UNHabitat (2014) Sustainable Building Design for Tropical Climates

This section focusses mainly on how a comfortable indoor climate can be achieved through passive design and minimal use of active systems. Energy efficient lighting, water heating and renewable energy are discussed in other sections.

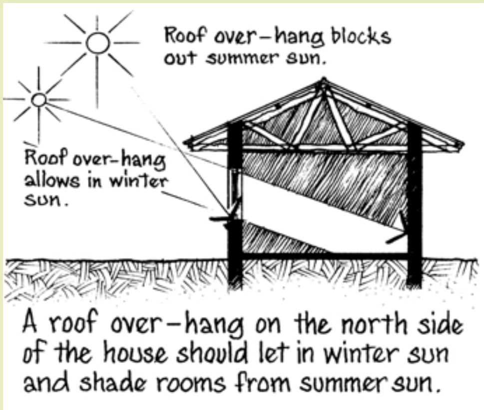
Energy Efficiency through Passive Design

The local climate plays the determining role in designing energy efficient buildings. The sun's movement, the prevailing wind direction, the temperature difference between day and night, and the humidity level are local climate conditions that vary from place to place. South Africa consists of several climate zones. Appropriate passive design measures and the need for active systems vary considerably in the different zones. Nevertheless, the basic principle remains that the suns warmth should be harnessed and retained in the colder winter months, and should be minimised during the hot summer months.

Examples of passive solar design are:

- **Orientation:** Depending on orientation rooms are warmer or colder. Well-used spaces should face north with overhangs over their windows. South facing rooms are cooler. East and west facing rooms can get very hot in summer as the low sun shines into windows without protection.
- **Shading:** Roof overhangs or other shading devices on the north side let in the lower winter sun but shade rooms from the higher hot summer sun. East and west facing windows often need vertical protection against the lower sun such as louvres or shutters. In hot climates vertical protection is also useful for north facing windows during equinox periods when the sun in lower in the sky.

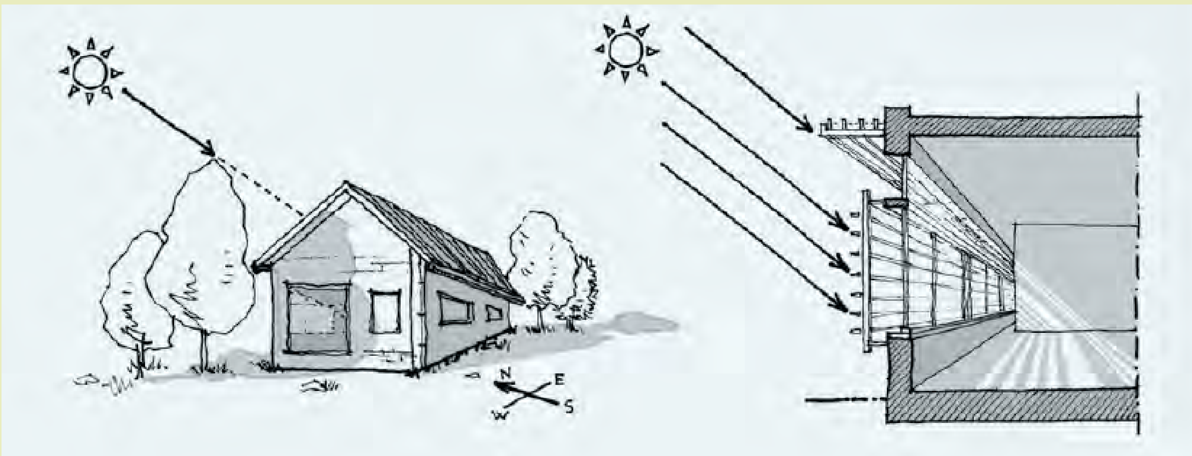
Figure 2: Advantages of a roof over-hang



Source: SEA (2009) How to implement energy efficiency and renewable energy options

- **Landscaping:** Planting evergreen trees or shrubs to block strong winds and deciduous trees to provide shade and reduce sunlight reflection in the summer, but let sun through during winter, help to reduce the need for heating and cooling.

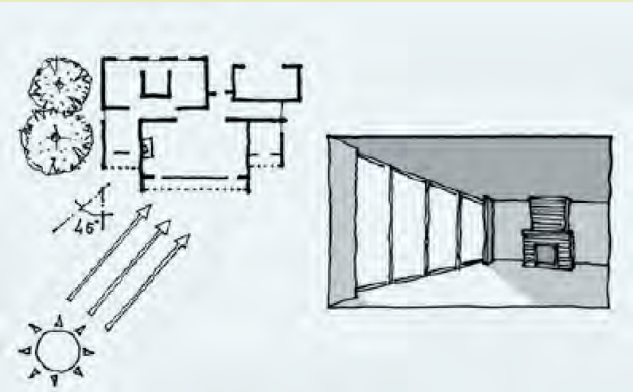
Figure 3: Protection of west facing windows by vegitation and louvres



Source: UN Habitat (2014) Sustainable building design for tropical climates

- **Windows**: Window in sensible orientation and size let in light and catch winter sun, but very large windows can prevent the retention of warm or cool air inside when desired. In some circumstances double glazing can help maintain internal temperatures, but it is relatively expensive.

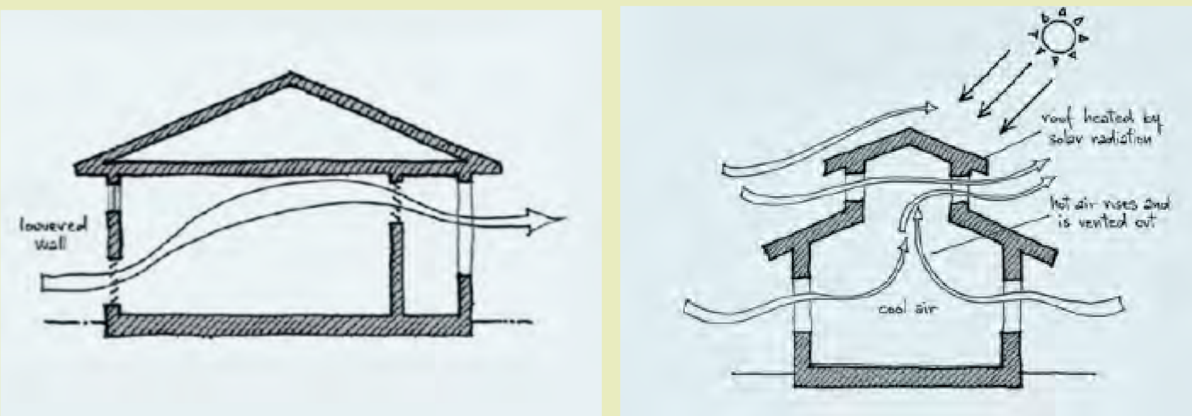
Figure 4: The low sun warms north facing rooms in winter



Source: UN Habitat (2014) Sustainable building design for tropical climates.

- **Ventilation:** Ventilation provides fresh air and cool breezes in summer. Ventilation is critical for health especially in rooms occupied by many people. In naturally ventilated buildings ventilation is achieved by opening windows. In addition air bricks ensure permanent ventilation.
- **Passive Cooling:** Natural ventilation can be enhanced by orienting the building to use the prevailing wind breezes for cooling. This requires inlet openings low to the ground and outlet openings in the opposite wall (cross ventilation). Opens plans maximise cross ventilation. Another method is to rely on 'the stack effect' of hot air rising inside and escape through vents in the roof. This also requires low level inlet openings.
- **Lighting:** Natural light through windows and light wells reduces the need for artificial lighting. Artificial lighting is an internal source of heat.

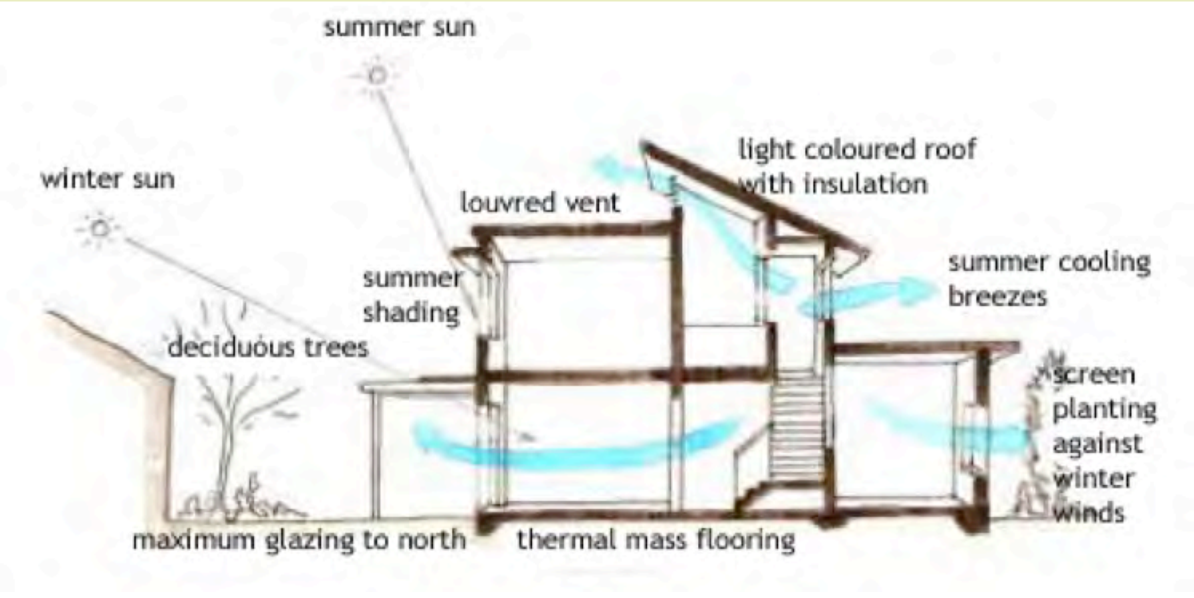
Figure 5: Cross-ventilation and 'stack effect' for ventilation and cooling



Source: UN Habitat (2014).

- **Building Materials:** Heavy materials such as concrete floors and brick walls absorb heat from direct sunlight during the day to release it at night, and absorb the coolness during the night to help reduce hot daytime temperatures. This contributes to keeping the building cool during the day and warm at night.
- **Surface Colours:** Light coloured paints and materials on roof and facades reflect unwanted solar radiation in summer (see textbox on Albedo Effect).
- **Insulation:** Insulation of the roof and (in cool climates) of the walls helps to keep the inside temperature warm in winter and cool in summer.

Figure 6: Combination of passive design measures for therma comfort



Author: Swapnika Reddy, 2015
https://www.slideshare.net/swapnika15/passive-coolingtechniques

Weather sealing and ventilation

A significant amount of energy is lost from buildings when the 'envelope' of the structure is compromised. Air leakage can result in major energy loss from a building, and ensuring the envelope is continuous and consistent minimizes this loss. Weather sealing is especially important in buildings with HVAC systems that need to work harder if conditioned air escapes through gaps.

Draft through gaps at doors and windows is the most significant concern and can usually be addressed at little cost. However weather sealing must not prevent sufficient ventilation. Especially in residential buildings with high occupancy such as low income homes a lack of ventilation often results in dampness and the development of fungus on walls. Fungus is a serious health hazard. In these cases health should be prioritised and air bricks installed to ensure permanent ventilation.

Many modern and especially commercial buildings have been built without much consideration of passive design and rely strongly on technology such as Heating, Ventilation and Air-Conditioning (HVAC) systems and electric heaters to provide a comfortable indoor climate. Using electricity for these functions is very inefficient and costly. Where active systems are needed, the following interventions can increase their energy efficiency:

- Replacement of electric heaters with gas heaters.
- Installation of efficient HVAC systems and minimal use of the systems only at hot times of day and year (see below for more detail).
- Installation of ceiling fans to increase air flow for comfort at higher temperatures that use far less power than air conditioners.
- Replacement of electric geysers with solar water heaters.
- Retrofitting of energy efficient lighting. It is noted that energy efficient lights produce less heat and thus reduce the need for cooling.

Implementation

Municipalities can influence the energy efficiency of buildings in three ways. Firstly, they have the responsibility to assess and approve development applications including adherence to energy efficiency and usage standards. Secondly, they can ensure that municipal buildings are energy efficient. Thirdly they can promote energy efficient buildings in their area of jurisdiction.

1. Development applications and approval. Municipalities are responsible for checking compliance with the NBR when they approve development applications. The standards for energy efficient design and construction and energy usage in buildings are part of NBR. Municipal building plan assessors need to apply the energy efficiency standards outlined above.
2. Municipalities must ensure that low-cost housing constructed in their area of jurisdiction complies with energy efficiency measures such as ceilings that have become standard through the directive of the Minister of Human Settlements of 1 April 2014.
3. Municipalities should strive to increase the energy efficiency of municipal buildings and facilities. This can be done through campaigns educating staff and municipal political leaders on energy efficiency in the workplace. The municipality should establish a policy that allows capital and maintenance budgets to be used for energy efficiency measures. The policy can also set targets for energy efficiency of new municipal buildings or for new buildings to achieve green star ratings. In addition, the EEDSM programme of the DoE provides grant funding for energy efficient municipal buildings. Further funding options for the implementation of energy efficiency measures are performance contracts with ESCO (see case study 5).
4. The municipality should educate building owners and developers on the benefits of energy efficient buildings. This can be done through campaigns and in collaboration with the local building industry. The municipality can also set conditions for sales of municipal land to investors such as that buildings must achieve Green Star ratings.

According to the post 2015 Natonal Energy Efficiency Strategy, the proposed targets for building are:

PUBLIC BUILDINGS

A 50% reduction in the specific energy consumption (measured in GJ annual energy consumption per m^2 of occupied floor area) by 2030 relative to a 2015 baseline.

RESIDENTIAL SECTOR

A 20% improvement in the average energy performance of the residential building stock by 2030 relative to a 2015 baseline, as measured by the energy consumption (excluding plug loads) per m^2 pf habitable space.

COMMERCIAL SECTOR

A 37% reduction in the specific energy consumption (measured as GJ annual energy consumption per m^2 of lettable / habitable floor area) by 2030 relative to a 2015 baseline.

Policy and Regulations

Buildings are the largest end users of energy globally and account for 40% of the world's end use of energy[1]. Energy efficient buildings make an important contribution to reduce energy demand and greenhouse gas emissions.

In South Africa the importance of energy efficient buildings has been acknowledged by government. The DoE has published the first draft Post-2015 National Energy Efficiency Strategy[2]. In its vision it promotes energy efficiency as the 'first fuel'. It contains baseline data for energy consumption in 2015 against which goals and targets for energy efficiency are proposed for different sectors.

The targets are to be achieved through measures like

- Successive tightening of standards;
- Green leases; and
- Utilisation of Energy Service Companies (ESCO).

The Strategy is still a draft for discussion and may change considerably but it clearly indicates that all sectors including municipalities to act on energy efficiency of buildings.

The South African Bureau of Standards (SABS) has published two standards for energy efficiency in buildings that must be adhered to in all new buildings, including low-cost housing, and in major refurbishments of existing buildings. As a private initiative, the Green Building Council South Africa (GBCSA) has been established. The GBCSA promotes green and climate appropriate buildings including higher energy efficiency. Both initiatives have resulted in considerable change in the building profession and industry.

National Building Regulations (NBR) for Energy Usage in Buildings

The NBR for Energy Usage in buildings have been published in 2011. They are based on the standards briefly explained below. These standards constitute a fundamental change to the building industry and practice in South Africa and a learning challenge for all who have to apply them. The construction industry has undertaken major capacity building efforts for building professionals. However, it is likely that capacity gaps persist, especially amongst officials such as building inspectors in smaller municipalities. This manual provides only an overview of the new regulations and does not replace capacity building and training.

Applying the new regulations requires some understanding of building physics because the regulations principally permit two routes of achieving the standards: the Prescriptive route and the

1 http://www.unep.org/sbci/AboutSBCI/Background.asp

2 Government Gazette 16 December 2016

Rational Design route. The prescriptive route applies the measures listed in the standards as 'deemed-to-satisfy' the requirements. It is the simplest route to compliance. However, for certain buildings the 'deemed-to-satisfy' measures cannot be applied, e.g. it may be impossible to design a north facing building on a small plot in a built up area or on a slope. In such situations, the Rational Design route offers greater freedom to achieve the energy efficiency targets. This route involves the modelling of the building and calculating its energy consumption. The Rational Design requires a specialist and is therefore generally more expensive.[3] The sections below only refer to the 'deemed-to-satisfy' measures.

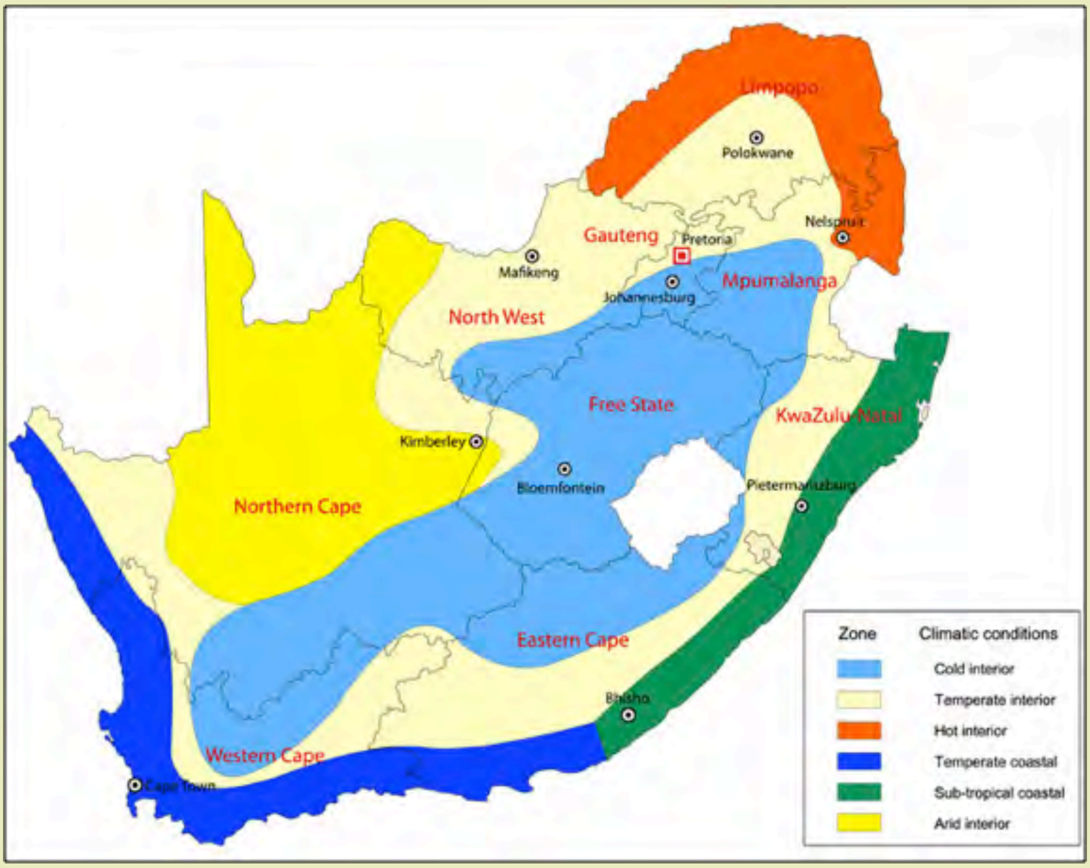
SANS 204: 2011 – Energy Efficiency in Buildings[4]

The SANS 204 standard specifies passive design and active systems' requirements for energy efficient buildings. It differentiates between buildings with natural ventilation and artificial ventilation / air conditioning. Efficiency requirements differ according to the climate zone in which the building is located.

CLIMATE ZONES

The standard defines six climate zones in South Africa indicated in the map.[5]

Figure 7: Climate zones in South Africa



Source: SANS 204 (2011) Edition 1.

3 Harris (undated) Handbook for the Application of the Amendments to the NBR for Energy Usage

4 SABS, SANS 204:2011 Edition 1

5 It has been acknowledged by the CSIR who has led the development of SANS 204 that the local climates in South Africa are so varied that up to 35 climate zones may be required to appropriately represent them. This is apparent for example in the significantly different climates of East London and Richards Bay who are currently in the same zone. The number of climate zones may be expanded in future updates of the standard.

Table 1: Description of climate zones with major cities

Zone	Description	Major cities
1	Cold interior	Johannesburg, Bloemfontein
2	Temperate interior	Pretoria, Polokwane
3	Hot interior	Makhado, Nelspruit
4	Temperate coastal	Cape Town, Port Elizabeth
5	Sub-tropical coastal	East London, Durban, Richards Bay
6	Arid interior	Upington, Kimberley

Source: SANS 204 (2011) Edition 1.

In these climate zones different energy usage is permitted and different 'deemed-to-satisfy' measures apply. The standard specifies maximum monthly and yearly energy consumption for buildings in the different climate zones. Compliance with the maximum permitted energy consumption can be achieved through passive design and energy efficient active systems.

PASSIVE SOLAR DESIGN

Deemed-to-Satisfy measures have been defined for:

- Building orientation: Spaces where people spend most hours of their days must face north. Uninhabited rooms such as bathrooms and storerooms can be used to screen unwanted western sun or to prevent heat loss on south facing facades.
- Sealing of the building envelop to limit air leakage: This is especially relevant for buildings with HVAC systems.
- Energy efficiency of building components such as floors, walls, roof, windows and shading: Building components must achieve thermal resistance values i.e. they must delay the transmission of heat or cold through the component by a certain number of hours. This can be achieved by using appropriate building materials and constructions. The number of hours varies in the different climate zones.

ACTIVE SYSTEMS – BUILDING SERVICES

Buildings require services for lighting, thermal comfort and hot water. The SANS 204 sets limits for their energy consumption. Examples are:

- Building designers are encouraged to maximise the use of natural light. Maximum standards for the energy consumption of lighting are prescribed.
- A minimum of 50% of the water heating requirements must be provided by means other than electric geysers. Alternative means include solar water heaters and heat pumps.
- In buildings with mechanical ventilation, HVAC systems must be designed to most efficient standards and should only supply areas in need of heating or cooling, not the whole building. It is recommended to set the thermostatic controls at 20°C in winter and at 24°C in summer.

SANS 10400-XA: 2011 – The application of the National Building Regulations Part XA: Energy Usage[6]

The SANS 10400-XA standard is a summary of the SANS 204 and other standards into a single reference for stakeholders to ensure compliance with energy efficiency requirements of the National Building Regulations (NBR). Requirements include:

- The orientation of buildings, with well-used areas facing North to make best use of natural sunlight and warmth;
- Suitable roof overhangs to keep out the high summer sun but let in the winter sun, when the sun is lower in the sky;
- Sensible fenestration (windows) to let in light and sun, but not so much that natural warmth or coolness cannot be retained;
- Use of appropriate heating, ventilation and air-conditioning installations where requires; and
- At least 50% of water heating must be done in an energy efficient way e.g. through a solar water heater or heat pumps.

The SANS 10400-XA is part of the NBR and must be adhered to. Municipalities are responsible for assessing and approving development applications including their adherence to the NBR (see section xx).

Green Building Council South Africa (GBCSA)

Green Building Councils exist in many countries. They are non-government and not-for-profit organisations promoting green buildings. In South Africa the GBCSA was established in 2007. "The Green Building Council South Africa leads the transformation of the South African property industry to ensure that buildings are designed, built and operated in an environmentally sustainable way."[7] The GBCSA does this by

- Raising awareness of the benefits of green building
- Supporting government to lead by example, to legislate and facilitate the adoption of green building practices.
- Recognising and rewarding industry leaders who achieve green building excellence.

The GBCSA has developed Green Star Rating Tools for the following building types

The tools rate green building measures in many categories such as Indoor Environment Quality (IEQ), Energy use, Water use, and embodied energy of Building Materials[8]. For each category credits are given if the building achieves improved environmental performance. The credits are weighted and a percentage score is calculated. If the score is sufficient the building will receive one of the following Green Star Certified Ratings:

- 4 Star Green Star Certified Rating (score 45-59) signifies 'Best Practice'
- 5 Star Green Star Certified Rating (score 60-74) signifies 'Australian Excellence'[9]
- 6 Star Green Star Certified Rating (score 75-100) signifies 'World Leadership'

6 SABS, SANS 10400-XA:2011 Edition 1

7 https://www.gbcsa.org.za/about/what-is-green-building/

8 Embodied energy is the energy that was used to produce the building material. For example cement has very high embodied energy and its use should be minimised.

9 The South African green star rating is based on the Australian system.

In the energy category the energy consumption of the building is modelled and compared to the SANS 204 minimum requirements. Credits are awarded for low consumption. In addition, credits are awarded for renewable energy installations.

The GBCSA has been very successful especially in the corporate sector and to some extent in the government sector. Green Star rated buildings have become prestigious attributes for companies and government institutions. To date more than 200 hundred buildings have been certified and rewarded four or more Green Stars.

Figure 8: The pictured new building occupied by the Department of Environmental Affairs in Pretoria has received the highest GBCSA rating of six Green Stars.

Source: GCBSA
https://www.gbcsa.org.za/news_post/public-get-to-experience-the-deas-leading-edge-green-head-office-with-the-green-building-council/

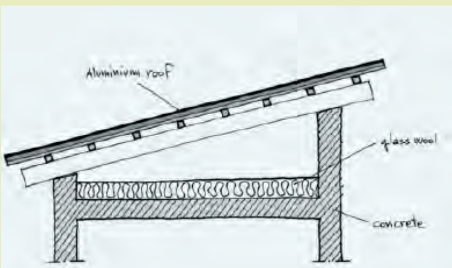
Retrofits to existing buildings

SANS regulations and the GBCSA rating system only apply to new buildings and to major refurbishments of old buildings but not to the existing building stock that makes up around 95% of all buildings. In order to increase the energy efficiency of these buildings retrofit measures are required. How to retrofit water heating and lighting has been discussed in previous chapters. Below are some examples of retrofit measures to improve the thermal performance of buildings and save energy for heating and cooling.

PASSIVE DESIGN

In existing buildings measures improving the energy efficiency are more limited than in new buildings. However effective retrofit measures include

Figure 9: Insulated ceiling



Source: UNHabitat (2014) Sustainable building design for tropical climates.

- Installation of ceilings and roof insulation. Especially in single story buildings the roof constitutes a large portion of the building envelope. The thermal performance of a roof can be improved through
    - the installation of aluminium foil insulation directly under the roof sheets; and/or
    - the installation of an insulated ceiling or the placement of insulation on top of an existing ceiling.
- Installation of shading devices such as awnings to north facing windows. In hot climate zones vertical shading devices

such as shutters and louvres reduce the heat gain of west and east facing windows and of north facing windows at equinox.

- Painting of roofs in light and reflective colours reduces the absorption of heat and results in a cooler interior.

Cool Surfaces: Cool Roofs (Albedo Effect)

Dark coloured roofs and other surfaces of buildings get very hot in the sun and transmit heat into the interior. White coloured roofs reflect the solar radiation keeping the interior cooler. This is called the Albedo effect. The term Cool Roof refers to roofs that reflect the radiation from the sun and increase the thermal comfort in buildings. The effect can be achieved or enhanced through reflective paints that are available in different colours.

The South African National Energy Development Institute (SANEDI) has conducted a project on cool surfaces. The project has established a database of approved reflective paint products.

The project focused on low-income housing and found that reflective coating dramatically improves the thermal comfort. The image shows corrugated iron sheets coated with cool paint. Before the coating they were too hot to touch, but after coating the temperature was reduced significantly.

However, the technology is also very valuable in buildings with HVAC. Cool surfaces reduce the cooling load and can cut the electricity used for air conditioning by up to 20% on the top floor.

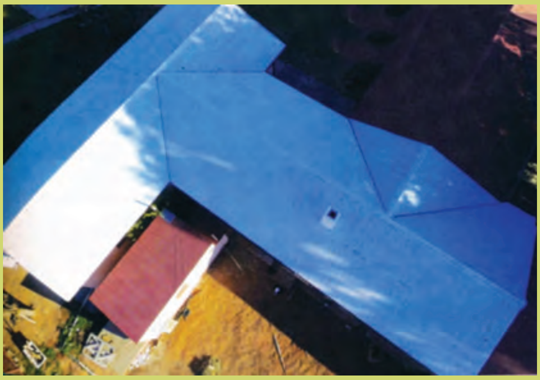
The image shows a cool roof in Groblersdal, Northern Cape, where the measured cooling effect in the building was between 7 to 10°C. However, SANEDI expects that the cooling effect in moderate climate zones will be between 2 to 4°C.

Figure 10: Reduced temperature of corrugated metal sheet through reflective paint

Photographer: Theresa Scheepers

Source: https://za.usembassy.gov/renewable-technology-makes-life-better-cooler-ask-kheis/

Figure 11 – Roof with reflective paint



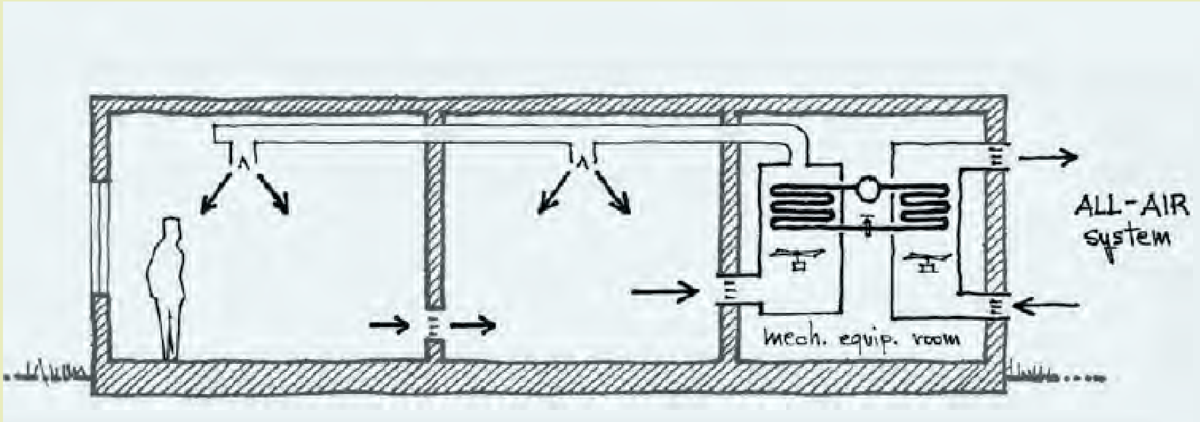
Source: courtesy of SANEDI http://www.sanedi.org.za/CoolSurface.html

ACTIVE SYSTEMS

HVAC systems are the main consumers of electricity in office and commercial buildings where they require 30% to 60% of the electricity used[10]. There are central HVAC systems, typically supplying large office and commercial buildings, and individual air-conditioning units supplying small buildings, single room or complement poorly performing central HVAC systems. There are many different types of central HVAC systems. The image below shows an all-air system where air is cooled and pumped through ducts and released into the rooms. Other systems use water as cooling medium or a combination of water and air.

10 van Els (2013) A simple guide to HVAC and lighting efficiency in commercial buildings. This guide provides details on energy efficient HVAC systems including retrofitting existing systems.

Figure 10: Central all-air HVAC system



Source: UNHabitat (2014) Sustainable building design for tropical climates.

HVAC systems should be designed in such a way that the temperature in different parts of a building can be regulated separately and switched off in rooms when they are not used (such as boardrooms). In older central systems this is often not possible. However, technical adjustments, improved management and behaviour changes of the occupants can increase the performance and energy efficiency of HVAC systems significantly. Below are a few measures to improve the energy efficiency of HVAC systems.[11]

- Using 'fresh' air to cool a building down at the start of the day. The outside air, even in summer, is cool early in the morning and by switching the air conditioning system's fans on, the cool air is drawn into the building. Not only does it lower the inside temperature, but it also flushes out the stale air from the previous day. In this way, the building is cool and fresh when the employees arrive, and operating of the energy intensive chillers is reduced.
- Adjustments to the temperature setting of the air conditioning system in line with the recommendations of SANS 10400 XA will result in substantial savings. The recommendation is for set points in winter at 20°C and in summer at 24°C. Each degree adjustment towards the outside temperature results in approximately 7% electricity savings of the HVAC system. A less severe difference between indoor and outdoor temperature is also healthier for the building occupants.
- Towards the end of the working day, the building's air conditioning system could "wander". This means allowing the temperature to gradually increase, given that employees are due to leave and will then encounter the temperature outside.
- In buildings that allow for natural ventilation (windows can be opened) the HVAC system can be switched off during months with moderate temperatures. This will require considerable education and campaigning as comfort at the workplace is a sensitive issue and many employees are so used to HVAC that they consider it a necessity at all times of the year.
- HVAC technology has improved greatly over the last years, and systems have become far more efficient. Some new air conditioning systems are 30% more efficient than their older counterparts.
- Heating requirements in South African buildings are relatively small and therefore most often provided by electrical elements in the HVAC system. This is a very inefficient way of heating. A several times more efficient system is a heat pump type HVAC system able to operate in reverse mode.[12]

11 For more detail see: UNHabitat (2014) and van Els (2013).

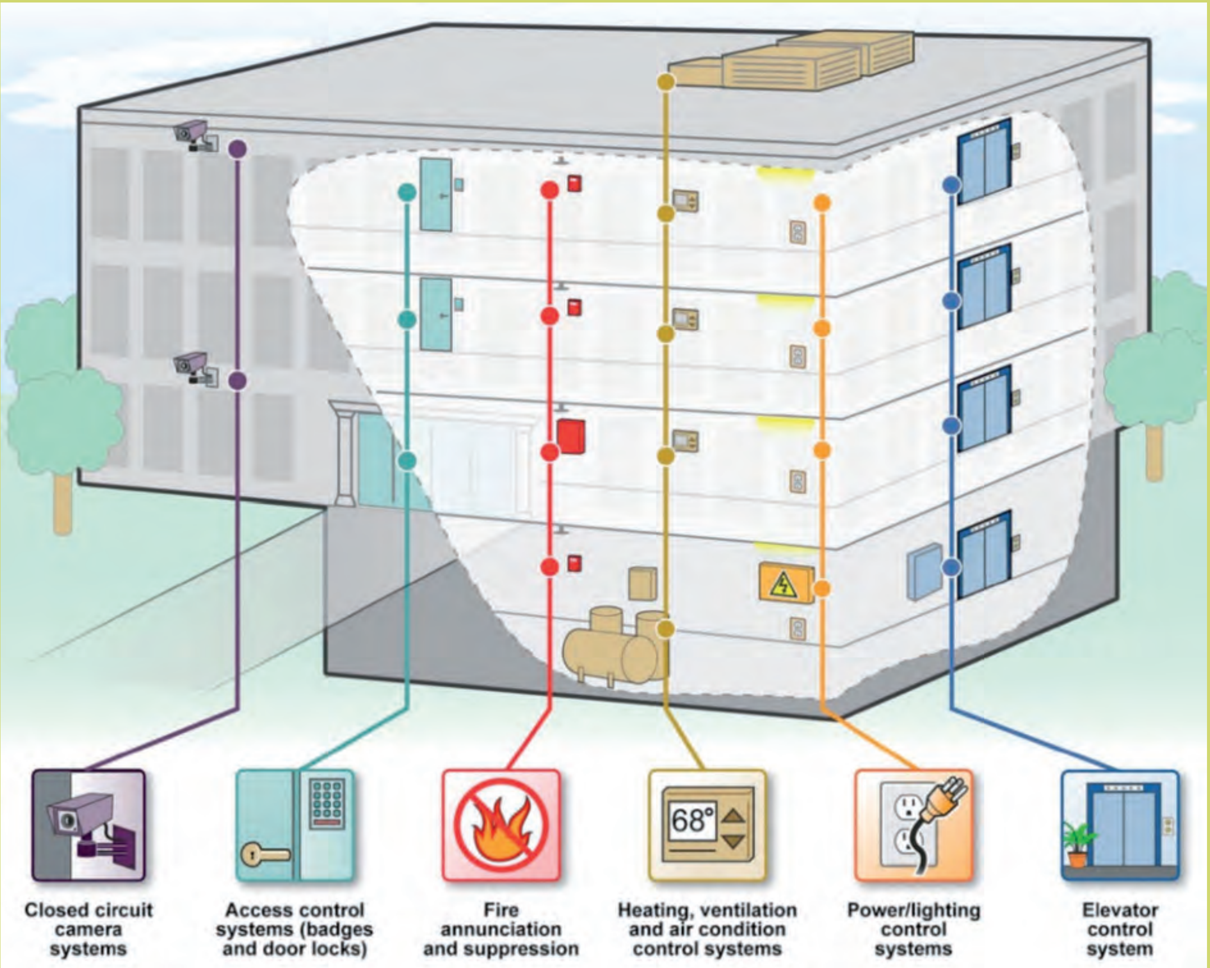
12 Van Els (2013).

Building Management Systems (BMS)

'A building management system (BMS), otherwise known as a building automation system (BAS), is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems.'[1]

BMS are typically installed in large commercial buildings, including Green Buildings where they ensure that systems operate efficiently throughout the life of the building.

Figure 11: Building Management System with multiple components



Source: US Government Accountability Office (2014) and GSA Should Address Cyber Risk to Building and Access Control Systems.

1 https://en.wikipedia.org/wiki/Building_management_system

BMS's main objectives are to keep the indoor climate within a specified range and provide lighting to rooms as required. They monitor the performance and device failures in systems, and provide malfunction alarms to building maintenance staff. Their core functions automate the following systems:

- HVAC,
- Lighting,
- Sun control, and
- Ventilation.

Additional functions can include:

- Electrical load management,
- Water systems,
- Security systems including access control,
- Fire detection, and
- Lifts.

A BMS can reduce the energy and maintenance cost of a building significantly compared to a non-controlled building. Older buildings have been retrofitted with BMS. This is typically financed through energy savings and savings associated with pre-emptive maintenance and fault detection

Financial Aspects

A 2016 study by the GBCSA of green star rated buildings in South Africa found that the costs of new green buildings are between 1.1 and 5% higher than the costs of conventional buildings[13]. This indicates that the extra costs of building green are marginal. Green buildings have substantially lower operating costs than conventional buildings of which energy costs are a large component. Therefore the business case for energy efficient buildings is strong.

This is reflected in the trend towards 'green leases'. A green lease contract combines the rent of space and the operating costs. Higher investment costs will result in higher rents but this is more than compensated by lower operational costs. The costs of renting green buildings are principally lower and more predictable than of conventional buildings as rising costs of services like electricity have less impact. Green features have often additional benefits regarding comfort and health and have become a marketing advantage.

There is a strong case for municipalities to apply green building principles to their own new buildings and to major refurbishments and to promote green building in their area of jurisdiction.

Barriers and opportunities

The retrofitting of existing buildings to increase the energy efficiency is generally more difficult and barriers differ according to the measures. The main barriers to retrofit are high investment costs for some measures and lack of capacity and technical expertise.

Barriers for energy efficient lighting measures are relatively low because typical payback periods are between two to four years.

13 https://www.gbcsa.org.za/news_post/building-green-costs-on-average-only-5-more-than-conventional-building-study/

Measures to reduce the energy consumption of HVAC range from low-cost measures, such as tuning the system, installing sensors and timers that have often pay back periods of less than a year, to major changes or the replacement of the HVAC system which have multi-year pay-back periods. Such measures also require significant expertise and experience.

Passive measures such as installation of shading devices, ceilings or reflective coating of the roof improve the thermal performance of a building and reduce the energy consumption of the HVAC system. However, the pay-back periods are building specific, e.g. measures to the roof have a much higher effect on energy consumption in single-storey than in multi-storey buildings. Choosing and designing the most effective measures requires significant expertise.

Costs and benefits of thermal energy efficient measures need to be designed and calculated for the specific building. Non-monetary benefits such as improved comfort and health of staff must be taken into account although they are difficult to monetarise.

Municipalities should use all funding opportunities for energy efficiency in public buildings (such as the EEDSM programme) and should train staff responsible for building management and maintenance in energy efficiency. A municipal policy on energy efficiency can provide a platform to raise awareness of politicians and staff and to initiate energy efficiency measures.

Case Study 1: Joe Slovo, Cape Town: Sustainable low-income settlement*

The Joe Slovo project is a national flagship housing project of the Department of Human Settlements (DHS). DANIDA, the Danish development funder, supported several sustainable energy interventions in the settlement, and Sustainable Energy Africa oversaw the implementation of these interventions together with JSA Architects.

The Joe Slovo settlement is situated in the suburb of Langa, 10 km east of the Cape Town CBD. The low cost houses in the settlement include the following sustainable design elements:

- *Improved thermal performance of buildings through insulated ceilings, roof overhangs and double storey, duplex block design i.e. reducing external wall exposure*
- *Improved energy services through energy efficient water heating through solar water heaters (150 litre low-pressure evacuated tube systems).*

Figure 12: Houses in Delft

Source: SEA (2014).

Figure 13 – Houses in Joe Slovo

Source: SEA (2014)

The images show the houses in Joe Slovo and conventional low-cost houses in Delft that were used to compare the impact of the sustainable features.

Solar water heaters

SWH were installed on all houses. A community survey conducted after occupation showed that the SWH were most appreciated measure. Prior to the installation households used an average of 8 kettles per day for water heating. Even on cloudy days in winter the SWHs were found to produce 30 to 40°C warm water.

Energy Efficient lights

The houses were equipped with CFL lights. It is noted that a safe disposal and replacement system is required to sustain this measure as poor residents may replace broken CFLs with cheaper incandescent light bulbs.

Thermal design features

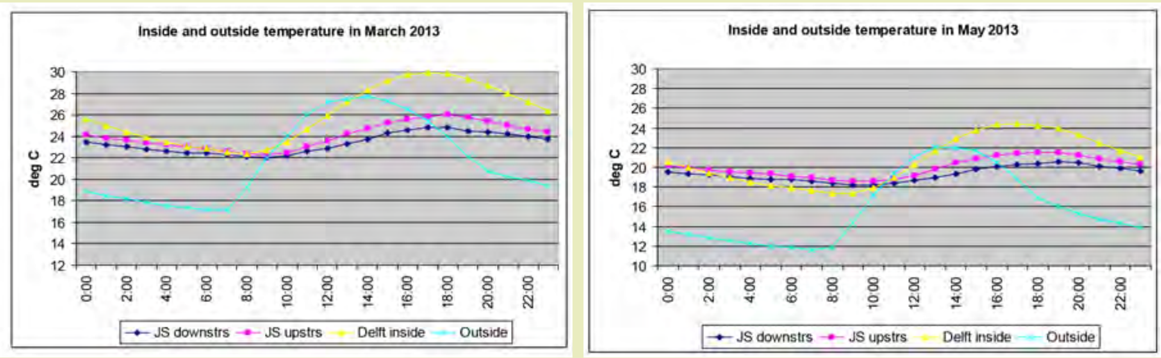
The thermal design was optimised with the help of a computer modelling package. The houses are double storey, and have shared walls reducing their exposure to outside air. Most houses are north facing with roof overhangs

* This case study draws extensively from: SEA (2014). Joe Slovo, Cape Town: Sustainable low-income settlement densification in well located areas. Unless referenced otherwise, information is sourced from this document.

shading windows on the top floor in summer. The houses have insulated ceiling which has become mandatory for low-cost houses through a directive from DHS in 2014.

The impact of the thermal design interventions was monitored and compared with a settlement of stand-alone RDP-type houses in Delft. It found improved thermal comfort in the Joe Slovo houses, being cooler in summer and warmer in winter than the houses in Delft. The figures below show the monitoring results of indoor and outdoor temperatures for Joe Slovo and Delft in summer (March) and winter (May) months. The indoor temperature in the Joe Slovo houses varies only between 18° and 26°C throughout the year while the indoor temperature in Delft houses varies between 17° and 30°C.

Figure 14: Comparison of indoor and outdoor temperature of houses in Joe Slovo and Delft



Source: SEA 2014

Case Study 2: Green Building, Cape Town

Being a promoter of sustainable energy approaches and practices, the founders of Sustainable Energy Africa wanted to show that a green office building can be built with limited financial resources. They aimed to do this through passive solar design and by reusing resources, recycling waste, reducing energy consumption, using renewable energy sources, locally sourcing materials, and reducing water consumption.

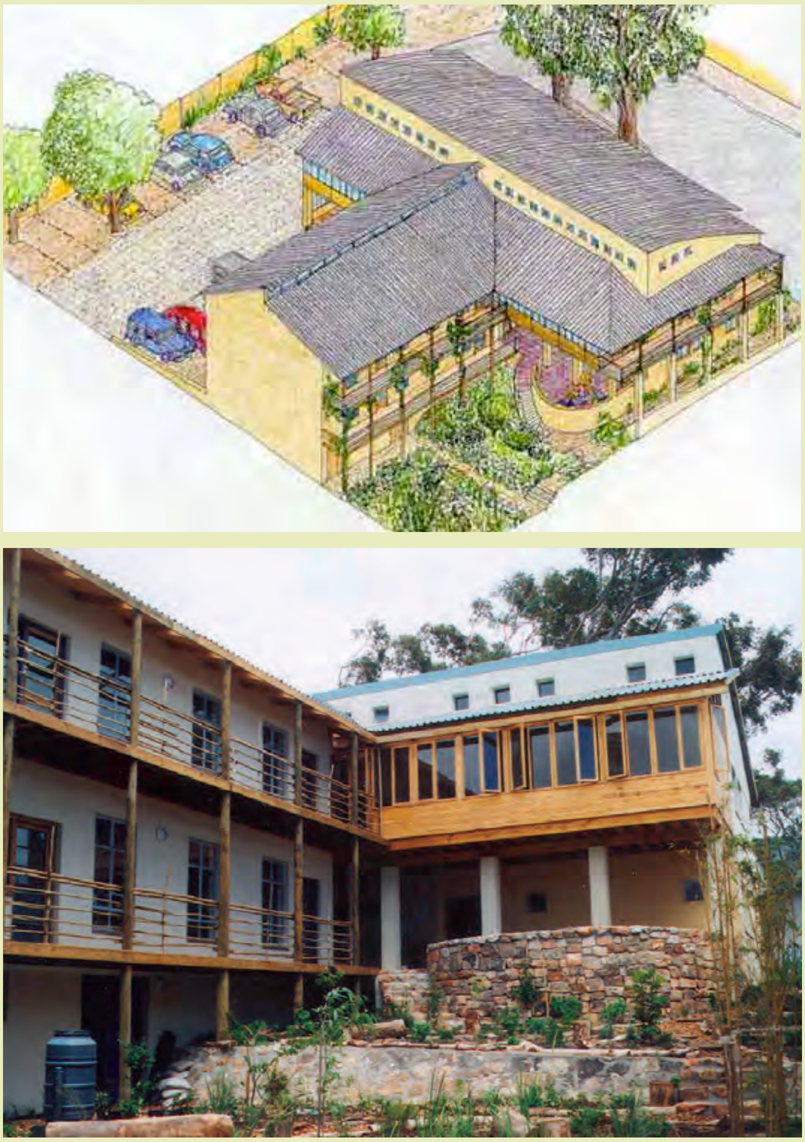
INTERVENTIONS

A number of passive solar design features were used to achieve the energy efficiency of the Green Building, including building orientation, shading of windows, and thermal mass. These dramatically reduced the energy required for heating and cooling. The use of natural light was maximized by optimising window area and avoiding deep office spaces. This has made artificial lighting during the day almost unnecessary. Hot water is generated by a solar water heater on the roof. Solar photovoltaic panels generate electricity that is fed back into the City's power grid if not consumed on site.

During the construction of the Green Building, recycled materials were used for windows, doors, and timber flooring. Reconstituted bricks containing 92% recycled material were used throughout the building. The materials were locally sourced, minimizing transport to the site.

Water consumption has been reduced by using dual-flush toilet cisterns and low-flow taps and shower heads. Recycled grey water and harvested rainwater take care of the water requirements of the water-wise garden. External paving in the parking lot of the Green Building allows water seepage into the aquifer.

Figure 15: Sketch of the Green Building in Cape Town



Source: SEA, 2009

The result of the green interventions is a building that surpasses most energy efficiency targets. An office building is considered efficient if it uses less than 100 kWh/m^2/year. The Green Building uses only 30-50 kWh/m^2/year, whereas conventional offices use 250-400 kWh/m^2/year. The cost of the building was 30% lower than the cost of a conventional building, and the value of the building increased by 32% after two years. Also, it has been consistently fully let since completion, showing that 'green' and 'commercially viable' are entirely compatible objectives.

AWARDS

The Green Building received the 2004 Sustainable Building Best Practice Award for noteworthy sustainable buildings in Africa, with a score of 3.9 out of 5 concerning social, economic, and environmental factors. It also received the 2004 Cape Times Caltex Environmental Award for outstanding achievement in environmental conservation.

Case Study 3: Eastgate, Harare, Zimbabwe*

The Eastgate Centre is a shopping centre and office block in central Harare, Zimbabwe. It provides 5,600 m² of retail space, 26,000 m² of office space and parking for 450 cars. It was probably the first building in the world to use natural ventilation and cooling to this level of sophistication.

Figure 16: Eastgate complex in Harare, Zimbabwe

Source: UNHabitat, 2014

The building form is two nine-storey parallel 146 m ×16 m plan blocks, linked by a 16.8 m wide glass-roofed atrium, with its long axis oriented east-west. The upper seven storeys of office accommodation have double slab floors to enable overnight cooling by outside air. The two lower storeys and the two basement car parking levels have conventional mechanical supply and extract ventilation; the former can be equipped with mechanical cooling if required by their retail tenants.

The building was modelled on the way that termites construct their nest to ventilate, cool and heat it entirely through natural means. The local climate – similar to the South African Highveld – with warm days and cool nights, is ideal for natural ventilation combined with night cooling. The other key factor (an economic one in this case) against the use of a conventional HVAC system was the high cost of importing such plant, the potential lack of skilled labour to service and maintain it, the cost of running it in energy terms, and the frequent power cuts.

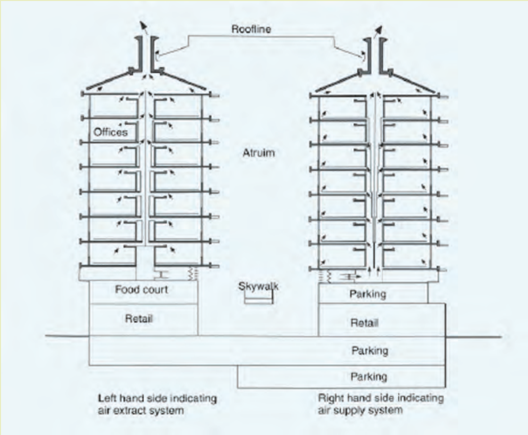
Appropriate building orientation, extensive shading and glazing restricted to 25% of the façade were used to keep external heat gains to a minimum, while great efforts were made to limit internal heat gains.

According to computer simulations, the natural stack effect was not sufficient to cool down the building so simple, low power, locally made fans are used to ensure that all floors receive the same quantities of cooling, fresh air.

The energy concept is based on the termite mound analogy: the building mass is used as insulation and the diurnal temperature swings outside keeps its interior uniformly cool. The architects and engineers devised an air-change schedule that is significantly more efficient than in other climate-controlled buildings in the area. Fans suck fresh air from the atrium, blow it upstairs through hollow spaces under the floors and from there into each office. As it rises and warms, it is drawn out through 48 round brick funnels. During cool summer nights, big fans send air through the building seven times an hour to chill the hollow floors. By day, smaller fans blow two changes of air an hour through the building. As a result, the air is fresh, much more so than that from an

* This case study draws extensively from UNHabitat (2014). Unless referenced otherwise, information is sourced from this document.

Figure 17: Section through atrium showing ventilation



Source: UNHabitat 2014

Figure 18: Eastgate atrium

Source: UNHabitat, 2014

air conditioner which recycles 30 percent of the air that passes through it. The distribution system incorporates small-capacity (250–500 W) electric heaters in the supply grilles. The exhaust air is finally extracted into vertical stacks, which in turn lead to the chimneys visible on the roof.

Eastgate's ventilation system has cost one-tenth that of a comparable HVAC system and uses 35 per cent less energy compared to conventional buildings in Harare. The peak temperature in the offices is some 3°C less than it is outside.

Case Study 4: Hotel Verde, Cape Town*

The Hotel Verde has received 6 stars, the highest rating by the Green Building Council South Africa (see section xx Energy Efficient Buildings) for Existing Building Performance it is also LEED (Leadership in Energy and Environmental Design by the US Green Building Council) Platinum certified for both Design & Construction as well as Existing Building: Operation & Maintenance.

Its energy efficient features include:

- *220 Photovoltaic panels,*
- *Three wind turbines (vertical axis),*
- *Regenerative drive elevators,*
- *Energy efficient lighting system with LED lights and occupational and daylight sensors,*
- *Energy-saving heating and cooling system coupled to ground source heat pumps,*

* All information fro this case study provided by André Harms, director and principal sustainability manager at Evolution Consulting (January 2017) www.hotelverde.com

Figure 19: Aerial view of Hotel Verde in Cape Town

Photo: André Harms

- *Intelligent Building Management System (BMS),*
- *Many passive design strategies such as double glazing and PV panels as shading devices of windows; and*
- *Energy generating gym equipment.*

Figure 20: Vertical wind turbines

Photo: André Harms

Figure 21: PV panels used to shade north facing windows

Photo: André Harms

The innovative HVAC system achieves extraordinary efficiency through a geothermal loop field coupled to ground source heat pumps for central heating/cooling and domestic water heating. The geothermal field consists of 100 boreholes, each approximately 65m deep. Each hole contains a U-bend pipe. Combined, there is approximately 13 km of piping beneath the footprint of the building. Water passes through these pipes to either dump heat (in summer) or gain heat (in winter) from the constant ground temperature at this depth of around 19.4°C, thus using the earth as a huge thermal battery.

This system is well suited for a hotel project in the Cape Town climate as the heating and cooling loads are reasonably balanced over an entire annual cycle and the ambient-, heating-/cooling- and ground-temperatures are such that one can extract energy out of the ground in winter and reject energy into the ground in summer.

The hotel has about 12000 m² usable surface area and the plant has a capacity of 304kW in cooling, 364kW of heating only or 182kW for heating plus 167kW for hot water generation.

Figure 22: Geothermal field of 100 boreholes extracting or dumping heat

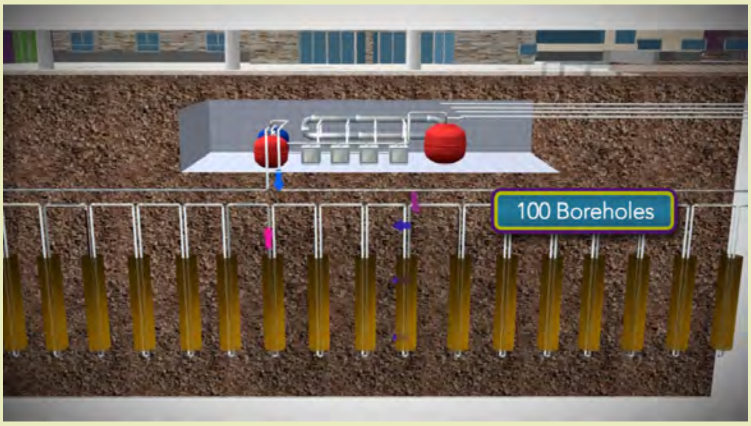


Photo: André Harms

At the time of construction (2013) the costs of the system were approximately:

- *Geothermal installation (incl. extra earthworks, P&G, fees etc.): R6m*
- *Plantroom: R9m – R10m (incl. equipment, logistics, installation, delayed commissioning, variation orders, fees etc.)*

The system saves around 50% of the electrical energy a conventional HVAC system would require. The expected payback period is 5 to 7 years.

Figure 23: HVAC plant room

Photo: André Harms

Figure 24: BMS monitor

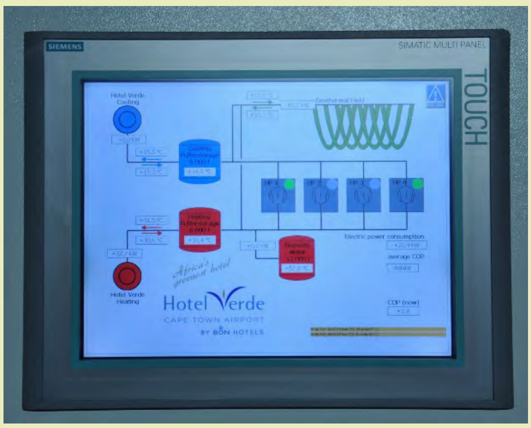


Photo: André Harms

In addition to the technical features education and awareness raising measures are in place. An internal sustainability TV channel displays figures of the BMS illustrating resource consumption and savings to the hotel guests. Signs encourage the use of stairs whilst the gyms' signature concept "What the Watt" engages the guests: the gym machines feed into the electricity grid and the user experiences how hard it is to generate electricity versus how easy it is to squander it.

All information from this case study provided by André Harms, director and pricipal sustainability manager at Evolution Consulting, January 2017.
www.hotelverde.com

Case Study 5: Performance Contracts for Energy Efficiency Measures

Energy performance contracts refer to the practice of contracting with energy service company (ESCO) to guarantee that the full costs of energy efficiency interventions will be paid back through the energy savings resulting from the interventions. For performance contracts to work, the savings during the contract period must be greater or equal to the investment costs.

There are two types of performance contracts:

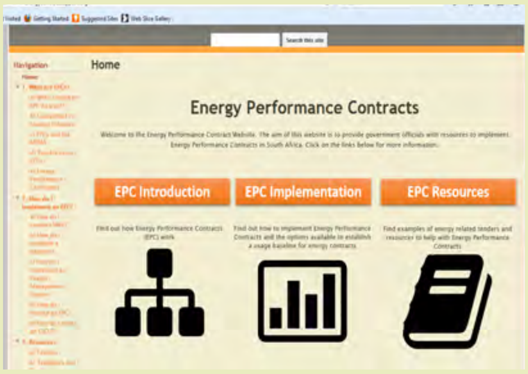
Guaranteed saving contracts

In the case of a Guaranteed Saving Contract the municipality pays for the energy efficiency measures and the ESCO implements them and provides the municipality with a financial guarantee that projected savings will be achieved for a number of years. If the savings are not achieved the ESCO will reimburse the difference to the municipality. The advantage of this type of contract is that the municipality has financial certainty that it will get its investment back over a specified period of time. A disadvantage is that procuring performance contracts through the municipal supply chain management system is difficult. However, the City of Cape Town has resolved these difficulties and has documented their experience with Guaranteed Savings Contracts.[14]

Shared saving contracts

In the case of a Shared Savings Contract the ESCO finances the energy efficiency measures through loans and the municipality pays for them through the savings that the measures achieve. The advantage of these contracts is that the municipality does not have a capital expense. The disadvantage of these contracts is that the interest on the loans increases the costs and the pay-back period. Therefore the contract period is likely to exceed three years, which requires a more complex procurement process by the municipality such as applying the process outlines in Section 33 of the MFMA. Also, maintenance of installed equipment during the contract period, adds to the contractual complexity. Very limited and not always positive experiences exist in municipalities with this type of contracts.

Figure 25:



Source: Sceenshot of http://www.energycontractsupport.org/

The South African Cities Network has set up a website (http://www.energycontractsupport.org/) where the concepts of contracting with ESCOs are explained in a step by step approach.

Further information on ESCOs can be found on the website: www.escos.co.za. This website makes reference to several cases studies in the private and public sector including Guaranteed Performance Contracting by the City of Cape Town.

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14 SALGA (undated) Energy Performance Contracting – experiences from the City of Cape Town http://www.cityenergy.org.za/uploads/resource_305.pdf

Support organisations

CSIR

Technical support

CSIR can offer support in the areas of research and technology (including testing), training and capacity building. Cities can engage with them as necessary.

www.csir.co.za

Department of Energy (DoE)

Capacity building, policy development, funding

www.dme.gov.za

Development Bank of Southern Africa (DBSA)

Debt Financing and a limited Technical Assistance grant facility.

www.dbsa.org

Overview

Transport enables trade, commerce, employment, social interaction and indeed brings people together out of their immediate communities in a national and increasingly global life. Still mostly relying on fossil fuel and using roads shared by multiple competing modes including private vehicles designed for very high speeds and accelerations, transport is also characterised by many negative externalities. These include urban congestion, being a dominant source of local air pollutants, a major source of greenhouse gases and accounting, in South Africa, for 12 944 fatalities in accidents in 2015 and many more serious injuries annually of which pedestrians constitute over a third (RTMC, 2016).[1]

In countries like South Africa that are reliant on rapidly increasing quantities of crude oil to fuel its transport system, there are additional risks to energy security and a negative impact on the national balance of payments. Given the complexity of transport systems it is not possible to explore the details of all the social costs and risks that make current transport systems unsustainable and furthermore impractical to detail the many policy and engineering solutions being attempted to mitigate these costs. However it is possible to articulate some key sustainable transport concepts, present broad best practice in policy and planning and feedback key lessons from recent transport projects in South Africa, as much as they exist in the public domain.

Transport is becoming an increasing priority for local government in South Africa, particularly in the large metros. This was given considerable momentum by the hosting of the 2010 World Football Cup which saw investment at scale by national government in the transport infrastructure of hosting cities. Efforts have generally been focussed on bus rapid transit (BRT) systems although Gauteng has also seen the implementation of the Gautrain high speed rail system and there is now a considerable body of experience from which to draw lessons from both successes and failures. The large projects undertaken, have generally not been primarily motivated by aspirations for sustainability and rather respond to growing congestion and the persistent problem of access to transport in cities and towns subject to sprawl and the location of poor communities on the urban periphery. Cities stand to gain considerably however in many spheres, long term efficiency not the least, by orientating transport policy and its implementation toward goals of sustainability. Investment in public transport, particularly, can offer social, economic and sustainability benefits.

Key concepts and features of the transport system

Below are some key concepts that underlie sustainable transport policy and technology levers and give an overview of the transport system in South Africa in a sustainability context.

The impacts of transport on sustainability

As alluded to above, the transport system has many impacts which are borne both by individuals and society at large. The current transport system and the urban environment that it serves however arose in response to the needs and desires of people and persists as a result of strong drivers. The impacts and drivers of a petroleum fuelled car centred transport system are contrasted in Figure 1 below. A great many costs and benefits, some quite intangible, are at play.

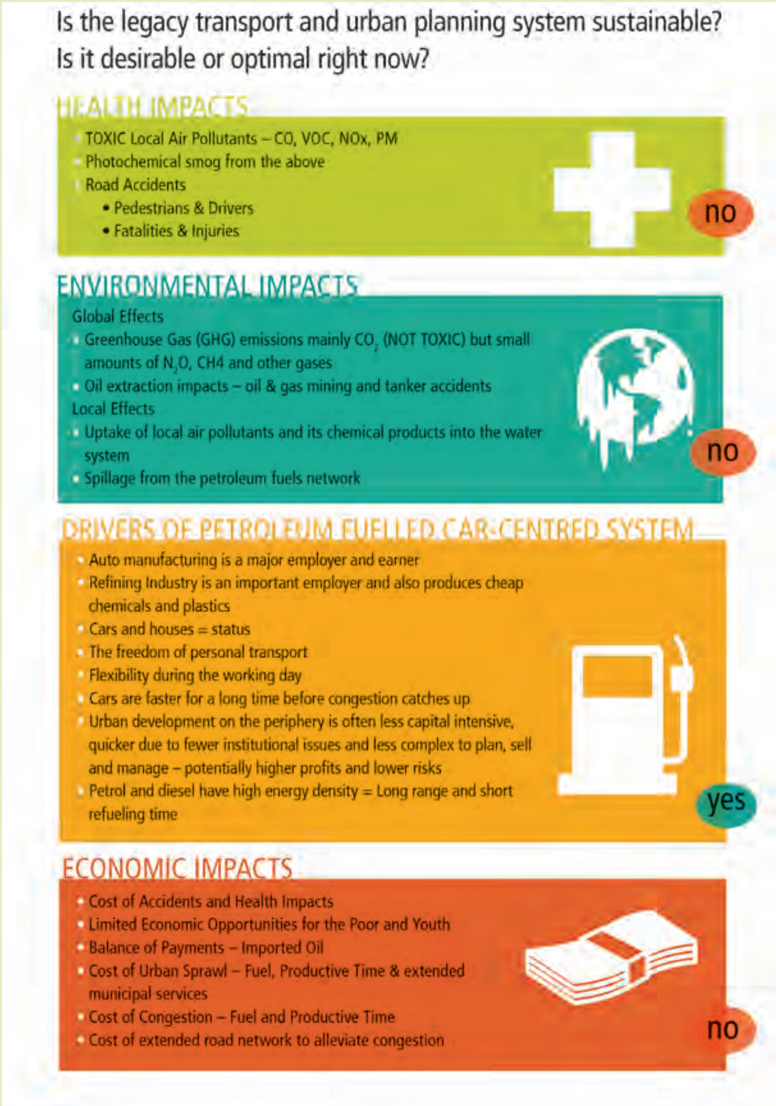
In general, the persistence over time of a pattern of car ownership and sprawl as a society's income grows, would suggest that people have been willing to pay for the impacts of the transport system. Wealthier countries have also been able to partially mitigate some impacts such as accidents and local air pollutants through regulation and enforcement. Transport globally is however a significant contributor to greenhouse gas emissions that pose a high

1 Road Traffic Management Corporation (RTMC) (2016) Cost of Crashes in South Africa Research and Development Report.

risk of negative and potentially catastrophic climate change. This has proved difficult to mitigate with the growth of the world population and economy despite the emergence of low carbon technologies. The rapid growth of cities in developing countries has also seen serious congestion and marginalisation of the poor due to constrained mobility that threatens the transition of these societies to a more prosperous and equitable level. This has seen renewed pressure and new thinking directed at changing the transport system and the urban form which it serves.

The rapid growth of cities in developing countries has also seen serious congestion and marginalisation of the poor due to constrained mobility that threatens the transition of these societies to a more prosperous and equitable level.

Figure 1: Contrasting the impacts and drivers of a petroleum fuelled car centred transport system



Mode choice and congestion

As shown in Figure 2 below, cars cause congestion in cities because they take up a lot of space. Motorcycles or bicycles take up less but there are safety risks unless there are dedicated lanes for the latter. Buses are safer and take up far less road space.

Figure 2: Passenger Modes and their Use of Road Space

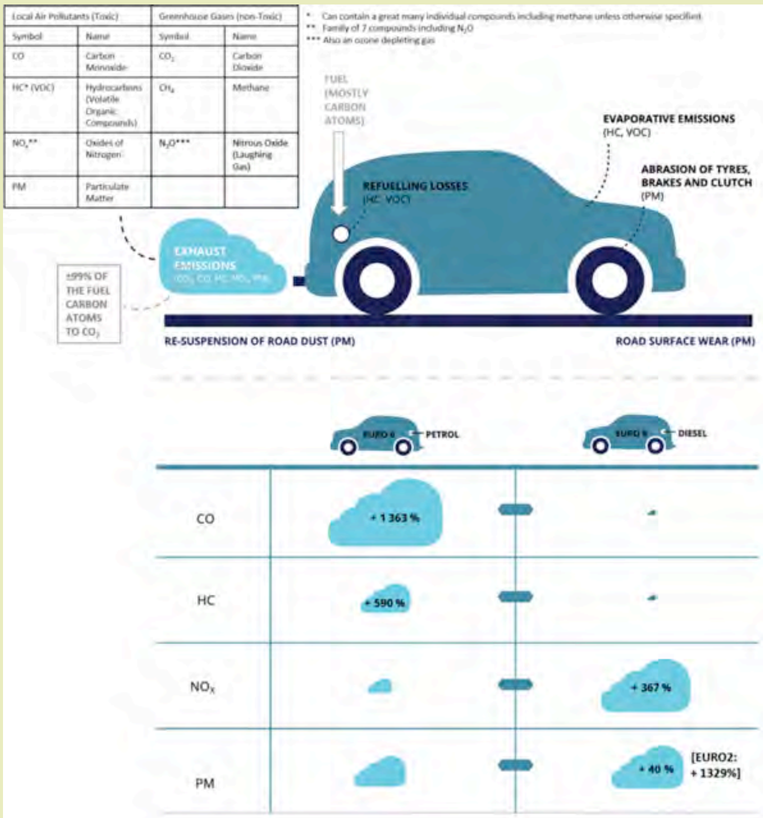
This set of photos demonstrates how the use of public transport, cyclists or private motorbikes over the use of private cars can reduce congestion in a city. Each option will transport the same amount of passengers!

Emissions from conventional Internal Combustion Engine (ICE) vehicles

The gaseous and particulate emissions from motor vehicles, particularly when petroleum fuelled, is a major source of impacts from transport. The main types of emissions and their relative scale in new technology petrol and diesel passenger cars is shown in Figure 3

Diesel light vehicles typically produce in the region of 10% less CO_2 than petrol fuelled equivalents however as shown below for some recent passenger car models from the South African market, vehicle size generally has a much greater impact on emissions. This is because larger vehicles will consume more energy when accelerating because of their higher mass and in certain cases are less aerodynamic and have more rolling resistance due to bigger tyres (SUVs).

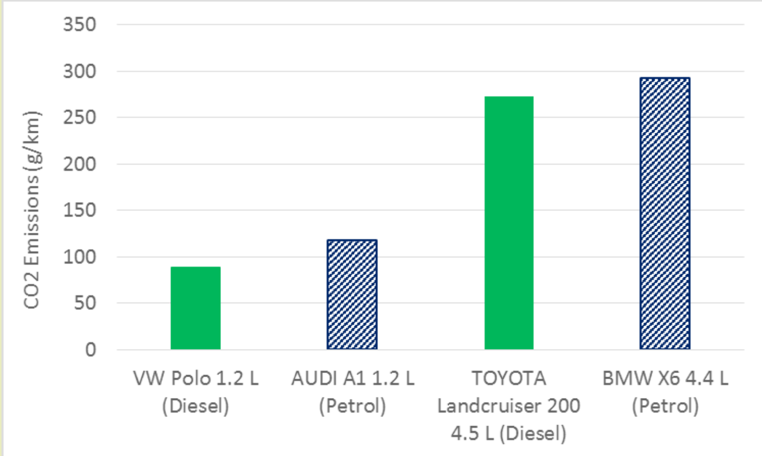
Figure 3: Sources of Toxic and Greenhouse Gas emissions from Motor Vehicles and their relative scale in new technology Euro 6 petrol and diesel vehicles



Source: Pastorello & Mellios (2016) Explaining road transport emissions –A non-technical guide. Copenhagen: European Environment Agency (EEA) adapted from the European Environment Agency.

The gaseous and particulate emissions from motor vehicles, particularly when petroleum fuelled, is a major source of impacts from transport.

Figure 4: relative impact of engine type and vehicle size (engine capacity in litres used as proxy) on CO_2 emissions as illustrated by selected recent light vehicle models



Source: data from manufacturer's published specifications

Useful transport indicators

In order to usefully quantify the demand for transport it is common to define it in terms of the following indicators:

- Trips – a single journey for one or more defined purposes e.g. work trips
- Vehicle kilometres (vkm) – The total distance travelled by a vehicle or fleet of vehicles in a specific time period. Longer trips will clearly require more vehicle km.
- Passenger kilometres (pkm) – the distance travelled by a single commuter for one or more trips e.g. A minibus with 10 passengers travels 1 km = 10 pkm. A car with one passenger travels 10 km = 10 pkm. Clearly then if there are more passengers in a vehicle there are more pkm for the vkm travelled.
- Tonne kilometres (tkm) – The distance travelled by a tonne of goods for one or more trips e.g. A truck with a 10 tonne payload travels 1 km = 10 tkm. A pickup/bakkie with a 1 tonne payload travels 10 km = 10 tkm

These indicators can be extended to energy and emissions as follows:

- Fuel Consumption (litres/100 km) – Most of us are familiar with this indicator usually expressed as litres of fuel consumed per 100 km travelled (litres/100 km) or its inverse Fuel Economy which is kilometres travelled per litre of fuel consumed (km/litres).
- Specific Fuel Consumption (litres/pkm or litres/tkm)– If the occupancy or payload of the vehicle is divided into fuel consumption it is possible to calculate the volume of fuel required to deliver a passenger km or tonne km
- Energy Intensity (MJ[2]/pkm of MJ/tkm) – Liquid fuels have quite consistent energy content, termed the Lower Heating Value (LHV) or Net Calorific Value, which for petrol is about 33 MJ/litre and for diesel about 36.5 MJ/litre. By multiplying this by Specific Fuel Consumption it is possible to convert to Energy Intensity. The fuel economy of an electric car is frequently expressed as kWh/km but this is easily converted to MJ/pkm by the factor 3.6 MJ/kWh.
- CO_2 Intensity (g CO_2/pkm or g CO_2/tkm) – As shown in Figure 3 above, liquid fuels are mostly carbon atoms and most of this becomes CO_2 in the combustion process. Given the narrow range of specifications of petrol and

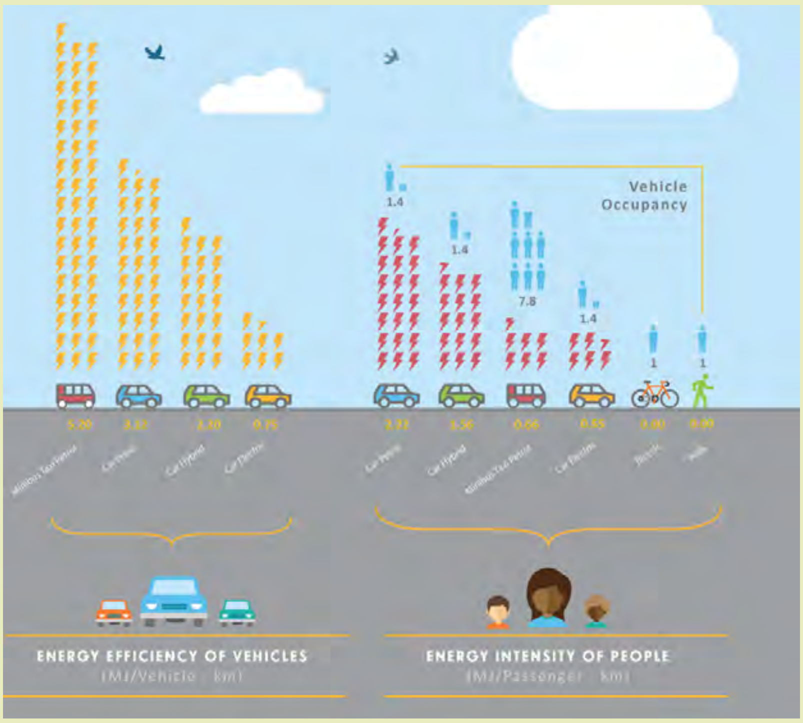
2 MJ is the symbol for Megajoule which is equivalent to 1 million Joules of energy

diesel, carbon content is quite consistent. Thus it is possible to readily estimate the amount of CO_2 in grams generated per pkm delivered by multiplying our energy intensity by emissions factors. These are around 75 g CO_2/MJ for diesel and 72 g CO_2/MJ for petrol. An electric car would not produce CO_2 emissions from the car at all.

- Wells to Wheels CO_2 intensity (g CO_2/pkm or g CO_2/tkm) – The emissions attributable to a trip are not just produced by the vehicle however. There can be considerable emissions produced in the supply chain of the fuel (including electricity) at mines, oil refineries and power stations. This is particularly important when assessing the impacts of electric vehicles fuelled by coal-fired power as discussed below in more detail.
- Lifecycle CO_2 intensity (g CO_2/pkm or g CO_2/tkm) – There are also emissions associated with the manufacture of the vehicle and the extraction and refining of its constituent materials like steel for the chassis and lithium for batteries. Including these emissions with the vehicle and fuel supply chain emissions would yield the full lifecycle emissions intensity. This becomes complicated to assess given the global nature of automotive parts production however and requires difficult to access data, complex analysis and specific expertise.

While fuel consumption will be higher for bigger and heavier vehicles, a number of factors drive a lower energy intensity for larger public transport and freight vehicles including reduced relative losses from drag, the fact that larger engines are generally more thermally efficient and that the cargo area/volume as a percentage of total increases with vehicle size. It follows from this that if it possible to double the load of goods or people on a vehicle with a marginal increase in fuel consumption large gains in efficiency when meeting transport demand can be made. A large city bus will for instance use around 2.5 times as much fuel per km as a minibus taxi but can carry more than 4 times as many people. This principle is illustrated for a number of examples below in Figure 5.

Figure 5: Energy efficiency of Vehicle Types and the Impact of Occupancy on Energy Intensity - Data typical of City of Cape Town



Source: Kane L (2016) What do we mean by low carbon transport? Undertstanding how people move in Cape Town. Cape Town : Open Streets Briefing Paper

In the discussion above that LARGE and FULL vehicles will use the least energy and produce the LEAST emissions when transporting goods and people.

BUT it is evident that LARGE and EMPTY vehicles will use the most energy and produce the MOST emissions when transporting goods and people.

Matching the vehicle to the application or the operational circumstances is therefore extremely important. In certain circumstances this may be a minibus taxi rather than a large bus.

Transport, the economy and the environment

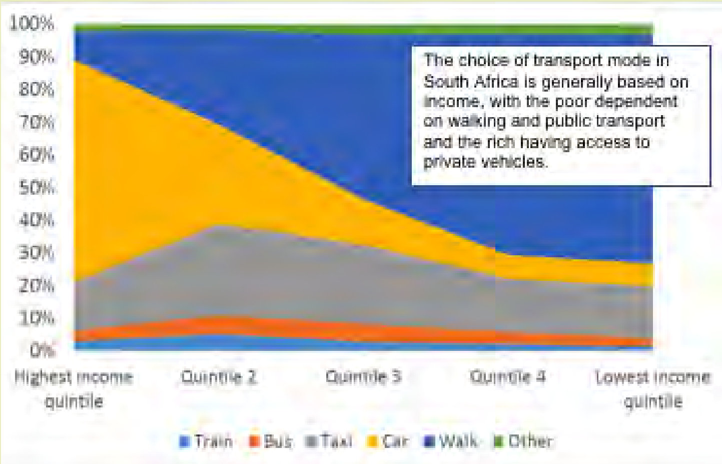
While reducing trips clearly saves energy, it is important not to lose sight of the direct relationship between trips and the economy. As well as being required for the exchange of goods, trips enable the personal interactions that open up new opportunities for people and organisations for future employment and trade. Different economic directions may be more or less transport intensive, but broadly transport demand will grow in lockstep with the economy over and above the population growth. There is thus a trade-off between economic growth and the constraints that arise on continued growth through congestion and the need for more transport infrastructure that may not have been priced into the cost of the goods being traded. The following important principles arise from this:

- Trips are economically beneficial but policy should aim to make these as short and efficient as possible.
- It stands to reason then that the design and co-location of commercial and industrial developments and the residential developments that feed them with labour need to facilitate trips that are as short and efficient as possible. See Transit Orientated Development (TOD) and Integrated Land Use Planning below.
- If such urban design facilitates a high proportion of non-motorised trips (walking and cycling) then substantial cost and emissions savings are possible.
- If mass transit is operated efficiently at high capacity in urban areas it can similarly have both substantial economic and sustainability benefits.
- On the other hand, public transport that poorly matches the urban environment it serves and has low average occupancy will have both economic and sustainability dis-benefits. This trade-off makes the operation of transport services extremely challenging because availability is a major component of the quality of service from the commuter's perspective but unused capacity is very costly for the operator. This speaks to the importance of investment in the people and systems that support operations.
- Mechanisms need to be put in place to price the future cost of transport infrastructure into public and private goods and services. Land Value Capture below briefly expands on this in practice.

Urban transport in South Africa – the passenger picture in brief

The broad transport situation in South Africa is well understood thanks to travel surveys undertaken at national and city level.[3, 4] As can be seen in Figure 6 below there is a marked contrast in mode choice between income groups, a very high share of walking trips for low-income commuters and a very high share of private car use for the highest income quintile.

Figure 6: share of modes in daily trips by income group (calculated using national household travel survey 2013 per person data for random travel day



3 Stats SA. National Household Travel Survey Statistical Release P0320. s.l. : Statistics South Africa, 2013.

4 Nel City of Cape Town: Secondary data analysis of the Household Travel Survey (2012) for the Low Carbon Central City Transport Strategy. s.l. : Report Commissioned by Open Streets http://openstreets.org.za/ (2016).

In a large metropolitan city like Cape Town, the modal split is around 50% private to 50% public transport going into the CBD (Nell, 2016). Surveys show that driver only car trips are over fourfold higher than passenger car trips (4) indicating that private commuting is generally by single occupancy vehicles which leads to increased congestion and inefficient fuel consumption with associated high levels of carbon emissions. The transport sector is currently responsible for about 25% of carbon emissions in South African cities with the share of car ownership having grown from 23% to 33% between 2003 and 2013. (SEA, 2015). [5]

Information on people's travel time budgets are gathered by the National Household Travel survey and this is useful in assessing the efficiency of the transport system and if congestion is affecting this. Evidence suggests that on average around the world and across cultures there is a preference for a daily time budget of around 1.1 hours, a number sometime referred to as the 'Marchetti' constant [6]. Surveys suggest average time budgets in South Africa are significantly longer than this and this tells a story of economic 'drag' due to transport difficulties and growing congestion as shown below.

Table 1: Indicative Change in commuter travel times by income group between 2002 and 2013 for Cape Town

	2002	**2013**	
Income level	**Total Personal Time Budget (hr/day)**	**Work Trips (hr/day)**	**Education Trips (hr/day)**
Low	1.6	1.8	1.0
Middle	1.1	1.9	1.0
High	0.9	1.7	1.1

Source 2002: Adapted from Behrens (2002) Findings of an activity-based household travel survey in Cape Town, with particular reference to walking as a travel mode. 21st Annual South African Transport Conference South Africa 15 – 19 July 2002.

Source 2013: Cape Town Household Travel Survey Data (separate study to NHTS) in Kane (2016) What do we mean by low carbon transport? Understanding how people move in Cape Town, Open Streets Briefing paper, September 2016.

Table 2: Daily Work Travel Times for South Africa by income group indicated by the National Household Travel Survey (NHTS) 2013

Income Group	**Excl. Walking Only Trips (hrs)**	**Including walking Only Trips (hrs)**
All	1.6	1.3
Highest quintile	1.4	1.3
Quintile 4	1.6	1.4
Quintile 3	1.7	1.3
Quintile 2	1.7	1.2
Lowest quintile	1.6	1.2

Source: Calculated from the published data files for NHTS 2013 available from Datafirst, University of Cape Town

5 SEA (2015) State of Energy in South African Cities, Sustainable Energy Africa, Cape Town.

6 Schafer & Victor (2000) The future mobility of the world population. Transportation Research Part A, 34, 171-205.

The data suggests the following:

- In Cape Town, whereas 10 years ago the car mode was a lot faster than public transport, evidence suggests this gap has closed significantly due to congestion.
- National figures for travel time are also very high relative to global norms although the car mode (high income) still has an advantage (dominates highest income quintile).

Informal or semi-regulated minibuses remain the dominant form of public transport in South Africa with an increased modal share indicated between 2003 and 2013, having apparently attracted learners and workers from walking, despite increased public investment in formal public transport. Available public transport services differ across cities. In most cities there are bus and minibus taxi systems, with rail found in the main metropolitan cities, but not in the smaller cities (Stats SA, 2013).[7] City bus and train systems provide the most efficient forms of transport in terms of energy per commuter kilometre; however, even though these are by and large the same price or cheaper than minibus taxis, they are sometimes underutilised. This is due to:

- Inconvenience. Bus and train systems do not service many informal settlements and efficient feeder systems to nodes in main routes are frequently not in place.
- Unreliable reputation although the perception of service of some BRT systems is good. The high end Gautrain has high levels of satisfaction but is expensive
- Perception that they are slower than taxis.
- Safety concerns, particularly on Metrorail trains.

There is a need not only for continued investment in large scale infrastructure to improve the formal public transport system but also investment in its operational systems in terms of security, fare systems and responsive operational management in order for it to improve its current share of commuters.

For many years scheduled bus services were operated by concessions to private operators such as Golden Arrow bus Service in Cape Town and Putco in Durban, administered by provincial government effectively operating on a substantial subsidy basis to cover areas and times of low demand. With exceptions, in general the quality of service has been low in terms of commuting speed, accessibility and reliability and on occasion subject to serious abuses of the subsidy. The Department of Transport and Metro Authorities took the opportunity of the 2010 World Soccer Cup to act strongly in favour of transport system reform. Large public transport projects initiated in South African cities in the last 10 years include the following:

- Gautrain high speed rail – Gauteng
- Rea Vaya BRT System – City of Johannesburg
- A Re Yeng BRT System – City of Tshwane
- MyCiti BRT System – City of Cape Town
- GoDurban Integrated Rapid Public Transport Network (IRPTN) – eThekwini
- GoGeorge Integrated Public Transport Network (IPTN) – George
- Libhongolethu Integrated Public Transport Network (IPTN) – Nelson Mandela Bay Municipality
- Yarona – Rustenburg's rapid transport service
- Ekurhuleni's Harambee Bus Rapid Transit (BRT) has undertaken initial testing and is set to launch in July 2017 [8]
- Polokwane's Municipality's Integrated Rapid Public Transport Service (IRPTS) is reported to be on schedule to go live in March 2018 [9]
- Buffalo City, Mangaung and Msunduzi completed public transport network development planning and service contract designs in 2013/14 [10] but the current status of these projects is unclear.

7 Stats SA (2013) National Household Travel Survey Statistical Release P0320.

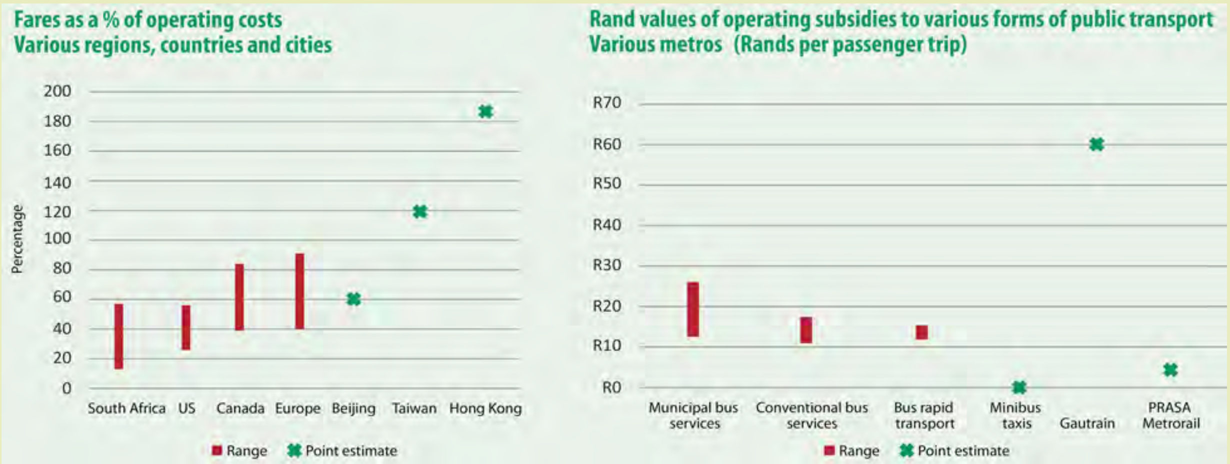
8 http://ewn.co.za/2017/02/08/watch-ekurhuleni-test-for-long-awaited-brt-system

9 http://www.observer.co.za/integrated-rapid-public-transport-service-on-track/

10 http://www.gov.za/about-government/government-programmes/bus-rapid-transit-system-brt

Despite vast capital expense, these projects have not however, in the view of some, delivered affordable and financially sustainable public transport. This is primarily, it is believed, because urban densities are generally low and where residential densities are high in former apartheid era townships, economic opportunities and infrastructure are limited and distances to potential work long, resulting in inefficient cities with long travel times. The costs of transport services and doing business are therefore high and this combined with the limited purchasing power of the lower income cohorts who are the primary public transport users, results in a smaller share of public transport costs being recovered than is generally the case in the rest of the world as shown in Figure 7 below.

Figure 7: Cost recovery Rate of Public Transport in South Africa compared to Selected Regions and Costs per Trip of Modes



Source: National Treasury (2014), Performance and Expenditure Review - Public Transport, Government Technical Advisory Centre, National Treasury, Pretoria.

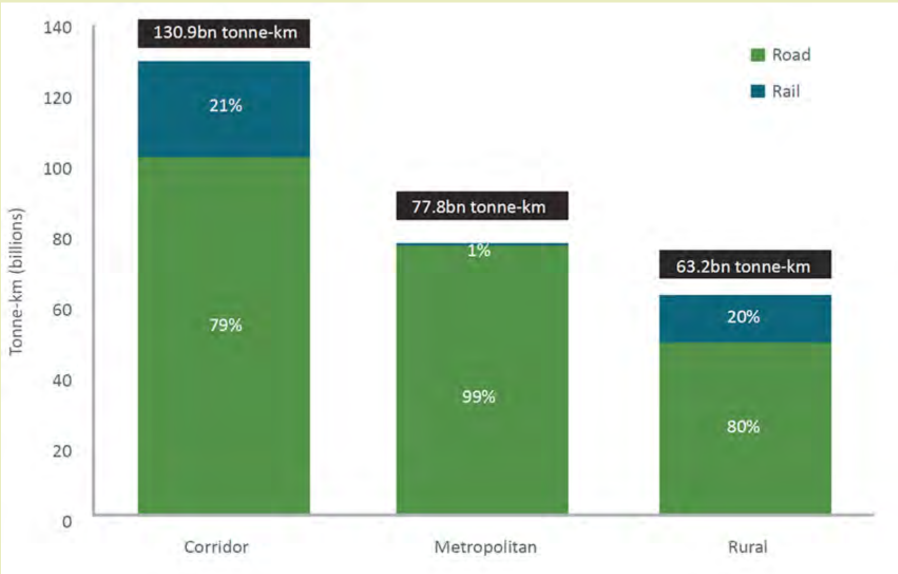
Also evident from Figure 7 is that while very large sums are spent on transport subsidies none of it, since the winding down of a difficult and sporadic taxi recapitalisation programme, is now spent on minibus taxis, the mode which conveys the vast majority of public transport passengers.

City bus and train systems provide the most efficient forms of transport in terms of energy per commuter kilometre; however, even though these are by and large the same price or cheaper than minibus taxis, they are sometimes underutilised.

Urban transport in South Africa – the freight picture in brief

South Africa's large cities are geographically dispersed across a large land area with its economic hub of Gauteng on an inland plateau, relatively far from the nearest port. It has been described as having a 'spatially challenged' economy (CSIR, 2013)[11] and the corridors between the major cities dominate the demand for general freight (excluding mining commodities) with most of that supplied by road transport as shown below.

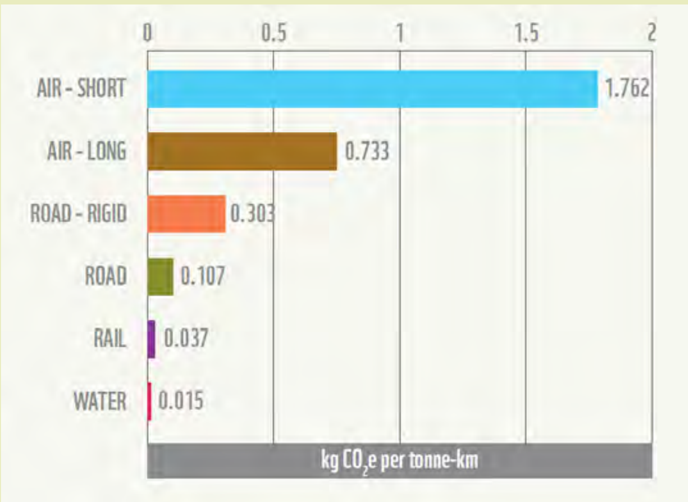
Figure 8: Distribution of General Freight Demand in the South African Economy in 2014



Source: Havenga, JH, et al. (2016) Logistics Barometer South Africa 2016, Stellenbosch University

Metropolitan freight actually contributes almost 50% of the total volume of freight demand in tonnes compared to 16% for corridor freight, but the shorter distance reduces its share of total freight tonne-km to around 15%. The energy and emissions intensity of freight transport varies markedly by mode as shown below with rail typically producing a third of the emissions of long haul road transport and a tenth of smaller rigid trucks.

Figure 9: Typical CO_2 equivalent Emissions Intensities of Freight Modes

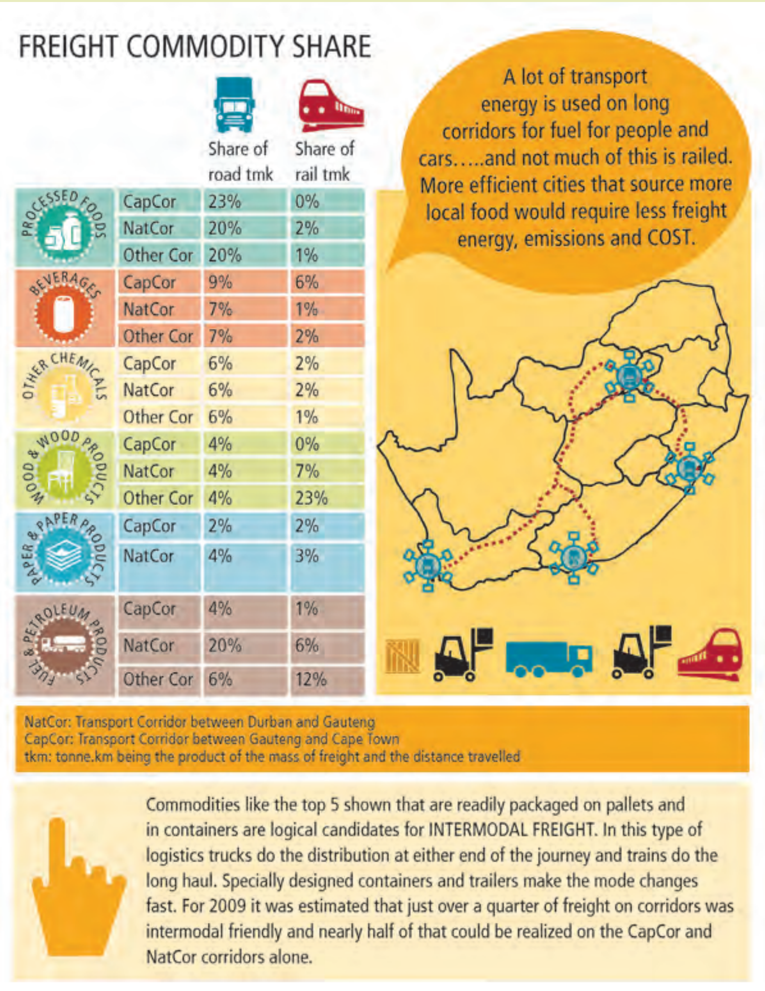


Source: WWF (2013), Low Carbon Frameworks: Transport - Understanding Freight Emissions, World Wildlife Fund

11 CSIR (2013) 10th Annual State of Logistics Survey for South Africa 2013 – Bold Steps Forward, Council for Scientific and Industrial Research (CSIR).

When corridor freight is regarded at a commodity level it is easier to see opportunities for making logistics more sustainable. As shown below on some corridors the most freight, energy and emissions intensive commodities emissions are processed food and petroleum fuels. This presents opportunities for reducing emissions by localising food or tolling certain commodities that make the whole intercity journey by truck.

Figure 10: opportunities for intermodal freight transport for key commodities and the freight impacts of moving petroleum fuels on major corridors in South Africa (2009 Data)



		Share of road tmk	Share of rail tmk
PROCESSED FOODS	CapCor	23%	0%
	NatCor	20%	2%
	Other Cor	20%	1%
BEVERAGES	CapCor	9%	6%
	NatCor	7%	1%
	Other Cor	7%	2%
OTHER CHEMICALS	CapCor	6%	2%
	NatCor	6%	2%
	Other Cor	6%	1%
WOOD & WOOD PRODUCTS	CapCor	4%	0%
	NatCor	4%	7%
	Other Cor	4%	23%
PAPER & PAPER PRODUCTS	CapCor	2%	2%
	NatCor	4%	3%
FUEL & PETROLEUM PRODUCTS	CapCor	4%	1%
	NatCor	20%	6%
	Other Cor	6%	12%

Source: Adapted from Centre for Supply Chain Management, Department of Logistics, University of Stellenbosch and the WWF

van Eeden & Havenga (2010) Identification of Key Target Markets for Intermodal Freight Transport Solutions in South Africa. Journal of Transport and Supply Chain Management.

The use of intermodal freight transport solutions does not have to damage the trucking industry because the number of trucking trips actually increases but they are far shorter. In fact the trucking companies would do as much or more logistics but their costs in terms of overtime, fuel costs, maintenance and insurance decrease. Consequently a joint venture between road hauliers and the rail utility could benefit all parties[12].

12 Centre for Supply Chain Management, Department of Logistics, University of Stellenbosch and the WWF

Corridor Freight and Intemodal Transport Solutions

- A lot of freight tonne.km is metropolitan as expected but nearly double this is on the corridors between metropoles: It's not in the city but it's of the city.
- It can see that rail is much less emissions intensive and fuel consumption and costs are lower but that it has a minority share of corridor freight. Rail lost market share because of speed and convenience but with new methods rail can be used in an efficient, cleaner and cheaper logistics process with intermodal transport.
- *"The process of intermodal transport consists of short-distance road feeder services to an intermodal terminal in a logistics hub where freight is consolidated into main-line block trains running the length of the corridor to a destination terminal. From the destination terminal, it is transported to distribution centres or end destinations via road transport"*, Centre for Supply Chain Management, Department of Logistics, Stellenbosch University.[1]

1 Havenga, Simpson, Fourie & de Bod (2011) Sustainable Freight Transport in South Africa: Domestic Intermodal Solutions. Journal of Transport and Supply Chain Management.

Electromobility in South Africa and potential impacts on sustainability in the short and long term

Electromobility refers to a broad category of vehicles which are generally characterised by having electric motors drive the wheels some or all the time instead of mechanical drive from an internal combustion engine. These include the following:

- Battery Electric Vehicles (BEV): Where externally charged batteries are the energy source
- Hybrid Vehicles: These have come to refer broadly to a hybrid of a battery electric vehicle and a combustion engine and fall into two main categories:
- Non Plug-in Hybrids: Also termed 'conventional' hybrids these vehicles are never connected to an external electricity source. The battery is kept charged by recovering braking energy and the combustion engine if necessary.
- Plug-in Hybrids: Plug-in hybrids can be fueled with both petroleum fuel and electricity from a filling pump or charger. The driver now has much more control over the share of electricity and petroleum fuel they use and can respond to the limits on availability of either. Some types of plug-in hybrids are called Extended Range Electric Vehicles (EREVs).
- Fuel-Cell Vehicles (FCV): Fuel Cells produce electricity from on-board hydrogen fuel. The electricity produced by the fuel cell can either supply the wheel motors directly or charge a battery, effectively acting as a range extender.

Battery electric vehicles, in general, have higher capital costs than conventional petroleum fuelled vehicles although prices are dropping with battery costs having fallen by a factor of 4 since 2008 (IEA, 2016)[13]. Electricity is furthermore significantly cheaper than diesel in most countries, including South Africa and maintenance costs are claimed to be around 30-50%[14] cheaper for battery electric vehicles. This may in certain circumstances offset a price premium over the lifetime of a high mileage vehicle like a public bus. Caution should however be exercised around the full costs of charging infrastructure, particularly if a project aim is to power vehicles with 'green' energy as discussed below.

While battery electric vehicles produce zero emissions from the vehicle itself, there may be considerable emissions associated with the fuel supply chain. In South Africa most electricity is produced from coal and therefore the emissions from coal power stations needs to be taken into account when comparing the current emissions of an electric car operating in South Africa to those of a petroleum fuelled vehicle. In addition, the supply chain of South African petroleum fuels is also higher emitting than globally typical particularly in terms of CO_2 because of a large Coal-To-Liquids (CTL) refinery [15].

To assess the current environmental benefits of electromobility the emissions need to be estimated for the supply and production of the fuel and electricity as well as those from the vehicle itself (wells-to-wheels basis). The results of such an assessment for selected passenger car models is shown below in Figure 11 and Figure 12[16]. The discretionary choice of whether to drive a big car or a small car makes a big difference to energy economy as demonstrated above and small conventional cars currently give rise to lower GHG emissions than battery electric vehicles in the South African context if CTL emissions are not considered. In this case non-Plug in hybrids seem to give rise to the least GHG emissions. If CTL is included at its national production share, battery electric vehicles significantly outperform gasoline fuelled conventional vehicles on a GHG emissions basis but small diesel fuelled IC engine cars are comparable because the CTL refinery produces proportionally less diesel.

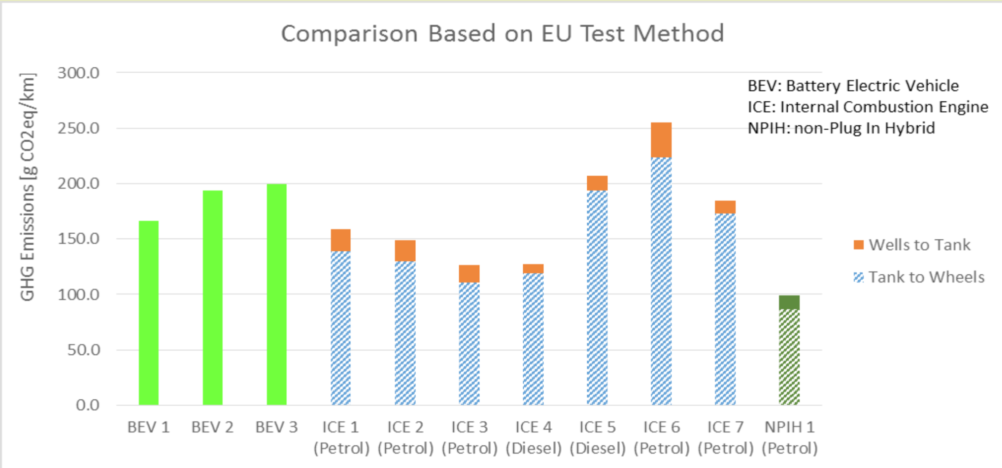
13IEA (2016) Global EV Outlook 2016 – Beyond one Million Electric Cars. International Energy Agency, Paris.

14Fuso Trucks: http://media.daimler.com/marsMediaSite/en/instance/ko/World-premiere-the-new-all-electric-Fuso-eCanter.xhtml?oid=13669591; BYD Buses: http://www.tct.gov.za/docs/categories/1562/Alternative%20transport%20solutions.pdf

15The CTL production process produces liquid fuels from coal by first gasifying the coal and then liquefying the gaseous products by catalysis in a relatively energy and greenhouse gas intensive series of processes.

16SEA (2016) Well-to-Wheels Greenhouse Gas Emissions and Energy Comparison between Battery Electric Vehicles, non-Plug in Hybrids and Conventional Passenger Cars for South Africa. http://www.cityenergy.org.za/uploads/resource_401.pdf; Excel Calculator: http://www.cityenergy.org.za/getfile.php?id=400&category=7

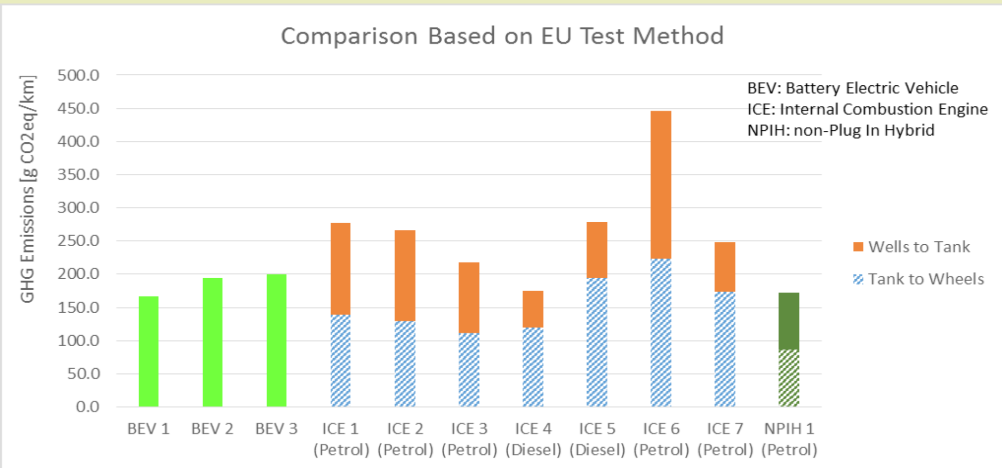
Figure 11: Wells-to-Wheels GHG Emissions for selected model passenger cars when CTL production is excluded from refinery supply system



Source: SEA (2016). Well-to-wheels greenhouse gas emissions

BEV: Battery Electric Vehicle, ICE: Internal Combustion Engine, NPIF: non-plug in hybrid. The models have been selected to cover a range of manufacturers and illustrate a range of emissions. For ICE vehicles the higher emitting models are heavier vehicles with bigger engines.

Figure 12: Wells-to-Wheels GHG Emissions for selected model passenger cars when CTL production is included in the Refinery Supply System

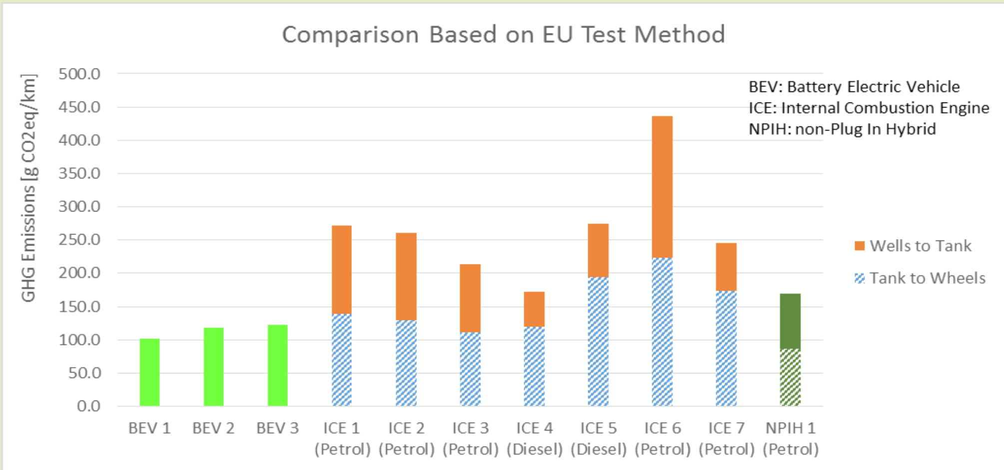


Source: SEA (2016). Well-to-wheels greenhouse gas emissions

BEV: Battery Electric Vehicle, ICE: Internal Combustion Engine, NPIF: non-plug in hybrid. The models have been selected to cover a range of manufacturers and illustrate a range of emissions. For ICE vehicles the higher emitting models are heavier vehicles with bigger engines.

Assuming, however, that 25% of battery charging is shifted from using the national grid to off-grid solar embedded generation at home and the workplace and that nuclear and renewable generation rises to a 25% share of grid electricity, then GHG emissions from the operation of battery electric cars would drop to around half of even small conventional cars and non-plug in hybrids as shown below.

Figure 13: Simulated Wells-to-Wheels GHG Emissions for Selected Model Passenger Cars when CTL production is included in the Refinery Supply System and 25% of BEV Charging is Embedded PV and Grid Electricity is 25% Nuclear/RE



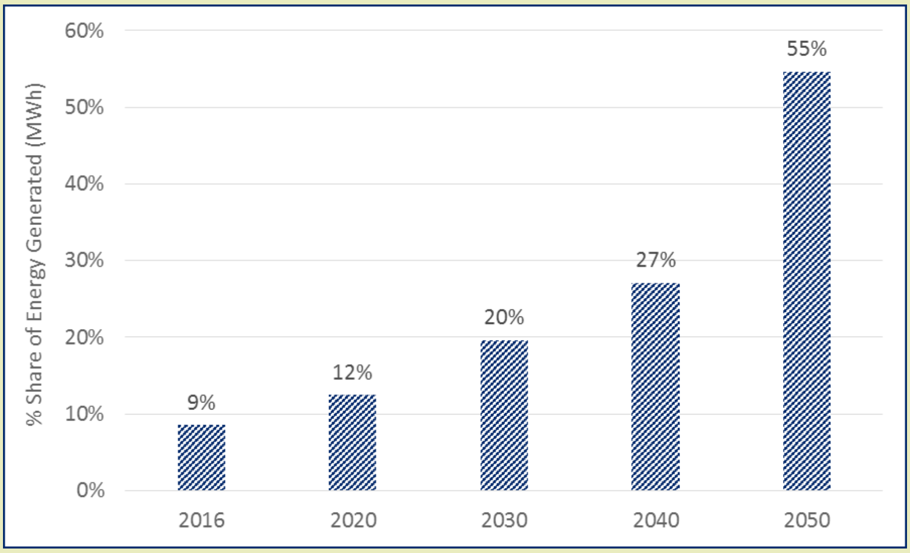
Source: SEA (2016).

In general, South Africa's coal intensive electricity supply means that the operational wells-to wheels GHG emissions from battery electric passenger cars are comparable to compact conventional passenger cars operating on crude oil distilled liquid fuels despite the far superior energy efficiency of the electric vehicles. This gives non-plug in hybrids a GHG emissions advantage in areas solely supplied by conventional refineries. There is however significant synthetic CTL fuel production in South Africa and if this is taken into account at its national share of production, then battery electric cars start to offer significant GHG emissions advantages over compact gasoline fuelled cars. Diesel fuelled cars are still comparable[17] because the CTL production is more gasoline heavy. Clearly then, in areas that are exclusively or mostly CTL supplied (such as areas of Gauteng), electric cars are significantly lower emitting on a relative basis with the caveat that if fuel demand were to drop in those areas because of electric cars, the CTL fuel would simply be distributed elsewhere given the nature of the supply system in the country.

If 25% of Battery electric vehicle charging is however shifted from the national grid to embedded solar supply at home and work and the grid electricity supply shifts to 25% nuclear and renewable sources, both attainable targets, then the operational GHG picture shifts unambiguously in favour of battery electric cars. The shift to carbon free energy sources supplying the electricity grid will however likely take quite some time as indicated by the latest Integrated Resource Plan Update Base Case results shown in Figure 14 below. Clearly then, in principle, South African policy supporting electric cars should incentivize small scale embedded charging as much as the cars themselves for the time being. The City of Cape Town is proposing rather 'wheeling' or 'offsetting' with solar energy to reduce the net emissions of their order of 11 electric buses from BYD, a chinese automobile manufacturer for the MyCiti service to come into operation at the end of 2017.

17 Diesel passenger cars still only account for around 10% of the car market if SUVs are included, with few compact models to choose from. In general, the fuel savings attained with diesel passenger cars have also not offset the capital and maintenance premium in South Africa.

Figure 14: Projected share of carbon-free electricity generated (Nuclear, CSP, Solar PV and Wind) in the IRP Update Base Case



Source: DoE (2016) Integrated Resource Plan Update Assumptions, Base Case Results and Observations, Department of Energy, Government Gazette, 25 November 2016, No. 40445

Hydrogen Fuel Cells

Research and development into the automotive applications of hydrogen fuel cells continues, including on heavy vehicles, as fuel cells have the potential to extend the range and terrain accessible by electric freight vehicles and commuter buses. A recently announced long-haul freight truck prototype, the Nikolai, a non-plug in fuel cell battery electric hybrid, claims an impressive just less than 2000km range[18]. Like battery electric vehicles, fuel cell vehicles have zero emissions from the tailpipe. While not as energy efficient as battery electric vehicles, fuel cell vehicles typically have an equivalent fuel economy 40-60% better[19] than conventional vehicles with less of an urban driving energy penalty as well as, in most cases, a greater driving range than battery electric vehicles.

While capital costs of emerging offers have come down, the advances have not been as great as for battery electric vehicles. The practical experience of the Stuttgart Public Bus Company Stuttgarter Strassenbahnen AG (SSB) offers useful perspective(Wiedermann & Raff, 2017)[20]. They ran two fuel-cell bus demonstrator projects ten years apart in 2003 and 2014, the latter involving 6 fuel cell-battery hybrid buses running as a fully integrated component of their service. The price premium of the buses relative to a conventional diesel bus came down from 5-fold in 2003 to two-fold in 2014 and energy efficiency improved from 22 kg H2/100 km in 2003 to10-14 kg H2/100 km in 2014 mostly due to regenerative braking technology.

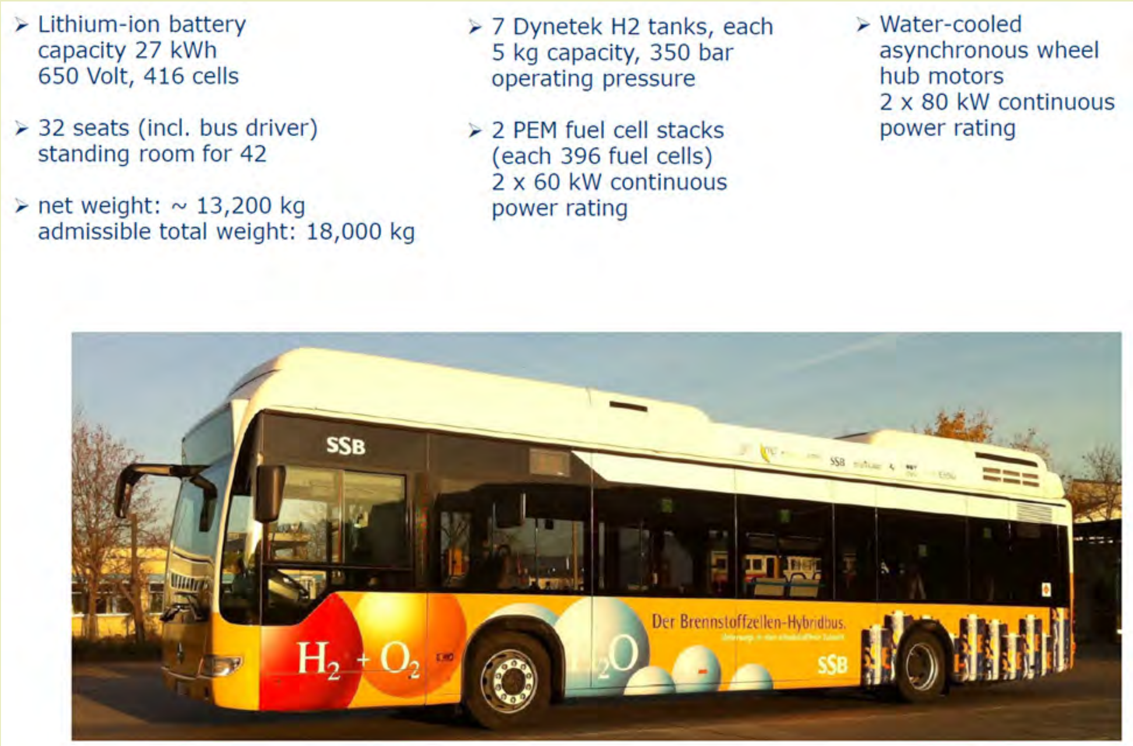
Hydrogen has very low volumetric energy density such that even when compressed to the very high pressure of 700 bar of modern hydrogen fuelling systems, it only has an energy content of around 9 MJ/litre compared to around 36 MJ/litre for diesel at atmospheric pressure. The challenge with hydrogen is therefore in the cost effective production, storage and distribution of the fuel. Global production of hydrogen is mostly by reforming of

18 https://nikolamotor.com/one

19 http://www.fueleconomy.gov/feg/fcv_sbs.shtml

20 Wiedemann & Raff (2017) Presentation at Fuel Cell Bus Workshop – Unleashing Industrial Opportunities for South Africa through a Zero Emission Choice. Department of Trade and Industry and GiZ workshop, Cape Town, 20th February 2017.

Figure 15: Hybrid Battery Electric Fuel-cell Hybrid Bus operated by SSB Stuttgart



Source: Wiedemann & Raff (2017) Presentation at Fuel Cell Bus Workshop – Unleashing Industrial Opportunities for South Africa through a Zero Emission Choice. Department of Trade and Industry and GiZ workshop, Cape Town, 20th February 2017.

fossil methane (Gupta, 2009)[21] and in 2003 SSB installed their own on-site Steam Methane Reforming (SMR) plant at considerable cost to the project but sold this plant and changed to sourcing hydrogen more cost effectively from a waste incineration plant for the 2014 project. SSB are very clear however that the 2014 project is still not financially viable without considerable external subsidy.

The leading concept for 'carbon-free' hydrogen production is water electrolysis supplied by solar PV electricity. This is potentially a useful way to store excess electricity produced by renewable plants at scale when demand is low. Aside from the efficiency penalty of converting electricity to hydrogen (around 25%) however, the costs of small on-site electrolysis has generally been high(Dodds &McDowall, 2012). [22] As such the costs in Germany of 'green' hydrogen from electrolysis is reported to be currently around Euro 9.50/kg compared to Euro 2.60/kg for hydrogen produced by SMR 21.

The Department of Science and Technology is supporting a concerted research initiative called Hydrogen South Africa (HYSA) which has three centres of excellence working to give the country a foothold in the industrialisation of the nascent global hydrogen economy.[23] They have developed production, fuel cell and storage technologies and potentially may make early public transport demonstrator projects viable in South African municipalities if their technical support can be combined with sufficient financial and institutional support.

21Gupta (2009) Hydrogen Fuel Production, Transport and Storage. Boca Raton: CRC Press Taylor and Francis Group.

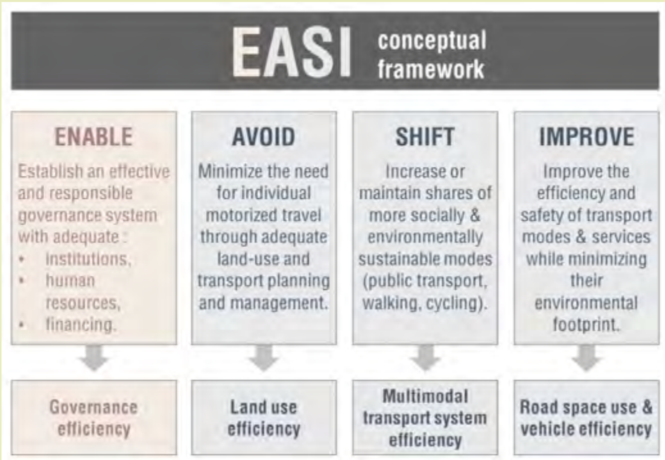
22 Dodds & McDowall (2012) A review of hydrogen production technologies for energy system models – UKSHEC Working Paper No. 6. London: UCL Energy Institute, University College London.

23 http://www.hysasystems.com/index.php/about-hysa

Concepts to policy frameworks

The concepts above have been structured into evolving policy frameworks designed to promote sustainable transport starting with Lee Schipper's World Bank Activity, mode Share, Intensity and Fuel mix (ASIF) framework (World Bank, 2016)[24] and the simplified Activity, Shift and Improve (ASI) (UNEP, 2011)[25] framework, both focussed on energy efficiency. A recently developed variation on these, EASI (World Bank, 2015)[26] has a strong additional institutional and governance component. EASI is outlined in Figure 16.

Figure 16: EASI– a robust conceptual framework to guide public action



Source: The World Bank (2015) Policies for sustainable accessibility and mobility in urban areas of Africa, Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan.

The 4 pillars of EASI expand into policy recommendations which are presented below. Current transport policies and implementations in South Africa are briefly assessed against these recommendations:

Table 3: Policy Recommendations to support the 'Enable' Pillar of the EASI framework

E1	To define, adopt and implement, at central government level, a national urban transport strategy that ensures the sustained development and management of urban transport systems.
E2	To ensure that the main urban transport public responsibilities at urban/metropolitan level are assigned and carried out.
E3	To set up an entity in charge of urban transport planning and of guiding and coordinating public action aimed at the provision of a multimodal urban transport system.
E4	To provide all institutions and stakeholders in the urban transport sector with adequate human resources.
E5	To increase financial resources allocated to urban transport systems and to ensure the availability of long-term funding for urban transport.
E6	To create the preconditions for continued civil society participation in the development of urban transport systems.
E7	To enhance the involvement of the private sector in the provision of transport infrastructure and services.

Source: The World Bank (2015), "Policies for sustainable accessibility and mobility in urban areas of Africa", Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan

24 World Bank (1999) Transportation and CO_2 Emissions: Flexing the Link – A Path for the World Bank. Paris: The World Bank.

25 UNEP (2011) Towards a Green Economy – Transport – Investing in Energy and Resource Efficiency. United Nations Environment Programme.

26 The World Bank (2015) Policies for sustainable accessibility and mobility in urban areas of Africa, Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan.

In South Africa a comprehensive national level transport strategy (E1) has been adopted in the form of the recently updated National Transport Master Plan (NATMAP) (DoT, 2016)[27]. Financial resources have been (E5) made available nationally to urban transport systems through programmes such as the Public Transport National Grant (PTNG) although the long term sustainability of current subsidy levels and established levels of compensation to minibus taxi operators, as formalisation expands, is in question (DoT, 2016). Large metropoles such as the City of Cape Town have however undertaken financial scenario analysis of their BRT expansion plans with the target of remaining within the target of 4% of property rates income in a future environment of reduced subsidy (City of Cape Town, 2015) [28].

Transport authorities (E3) have been set up by Cape Town (TCT) and eThekwini (ETA) but urban passenger rail is still centrally administered by PRASA and legacy subsidised bus contracts with private concessionaires are still administered by provincial governments. The steady expansion of Integrated Public Transport Network (IPTN) projects in the large metropoles and some secondary cities like George and Rustenberg over some 10 years has built a cohort of supporting professionals, private suppliers and to a lesser extent civil society bodies that to some degree address the remaining policy recommendations above in key regions. A good start has therefore been made on the 'enable' pillar with the potential to leverage the emerging institutional expertise to overcome the many challenges to expanding current systems, extending systems to new regions and improving the financial sustainability of all networks.

Table 4: Policy Recommendations to support the 'Avoid' Pillar of the EASI framework

A1	To plan for urban forms and land use that minimize the need for individual motorized travel and promote public transport and non-motorized transport modes.
A2	To deploy transport infrastructure and services in a manner that promotes sound urban forms and land use.
A3	To strengthen land use management.

Source: The World Bank (2015), "Policies for sustainable accessibility and mobility in urban areas of Africa", Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan

Generally low urban densities have been widely identified as a barrier to the financial sustainability of public transport in South Africa. Cape Town has identified Transit Orientated Design (TOD) in urban planning as a long term cornerstone of its plan to make its public transport network more financially sustainable. It is not clear however whether private developers and supporting professionals in the main as yet prioritise integration with a low carbon transport system. Furthermore, legislated public consultation processes can have the outcome of stalling mixed use developments at increased densities due to conflict with private interests. Broad policy is in place for this pillar in the large metros but implementation at scale will likely take some time. Secondary cities implementing public transport projects will be even more vulnerable to operational efficiency problems due to unsuitable urban form. Integrating land use efficiency through the urban planning and approval functions will therefore need to form a key component of long term planning for future projects.

27 DoT (2016) National Transport Master Plan, Synopsis Update, Draft Final Report, Pretoria: Department of Transport, Republic of South Africa.

28 City of Cape Town (2015) MyCiTi Business Plan 2015 Update Phase 1 and N2 Express, Transport for Cape Town (TCT), Cape Town.

Table 5: Policy Recommendations to support the 'Shift' Pillar of the EASI

S1	To adopt and systematically introduce, at all levels and scales, a multimodal approach to the development and management of urban transport systems.
S2	To develop and maintain for each urban area a pedestrian network that is continuous, safe and accessible for all throughout the day; and to develop and maintain bicycle paths with similar characteristics.
S3	To provide an integrated and hierarchical public transport system that is efficient, reliable and capable of serving the needs of constantly evolving populations and the urban economy.
S4	To plan and implement mass transit systems that operate on exclusive infrastructure and can form the backbone of the urban public transport system.
S5	To enhance the level of service provided by paratransit (minibus taxi) operators by way of full integration in the public transport system, which requires restructuring, modernizing and promoting them.

Source: The World Bank (2015) Policies for sustainable accessibility and mobility in urban areas of Africa, Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan

The public transport projects of the last 10 years were initially very BRT focussed in what has been described as BRT "mania" or "fever" inspired by the remarkable achievements in South America particularly in the cities of Bogota and Curitiba. The political considerations of the times have made the rapid provision of modern formal motorised transport a priority and a multimodal approach, particularly inclusive of non-motorised modes, has perhaps suffered. An early recognition in eThekwini that the structure of the city precluded meeting major demand with full BRT and that an integrated multi-modal system centred around the existing rail network was more practical was, for example, subsumed by the Department of Transport's then focus on BRT as a condition for grant funding (Esteves & Bannister, 2015)[29].

The reframing of large scale national grant funded initiatives as Integrated Public Transport Network (IPTN) projects has however broadened the scope of planning and responses to challenges considerably. The City of Cape Town has indicated its intention of implementing the future phases of its public transport network expansion as a 'hybrid' system which, recognising the efficiency of the minibus taxi industry, aims to integrate an improved quality minibus service as feeders to trunks and core feeder routes with the possible further integration of the legacy provincially contracted private bus company (GABS) (Naidoo, 2016)[30]. The Go George IPTN directly purchased minibus taxis modified for full disabled access and fare system integration and have maximised flexibility in their fleet and scheduling to optimise financial sustainability.

Given the high walking mode share in low-income groups and the high rate of pedestrian fatalities, robust pedestrianisation initiatives are justified on safety and cost considerations alone but in general have yet to be prioritised outside of a broad commitment to TOD principles. Investment in cycling infrastructure is however more difficult to justify given the current low mode share but has niche applications. Aside from non-motorised transport then, the trend in policy implementation in current IPTNs has shifted broadly in line with the "shift" pillar recommendations above and future projects can draw directly from the planning and practice innovations currently unfolding.

29 Esteves & Bannister (2015) Implementing BRT in eThekwini. [Online] Available at: http://www.erln.co.za/images/jevents/5624aa29b92726.87366313.pdf

30 Naidoo (2016) Cape Town's Experience – Presentation to SABOA, Transport and Urban Development Authority, City of Cape Town.

Table 6: Policy Recommendations to support the 'Improve' Pillar of the EASI framework

I1	To improve planning, operation and maintenance of urban roads taking into account and balancing the needs of all transport modes and keeping the use of individual motorized vehicles under check.
I2	To define and implement realistic and gradually more demanding requirements in terms of fuel components, energy efficiency and gas emissions.
I3	To promote safe and environmentally responsible behavior by all urban transport stakeholders, by strengthening technical control of vehicles and by keeping the public informed of the negative externalities of individual motorized transport.

Source: The World Bank (2015) Policies for sustainable accessibility and mobility in urban areas of Africa, Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan.

After the initial phases of IPTNs all implementing municipalities are acutely aware of the risk of reliance on subsidy and are focussing on operational efficiency of their bus fleets through mixing bus sizes, moderating expensive peak services and investing in control centres that monitor and respond flexibly to demand.

While the mass transit programmes discussed above do not, in general, have an implicit sustainability rationale, many of the larger metropoles have compiled greenhouse gas inventories and are in the process of setting mitigation targets. The impact of vehicle occupancy on energy efficiency is seen in Figure 5 above and it is likely that this will lead to policies targeting control of private motor vehicles and higher occupancies. These might include permission to use restricted lanes for cars carrying passengers or relaxation of restrictions to access parts of the central city for cars with passengers. Other than a small national level carbon tax on the purchase of passenger cars and light trucks there is, for the time being, little activity aligning with the 'improve' pillar of policy recommendations as regards private vehicles.

Electric vehicles are seeing rapid growth off a low base in Japan and Norway[31] and offer opportunities for energy efficiency but as is discussed in more detail below, South Africa's coal fired electricity largely erodes these gains unless solar charging is implemented.

31 https://electrek.co/2017/02/15/norway-electric-vehicle-market-share-record/

Implementation

A universe of implementation measures, appropriate to local government, that align with the EASI framework and thus promote sustainable transport are presented below in Table 7.

Table 7: Selected Sustainable Transport Implementation Measures for Local Government

Type of Measure	Description of Measure
Taxes	Congestion charges, vehicle registration fees, road tolls (e-tolls). Vehicle emission taxes at license renewal. Parking charges for high emission or low occupancy vehicles. Emission tolls on freight delivered by road corridors, in particular processed food.
Incentives	Reduction of parking costs and relaxation of access restrictions for low emission vehicles. Rebate of tolls for freight delivered by rail or multi-modal rail technologies. Waive vehicle licensing costs for low emission vehicles.
Subsidies	Access national Transport infrastructure and operations subsidies. General Revenue Funds (national, provincial and local levels for parking, road development, transport infrastructure and road transport operation).
Regulations	Regulatory restrictions to encourage modal shifts (road to rail). Restriction on use of private vehicles in certain areas and at certain times. Restriction on the use of higher emitting and low occupancy vehicles.
Planning	Urban planning and zoning restrictions e.g. enforce the urban edge and limit access to the CBD. Management of investment and usage of transport infrastructure. Development of NMT/bus/public-transport lanes/zones. Limitation of parking for private vehicles in congestion zones. Sector specific energy performance and GHG targets based on scenarios developed for a State of Energy.
Standards	Develop minimum policy level of service specifications for public transport services (e.g. operating times and frequency). Emissions standards for public transport fleets and municipal vehicle fleets .
Information Programmes	Information campaigns on externalities of car use and promotion of public transport alternatives. Marketing of public transport services. 'Green / Eco Driving' Campaigns.
Government Procurement of Public Goods or Services	Low emission vehicle procurement for IPTN systems. The Green Energy Efficiency Fund (GEEF) (facilitates the implementation of energy efficiency initiatives and renewable energy projects).
Direct Infrastructure Investment	Energy management and monitoring systems for fleets. Investment in alternative fuel infrastructure e.g. solar charging points for EVs. Investment in low emission vehicles for municipal fleets. Investment in mass public transport with dedicated infrastructure. Investment in transit (expansion of transport network) and non-motorised transport (Pedestrian walkways or cycle lanes).
Institutional Measures	Creation of a Transport Authority with a clear vision, mandate and resources. Integration of transport planning with environmental and urban planning. Integrate minibus taxi operators not yet incorporated as operators or shareholders of IPTNs to support the system on feeder routes. Collaborate with tertiary institutions on transport system engineering and management course content design. Offer bursaries and internships linked to human resource supply.
Research and Development	Continued investment in the development of energy and environment systems models and traffic flow models and their application to inform decisions on targets, policy evaluation and development impacts. Collection and dissemination of transparent, replicable, comparable and accurate public data on transport.

**See Section 8, Appendix – Overview of measures and responsibilities in GIZ's Urban Transport and Energy Efficiency Module 5h of the Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities for an extensive list of available measures.*

It is beyond the scope of this chapter to explore this entire universe of measures in detail. However, given the growing prevalence of single occupancy private vehicles in South African cities and their associated externalities, travel demand management strategies for this mode are discussed in more detail below.

Implementation Priorities in the Words of Practitioners

Some leading local practitioners in sustainable transport contributed their thoughts:

Lisa Kane, Independent Researcher, Consultant and Activist

- Think of road space as a precious resource – like water or energy – and allocate it efficiently. Single Occupancy Vehicles (SOV) are energy intensive and space intensive. Too many SOVs leads to congestion and delays for road-based public transport, walking and cycling (which are far more energy and space efficient). Public transport investment needs to be prioritised over road building for SOVs for congestion and energy reasons. Within 10 years there will need to be looking at restricting SOV use in most of our cities and large towns, as developed cities do, either by congestion pricing, higher parking fees or SOV-use restrictions. There also needs to be more 'squeezed' out of our roads by optimizing traffic signals better and investing more in junction design to improve bottlenecks.
- Make best use of vehicles already in use. At the moment cars are used very inefficiently and mainly by one person only. Car-pooling apps and autonomous vehicles look set to blur the line between private and public transport. This is a good thing for energy efficiency. Local government needs to remove barriers to, and invest in, technologies which improve the efficiency of existing vehicle use (e.g. car-pooling apps, public transport apps, walking apps).
- The barriers to technology uptake can be in surprising places. For example, the legality of car-pooling is not 100% clear at the moment and this has implications for car insurance. Public transport apps require access to data and forward thinking about open data policies in local government.
- Reduce the need to travel. Any large destination such as school, college, workplace, retail mall, hospital is also a large attractor and producer of movement. Many of these are managed by local or provincial government. Micro-changes at large destinations attracting many SOVs can have large impacts over time. Site-based travel planning could involve changes to timetables or work hours to enable sharing of vehicles or public transport, working with suppliers to reduce travel, educating students and staff about transport efficiency. There are many potential win-wins to looking closer at travel on a site-by-site basis: more work flexibility for staff with potential for better work outcomes, less time spent in traffic, reduced travel costs for individuals. The local authority itself is a good place to start with this.

Geoff Bickford, Programme Manager, South African Cities Network

- Action oriented integrated land use transport planning. Municipalities will need to ensure that actual land use and transport decision making is co-ordinated to give effect to good quality lifestyles based on public transport.
- Place a priority emphasis on walking, cycling and public transport over roads. Municipalities have ownership and control over the municipal road network and transport planning and design for this network. Despite the existing policy rhetoric municipalities have not managed to prioritise pedestrians and cyclists.
- Factor in the true cost of driving private vehicles. Currently the way transport is funded subsidises drivers. Municipalities will need to get drivers to pay the true cost (to society, the environment and the municipality) of driving, and capture these revenues to fund the improvement of sustainable transport options.

Promotion of travel demand management strategies to minimize passenger cars or single occupancy vehicles (SOV)

The upgrade of a public transport system to a more reliable, convenient and safe system can encourage people to change to public transport. Other strategies need to be put in place to encourage movement away from automobile dependence.

These strategies include:

- Implementation of high occupancy vehicle lanes, which mean that cars with three or more occupant can have access to a dedicated lane. This lane usually moves more quickly during the peak periods, with free flowing traffic rather than the bumper-to-bumper traffic that is common in the peak periods.
- Employer programmes which aim to encourage the use of alternative transport, such as public or non-motorised transport or car-pooling, to get to work. This could include preferential parking for those carpooling, subsidies for public transport tickets, guaranteed ride home and moving away from subsidized parking for single occupancy vehicles. Staggering of working hours within localities can also help reduce the expensive peak demand on public transport services and make them more financially viable.
- Park-and-Ride schemes allow people to park their cars at public transport interchanges and continue the journey on public transport. An important aspect here is the need for security at the site, in order to ensure the safety of the commuters as well as making sure that the cars are secure.
- The cost of traveling by private vehicle should also be looked at, including the need for accurate parking charges in the CBD. An international trend, which has been successful in a number of cities including London, Rome and Milan (see box), is the implementation of a congestion charge for access into certain areas of the CBD. The money taken from the charge covers the operational costs of the service as well as upgrading aspects of the public transport system.

The travel demand management strategies can only work if there are suitable alternatives put in place for the commuter.

'Area C' in Milan

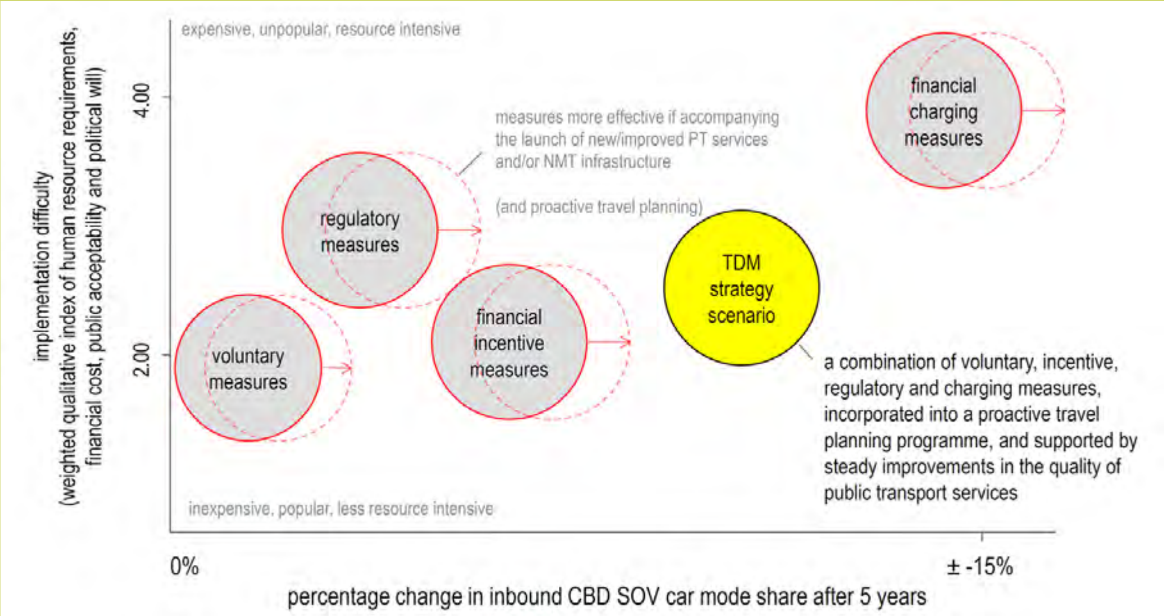
- 79% of citizens voted for a traffic restricted zone
- The central area of Milan (4.5% of area) was cordoned off by special gates in 2012. Cameras detect vehicle entrance with ANPR (Automatic
- Number Plate Recognition) technology.
- A daily entrance ticket costs €5 (congestion charge)
- Access for low emission and public transport vehicles is free.

Source: http://www.c40.org/case_studies/milansareacreducestrafficpollutionandtransformsthecitycenter

Travel Demand Measures (TDM) Measures to Reduce Single Occupancy Vehicles (SOV) – How much can they Achieve?

The potential range of effect of TDM in reducing SOV, as seen in various cities globally, was reviewed to assist with the design of a Travel Demand Management (TDM) strategy for Cape Town. The difficulty of implementation of types of measures was also assessed:

Figure 17: Hypothetical TDM strategy effectiveness in Cape Town based on effects in other cities (the yellow circle is a mix of the other measures)



Source: Behrens R, Adjei E, Covary N, Jobanputra R, Wasswa B, Zuidgeest M (2015). A Travel Behaviour Change Framework for the City of Cape Town, Proceedings of the 34th Southern African Transport Conference.

- Financial charging (see case of Milan above) seems most effective but could be difficult to administer and be unpopular (see high difficulty score above).
- In combination with other measures and with the correct packaging, sequencing, targeting and resourcing, a 10% reduction in the SOV mode share of traffic travelling in and out of the city centre could be achieved.

Provision of reliable, quality and financially sustainable public transport (Shift)

Public transport is an essential pillar of sustainable transport and that in order to compete with passenger cars it needs to be of sufficient reliability and quality. South Africa has seen concerted investment in public transport since the build up to the Soccer World Cup in 2010. Integrated Public transport systems mostly focussed on a high quality bus service have emerged and are emerging at different rates in the large metropoles but as the system grows so does the pressure on the state to subsidize this emerging system.

The most challenging areas from a financial sustainability perspective are former townships and low-income dormitory suburbs on the periphery. These areas are characterised by high densities that should help public transport economics but their isolation, low levels of local industrial and commercial development and high levels of informality place pressure on fares and create a highly peaked (and inefficient) demand profile.

Aside from a burgeoning global literature, the expansion of increasingly complex networks in the large South African metropoles has seen the growth of in-depth local expertise and a great many high quality local resources and analyses on the subject of public transport now exist published by transport authorities, consultants, academics and civil society. Key issues and details of some of the levers available to practitioners in carrying on this difficult but essential national enterprise will be highlighted.

BRT – what and why? (Shift)

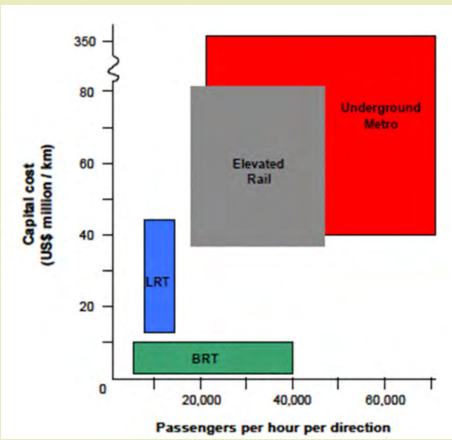
Public transport customers typically give the following reasons for switching to private vehicles:

1. Inconvenience in terms of location of stations and frequency of service;
2. Failure to service key origins and destinations;
3. Fear of crime at stations and within buses;
4. Lack of safety in terms of driver ability and the road-worthiness of buses;
5. Service is much slower than private vehicles, especially when buses make frequent stops;
6. Overloading of vehicles makes ride uncomfortable;
7. Public transport can be relatively expensive for some developing-nation households;
8. Poor-quality or non-existent infrastructure (e.g., lack of shelters, unclean vehicles, etc.)
9. Lack of an organised system structure and accompanying maps and information make the systems difficult to use; and
10. Low status of public transit services.

Source: Wright (2002 edition) Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities – Module 3b, Bus Rapid Transit, GiZ.

Bus Rapid Transit (BRT) has become synonymous with the South African public transport project since the build-up to the soccer world cup 2010. BRT is a bus-based mass transit system that has the potential to deliver high capacity public transport at a cost that is far more affordable for developing countries than rail options as shown in Figure 18 below.

Figure 18: The Financial Rationale for BRT – Mass Transit at Relatively Low Capital Cost



Source: Wright (2002 edition) Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities – Module 3b, Bus Rapid Transit, GiZ, http://www.sutp.org/files/contents/documents/resources/A_Sourcebook/SB3_Transit-Walking-and-Cycling/GIZ_SUTP_SB3b_Bus-Rapid-Transit_EN.pdf

It achieves this not only through engineering and systems features but also through a range of best practice approaches across operations that extends to safety, communications and public relations with an overarching focus on the customer. These detailed aspects of BRT are now well standardized around key aspects such as the following

- Efficient pre-paid, contactless and integrated fare collection
- Busway alignment
- Priority at intersections
- Dedicated right of way and corridor selection
- Quality of Service Planning and Operations
- Quality of Infrastructure
- Quality of Communications
- Accessibility and integration with other modes

These can be assessed and scored relative to documented best practice such as the BRT Standard [32]. As well as establishing a global standard for public transport that can compete with private transport, this enables transport authorities to implement pragmatic aspects of BRT as resources allow while still integrating these incremental improvements into a greater philosophy of service delivery. The BRT standard has 30 scoring criteria and 8 criteria for deductions of which the following are a few examples:

EXAMPLE 1: EXPRESS, LIMITED, AND LOCAL SERVICES

Mass-transit systems can significantly increase operating speeds and reduce passenger travel times by providing limited and express services. Instead of stopping at every station in the manner of local service, limited services skip lower-demand stations and stop only at major stations that have higher passenger demand. Express services usually collect passengers at one end of the corridor and drop them off at the other end.

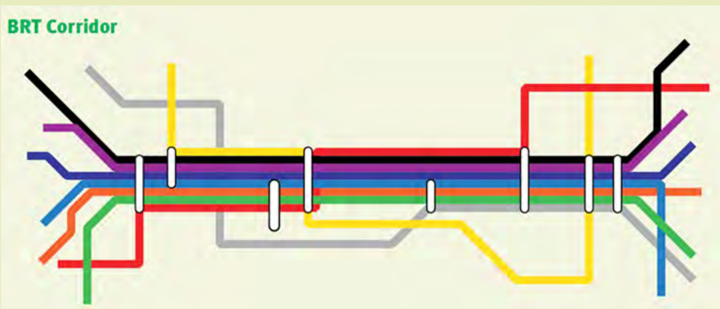
EXAMPLE 2: MULTIPLE ROUTES

Having multiple routes that operate on a single corridor helps to reduce door-to-door travel times by reducing transfers.

This can include:

- Routes that operate over multiple corridors, as exists with TransMilenio in Bogotá or Metrobús in Mexico City;
- Multiple routes operating in a single corridor that go to different destinations once they leave the corridor, as exists with the Guangzhou, Cali, and Johannesburg BRT systems.

Figure 19: Multiple Routes on a BRT Corridor



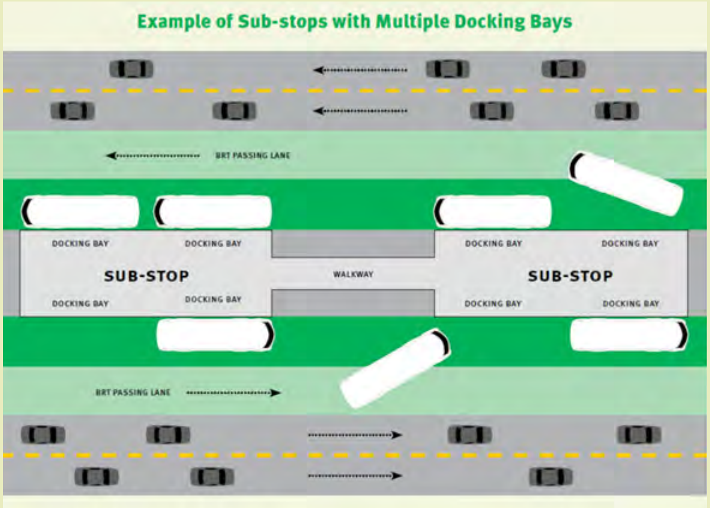
Source: The BRT Standard 2014 Edition

32 The BRT Standard 2014 Edition

EXAMPLE 3: STATION CONFIGURATIONS – PASSING LANES; MULTIPLE DOCKING BAYS AND SUB-STOPS

Passing lanes at stations allow express service to overtake stopped buses from local services while multiple docking bays and sub-stops prevent congestion by allowing buses to pull up behind one another to disembark passengers as shown below

Figure 20: High scoring BRT station configuration with passing lanes and multiple docking bays and sub-stops



Source: The BRT Standard 2014 Edition

EXAMPLE 4: INTEGRATION OF BIKE LANES WITH BUSWAY

Integration with other modes, especially sustainable modes, is prioritised in best practice BRT design. Cycling access and dedicated cycling path provision along corridors gives commuters this sustainable option and allows access to the BRT service.

Figure 21: Cape Town's myCiti service is a hybrid system with some routes operating in mixed traffic but they score full BRT Standard points for this cycling path along the length of a transit corridor

Source: The BRT Standard 2014 Edition

"Latin America is today the epicentre of the Global BRT movement. A third of BRT route kilometres and nearly two thirds (63%) of ridership are in Latin America (Cervero, 2013)[1]

"If you have the correct town planners and engineers who understand the bigger picture and who can actually incorporate local conditions in the city's planning, they can ensure that the BRT system is sustainable. But if you have somebody who doesn't understand the background and just wants to replicate other places, you are not going to have a sustainable (economically) system", Prof. Wynand Steyn, Chairman of the 34th annual Southern African Transport Conference (SATC)[2]

It does not make sense for South Africa to only be a follower of Latin America in the implementation of BRT and public transport in general. Objectively, our combined challenges such as lower urban densities, security issues, huge income disparities, poor distribution of commercial activity along transport routes and less depth in operational experience and competitiveness are in general greater and projects will fail in the long term if there are no evidence of significant customisation and innovation. The development pathway will necessarily be longer and more arduous and plan for these setbacks should be expected.

1 Cervero (2013) Bus Rapid Transit (BRT): An Efficient and Competitive Mode of Public Transport, Institute of Urban and Regional Development, University California Berkeley, Working Paper 2013-01.

2 http://www.bloemfonteincourant.co.za/mangaung-has-fallen-behind-with-brt-system/

While BRT is much cheaper than rail because the capital equipment is less extensive, the multifaceted high standard of service benchmark described above means it is still very expensive in a South African context especially in relation to the dominant minibus based paratransit. The spatial characteristics of our cities make financially viable public transport challenging. Urban planning is therefore a key aspect of success as well as operational excellence. The entry of modern bus services into poor informal areas on the periphery, in particular, needs to be coupled with long terms plans for urban land renovation and management and fostering of local commercial enterprise.

TOD – Transit Orientated Development (Avoid, Shift, Enable)

The imperative to integrate public transport in the urban development process arose as a necessity in the face of the difficulties of developing viable and competitive public transport services. This gave rise to the notion of Transit Orientated Development (TOD) which has been described as follows:

TOD: "Compact, mixed-use, pedestrian-friendly development organized around a transit station. TOD embraces the idea that locating amenities, employment, retail shops, and housing around transit hubs promotes transit usage and non -motorized travel (Suzuki et al., 2015).

TOD is an approach to planning of which the guiding principles are as follows:

8 key Principles to Guide "Transit-oriented development"

The Institute for Transport and Development Policy's Principles of Urban Development for Transport in Urban Life:

1. [walk] Develop neighbourhoods that promote walking
2. [cycle] Prioritize non-motorized transport networks
3. [connect] Create dense networks of streets and paths
4. [transit] Locate development near high-quality public transport
5. [mix] Plan for mixed use
6. [densify] Optimize density and transit capacity
7. [compact] Create regions with short commutes
8. [shift] Increase mobility by regulating parking and road use

> "TOD implies high quality, thoughtful planning and design of land use and built forms to support, facilitate and prioritize not only the use of transit, but the most basic modes of transport, walking and cycling."[1]

1 Institute for Transport and Development Policy (ITDP), (2014) "TOD Standard v2.1"

Some key aspects of TOD and possible mechanisms for financing the required shift are explored below.

LAND USE PLANNING AND URBAN DENSITY (AVOID, SHIFT, ENABLE)

It stands to reason that the way in which a city is organised will have an effect on the efficiency with which it functions, particularly transport. The financial sustainability of high quality public transport in South Africa is extremely challenging and so it is important for transport authorities to leverage the advantages of planning interventions as much as possible even though these can take many years to bear fruit. This is a vast and specialised subject and will be limited to two related planning criteria that are supportive of public transport; mixed land use and urban density, briefly explaining these, how they could be assessed and their impacts.

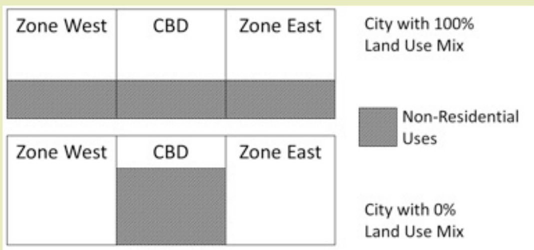
What is mixed land use?

A mixed or integrated land use environment is one where commercial/industrial, residential and educational land uses are proximate instead of concentrated remote from each other in large and unintegrated areas.

How can land use mix be measured?

A practical indicator for land use mix is the proportion of area taken up by non-residential uses in a zone or zones of interest relative to the situation in the CBD, as illustrated in Figure 22 below. Thus for a land use mix of 0%, all of the non-residential land uses are situated in the CBD, representing a monocentric city with segregated land uses. At a land use mix of 100%, each zone has a proportion of the non-residential land uses that is equal to the total proportion, including the CBD.

Figure 22: A method for measuring urban land use mix: as the average proportion of the area that is taken up by non-residential uses in zones of interest relative to that proportion in the CBD



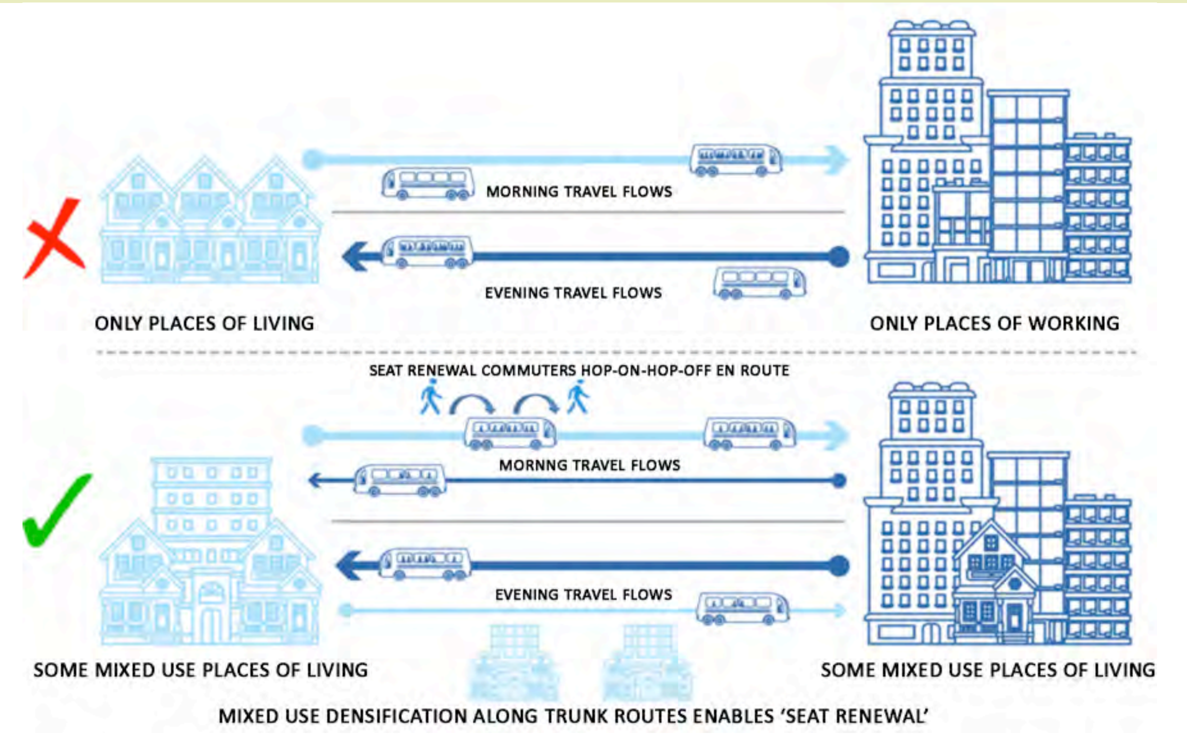
Source: adapted from Cooke (2016) Investigating the relationships between land use characteristics, public transport network features and financial viability at a corridor scale, MSc Dissertation, Department of Civil Engineering, University of Cape Town.

What are the benefits to public transport of mixed land use?

A residential area may be very dense and promise an economy of scale to a public transport system but will likely have very low levels of activity during core working hours. This gives rise to tidal flows of commuters leaving to and returning from work and education at peak hours. Not only does this require a system with a large capacity for the peak that is underutilised outside of peak but tends to create a situation where overfull buses or trains travel in one direction at peak but return empty to their origin as they circulate to meet overflow or off -peak demand. These empty trips have a financial performance of zero.

As shown below in Figure 23, in a mixed land use scenario however commuters will tend to travel in both directions, termed bi-directional flow, reducing both empty trips and congestion. This bi-directional flow will reduce car congestion as an additional benefit. If mixed use development was to extend along a transit corridor 'seat renewal' will occur whereby there is a regular exchange of passengers embarking and alighting at stations between terminals. This creates a higher turnover of fares and opens up space for better cost recovery by moving away from distance based to trip based fares with the added benefit that poor people remaining on the periphery are not penalised.

Figure 23: The benefits of mixed land use and densification: reduction of empty trips, bi-directional flow and seat renewal

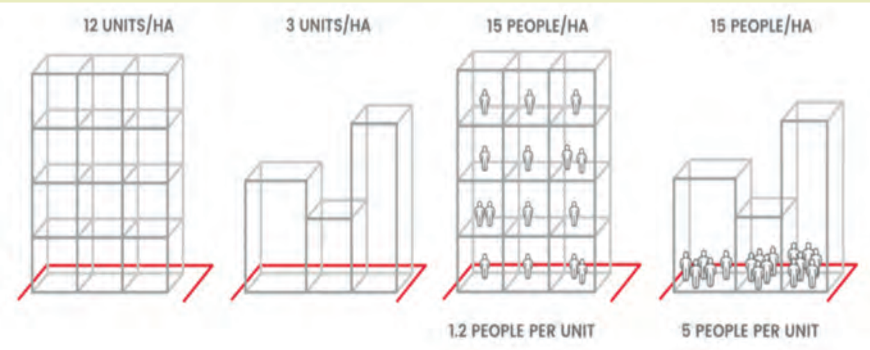


Source: Adapted from Bickford and Khoza (2016) Transit Oriented Density Framework – Towards a Deeper Understanding of Density, South African Cities Network (SACN), Johannesburg.

What is Urban Density?

Density, as commonly defined in urban planning terms, is the concentration of people, domiciles or activity within a given space. It may be relatively fixed such as the number of dwelling units per hectare (du/ha) or it may be in flux such as the number of people per hectare (pax/ha) within the CBD during certain times of day. Figure 24 below shows how the two commonly used planning definitions of units or dwelling units per hectare and people per hectare relate to each other for different spatial configurations.

Figure 24: Relationship between commonly used planning definitions of urban density



Source: SACN Bickford and Khoza (2016) Transit Oriented Density Framework - Towards a Deeper Understanding of Density, South African Cities Network (SACN), Johannesburg.

Both du/ha and pax/ha are useful from a public transport planning perspective as they will reflect in some measure the potential concentration of demand for a service. Such densities are expressed in gross base, gross or net terms, which according to the City of Cape Town's Densification Policy (CoCT, 2012)[33] are defined as follows:

- **Gross urban density (du/ha):** The number of dwelling units per hectare of land calculated in a designated area on the basis of land used for residential purposes and other land uses, such as industry, commerce, education, transport and parks. Excluded are land-extensive uses, such as agricultural land and natural areas/ nature reserves/parks.
- **Net urban density (du/ha):** The number of dwelling units per hectare of land calculated on the basis of land used for residential purposes, including the garden and off-street parking, if any.
- **Gross base density (du/ha):** The average number of dwelling units per hectare across the city as a whole or a smaller unit, excluding land-extensive uses, such as agricultural and rural land and large natural areas/nature reserves.

The Cape Town Densification Policy, for example, targets a gross base density of 25 du/ha but a net density of 100-375 du/ha (equivalent to a gross density of about 50-180 du/ha) on activity routes. These are routes of significant scale where public transport corridors would typically be planned. However, from Figure 24 it can be seen that dwelling units per hectare will translate to variable concentrations of people and will furthermore not reflect the general suitability of the urban environment for public transport. Additional indicators can contribute then to a richer picture of density that supports mass transit.

The theory of Transit Orientated Development (TOD) has informed the emergence of a broader range of urban density related indicators. The South African Cities Network (SACN) has developed a Transit Orientated Density Assessment Framework of 10 indicators which are summarised in Figure 25 on the next page:

33 City of Cape Town (2012) Cape Town Densification Policy, February 2012

Figure 25: South African Cities Network (SACN) Transit Orientated Density Assessment Framework

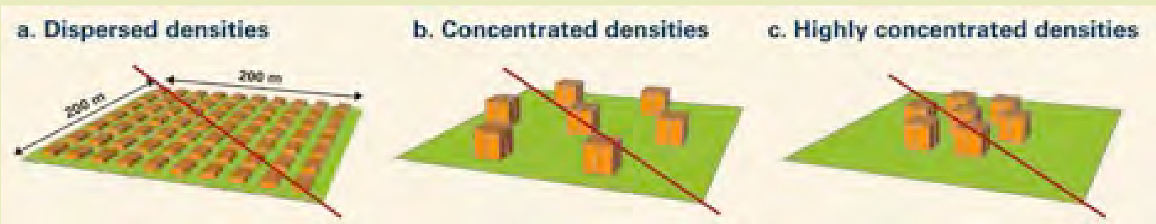
Source: Bickford and Khoza (2016) Transit Oriented Density Framework – Towards a Deeper Understanding of Density, South African Cities Network (SACN), Johannesburg.

SACN has developed this framework to give an overall assessment at different scales (site, zone, city) of the land use characteristics that support viable mass transit. Maintaining such sets of indicators offer the potential to now systematically assess the progress of the urban environment towards public transport friendliness and sustainability in general. Other research has focussed on density relative to the transit corridors themselves and this has given rise to the idea of "articulated density" or more simply "people near transit" discussed below.

What is Articulated Density (people near transit)?

Densities that are strategically distributed across parts of a metropolitan area are more important for enabling transit and land-use integration than average population densities. This is termed "articulated density" and is illustrated in principle below in Figure 26. All three layouts have the same average population density but the layout in panel c is better suited to mass transit than that in panel a because more people will be near the mass transit line and not need to make long feeder trips.

Figure 26: Three configurations of the same average density relative to an illustrative mass transit line (red diagonal)



Source: Suzuki, Cervero & Iuchi (2013) Transforming Cities with Transit, Washington DC: World Bank.

Los Angeles which has a relatively high, evenly distributed average population density is often cited as an example of unsupportive or dysfunctional density, which aggravates congestion and poorly supports competing mass transit (Cooke, 2016).[34] Curitiba by contrast has relatively low average population density but has achieved high articulated density through long term integrated planning which contributes to the success of its high capacity and unsubsidised BRT system (Suzuki et al. 2013).[35]

How can articulated density be measured?

The Institute for Transportation and Development Policy (ITDP) [36] has proposed an indicator called *"People Near Rapid Transit"* (PNT) as the proposed indicator for Sustainable Development Goal Target 11.2 [37]. PNT measures the number of residents in a city who live within a short walking distance (1 km) of high-quality rapid transit. This is generally equivalent to a 10- to 15-minute walk, depending on factors specific to the local environment like topography and pedestrianisation. The intention is to estimate accessibility and rapid transit coverage in large cities and provide a high-level proxy for the integration of land use and transport. The basic features of the methodology is as follows:

- The indicator is expressed as a percentage of people in the area being evaluated that live near (< 1km) mass transit.
- Mass transit is limited to high capacity modes: Light rail, BRT or metro line.
- Criteria around station spacing, route capacity and fare collection are set.
- Census data at neighbourhood and preferably block level is preferred but spatial imagery- based approximations may suffice where data is limited.

The ITDP evaluated their PNT indicator on a number of OECD and non-OECD cities including Johannesburg which is compared to Rio de Janeiro in Figure 27 below. The challenges of integrating public transport with the existing urban form in South Africa are clearly evident and speak to the use of this indicator in our cities. If the Rea Vaya system is extended to dense areas in the west however, PNT will improve markedly.

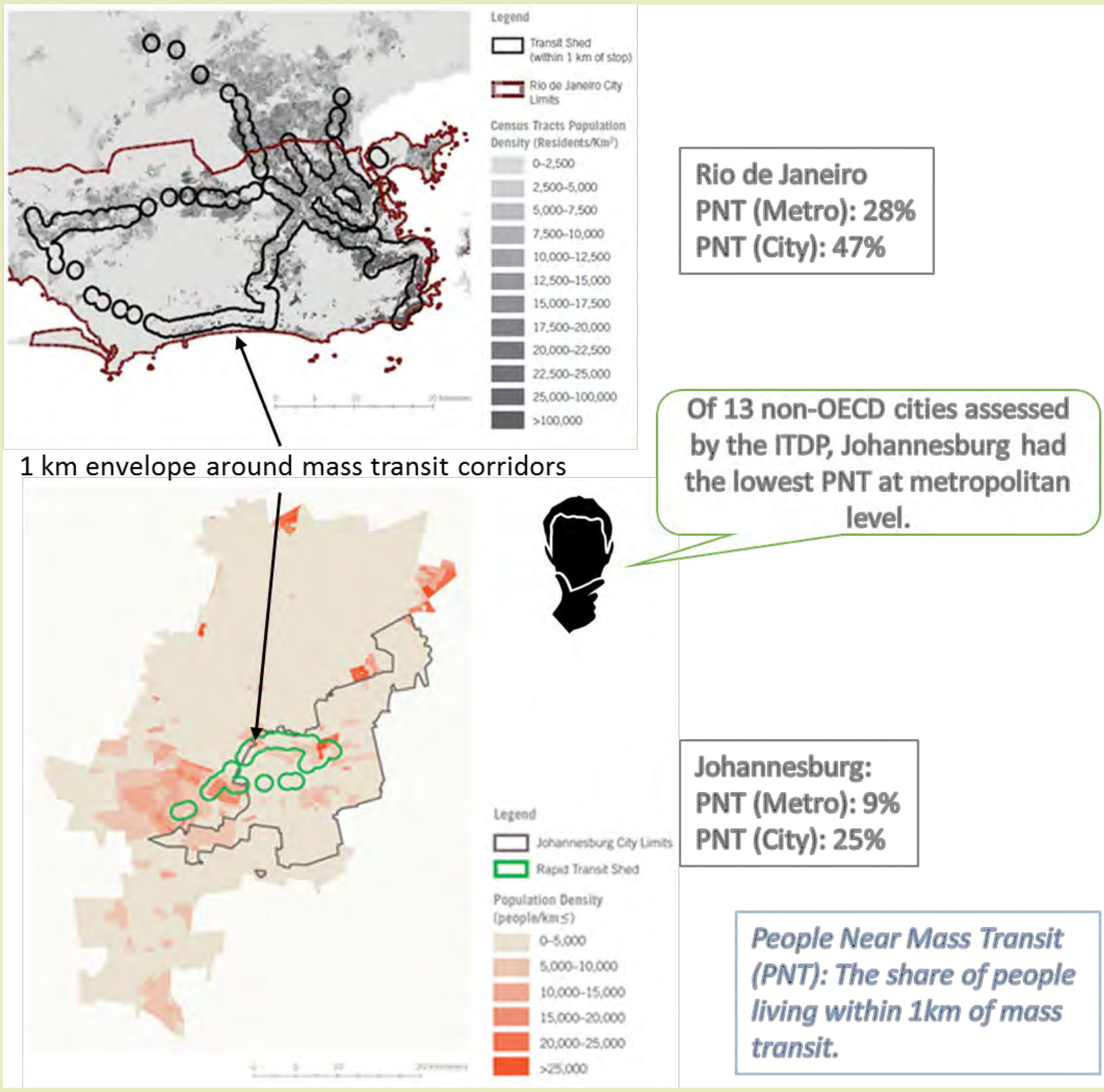
34 Cooke (2016) Investigating the relationships between land use characteristics, public transport network features and financial viability at a corridor scale, MSc Dissertation, Department of Civil Engineering, University of Cape Town.

35 Suzuki, Cervero & Iuchi (2013) Transforming Cities with Transit. Washington DC: World Bank.

36 Marks, Mason & Oliveira (2016) People Near Transit: Improving Accessibility and Rapid Transit Coverage in Large Cities. Institute for Transportation and Development Policy (ITDP), October 2016.

37 SDG Target 11.2: By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.

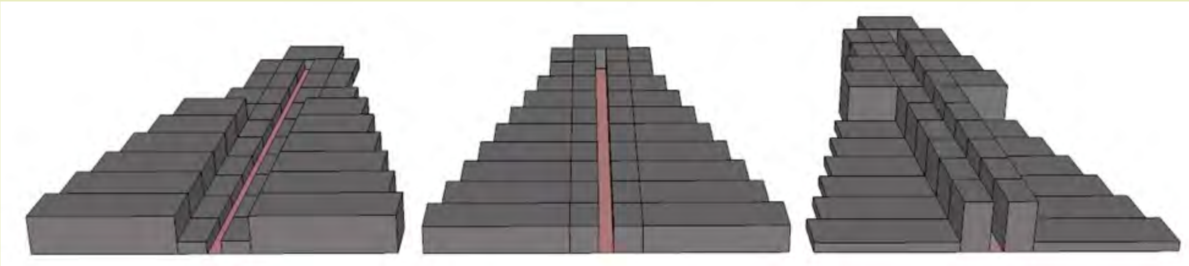
Figure 27: Comparison of the “People Near Rapid Transit” (PNT) indicator assessment of articulated density for Rio de Janeiro and Johannesburg



Source: Marks, Mason, Oliveira (2016) People Near Transit: Improving Accessibility and Rapid Transit Coverage in Large Cities, Institute for Transportation and Development Policy (ITDP), October 2016.

The PNT concept has been independently used at the University of Cape Town to model the potential impacts of improved articulated density (and land mix) on a representative South African transport corridor with feeder routes (Cooke, 2016). The simplified corridor is shown below in Figure 28. Each block segment is a component of the passenger catchment area of the transit corridor called a Traffic Analysis Zone (TAZ). The arrangement is triangular with the CBD at the point of the triangle and the catchment widening with distance from the CDB. The smaller TAZs adjacent to the central trunk are called TOD zones and the people in that zone can access the trunk directly without a feeder trip. In likewise fashion to PNT, if articulated density is 20% then 20% of the people in the catchment area will be in the TOD zones and similarly if articulated density is 80% then 80% of the people in the catchment will be in the TOD zones.

Figure 28: Quantification of articulated density on three illustrative trunk corridors with the same gross population density: 20% (left); 43% (centre) and 80% (right) The height of the block segments represents localised population density



Source: Cooke (2016) Investigating the relationships between land use characteristics, public transport network features and financial viability at a corridor scale, MSc Dissertation, Department of Civil Engineering, University of Cape Town.

What are the potential impacts of articulated density?

The potential impacts of articulated density will be explored using selected results of Cooke's recent modelling study, given its local focus. The current South African situation was deemed to have, in general, poor articulated density of around 20% as illustrated in Figure 28 on the far left above. When density articulation was varied while keeping gross population density at 50 pax/hectare, significant cost reductions were evident for both the simulated operator and authority for the two classic system arrangements:

- Trunk-Feeder: Feeder lines feed terminal stations at intervals on the main trunk
- Corridor service: Each feeder line does direct to CBD terminal stations at the end of the trunk.

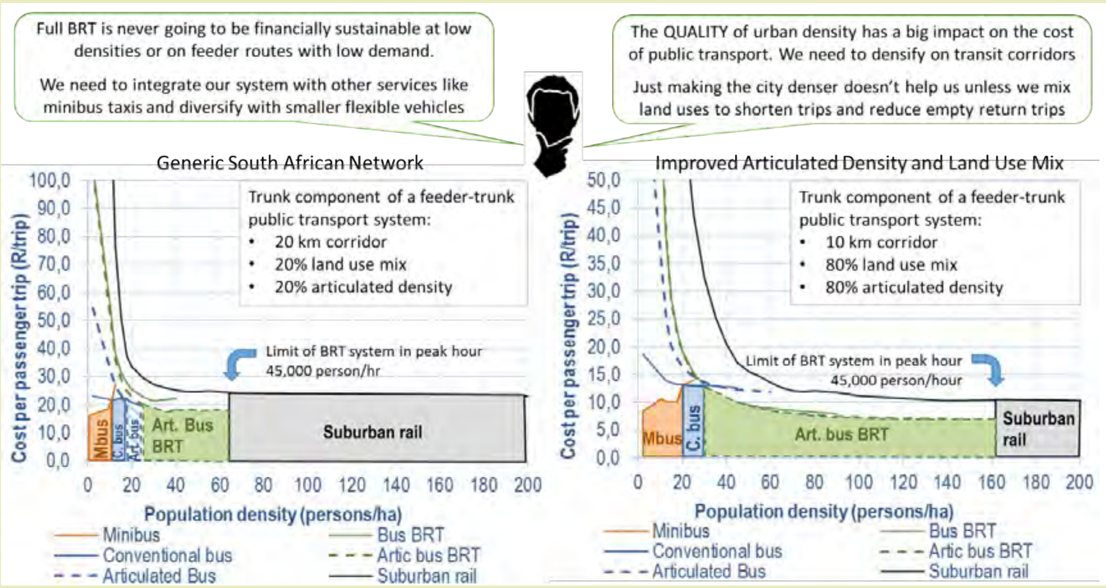
Figure 29: Cost components when varying density articulation on a 20km corridor

Source: Cooke (2016) Investigating the relationships between land use characteristics, public transport network features and financial viability at a corridor scale, MSc Dissertation, Department of Civil Engineering, University of Cape Town.

What are the impacts of density and articulated density in combination with land use mix?

Articulated Density and land use mix are potentially complementary in practice because various uses benefit from proximity to a transit corridor and such developments might be more attractive to both developers and tenants. Cooke (2016) combined the impact of articulated density with land use mix which was quantified as shown in Figure 22. The effect of varying gross density on the cost of various modes, was tested for the classically South African situation and contrasted with a more ideal situation of 80% articulated density, 80% land use mix and a shorter corridor of 10km instead of 20km. The results below show a marked impact on costs and the gross density at which different modes become viable.

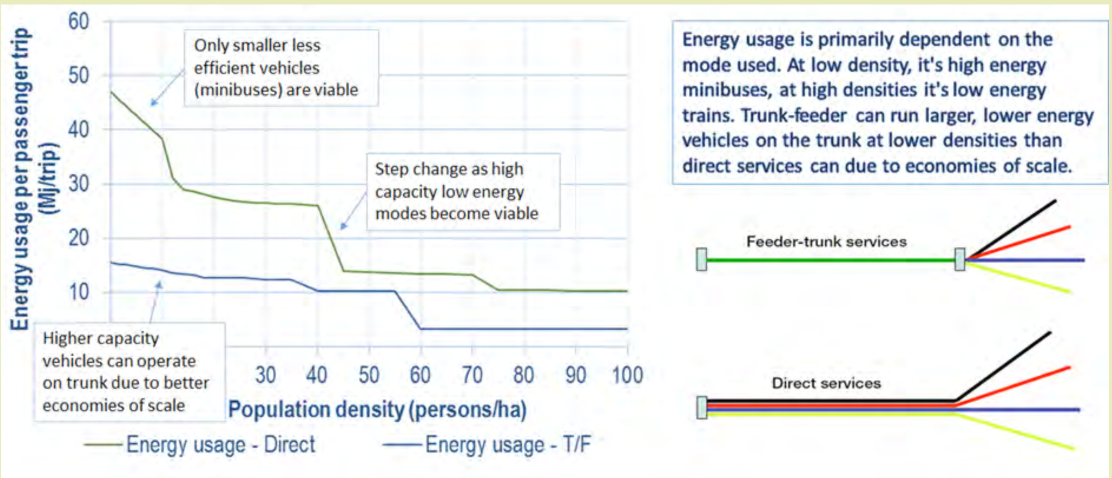
Figure 30 - Simulated Effect of increasing population density on the total cost of different modes for a generic South African Public Transport Network contrasted with a Network having more Supportive Land Uses



Source: Adapted from Cooke 2016) Investigating the relationships between land use characteristics, public transport network features and financial viability at a corridor scale, MSc Dissertation, Department of Civil Engineering, University of Cape Town.

The energy intensity of operation was also assessed for the two different system configurations in response to population density as shown below in Figure 31.

Figure 31 - Simulated Effect of increasing population density on the energy intensity of public transport supply for Trunk-feeder and Direct System Configurations



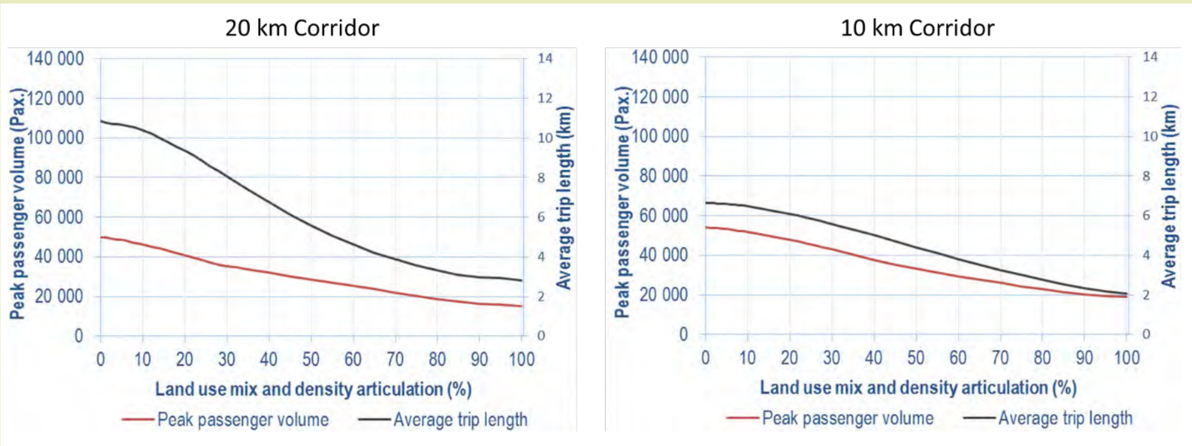
Source: Cooke (2016) and Wright (2002)

What can be learnt from these cost simulations of articulated density and land use mix change?

The purpose of this type of modelling exercise is not to replicate reality precisely but several powerful indicative insights arise out of the work as follows:

- The cost of the modes that require large vehicles and extensive infrastructure like articulated bus BRT and Light Rail are very high at low gross densities as expected, because low demand doesn't offset their capital and operating costs.
- At low gross densities minibuses and conventional buses are more cost effective. This effect is even more pronounced for feeder routes to the trunk (not shown – see Cooke 2016) where minibuses are still more cost effective even at quite high gross densities
- In a situation of unsupportive land use conditions however, increasing gross density beyond a certain point does not strongly reduce the cost of a public transport system even on the trunk because the peak demand increases, making the system more inefficient.
- A high peak demand makes the system inefficient because the system has to be scaled for the peak but is underutilised off-peak.
- A more supportive land use environment, aside from significantly reducing the costs of the high capacity modes, also improves the response of the costs of these modes to increasing gross density. This is because peak passenger volumes and average trip length are reduced as shown below.

Figure 32: Effect of increasing complementary land use mix and density articulation on peak passenger volume and average trip length for a constant gross density of 50 pax/hectare



- From the above comparison between a 10 km and 20 km corridor it can be seen how longer corridors create a large catchment area with long feeders leading to high average trip length which amplifies the problems of low land use mix.
- A direct system configuration is likely to be cheaper at low densities because of lower infrastructure requirements although this difference reverses as densities increase. The direct configuration is however likely to be significantly less energy efficient in the low density scenario. Generally, there seems to be a long term cost and sustainability advantage to planning for trunk-feeder systems.

LAND VALUE CAPTURE (ENABLE)

The structure and historical legacy of South African cities is characterised by sprawl, concentrations of poverty on the periphery and service backlogs. This places enormous strain on their financial sustainability. The historical model of state subsidy and partial recovery of this from fares is therefore less and less viable. It is thus critical to integrate municipal finance aspects into sustainable development planning, particularly for capital intensive public transport infrastructure and to innovate where possible. A group of instruments and policies called "Land Value Capture" (LVC) (also called Land Based Financing) are described as follows:

> *"(Land) Value capture is a term used to describe the process of extracting (in different ways) the additional value that accrues to a property following different types of public investment (e.g. The Gautrain). The value extracted is therefore the value over and above the value the property would have had without the public investment. The additional value created by the investment is often termed the "value increment". Since the additional value was created because of the state's actions rather than the owner's, it is arguably justifiable for the state to lay claim to this additional value through various mechanisms for some public purpose." (McGaffin et al. 2016)*[38]

Land value capture has been used only on occasion by city governments in South Africa although interest is growing and some of its tools like raising finance through bonds or special rates assessments are established practice.

Land value capture increments are generally classed in two categories:

Use-related (also called development or project based) value capture mechanisms: These mechanisms accrue value to a public good directly from the increased value of properties that arises from regulatory changes or infrastructure investment by selling or leasing land or selling or trading development rights.

Income-related (also called tax or fee-based based) value capture mechanisms: These mechanisms accrue value to a public good more indirectly by extracting surplus from property owners, through a tax or fee instrument such as a property tax, betterment charges or special rates assessment.

The process of land Value Capture is shown schematically below in Figure 33, linking these the two categories above to typical mechanisms that have been used to date and emphasising the oversight and technical inputs that are required for success. The mechanisms themselves are briefly described in Table 8 and Table 9 on the following pages.

Table 8: Use-related (also called Development or Project based) value capture mechanisms

Density Bonuses[1]	A zoning-based incentive aimed at encouraging developers to provide certain public amenities or to meet certain public objectives in exchange for allowing greater floor area and/or building height. The idea is that the additional revenue that the developer could generate from the sale of additional units would compensate for the inclusion of affordable housing or unprofitable public amenities.
Air-Rights[1]	The granting of air rights above public infrastructure to the private sector could be aimed at encouraging the provision of public amenities, affordable housing, encouraging greater densities and increasing the City's tax base.
Tax Abatement	This is a reduction or exemption from taxes for a specific period of time in a designated area, usually to stimulate investment in locations with lower demand. An example of this in South Africa is the Urban Development Zone.
Lease or Disposal of State-owned Land	Instead of maximising the market value of the land sale or lease, the state may choose to prioritise other policy objectives, such as affordable housing in well located areas. However, such leasing or disposal could also represent an income-generating opportunity.
Land-adjustment[2]	Landowners pool their land together for reconfiguration and redevelopment, and contribute a portion of their land to raise funds to partially cover the public infrastructure development costs. Transit- Oriented Development land readjustments have been widely used in countries such as Japan to secure land, share infrastructure costs with the private sector, and to achieve a desired urban form.

1: Where a density bonus applies to building height its sometimes also referred to as an 'air right'. Leveraging 'air rights' have been successful in Brazil where rights to multi-storey development were curtailed in many cities, increasing their value and then traded or sold

2: Also sometimes called land re-adjustment

Source: adapted from McGaffin et al. (2016)

38 McGaffin et al. (2016) Value Capture in South Africa – A way to overcome urban management challenges and unlock development opportunities? UCT-Nedbank Urban Real Estate Research Unit, Department of Construction Economics and Management, University of Cape Town.

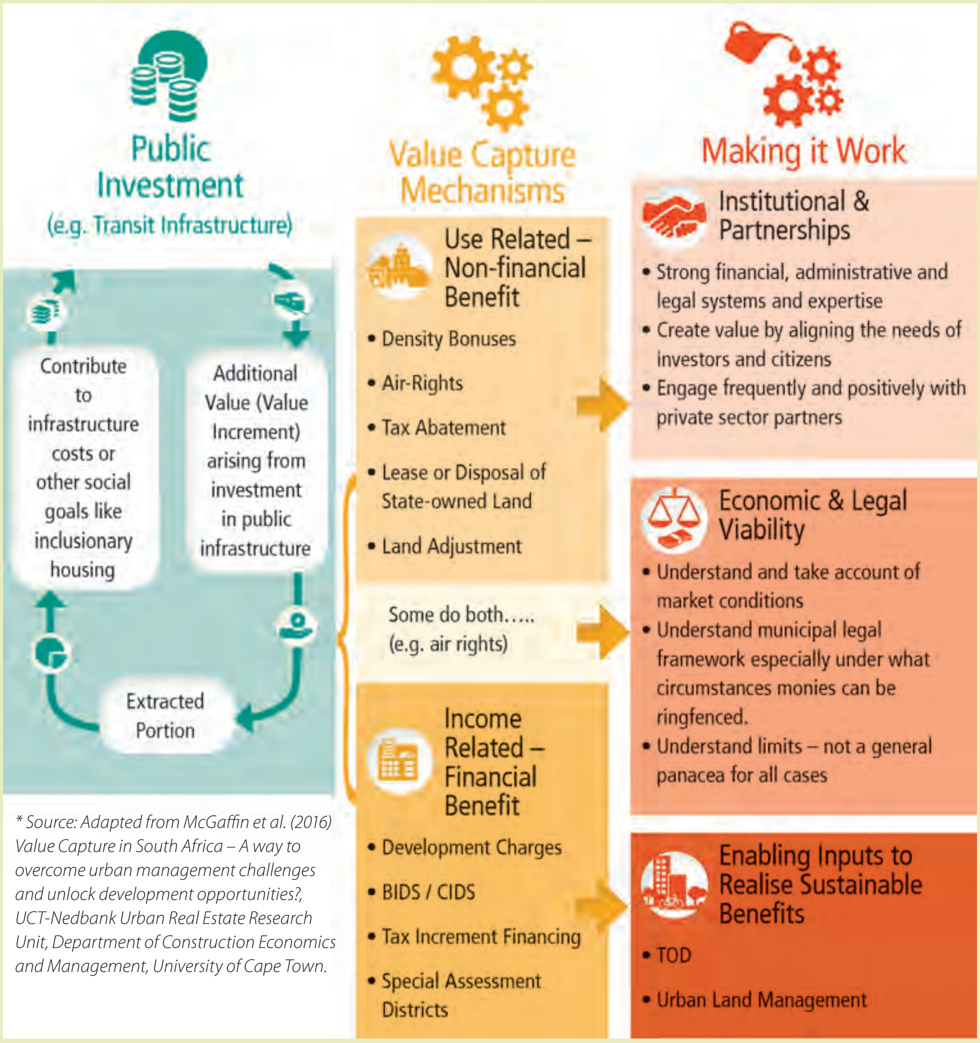
Table 9: Income-related (also called tax or fee-based based) value capture mechanisms

Development Charges	A well-known levy imposed on developers to pay for infrastructure requirements resulting from additional and expanded land uses
Business or City Improvement Districts (BIDS/CIDS)	These are delineated zones where an additional charge is levied on properties to finance top-up services to supplement the standard services provided by the state, often focused on security and cleansing. They often perform additional roles, such as area marketing, which together with the increased security and cleanliness, have demonstrably resulted in increased property values. Essentially then these are 'betterment charges'.
Tax Increment Financing (TIF)[1]	TIF schemes enable municipalities to borrow against the future anticipated incremental tax revenue (property rates in South Africa) that would be generated within a specific geographic area as a result of the construction of large-scale infrastructure.
Special Assessment Districts (SAD)[1]	These are similar to TIFs except that the income that is used to repay public funds or borrowings is in the form of a levy that has been agreed to upfront with the affected property owners within the SAD. This reduces the financial risk for the municipality, which instead is spread amongst the property owners.

1: TIF schemes usually involve the raising of a bond on the back of the expected increment income that would accrue as a result of the infrastructure investment. If the interest on the bond is to be covered by the existing or increased property rates of the owners benefitting from construction, the only way to ring-fence this income under South African law would be through structuring it as a special rates assessment.

Source: Adapted from McGaffin, R, et al. (2016)

Figure 33: One route for meeting the challenge of financing sustainable transport in South Africa's tightening fiscal environment – Land Value Capture



** Source: Adapted from McGaffin et al. (2016) Value Capture in South Africa – A way to overcome urban management challenges and unlock development opportunities?, UCT-Nedbank Urban Real Estate Research Unit, Department of Construction Economics and Management, University of Cape Town.*

It has been argued that use-based LVC has certain advantages over income-based LVC as follows (Suzuki et al. 2005) [39].

Use-based LVC Advantages

- The financing of capital-intensive transit infrastructure and transit-oriented development related investments without creating what is effectively a disincentive[40] to developers to invest through taxes and fees which can also give rise to public opposition.
- The potential to generate expanding revenues in the longer term, relative to the immediate land value increment, arising from higher transit ridership, retail shops, leisure facilities, parking, and residential buildings in the precinct of station areas.
- A collaborative relationship is necessarily forged between government, transit authorities, developers, businesses, and residents in and around stations rather than just unilateral action by government or transit authorities.

Against this need to be considered the following cautions.

Use-based LVC Cautions

- Use-based LVC requires complex property development processes involving a number of regulatory, legal and commercial processes. A land price needs to be decided on or projected up-front based on market trends, and the distribution of profit or of potential profit needs to be decided though negotiations, based on the contribution of each stakeholder. This requires municipalities, in general, to be quite highly capacitated with professional and business skills.
- A healthy property market with rising prices creates a conducive environment for use-based LVC but a lack of caution and analysis can expose governments and transit authorities to high risk particularly if excessive speculation is distorting prices and perceptions of value.
- Use-based LVC requires favourable 'macro' conditions, a strategic vision, a supportive regulatory and institutional framework, and considerable expertise. These conditions don't necessarily co-exist as a matter of course, especially in the developing economies who need innovative financing the most.
- Income-based LVC (taxes and fees) has the advantage of sustainability as its not dependent on a finite land resource or the cyclical appetite for projects of the market. There is no reason not to combine the use of use-based and income-based LVC judiciously and appropriately. The adoption and implementation of LVC should therefore depend on the conditions and needs of each city.

In addition to these general cautions South Africa has its own challenges

South African Challenges

- Available land in cities is predominantly privately owned and state land is difficult to obtain due to lack of clarity in terms of nominal ownership by a department or state entity or their jurisdiction over a transaction. Furthermore because expropriation is such a sensitive political issue in South Africa and the region, perceptions of state coercion in the use of land can quickly create negative sentiment.
- The greater share of market demand prefers a product that does not necessarily achieve the land use mix and density needed for transit orientated development. Stakeholders who buy-in to mixed and densified development therefore need to change customer preference.

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39 Suzuki, Murakami, Hong, Tamayose (2015) Financing Transit-Oriented Development with Land Values – Adapting Land Value Capture in Developing Countries. The World Bank Group.

40 Also termed 'regressive taxation' or 'fiscal or market distortion'.

- The greater share of market demand in population terms sits in the low to lower middle income segments where subsidisation levels, household affordability and access to finance inhibit an initially more expensive but more sustainable residential product in the medium term.
- Current poor economic growth limits demand for job creating land uses.
- There has as yet, in practice, been limited appetite in leadership to limit the award of land use rights to direct the market into desired locations and away from the sprawl city. In part this relates to the extreme pressure on local government to facilitate economic growth of any kind. It is unlikely, for instance, that 'air rights' could be leveraged because in general they would be granted virtually unconditionally. As noted by Zack and Silverman, "Within local government the old fashioned planning functions of zoning, regulation and enforcement have been down-graded, become outmoded and are considered less important than either strategic planning or service delivery"(Zack & Silverman, 2007) [41].

Historically poor areas stand to gain the most from mixed use developments integrated with transport but urban management challenges that discourage investment remain challenging and administratively demanding. The availability of capacity can limit the scope of projects. As has been noted, "Integrated development can only follow capacity, not vice-versa" (Demacon 2010), [42] that being said, township renewal programmes have been extensively pursued, particularly large retail developments chasing rising incomes in these areas, but including projects with a larger social vision for instance the development of Khayalitsha CBD (Clacherty 2010) [43].

These challenges are however, in the main, not out of the ordinary for a developing country and no reason not to move forward boldly. Indeed, the country has seen a great deal of experimentation, a measure of success and much learning put into the public domain in the last 20 years. Innovative land value capture will to some degree need to become a driver of the changing urban landscape to achieve sustainability and quality of life in our growing cities and towns.

Effect of global legislation through technology import (Improve)

The effect of global legislation on the emissions and fuel economy of vehicles is an important consideration in assessing the cost benefit of proposed vehicle procurement interventions to promote transport sector sustainability. Global legislation has been a driver of technology change, commercialisation and mass production of vehicle environmental solutions since the early 90s and this technology change tends to disseminate into subsidiary markets like South Africa. However, it is important to understand under what circumstances this will occur effectively. The technology that has been developed in response to legislation limiting emissions of local air pollutants (CO, NOx, VOC and PM) has mostly relied on treating the exhaust gases chemically or capturing the pollutants in devices located in the exhaust. Engine innovations have also been required to enable this or enhance this particularly in the control of fuel and air in the engine. As shown below for the case of local air pollutants that directly affect the health of mostly urban dwellers, the introduction of exhaust gas after-treatment using catalytic converters and particulate traps has apparently been highly effective.

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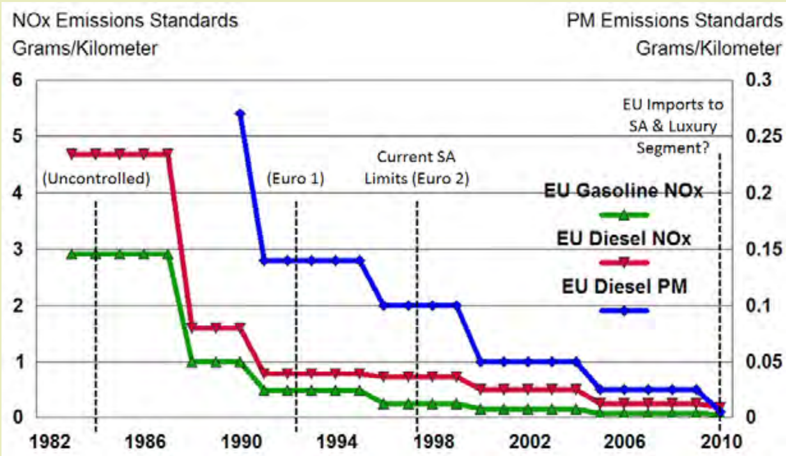
41 Zack & Silverman (2007) Using Regulation as a tool for better urban management, National Treasury, DBSA, South African Cities network and Department of Provincial and Local Government.

42 Demacon (2010) Impact of township shopping centres market research findings and recommendations, Demacon Market Studies.

43 Clacherty (2010) Operations and Management of Township Nodal Developments: Khayelitsha Business District Case Study, Training for Township Renewal Initiative, South African Cities Network and National Treasury.

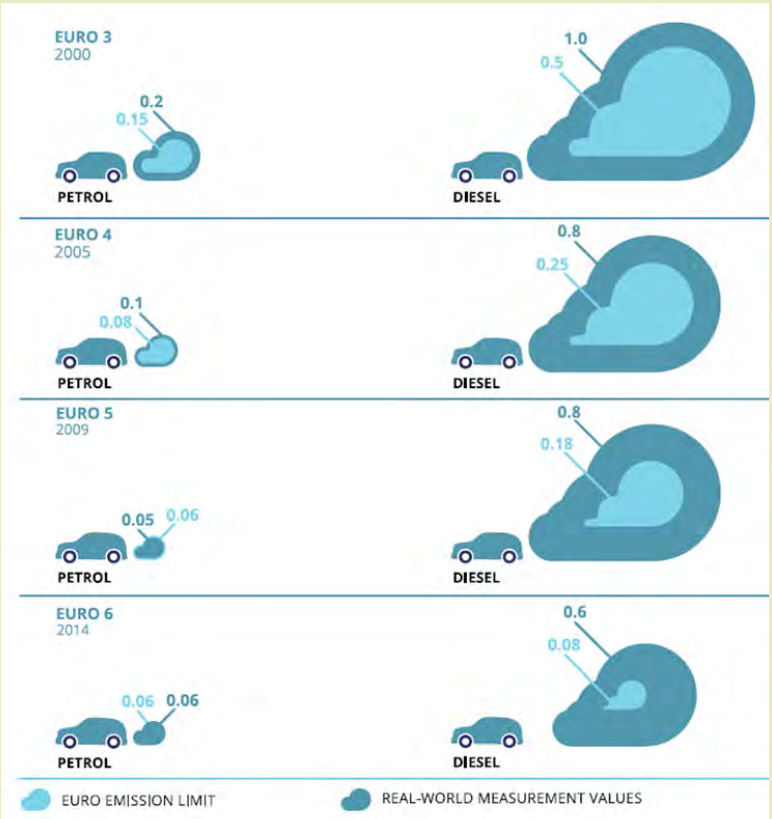
Figure 34: Evolution of European Emissions Legislation for Oxides of Nitrogen (NOx) and Particulate Matter (PM) for Diesel and Petrol Passenger Cars



Source: Walsh (2013) The Future of Vehicle Emissions Regulation in the EU and Internationally, Slide Presentation, European Commission Environment Green Week Conference, Brussels 4-7 June 2013.

The conformance to the emissions limits above is however measured by a standardised test method that has been shown to significantly under-report emissions, especially for diesel passenger cars as shown below.

Figure 35: Comparison of Real-world conformance to NOx Emission Standards by Fuel Type and Legislation Level for the EU



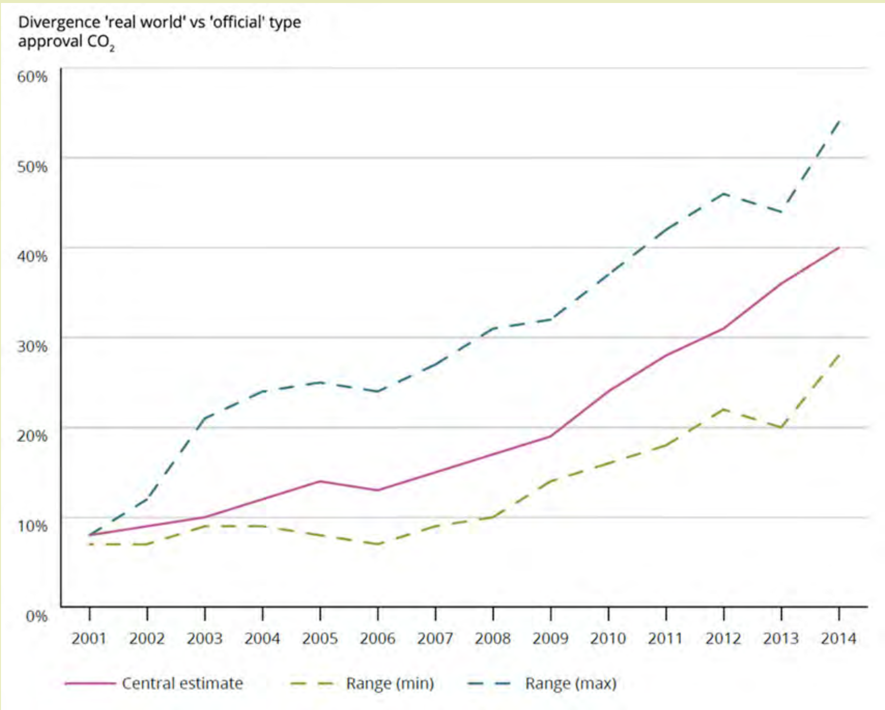
Source: Pastorello & Mellios (2016) Explaining road transport emissions - A non-technical guide. Copenhagen : European Environment Agency (EEA).

These devices also degrade with time and can be significantly affected by octane enhancing additives in the fuel or the fuel sulphur level (often used as a proxy for fuel cleanliness). With an older fleet for which there is no regular in-service testing there is therefore no guarantee of the actual emissions level. It can be assumed though that, in general, in a subsidiary market like South Africa, where there is a moderate emissions standard for new vehicles with many higher standard vehicles imported, that on average emissions are much lower than an untreated exhaust on a per car basis.

The European Union legislated against passenger car CO_2 emissions in 2009 with Regulation EC No 443/2009 which stipulates a 120 g/km CO_2 fleet average emissions level for each manufacturer [44]. The limit drops to 95 g/km CO_2 fleet average emissions per manufacturer from 2020. Vehicles under 50 g/km earned super credits for manufacturers for a limited window till 2016 which effectively incentivised electromobility technologies.

As with local air pollutants the standard EU test method under reports real world fuel consumption and CO_2 emissions but this gap has been widening over time as shown below.

Figure 36: Divergence of real-world CO_2 emissions from manufacturers' type approval CO_2 emissions



Source: Pastorello & Mellios (2016) Explaining road transport emissions - A non-technical guide. Copenhagen : European Environment Agency (EEA).

The reduction of emissions of both local air pollutants and greenhouse gases from our vehicle fleet in response to importing new technology is therefore quite uncertain and will be less than the stringency of the legislation suggests. It is therefore important for cities to track real world emission levels as follows based on the "to measure is to know" principle:

- Using ambient air quality stations in the metropoles, keeping levels of service adequate and making data easily and freely available.
- Regularly estimate the vehicle fleet energy intensity using data from the registration database and fuel sales to assess whether this is being mitigated in response to technology change.

44 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32009R0443

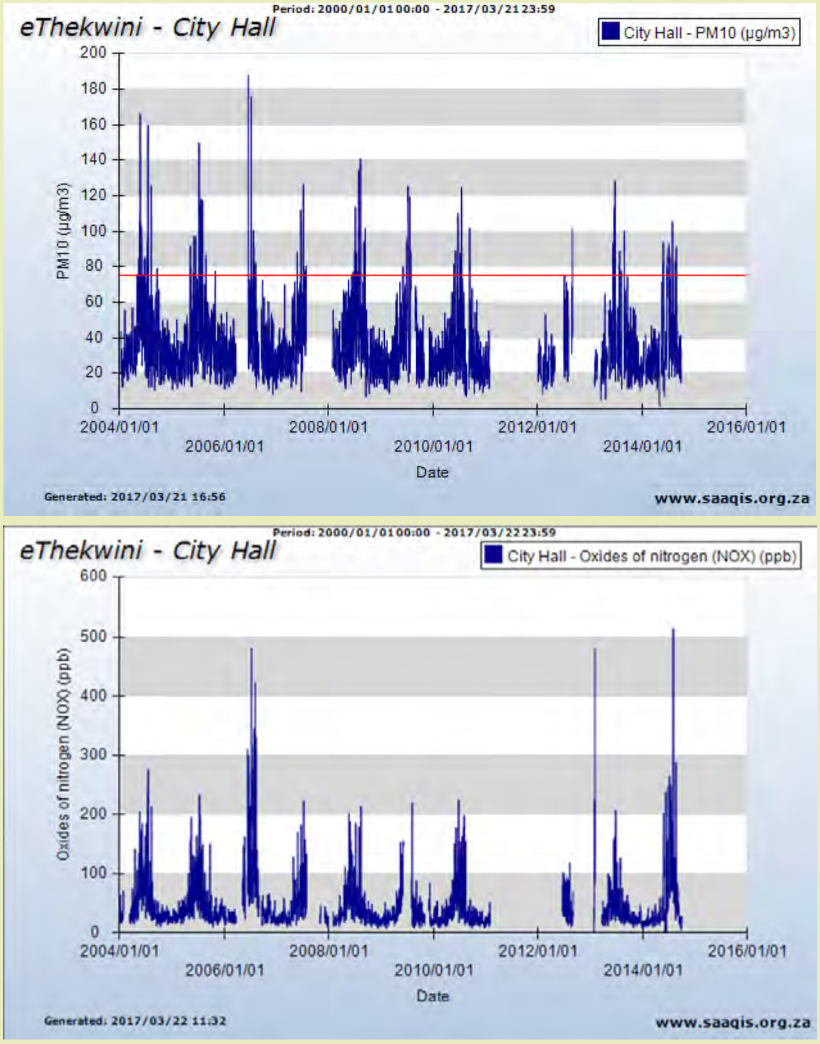
Ambient Air Quality Monitoring in South Africa – Where is our Air Quality going?

Air quality as reflected by the concentration of a number of pollutants is measured at a number of monitoring stations in the major metropolitan areas including Johannesburg, Tshwane, eThekwini, Ekurhuleni and Buffalo City.

The data can be viewed online at www.saaqis.org.za. Graphs like that below can be generated by monitoring station and pollutant.

The seasonal variability of pollutants due to weather make the data quite noisy but more problematically, underfunding means most data series have long gaps due to instrument problems that can't immediately be addressed.

Figure 37: Daily Average Concentrations of PM10 and NOx for City Hall



Source: www.saaqis.org.za

The daily averages above also do not show the number of hourly exceedances of health standards so a lot of analysis is required to assess with precision whether our air quality has got worse or stayed the same.

From the data for various cities it can however be seen that other than a reduction in SO_2 from reduced fuel sulphur content, environmental regulations are not driving substantial reductions in the other harmful pollutants probably largely because industry and the car population is growing, even if the cars are getting cleaner. Furthermore, the real world emissions of cars seem to be higher than that promised by the standards, as seen above.

Data quality needs to improve if the constitutional right to clean air is to be fulfilled: Measurement is essential for knowledge.

Interventions in Freight Transport

New truck technologies (Improve)

Auto manufacturers are in the early stages of rolling out a number of fully battery electric truck models for local delivery applications which offer zero-emissions at city level and in the longer term, reduced emissions at national level as the electricity supply becomes lower emitting. The Mercedes-Benz Urban eTruck is based on a heavy-duty, three-axle short-radius Mercedes-Benz distribution truck. This vehicle is specified for a 25 tonne Gross Vehicle Mass and a 200 km range making it a candidate for daily city deliveries of bulkier freight like building materials. From the same Daimler stable, the smaller 6 tonne fully electric Mitsubishi Fuso e-Canter is slated for a small series production run in 2017. [45]

Figure 38: Mercedes-Benz Urban eTruck – fully electric urban freight delivery for bulkier commodities

Source: Copyright - Daimler https://www.daimler.com/products/trucks/mercedes-benz/urban-etruck.html

The emergence of battery electric technologies across the full weight capacity range required for urban deliveries opens the possibility, in the near future, of creating traffic restricted zones that only allow zero emission vehicles without exemptions for delivery vehicles.

The potential of hydrogen fuel cells as range extenders for heavy-duty electric trucks has been discussed above. These could potentially operate on the long corridors supplying goods to and exporting goods from South African cities. This is a longer term low emission solution, given the difficulties and costs in creating a hydrogen fuelling infrastructure. The promotion of inter-modal freight discussed below offers a more immediate prospect for reducing emissions from the energy intensive arterials to our cities.

Promoting intermodal freight transport solutions in South Africa at a city level (Shift)

There is potential for multi-stakeholder financial benefits offered by the development of intermodal freight transport systems for suitable classes of commodities and there have been various local projects to develop the required engineering. It may require ongoing collaboration between multiple stakeholders, including municipalities, to see

45 http://media.daimler.com/

significant impact. There are a number of measures cities can consider to promote intermodal freight transport along corridors as follows (Havenga et al.2011):[46]

- Inclusion of GPC Scope 3 Freight Transport emissions in the city's Greenhouse Gas (GHG) Inventory according to the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) (WRI, 2014) [47]. According to the GPC standard, inclusion of Scope 3 road transport emissions is discretionary. This will include an estimate of GHG emissions arising from 50% of the distance covered by freight transport trips originating and ending within the city boundary along corridors. The data required to make this estimate can be obtained from sources such as the Centre for Supply Chain Management, Department of Logistics, University of Stellenbosch.
- Acting to initiate engagement between the stakeholders needed to develop local intermodal freight transport solutions as follows:
    - The Rail Transport Authority (Transnet) and any relevant private rail freighters
    - Road hauliers of intermodal friendly commodities
    - Producers and packagers of intermodal friendly commodities
    - Interested container, trailer and rolling stock engineers and suppliers
    - Third parties who stand to gain from reduced impacts, risks and costs such as insurers, authorities responsible for national highway maintenance and National Treasury
    - Relevant national ministries such as the Department of Transport
- The setting of GHG mitigation targets for corridor freight in conjunction with stakeholders based on the inventory.
- Allow access to traffic restricted areas only for local goods and for intermodal friendly classes of goods that have been transported intermodally.
- Exemption from inner city tolls (where these are in force e.g. Gauteng) for vehicles towing specialised intermodal freight trailers.

46 Havenga, Simpson, Fourie & de Bod (2011) Sustainable Freight Transport in South Africa: Domestic Intermodal Solutions. Journal of Transport and Supply Chain Management.

47 WRI (2014) Global Protocol for Community-Scale Greenhouse Gas Emission Inventories An Accounting and Reporting Standard for Cities. World Resources Institute (WRI), C40 Cities, ICLEI.

Case Study 1: Go George Integrated Public Transport Network – A Case of innovative technical solutions and a rocky implementation road

Go George *is the first high quality public transport project to be implemented outside of the big metros in the municipality of George in the Southern Cape. Go George began with a municipal mobility strategy in 2003 and negotiations with the minibus taxi industry began in 2007 with Phase 1 only rolling out in December 2014 after challenging and protracted negotiations. The following are the main features:*

- *George had limited resources and the project has been a three way collaboration between the provincial government's department of public works, The national Department of Transport who grant funded the project and George municipality.*
- *Minibus taxi operators could choose whether to 'buy-in', in other words become shareholders in the new system using part of their compensation or 'buy-out' and take compensation for the loss of their business entirely in cash. It is useful to compare the final settlement with projects in other cities* [48]*:*
  - *The average lump sum paid out to affected minibus taxi operators in George was R260 000*
  - *This is just over half of the R500 000 paid out by MyCiti in Cape Town excluding a scrapping allowance for relinquished vehicles. Operators could use this compensation to buy shareholding in the new operating company.*
  - *Rea Vaya in Johannesburg agreed to pay month instalments of R5 500 to shareholders for a maximum of 4 years until replaced by dividends generated by the Vehicle Operating Contractor (VOC) of which the former minibus owners are now shareholders. In the Rea Vaya arrangements operators could only 'buy-in'. In practice the City of Johannesburg is financing the VOC through operational payments to continue these instalments and if this should continue over the 12 year contacting period the payout will be R792,000 in real terms.*
  - *The currently non-operational Libhongolethu IPTN in Nelson Mandela Bay has enjoyed the least implementation success extending to a relatively onerous settlement for the city that was paying out R6 500 per month to former operators on BRT pilot routes who relinquished their vehicles, with a later settlement guaranteeing a "profit" of R8 000 per month for the entire 12 year contracting period to minibus taxi operators operating outside of the pilot routes. This equates to a total of R1,152 million in real terms.*
  - *In the now famous cases of Bogotá in Columbia and Curitiba in Brazil, existing paratransit operators that became shareholders were guaranteed a return that would replace and possibly exceed their former livelihood but did not receive additional cash payments. In Bogotá there was a competitive bidding process in which former operators received preference. In Curitiba it was mandatory for operators to consolidate into smaller consolidated formal operating companies that received concessions.*
- *In spite of the long and complex negotiations, the* Go George *service was violently disrupted, allegedly by disgruntled minibus taxi operators in August 2015 and four buses were burnt and 9 arrests made. The stated grievances cited a loss of livelihood due to the service.* Go George *has since resumed normal operations but future roll-out in areas serviced by minibus taxi operators who have bought out or were outside the process*

48 Von der Heyden, Hastings & Leitner (2014) Models and Implications for Industry Compensation in the Restructuring of Public Transport In South Africa. Proceedings of the 33rd Southern African Transport Conference (SATC 2014), (Pp. 385-398). Pretoria, South Africa.

may be difficult. It is not clear if the relatively lower compensation compared to other projects contributed to grievances and there is at least reason to question the virtues of a "buy-out" option given that a livelihood is lost as a consequence.

- *Of six planned phases, three are implemented with the 4th phase intended to be rolled out at the end of 2016*
- *Three sizes of bus are used, depending on demand, to optimise operational efficiency. The service is extended to areas that were too space restrictive even for midi-buses and therefore a minibus variant was developed with local suppliers that had the necessary fare collection and display equipment but also enabled 'universal access' for disabled commuters in compliance with the Department of Transport's grant stipulations.*
- *Currently the service sells about 11 000 tickets daily and is reportedly popular although it still requires substantial levels of subsidy.*
- *Tickets are pre-bought but tickets can still be bought on the bus with the correct change.*
- Go George *appears to have been a success on many levels despite problems and forms an extremely useful learning platform for IPTN rollouts in other secondary cities*

Figure 39: Converted Minibus Taxi developed by DBSA for Go George Integrated Public Transport Network

Source: GoGeorge http://www.gogeorge.org.za/wp-content/uploads/2016/02/Minibus-with-wheelchair-lift-1.jpg

Case study 2: The Mother of BRT in Africa – MyCiti Bus Rapid Transit System and the City's Transport and Urban Development Authority (TDA)

In common with other recent city driven public transport improvement initiatives, Cape Town's started with a bus service with a BRT vision established for the 2010 Soccer World Cup. This was called myCiti and has grown significantly since that time.

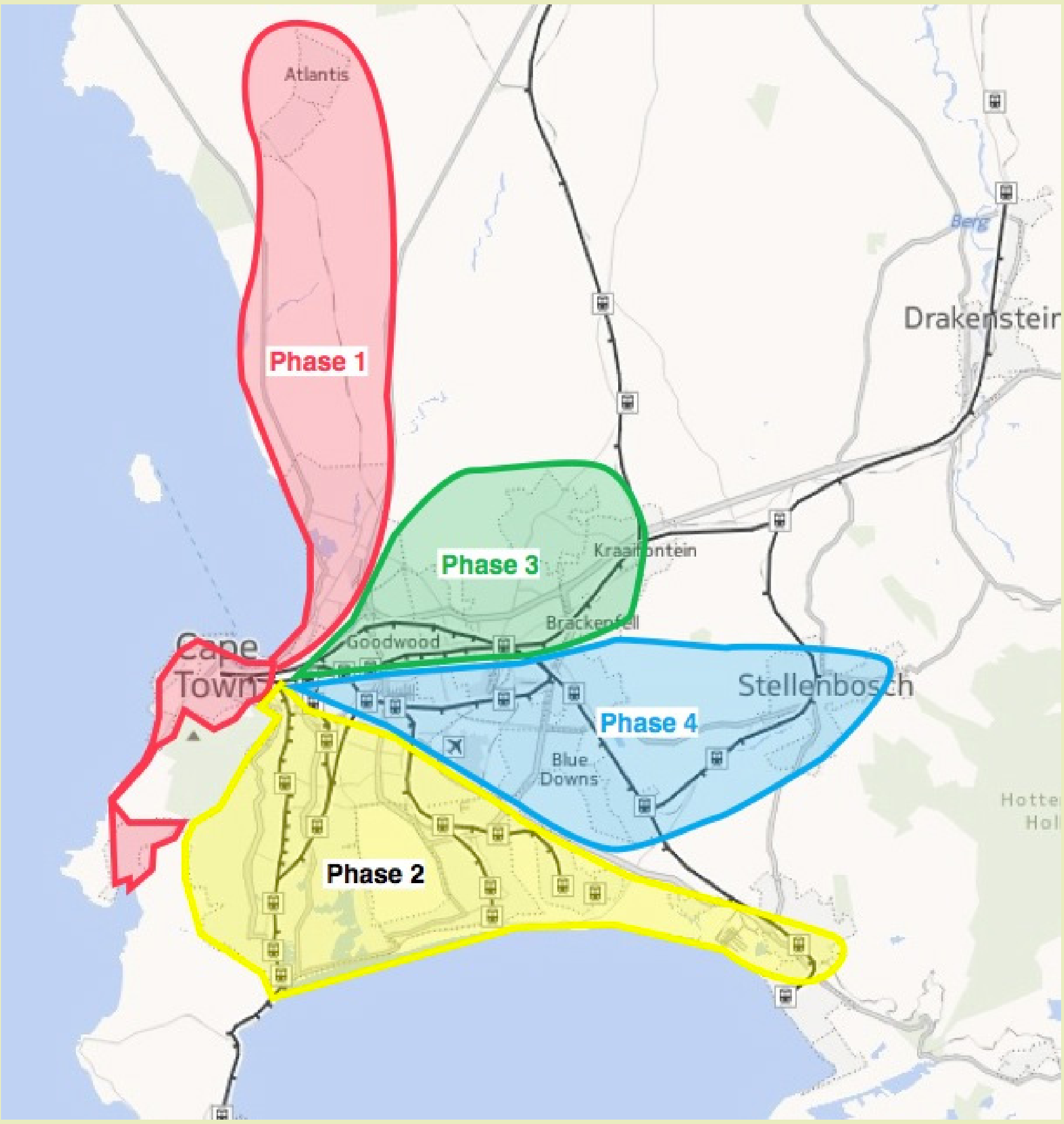
Figure 40: myCiti Bus and Route Schematic Map

MyCiti in a nutshell

- The biggest of the new IRT/BRT/IPTN systems – at around 67,000 passengers per weekday
- Operates 18m and 12m vehicles on trunks and 9m buses on feeders
- 558 drivers on 255 peak time buses
- The 377 vehicles are operated by private operators
- 3 X 12 year operating contracts
- 1 X 3 year operating contracts
- Two of these operating companies owned and run by previous informal minibus taxi operators
- Automated fare system using bank cards with back office function in the banks
- 44 routes with BRT style 42 stations (pre-swiping of cards) and over 700 open stops (cards swiped on bus).

The myCiti system is planned in 4 Phases as shown below. Phase 1 and the N2 Express routes connecting the Airport, Mitchell's Plein and Khayalitsha are operational, work has begun on Phase 2A, the Lansdowne-Wetton Corridor

Figure 41: Planned Phases of the MyCiti System



Source: futurecapetown http://futurecapetown.com/wp-content/uploads/2012/10/Screen-Shot-2012-10-16-at-12.01.29-AM.jpg

Establishing a dedicated transport authority is recognised as a cornerstone of establishing and operating a modern mass transit system. A Transport Authority called Transport for Cape Town (TCT) was established by Cape Town Constitution Bylaw, No. 7208 in 2013 to administer an Integrated Public Transport Network. This entity recently subsumed urban planning to become the Transport and Urban Development Authority (TDA). The long term outcome of this arrangement as it evolves in response to political and developer interests is worth watching by other cities and other transport authorities.

The planning process of TDA has been well documented in the public domain [49, 50]. At a high level, the following are some key pillars of this planning:

- *Planning driven by data gathering, indicator development and modelling*
- *Profiling of transport user groups and requirements*
- *Development of a Transport Development Index (TDI) [51] to benchmark the state of transport in the city (partly based on the Arthur D Little Mobility Index) [52]*
- *Detailed Temporal traffic demand modelling (using EMME/3) of travel analysis zones across the city linked to estimates of system cost. This allows the operational and cost impacts of interventions like peak moderation and bus headway (time between buses) adjustments to be estimated as well as the impacts of land use change patterns.*
- *Real time monitoring of the fleet (Control Centre contract has been problematic and only now reinstated with the control centre set to be operational in mid-2017 [53])*

NMT and pedestrian accidents

Enabling Non-Motorised Transport (NMT) is a cornerstone of both BRT and TOD. This is something of a developed country perspective as South Africa has a very high NMT (but low bicycle) share. This is not however by choice of the commuters themselves. While it is desirable to promote NMT with high income commuters, objectively, the safety of existing walkers (and cyclists) is of more immediate concern. The rate of pedestrian accidents in South Africa is high, likely because the high walking mode share (Figure 6) is combined with a legacy of car dominated cities with relatively poor pedestrianisation. Pedestrian accidents have historically been reported to be particularly high in Cape Town [(54)] possibly, in part, because of the bisecting of dense neighbourhoods by the N2 highway which is difficult to mitigate now.

In general the NMT network is extensive, with around 435 km of walkways and cycleway reported to have been constructed between 2006 and 2013 [55]. TDA undertook 6 NMT projects in the 2014/15 year covering about 27 km in total. Accidents are also part of their TDI index but it is not clear if pedestrian accidents are carved out of this or if there has been any analysis of opportunities to reduce pedestrian accidents. This issue is however highlighted in the public comments to the Integrated Transport Plan. TDA are developing an NMT Bylaw with the goal of "regulating the provision, operations, maintenance and enforcement required for NMT to be integrated into the overall public transport system" [51].

Cycling accidents have however been reviewed as part of the recently published Draft Cycling Strategy for the City of Cape Town[56] which has as its vision:

> *"Cape Town is the premier Cycling City in South Africa where cycling is an accepted, accessible and popular mode of transport for all – residents and visitors alike."*

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49 City of Cape Town (2015a) Comprehensive Integrated Transport Plan 2013 – 2018, 2015 Review. Transport and Urban Development Authority (TDA).

50 City of Cape Town (2015b) MyCiTi Business Plan 2015 Update – Phase 1 and N2 Express. Transport and Urban Development Authority (TDA).

51 http://www.tct.gov.za/en/uap/tdi/

52 Van Audenhove, Korniichuk, Dauby & Pourbaix (2014) The Future of Urban Mobility 2.0 Imperatives to shape extended mobility ecosystems of tomorrow. Arthur D. Little and UITP.

53 http://www.tct.gov.za/en/news/general/myciti-control-centre-to-track-all-myciti-buses-within-next-few-weeks/page-1/

54 Liebenberg & Garrod (2005) Alleviation of the Pedestrian Safety Crisis in the City of Cape Town. Proceedings of the 24th Southern African Transport Conference (SATC 2005).

55 City of Cape Town (2013) 2013 – 2018 Comprehensive Integrated Transport Plan. Transport and Urban Development Authority (TDA).

56 City of Cape Town (2017) Draft Cycling Strategy for the City of Cape Town. Transport and Urban Development Authority (TDA).

The strategy has the following long term desired outcomes:

- *An increased mode share of cycling from 1% to 8% by 2030 (trips of 10-15km are targeted);*
- *Cycling has significantly contributed to a substantial reduction in congestion and GHG emissions in the City by 2030;*
- *More people across all sectors of the population have access to affordable bicycles and are cycling;*
- *There has been a substantial shift to utility cycling;*
- *Cycling is substantially safer and secure;*
- *Cycling infrastructure and systems serve the needs of cyclists; and*
- *Cycling is an accepted means of travel.*

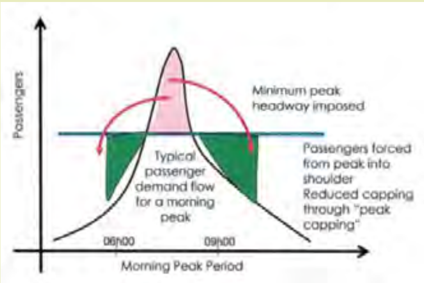
Cost Recovery and Financial Sustainability

The initial service level of a bus service is based on prospective passenger demand and myCiti policy has been to adjust this after 6-8 months in the form of peak moderation and reduction of late night services. Moderation and optimisation of the system has enabled myCiti to achieve an increase in cost recovery from 25% at the start of operations to 37% in September 2014 and another high watermark of 50% in October 2016.

Essentially peak moderation is a trade-off between the quality of service in terms of meeting unmanaged passenger demand and the operating cost of the system by limiting services at the morning and evening peaks usually by increasing headways (the times between buses). The concept is shown below in Figure 42.

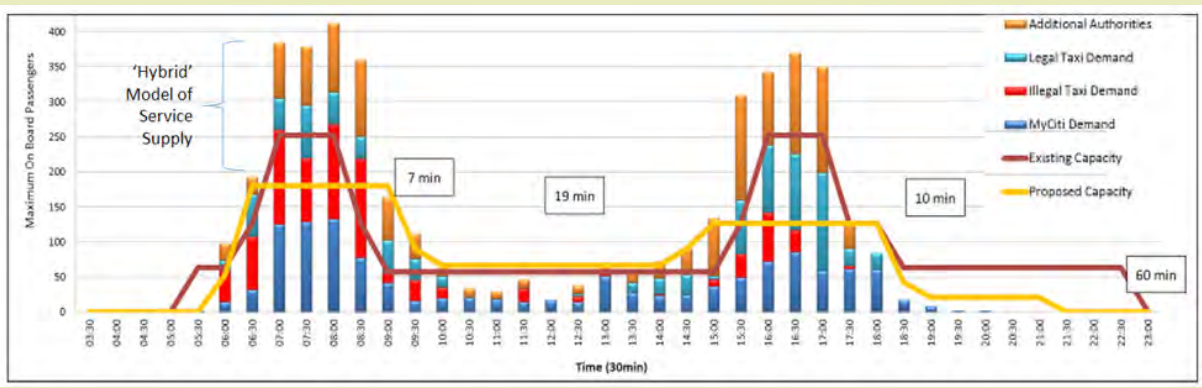
This is illustrated for an actual route analysis for a full day below contrasting the current capacity of the myCiti system with a proposed flattened capacity with increased headways that will capture the shoulders of the peak. The other bus authority (Golden Arrow Bus Service) and legal minibus taxis cater for the unmet peak not willing to shift in a 'hybrid' bus system that for the time being is more financially sustainable.

Figure 42: Illustration of 'Peak Capping' by imposition of minimum headway and capacity constraint



Source: Bosch D, Grey P, Bulman A, van Ryneveld P, "Business Development: Models and optimisation, Slide Presentation UATP Workshop (2015) Best Practice in Public Transport Africa for Africa.

Figure 43: Example Route with Proposed Moderation of myCiti capacity at Peak in a more financially sustainable 'hybrid' bus system



Source: City of Cape Town (2015b) MyCiTi Business Plan 2015 Update – Phase 1 and N2 Express, Transport and Urban Development Authority (TDA).

While initial moderation efforts have been successful, net revenue growth has been small mainly due, it seems, to the difficulties with attracting taxi passengers and challenges related to the enforcement against illegal taxis which retain a high share of peak demand as shown above. A key aspect of business planning has therefore been the efforts toward continued integration with other modes, discussed briefly below.

Moving Towards a Hybrid System – Potential Integration with Minibus Taxis, Golden Arrow Bus Service (GABS) and Metrorail

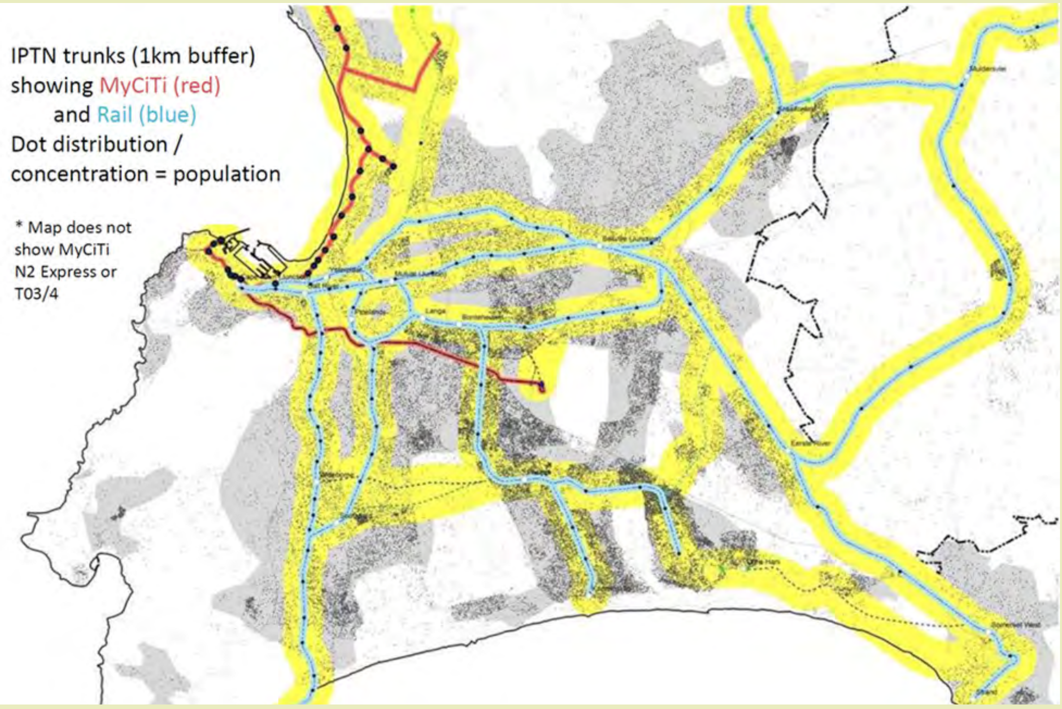
While still TCT, the mandate of TDA was the planning and administration of an Integrated Public Transport Network (IPTN). It is now clear that a BRT solution for meeting the full demand on every corridor is not financially viable. Therefore integration with other services in a hybrid system particularly on feeder routes and off-peak times is being pursued as this offers the potential to reach the goals of an efficient and reliable public transport service without excessive new capital costs. There are three main opportunities:

- *The Golden Arrow Bus Service (GABS)*
- *The minibus taxi paratransit service*
- *The Metrorail service*

Golden Arrow bus service is a larger conventional bus service with wide coverage, high capacity (around 250,000 passenger trips/day) and a long history. Its operations are subsidised through a Public Transport Operating Grants of around R870 million administered through the Provincial Government which could help make a unified entity more financially sustainable.

Around 12,000 minibus taxis, both legal and illegal, operate in the city. The industry is plagued with sometimes violent competition for routes but its high mode share and efficiency means that continued integration into the formal system is a difficult but essential task.

Figure 44: Cape Town's Rail Network (blue) relative to population density



Source: Bosch, Grey, Bulman & van Ryneveld (2015) Business Development: Models and optimisation, Slide Presentation UATP Workshop, Best Practice in Public Transport Africa for Africa

The national state owned enterprise the Passenger Rail Agency of South Africa (PRASA) operates an extensive suburban network of 610 km (Figure 44) through its Metrorail commuter services division.

The potential for a highly effective integrated transport system is clear but the legacy of jurisdictional arrangements are now somewhat at odds and furthermore tied in with national politics. Recent years has seen a great deal of negative publicity regarding the quality of service of Metrorail in Cape Town regarding reliability and safety, with vandalism of infrastructure arising from both protest and criminality reportedly common. In the midst of this commuter rail crisis, discussions with the City of Cape Town have been ongoing around the first steps of improvement and integration including fare system integration and signalling upgrades.

Case Study 3: Bogotà's Trans-Milenio – the BRT Catalyst

Figure 45: Dedicated Busway with passing lane – TransMilenio Bogotà

Source: TransMilenio SA

Bogotà is one of the most densely populated cities in the world. In the 1990s, many of the main road ways were heavily congested and the traffic speed during rush hour was only 10km/hour. The use of private cars was a major cause of congestion. Although ± 71% of motorized person trips were made by bus, 95% of road space was used by private cars, which transported only 19% of the population.

By the end of the decade, a new mass transit system, named TransMilenio was designed and partially implemented to solve these large inefficiencies of mass transit in Bogotà. Along with the mass transit system in Curitibà, TransMilenio has earned a reputation as one of the most successful and cost effective mass transit systems ever implemented[57] and furthermore this was achieved in a hitherto chaotic developing country city dominated by paratransit. It has since been the site of many study tours by policy makers and transport professionals, including from South Africa.

TransMilenio is a flexible bus system that uses exclusive bus-ways to feed people into and out of the central business district (CBD). The stations are located in the middle of the road to facilitate the transfer between buses in both directions. The bus stops are 57 stations, located every 700 meters and are equipped with pay booths, registering machines, surveillance cameras and infrastructure such as bridges, pedestrian

57 Pienaar, Krynauw, Perold (2005) Public Transport: Lessons to be Learnet from Curitiba and Bogota, Proceedings of the 24th Southern African Transport Conference (SATC 2005)..

crossings and traffic lights designed to ease the entrance of passengers into the system.

At the end of the corridors, three principal access stations were built as the meeting point for feeder buses and buses from traditional systems that work in the neighbouring municipalities.

TransMilenio quickly grew to a capacity of 800,000 commuter trips per day and is impressive in terms of the scale of logistics alone. A survey conducted 2 years after TransMilenio was introduced revealed:

- *32% decrease in travel time for users.*
- *80% decrease in traffic accidents.*
- *30% decrease in the number of fatalities caused by traffic accidents.*
- *30% decrease in noise pollution.*
- *37% increase in time spent by mothers and fathers with their children.*
- *There have been a number of criticisms based on the way the system works.*
- *Buses and stations are often packed to or beyond safe operating capacity, even during non-rush hour periods.*
- *The use of diesel buses instead of clean burning natural gas or electric-powered light rail is best defined as an economic decision made to benefit the private contractor and not the best interest of the city.*
- *Because TransMilenio is based on diesel rather than electric energy, its costs increase with increasing oil prices and this causes the fares to be increased to meet this cost.*
- *Many users complain about pick-pocketing inside the bus, a problem which is made worse by overcrowding.*

In addition to exclusive bus-ways, the City of Bogotà has 230km of bike lanes, with plans to increase this to 350km, as well as expanding sidewalks and adding a 17km pedestrian zone. Among the travel demand management (TDM) measures instituted are forbidding private cars to operate in Bogotà CBD during the morning and evening peak. Parking fees were increased by 100% and fuel taxes were increased by 20%. Bollards were built to prevent people from parking illegally on the sidewalk. A key promotion measure is "car free day" held once a year on a week day and car-free Sundays on particular roads.

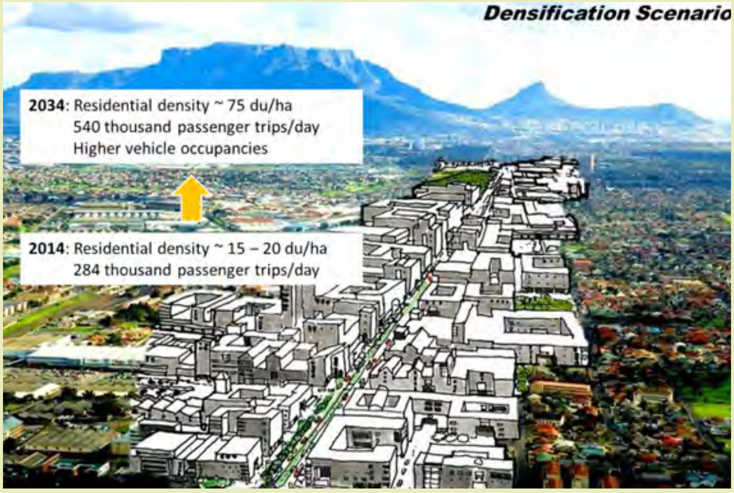
Case study 4: Urban densification and transport energy and emissions – Voortrekker Road

This case study explores some of the results of a technical support study [58] for the City of Cape Town undertaken in 2014 and funded by the SAMSET project (http://samsetproject.net/). The Voortrekker Road Corridor is one of the key routes in Cape Town's transport network, and at the time the City was prioritising the densification of the corridor to promote a more efficient transport system amongst other goals. This study assessed the energy, carbon emissions (CO_2) and energy cost implications of such densification compared with a 'business as usual' approach of more sprawling, low density urban expansion. The densification assessment assumes just over a doubling of the population along the corridor in 20 years (by 2034) raising urban densities from the current 15 to 20 dwelling units per hectare to the level of 75 dwelling units per hectare to a depth of 500m along 40% of the 17 km length of the road (Figure 46). This was contrasted with an alternative scenario of accommodating this population increase in more outlying areas such as Fisantekraal or the proposed WesCape development (Figure 47).

A model of energy consumption by mode was developed for this purpose, combining current traffic observations by mode and expert opinion in the City of Cape Town to estimate the future transport system characteristics for the densification and the sprawling scenarios.

58 Sustainable Energy Africa (2014) Voortrekker Road corridor densification in Cape Town: Energy and Carbon emissions analysis. Report prepared for the City of Cape Town, http://www.cityenergy.org.za/uploads/resource_313.pdf

Figure 46: Voortrekker Rd Densification Scenario: Urban densities rise from the current 15-20 dwelling units/hectare to a level that makes public transport sustainable (75 dwelling units/hectare)



Source: City of Cape Town Website - Spatial Planning and Urban Design Department

Figure 47: Low Density Alternative Scenario: Voortrekker Rd does not densify and the additional population is accommodated on the urban periphery requiring more trips (Less local employment) at double the distance

The results of the modelling show that very significant energy and cost savings accrue for the densification scenario by 2034 as shown in Figure 48 and Figure 49 on the nextpage.

The social cost of fuel savings arising from this reduction in energy demand are substantial reaching nearly R1 billion per year by 2034 in real terms assuming a base year cost of around R14/litre for petrol and diesel, escalating by a conservative 2% per annum in real terms.

These results only consider behaviour changes, which are difficult to model, quite superficially and likely underestimate their potential. For example, the higher concentration of people may result in greater economic activity in the immediate area, and appropriate mixed zoning may lead to more amenities and services in the locality, both leading to reduced travel needs. On the other hand implementation involves many challenges as follows in the information box on the next page:

Figure 48: Modelled Impact of Voortrekker Rd on Transport Energy Demand (CO_2 reduction is proportional)

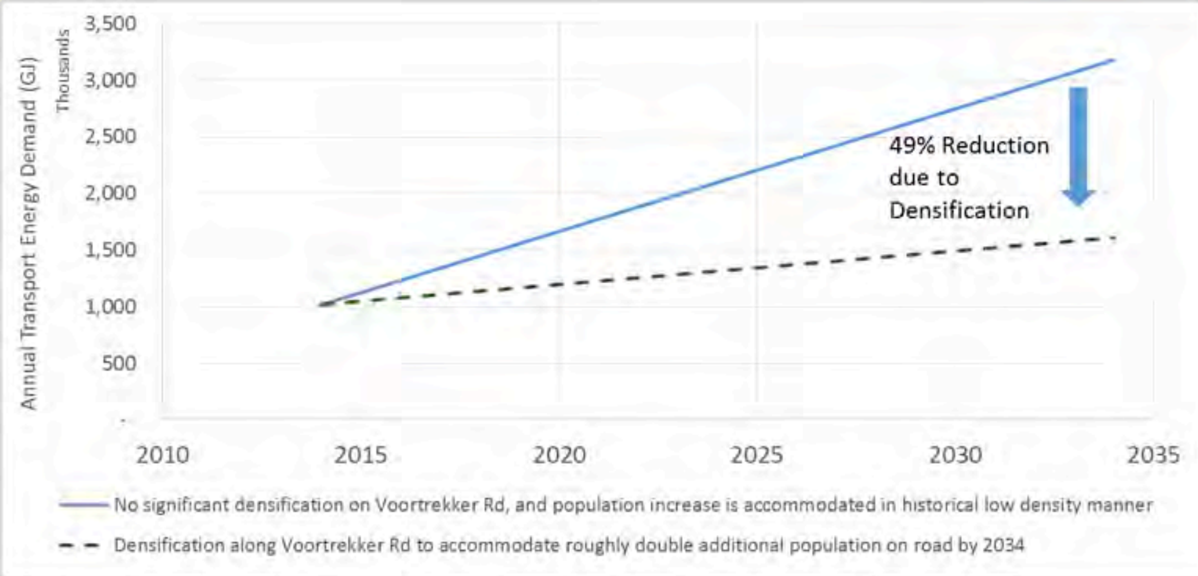
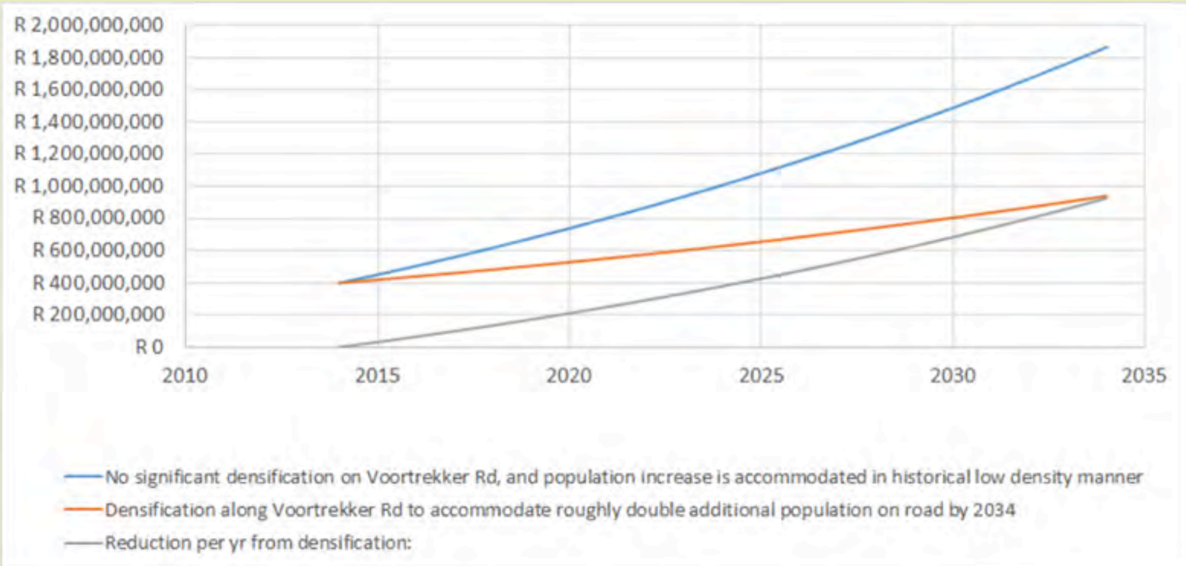


Figure 49: Modelled Energy Cost Savings (Real - assuming 2% escalation) of Densification of Voortrekker Rd



Challenges to Densification

The benefits of densification in South African cities are clear. Indeed, a lot of key social and economic interventions such as public transport and municipal / utility services can't be implemented and extended sustainably and affordably without it. Thus densification has been a policy goal for some time but has proved very challenging. While the type of modelling above is all very well, a number of critical barriers exist:

- The availability of land within inner cities is problematic. State land can have 'proxy' owners such as departments or state owned entities that defend their territorial rights. There is no legal framework to prioritise the housing crisis and compel state entities to make underutilised state land available to the market or to local government for rezoning and development,

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- The availability of land within inner cities is problematic. State land can have 'proxy' owners such as departments or state owned entities that defend their territorial rights. There is no legal framework to prioritise the housing crisis and compel state entities to make underutilised state land available to the market or to local government for rezoning and development,
- Similarly there is no policy or regulatory framework at national, provincial or local government level that compels private sector contributions towards accommodating poorer households on private land in more socially and environmentally sustainable locations.
- Developers respond to market opportunity. The typical household that would be the target of densified urban developments AT SCALE frequently fall in a gap above the income threshold for a state subsidy but below the level considered viable for home loans by the banks. At national government level the need for reform of the social housing subsidy framework is well understood but implementation appears to have stalled.
- Most housing demand sits in the poorest segment of the community that is dependent on state subsidy which is awarded within the framework of a state housing policy that doesn't necessarily consider urban form, the burden of long commutes, integration with transport systems or sustainability and crowds out other responses to the problem.
- The problem with trying to drive residential densification with transit planning as a way to fulfil Transit Orientated Development (TOD) goals, is that they operate on very different lead times.

Until these challenges are addressed, densification may be limited to isolated 'gentrification' developments. Implementation of densification therefore involves the co-operation and buy-in of many partners: local government, provincial government (administer housing subsidies), national government, property developers, potential commercial tenants in mixed use developments, civil society in the housing sector and financial institutions.

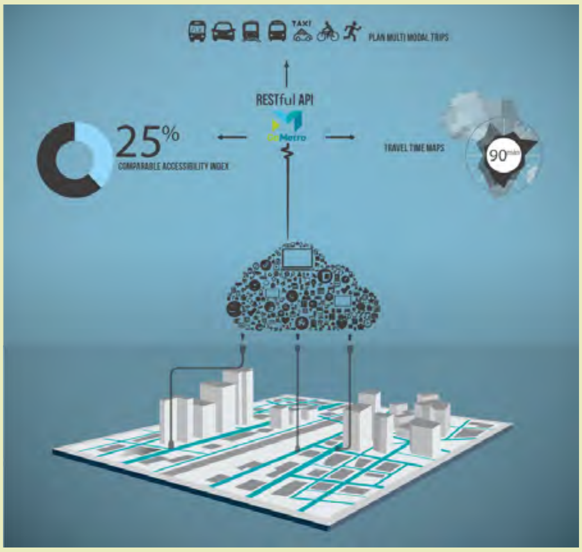
Case study 5: The SMART City – Mobile apps to close the gap between supply and demand

South Africa has seen the emergence of at least two technology companies supplying mobile platform smart travel apps; GoMetro (www.getgometro.com) and WhereIsMyTransport (https://whereismytransport.com/).

In both cases the main value proposition is the delivery of static schedule information as well as real time information on transport scheduling adjustments, timetable changes or delays to commuters for a range of modes including buses and trains and even paratransit. This opens up the potential to capture commuter movement data to sell back to suppliers and also to sell advertising. Both of these services to demand and supply sides working together make the system potentially far more efficient.

In the case of GoMetro the apps available to commuters have not only been developed for smart phone but also for cheap low-tech phones by using Unstructured Supplementary Service Data (USSD) technology (similar to Short Message Service) which exchanges text strings with low data requirements.

Figure 50: A Fast Moving Tech Landscape: SA Start-ups GoMetro and WhereIsMyTransport Offer Data Services to Commuters (mobile phones), Suppliers and now Analytics for Developers



Source: GoMetro

Resources

GiZ's Sustainable Urban Transport Project (SUTP) – Sourcebook Modules

The SUTP Sourcebooks investigate the key areas important for a sustainable transport policy framework in developing cities. The sourcebooks are periodically updated.

http://www.sutp.org/en/resources/publications-by-topic/sutp-sourcebook-modules.html

Energy Efficiency in Municipal Water and Wastewater Works

Overview*

Water and wastewater infrastructure is one of the major consumers of energy within municipal operations and service delivery. Figures differ widely (particularly as many municipalities still do not routinely collect or monitor all sites of municipal electricity consumption), but the indications are that on average water and wastewater accounts for some 17% of energy consumption in a South African metro. In terms of electricity consumption alone (i.e. excluding liquid fuel use for vehicles), the proportion is far higher – often representing as much as 25% of the entire municipality's electricity bill.

As electricity is a critical input for delivering municipal water and wastewater services – usually representing around 30% of the costs of running the service – such costs often represent a high and even unsustainable operating cost (Feng et al. 2012[1]). This sector has been shown to hold the greatest electricity savings potential within municipal operations and is thus a high priority for energy efficiency investment by municipalities (SACN, 2014[2]). Efficiency measures can achieve savings of up to 25% within this area (Feng et al. 2012).

Operational cost savings are even more critical when considering future urban energy demand. Cities are growing and demand for water and wastewater services will increase into the future. New technologies, aimed at meeting stricter water treatment quality requirements, are often more energy intensive. South African electricity prices are predicted to grow at a steep rate in the coming years. Efficiency offers an important opportunity to achieve greater levels of long-term environmental and fiscal sustainability.

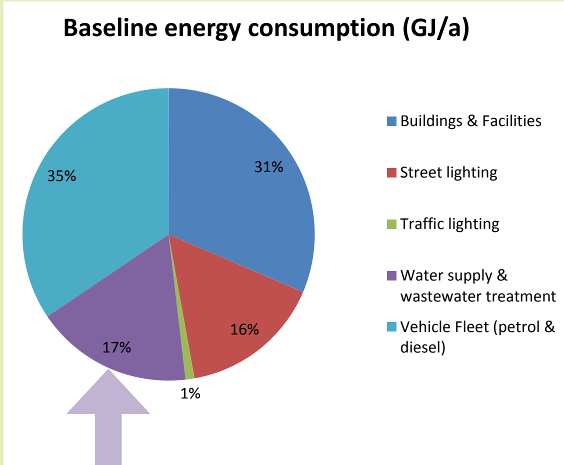
Energy is consumed at a number of points in the water and wastewater treatment infrastructure cycle.

1 Feng L et al. (2012) A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities. Energy Sector Management Assistance Program, technical report 001/12. World Bank, Washington, DC.

2 SACN (2014) Modelling Energy Efficiency Potential in Municipal Operations in the Nine Member Cities of the SACN, produced by Ndlovu, M, and SEA

* Much of the information in this chapter is taken from: Feng L et al. (2012). A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities. Energy Sector Management Assistance Program, technical report 001/12. World Bank, Washington, DC. The text of this publication may be reproduced in whole or in part and in any form for educational or non-profit uses, without special permission provided acknowledgement of the source is made.

Figure 1: Average metro baseline energy consumption per sector (GJ)



In terms of electricity consumption alone, Water Supply and WWTW represent around 25% of all municipal electricity consumption and offer the greatest energy efficiency savings opportunities.

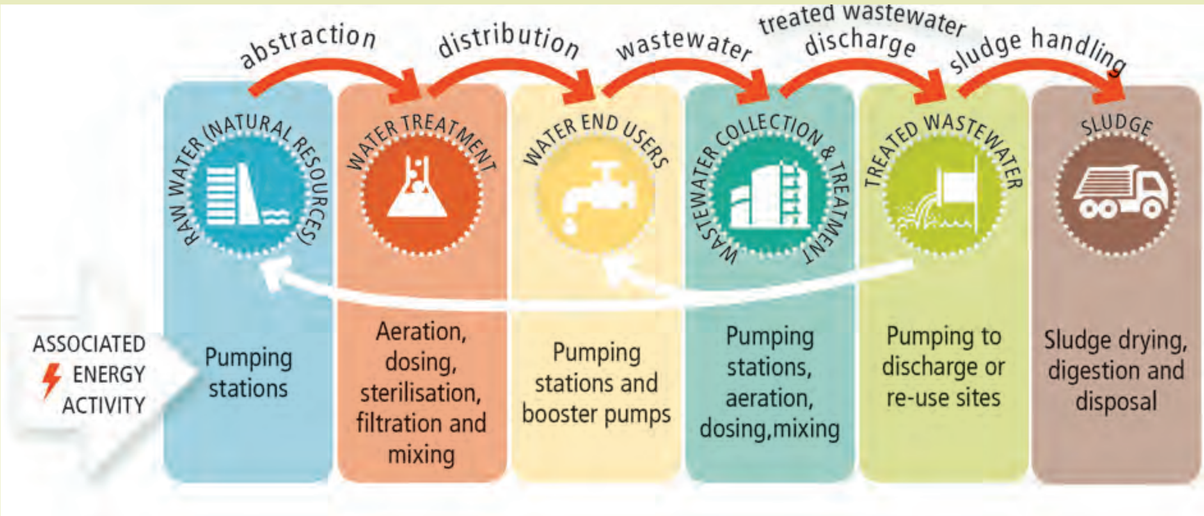
Source: South African Cities Network (2014) Modelling Energy Efficiency in the Nine Member Cities of SACN.

As electricity is a critical input for delivering municipal water and wastewater services – usually representing around 30% of the costs of running the service – such costs often represent a high and even unsustainable operating cost.

Establishing baseline costing for energy within the Municipal Water Services Sector

Financial ring-fencing of water services provision is a legal requirement in terms of the Water Services Act (1997: Section 20 (1)). The Department of Water Affairs quality assurance benchmarking initiative (the Blue and Green Drop) and the SALGA-WRC Municipal benchmarking initiative are focusing more attention on this compliance parameter. Establishing baseline costing for energy, given that it is usually the single highest cost in delivering the service, is good management practice and will provide a strong basis from which to calculate and motivate the financial opportunities that efficiency measures may provide.

Figure 1: The water services cycle



Source: Adapted from SALGA Energy guideline series (see references)

The relative energy consumption of a water supply system will differ substantially depending on the location of the raw water and the terrain in which the bulk supply must be distributed. Gravity-fed systems will obviously substantially reduce pumping costs. Ground-water supply systems are more energy intensive than surface water-based systems. However, groundwater usually requires much less treatment than surface water, often only the chlorination of raw water, which requires very little electricity.

By far the most energy using activity in all areas of water supply, whether ground or surface, is that of pumping.

Energy usage in wastewater treatment plants will also vary substantially, depending on treatment technologies which are often dictated by pollution control requirements, land availability and budgets. Advanced wastewater treatment with nitrification can use more than twice as much energy as the simple trickling filter system. Pond-based treatment is low energy but requires large land area. In wastewater treatment plants most of the electricity is consumed by the aerators and mixers.

Administrative and production buildings of water and wastewater treatment plants use a small percentage of the total electricity consumed within these facilities.

The table below provides a guide to the relative energy intensities of the different elements of the water supply and distribution infrastructure system for South Africa. For optimal interventions a municipality would need to have a good idea of what the most energy intensive aspects of their system were.

Table 1: Energy consumption range for the South African water supply chain

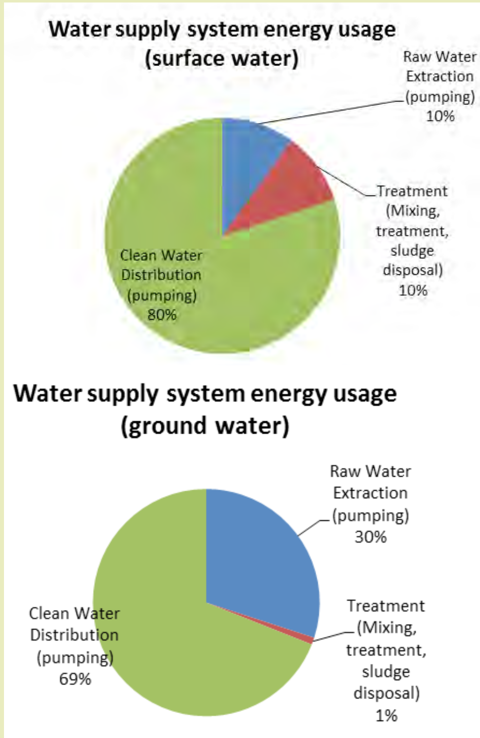
Process	Min (kWh/Ml)	Max (kWh/Ml)
Abstraction	0	100
Bulk distribution	0	350
Water treatment	150	650
Reticulation (potable and waste water)	0	350
Wastewater treatment	200	1,800

Source: Swartz et al. (2013) in SALGA Guideline Energy Series EE and RE in Municipal Water and Wastewater Treatment.

Energy efficiency approaches: technologies and interventions

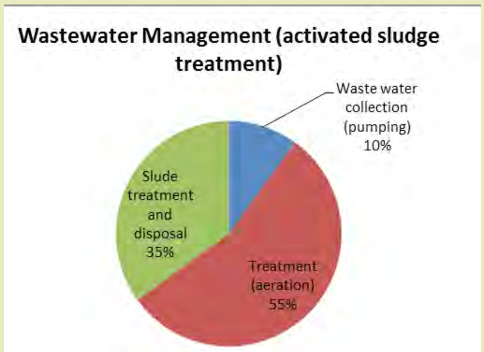
The major technologies that consume energy within the water services system are those related to the activities of pumping and water treatment. However, approaches to efficiency within the sector increasingly emphasise that a system approach is important for maximising cost-effective energy savings. This requires optimisation of system architecture (right-sizing of systems – and dynamically as they adapt to new demand regimes) and operation (energy management systems), rather than just focussing on specific equipment or technologies in isolation. Establishing best practice and ongoing monitoring and maintenance is a vital element in maintaining efficiency of systems.

Figure 3: Water supply energy usage for surface and ground water systems, noting that figures are global rather than local



Source: SEA adapted from Feng L et al (2012). A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities. Energy Sector Management Assistance Program, technical report 001/12. World Bank, Washington, DC.

Figure 4: Wastewater management energy usage noting that figures are global rather than local



Source: SEA adapted from Feng L et al (2012) A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities. Energy Sector Management Assistance Program, technical report 001/12. World Bank, Washington, DC.

Most of this chapter concentrates on the water service system (water supply and wastewater treatment), however working with water demand management is also important as reduced demand for water will translate into reduced energy required to operate the system. In addition, the water system also offers opportunities for renewable energy generation. These include biogas to energy from wastewater treatment and microhydro or mini hydropower generation from within the water distribution system.

Energy Efficiency in Water and Wastewater Treatment Works: Key elements

The 'system' approach aims to minimize energy throughout the varied elements of the system and in such a way that the entire system is optimised for water, energy and cost effectiveness. This also requires a dynamic approach whereby demand and supply elements are integrated to ensure system is constantly adjusted to new demand levels post efficiency achievements.

Figure 5: Energy efficiency in water and wastewater treatment works: key elements

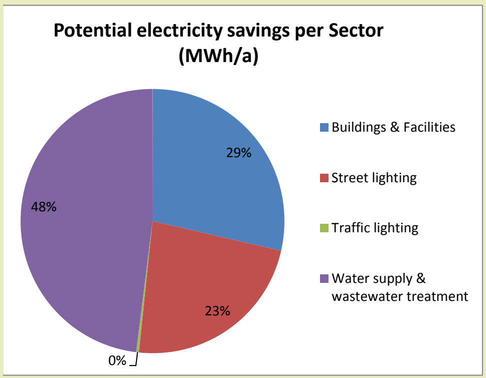
Water Supply-Side Efficiency Measures	**Water Demand-Side Efficiency Measures**	**Wastewater treatment and Renewable Energy Generation**
		
Network pressure management (leak and loss reduction) Operations and maintenance Pumping systems (improving, bringing in new technologies and and continuous right sizing pumping systems – using VSD for example – after reducing demand) Water treatment (upgrading aeration blowers, etc.)	Water efficient household appliances Industrial water reuse Leak and water waste reduction in household and industrial sectors	Wastewater treatment processes (most efficient within given context and sanitation requirements) Anaerobic digestion of sludge Biogas to energy (15% or more of power requirements) Micro or mini hydro power generators in water distribution pipelines

Source: SEA, adapted from Feng et al. (2012) A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities. Energy Sector Management Assistance Program, technical report 001/12. World Bank, Washington, DC.

Implementation

When all potential efficiency interventions are considered, the area of water and wastewater treatment in municipalities offers the greatest electricity savings opportunities. A study on South African metros indicated that this sector could contribute 48% towards all known electricity efficiency opportunities within the operations of a municipality (SACN, 2014). Given this savings potential, this sector should be viewed by municipalities as a high priority for energy efficiency investments, with the potential for high returns – saving the municipality money within a short period of time.

Figure 6: Potential electricity savings per sector (MWh/a)



Source: SACN (2014) Modelling Energy Efficiency Potential in Municipal Operations in the Nine Member Cities of the SACN, produced by Ndlovu, M, and SEA.

According to Feng et al. (2012) review of existing literature, most of the common technical measures applied to address energy efficiency in water and wastewater treatment plants generate 10 to 30 percent energy savings per measure and have 1 to 5 year payback periods. The financial viability of energy efficiency in wastewater works is dependent on a couple of factors including: conditions of the facility, technologies used at the water works, energy prices and other factors affecting the technical and financial operations of the individual plants. Feng et al. (2012) identify two areas with most potential – pumps of most types and functions, and aerobic wastewater treatment systems. Potential energy savings include:

Pumps and Pumping (Common potential ranges: 5 – 30%):

- 5 – 10% by improving existing pumps
- 3 – 7% through improvement to new pumping technology (pump technology is generally mature)
- Gains up to 30% are possible through maintenance improvement and closer matching of pumps to their duties (such as, using VSDs).
- More complex and large-scale pumping energy savings are feasible but frequently show marginal payback using current financial analysis.

Aerobic Sewage Treatment (Up to 50%)

- Simple gains of up to 50% are possible on some aerobic wastewater systems by aligning control parameters with the discharge standard
- Up to 25% in activated sludge process wastewater plant

Benefits of energy efficiency within a Water and Wastewater Treatment Works process include:

- Lower cost to consumer: these cost savings come in the form of direct electricity savings as well as savings in maintenance and replacement costs
- Ability to serve new and growing urban populations
- GHG mitigation
- Energy security
- Long-term fiscal stability for municipal services
- Enhance a municipality's Blue Drop/Green Drop status

Table 2: At a glance: remedial actions to improve energy efficiency

Typical short term remedies, all low cost giving quick payback and savings of up to 15%	Longer term remedies, larger investments, but with savings potential of 30 – 40%
• Visibility of individual pump efficiencies allows improved scheduling • Wherever possible run most efficient pumps, particularly in peak tariff periods • Do not run pumps in parallel into same column • Remove redundant / mismatched units in parallel • Change motor speed or trim the impeller • Replace low cost components e.g. by-pass flow assemblies • Reshuffle pumps to ensure unit matches requirement	• Refurbish pump • Replace impeller • Replace pump • Pump / system coating • Install VSD • Overhaul system – pipes, valves etc. • Improved maintenance planning • Develop best practices operations manual

Source: John Schulkins, Business Development Director TAS Online, presentation to Urban Energy Network meeting, October 2015.

Additional cost savings can be achieved through efficiency interventions

The installation of high efficiency motors may provide the following benefits over standard motors:

- Cooler operating temperatures due to lower heat generation, resulting in lower maintenance and a longer life.
- Improved tolerance to voltage variations and harmonics.
- Extended manufacturers' warranties.

Aerator-use pattern optimization provides:

- Reduced maintenance costs and extended life span of aerators where the aeration hours are reduced.

Source: SACN (2014) Modelling Energy Efficiency Potential in Municipal Operations in the Nine Member Cities of the SACN, produced by Ndlovu, M, and SEA.

Although the data is already relatively old and many new interventions have taken place in the intervening years, the assessment done on metros for efficient pumps and VSD retrofits (SACN, 2014) indicates that substantial energy, carbon and financial savings are possible.

Table 3: Indicative potential energy, carbon and financial savings from energy efficiency retrofits (efficient pumps and VSDs) in water supply and wastewater treatment plants in South African metros

Water supply and wastewater treatment plants	Total current consumption p.a.	%saving	Existing retrofit penetration	Proportion of energy consumption by retrofitted plant	Proportion of energy from unretrofitted plants	Total remaining saving potential for full retrofit	Potential carbon savings from retrofits	Financial saving
Units:	MWh/yr	%	%			MWh/yr	tCO_2e/yr	R/yr
Buffalo City	10,208.50	22%	7%	5%	95%	2,078.29	2,140.64	R 1,143,062
Cape Town	237,392.17	22%	0%	0%	100%	51,039.32	52,570.50	R 28,071,624
Ekurhuleni	58,764.96	22%	0%	0%	100%	12,634.47	13,013.50	R 6,948,957
Ethekwini	71,839.02	22%	0%	0%	100%	15,445.39	15,908.75	R 8,494,964
Johannesburg	180,000.00	22%	0%	0%	100%	38,700.00	39,861.00	R 21,285,000
Mangaung	121,576.66	22%	0%	0%	100%	26,138.98	26,923.15	R 14,376,440
Nelson Mandela Bay	50,447.09	22%	0%	0%	100%	10,846.12	11,171.51	R 5,965,368
Tshwane	47,684.00	22%	0%	0%	100%	10,252.06	10,559.62	R 5,638,633

Municipal focus areas

Broadly, typical system inefficiencies that will require addressing include inadequate pump specifications, change in operating conditions and lack of regular and structured maintenance. Identified solutions include installing variable speed drives (VSDs) for large pumps and replacing inefficient pump sets for all water pumping systems and upgrading aeration blowers for optimising efficiency in wastewater treatment. Network Pressure Management is important for efficiency and loss minimisation. Establishing and implementing a maintenance regime with the associated, necessary budgetary resources is vital.

The following areas of implementation will be outlined:

- Pumping systems and motors
- Network pressure management and leak and loss reduction
- Aeration in wastewater treatment
- Anaerobic digestion in activated sludge wastewater treatment
- Load shifting opportunities in water and wastewater works

(Key sources in the implementation steps below include: The Energy Trust of Oregon, 5/12[3], Feng et al. (2012[4]) and the WRC Research Report TT 565/13.)

Pumping systems and motors

It is important to ensure hydraulic system equipment is suited to load and equipment is receives regular maintenance. Pump efficiency is critically dependent on maintenance and operational aspects. Development of a best practice operations and maintenance manual will ensure these activities are regularly conducted.

Operations and maintenance measures to improve pumping system efficiency, which can deliver a simple payback of less than one year:

- Determine pump system efficiency over the range of pumping requirements and stage pumps for optimum energy use.
- Adjust basin fluid levels to decrease pump head and reduce pump load. Wet-well levels can be raised in pumping stations to reduce pump head.
- Identify and adjust poorly calibrated valves that decrease pump efficiency.

Capital improvements to pumping systems:

- Pumping accounts for as much as 67% of the energy used to operate a typical municipal treatment facility (water and wastewater). Improvements can substantially reduce facility energy use and costs.
- Install VSDs on pumps that move varying volumes of fluid to adjust speed to match pumping demand in real-time. When less pump flow or pressure is required, pump speed and accompanying energy use will be reduced.
- Replace worn or inefficient pumps with new, high-efficiency pumps that use less energy and operate with less maintenance and downtime.
- Oversized pumps that operate at constant flow are good candidates for impeller trims. Trimming the impeller is frequently a lower-cost alternative to making larger capital investments in pumps, motors or control technology.
- Install different sized pumps in new plants or during plant expansion. As seasonal flows change, controls can bring different pump combinations online to match pumping need.
- Improve piping and valves to decrease friction losses

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3 Energy Trust of Oregon: Water and Wastewater Treatment Energy Savings Guide, 5/14: www.energytrust.org/industrial-and-ag.

4 Feng L et al. (2012). A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities. Energy Sector Management Assistance Program, technical report 001/12. World Bank, Washington, DC

Evaluating pump efficiency:

Standard practice in evaluating pump selection on the basis of efficiency should be a comparison of pump options under specific operating conditions prior to pump selection, i.e. density and type of medium, flow velocity, pipe design, spares availability, maintenance and repairs skill at hand, etc. It is possible that initial higher capital cost pumps may have a longer life cycle and lower operations and maintenance costs associated, thus the full lifecycle costs should be compared (WRC Research Report TT 565/13).

Water distribution:

The efficient management of water distribution across the supply system is an important opportunity to achieve energy and cost reductions. This is a complex area and the optimisation of water distribution of large systems needs to be automated. Any modelling required to achieve optimal performance needs to be based on extensive historical records. If minimum emergency levels are not maintained in all reservoirs it may become necessary to pump during peak periods which will negate any energy savings achieved (WRC Research Report TT 565/13).

Managing seasonal peaks:

Design and implement a flexible system that allows facilities to adjust to high and low seasons, ensuring that the system does not have to run at a maximum demand capacity throughout the year.

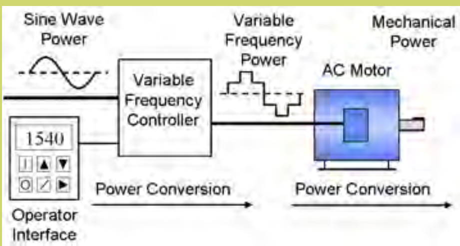
Variable Speed (or Frequency) Drives

Optimal energy savings are achieved by combining newer, more efficient pumps with variable speed drives. Without the variable speed drives, optimal energy savings cannot be achieved.

Variable Speed Drive (or adjustable speed drive) is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage. Over the past 40 years power electronics has greatly improved the cost, size and performance of this technology through advances in semiconductor switching devices, drive topologies, simulation and control techniques, and control hardware and software.

Variable Speed Drives improve pump and fan efficiency by reducing motor shaft speed to the minimum revolutions per minute, rpm, necessary to satisfy flow requirements. The flow produced by a pump or fan is directly proportional to shaft speed, while the power requirement for that flow is proportional to shaft speed cubed. For example, at 80 percent of full-load flow, a pump or fan operates at 80 percent of full load rpm, but uses only 51 percent of full-load power, yielding a steady state energy cost reduction of 49 percent. At 50 percent of full-load flow, the pump or fan operates at 50 percent of full-load rpm, but uses only 13 percent of full-load power, yielding an energy cost savings of 87 percent.

A variable-speed (or frequency) drive consists of the following three main sub-systems:



The **AC electric motor** used in a VFD system is usually three-phase induction motor. The VSD **controller** is a solid-state power electronics conversion system consisting of three distinct sub-systems: a rectifier bridge converter, a direct current (DC) link, and an inverter. The **operator interface** provides a means for an operator to start and stop the motor and adjust the operating speed. The operator interface often includes an alphanumeric display and/or indication lights and meters to provide information about the operation of the drive.

Source: C J Cowie at the English language Wikipedia, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=9890713 and curid=3139500

An operations and maintenance guide to identifying the sources of energy waste and possible corrective measures within water and wastewater pumping systems

Mechanical problems in the Pump

Pumps wear out over time. This can be seen by viewing the original pump efficiency curves and comparing them with current data from the field. If the pump is no longer running on its curves, there are a number of reasons that must be investigated:

- worn or modified impeller
- excessive roughness in the casing
- worn bearings
- clearances that have drifted out of tolerance
- pump not running at stated RPM

Maintenance personnel need to determine the problem and make the necessary corrections if they are cost-effective.

Inefficient motors

Recent improvements in motor technology have resulted in motors that are substantially more efficient than old, standard efficiency motors. It is easy to compare the efficiency of a new motor with that of an existing motor and determine the savings in energy. In general, large motors that run most of the time will have a short payback period while motors that only run occasionally, such as stormwater pumps, will have a much longer payback period and are not likely candidates for replacement.

Poor pump selection or a change in the system

Sometimes a pump may not have been sized correctly, or may have been sized correctly but the system may have changed, which affects the operating point. This may occur when the system head is higher than expected at that flow rate due to smaller pipes that the pumps was sized for (or pipes becoming rougher over time or an important valve mistakenly closed), or a tank water level that was not considered – or has since changed – in design. A quick indicator of this is a pump that is not running at its nominal flow, such as a 2000 litre/ minute pump that is running at 1500 litres/minute.

Incompatible pump combinations

A pump which is efficient when running alone may run poorly when in combination with other pumps. An indication of this problem would be were a nominal 4500 litres/min pump that usually produces roughly 4500 litres/min when running by itself only produces 3400 litres/min when run in combination with other pumps. This usually indicates a lack of capacity in the piping system as the pumps 'fight' with one another. The pump with the highest head wins. The long term solution usually lies in adding piping capacity (i.e., flattening the system head curve). However, in the short run, avoiding bad combinations, usually by pumping at a steadier rate, can reduce energy waste.

Pumping through control valves

In some cases a pump may be producing too much pressure for the desired system, especially for a system with no storage. The pressure can be reduced using a control valve (pressure reducing or manually controlled). However this is not energy efficient. Reducing the pump speed with a variable speed drive (VSD), trimming the impeller or installing a lower head pump will all result in energy savings when compared with a throttled valve.

Pumping through undersized or rough pipes

More energy is required to pump water through pipes with high lead loss than lower head loss. Excessive head loss could be due to undersized pipes or pipes that may have been correctly sized at one time but have lost carrying capacity due to tuberculation or scale. Incorrectly closed valves can also have the same effect. Increasing the system by adding piping, cleaning pipes, or opening valves can reduce energy use. This problem of inadequate pipe capacity is usually not severe in water distribution piping since most of the energy is used to raise the water from one pressure zone to the next and system head curves are relatively flat. It is usually most critical in long transmission mains and sewage force mains (rising mains) where more of the energy is directed to overcoming head loss rather than lift.

Poor layout of pressure zones

In many systems, pressure zone boundaries have been set up in such a way that customers at the lower elevations in a zone receive water with excessive pressure. The zone boundaries can be moved by modifying valving to place those customers in a lower pressure zone. This means that less water needs to be pumped into the upper zone with a corresponding reduction in energy. Lowering pressure has the additional benefit of reducing leakage.

Oversized pumps

Engineers are taught to be conservative in their design, but oversizing of pumps can lead to energy waste. If a pump is sized to efficiently produce 100 litres per second (L/s) at peak flow but the normal demand is 20 L/s, the pumps will not be efficient. Right sizing of pumps so that they will be operating near their best efficiency points is the optimal solution. For example, where the (rare) peak demand is 100 L/s, the lowest capital cost design may be two 100 L/s pumps, but if the average flows are much lower, it will be better to three 50L/s pumps, which can still meet peak demands with one pump out of service, but will normally be operating near their best efficiency points.

Source: Walski T and Andrew T (2015). Energy Savings in Water and Wastewater Systems, A Bentley White Paper.

Network pressure management and leak and loss reduction

Rehabilitation of leaky networks and active leakage control through pressure management offers important efficiency opportunities. These should be identified and brought together in an holistic and proactive Leakage Management Strategy, with associated water loss reduction targets. Actions include:

- Undertake pressure reduction management in water distribution systems/networks. Integrate and consider peak demand needs and that of adjacent supply zones in the design.
- Replace redundant or aged water distribution infrastructure and do ongoing repairs and maintenance (asset renewal projects).
- Install metering to check and monitor supply zones for losses, and minimise repair times for visible and detected leaks.

- Where an unanticipated supply or pressure problem arises (e.g. unexpected changes in flow or pressure from a burst pipe) a rapid, reactive pressure control should be undertaken.

Managing leaks and losses also requires engagement with water users. Best practice in leak and loss reduction within the broader water user community indicates positive outcomes can be achieved through:

- Implementing monitoring system to detect leakage and reconcile unaccounted losses combined with a leak repair programme.
- Extensive community and council consultation of the causes and interventions proposed to reduce water losses. Use a multi-disciplinary approach that involves the water technicians, meter readers from the finance department, billing department, GIS staff, councillors and community.
- Use local skilled and unskilled labour to repair and replace faulty or dilapidated plumbing fixtures.
- The introduction of a rising block tariff for water consumption can save water and related energy costs. There are many other water demand management approaches that should be considered, including awareness campaigns, promotion of low flow plumbing fixtures and engaging high volume users to jointly identify potential water savings operations modifications.[5]

Aeration in wastewater treatment

Aeration uses between 40 – 60 % of the energy consumed in a typical wastewater treatment plant in typical activated sludge treatment processes. Much of the remaining energy consumption is pumping related – and the section of pumping above pertains.

Development of new or alternative wastewater treatment processes and systems (both centralized and decentralized) should aim towards low-energy processes, especially regarding the high energy requirements for aeration in biological systems (WRC TT565/13).

Simple operations and maintenance, O&M, adjustments to existing aeration equipment can pay back quickly in reduced energy costs:

- Optimise the dissolved oxygen (DO) set point to reduce the amount of blower energy. It's not uncommon for systems to operate with DO levels that exceed what is required.
- Adjust the position of DO sensors to provide a more accurate assessment of DO levels.
- Adjust control systems to optimise mechanical mixing and bubble diffusion.
- Implement the Most Open Valve strategy in which the aeration zone with the highest oxygen demand is opened fully to reduce pressure at the blowers. DO levels in remaining aeration zones are controlled by valves that maintain the proper DO set point for each zone.
- Adjust the placement of mechanical mixers for more efficient oxygen transfer.

Possible upgrading of aeration basin technology:

- Upgrade from coarse bubble diffusion to fine bubble diffusion to increase the efficiency of oxygen transfer and reduce blower load while maintaining proper DO control.
- Install automated DO controls to reduce aeration energy by up to 40% compared to control systems that use manual sampling. Systems that rely on manual DO sampling often operate at levels that are much higher than necessary. Installing a DO sensor with integrated aeration control allows levels to be maintained within a narrower band, thereby reducing blower load.

5 Swartz et al. (2013) Energy Efficiency in the South African Water Industry: A compendium of best practices and case studies, Research Commission Research Report TT 565/13.

- Add DO probes to different zones of the aeration basin to provide more accurate DO readings and optimise aeration for each zone.
- Upgrade systems that use mechanical mixing by installing controls that cycle on and off in response to process control parameters.
- Retrofit mechanical mixers with variable speed, or frequency, drives (VSDs) which adjust the speed of the mixer motors to match the process needs in real-time. Typical simple payback of 2 – 7 years.

Improve the efficiency of the blower system through operations and maintenance measures:

- Adjust controls to optimise blower staging.
- Optimise DO set points to allow for blower system flow reduction.
- Find and reduce obstructions to blower airflow to decrease the pressure in the blower system, with accompanying energy savings.

Capital improvements to blower system:

Up to 75% of the lifecycle cost of a blower system is attributable to energy use. When replacing an existing blower system, select a blower appropriate for the application.

- Install controls that allow staging of systems that have multiple blowers. Control systems optimise blower staging based on system requirements.
- Upgrade to a high-efficiency turbo blower system, which uses very high-speed motors and air-bearing technology to efficiently produce airflow. Turbo blower systems are typically VSD-equipped, and are capable of providing a range of airflow based on DO sensor feedback. Typical simple payback of 2.5 – 7 years.
- Add VSDs with sensor control to existing centrifugal blower systems to adjust the speed of the blower to system demand, thereby reducing energy use when oxygen demand is lower. Typical simple payback of 2 – 6 years.
- Identify oversized blowers and investigate purchase of more appropriately sized blowers.

Figure 7: Aerator at Kelvin Jones, Nelson Mandela Bay

Source: Energy Cybernetics (2008) SACN, 2014

Anaerobic digestion in activated sludge wastewater treatment

Anaerobic digestion accounts for some 14% of the energy used at a typical activated sludge wastewater treatment plant (Oregon Energy Trust, 5/14[6]).

Improve the efficiency of the digester mixing (reducing energy demand and improving digester gas yields):

- Adjust existing digester mixing systems to use the minimum number of mixers possible for adequate mixing of influent and a high volume of gas.
- Optimise mixer speed in systems with VSD-controlled motors to reduce energy use while maintaining a high output of digester gas.
- Replace mixing systems that are not functioning correctly or operating inefficiently with higher efficiency systems.
- Upgrade existing systems such as gas lance or draft tube systems to a linear motion mixing system.

Further energy savings can be realised from reducing pressure on the water feeds and also through power factor correction.

Load shifting opportunities in water and wastewater works

While municipalities can realise energy and financial savings from energy efficiency interventions in the water treatment system, load shifting holds an additional significant financial saving. Financial savings of up to 40% can be realised by running the water pumps and reservoirs during off-peak hours, when electricity costs substantially less (Energy Cybernetics, 2008 in SACN 2014*)*.

Pumping stations can be run at their highest possible capacity during off-peak periods in order to build reservoir capacity. During peak electricity demand periods, the reservoir would be full enough to switch off some of the load. Customers will continue being supplied by the stored capacity provided by the destination reservoirs.

In wastewater treatment plants load shifting cannot be done in the pre-treatment chambers as they have to operate 24-hours a day. Flexibility exists in the aeration and mixing chambers which can be switched off for a longer period-up to 12 hours (Energy Cybernetics, 2008, in SACN, 2014). Load shifting can therefore be focused on this section of the wastewater treatment works. Load shifting can be more easily done in a plant with VSDs than those without. It might not be possible to switch off all extra pumping manually, but VSDs can be used to over-aerate the effluent during off-peak periods and then be switched off during peak hours or periods of constrained electricity supply. If load shifting is considered in wastewater treatment plants, microbial loads may be an issue and they would need to be monitored.

For load shifting to work municipalities or wastewater utilities will have to do the following:

- Install meters to monitor the exact operation of the aerators (real time metering) and an energy management system;
- Draft detailed designs of load shifting opportunities: identify units with high energy consumption during maximum demand periods when high tariffs apply and shift work periods to time spans when lower tariffs apply.
- Maintain supply MVA against set point MVA and load shed when exceeding set point.
- Gather dissolved oxygen data from the wastewater plants to determine how the aerators typically aerate the plant i.e. whether they over, under or just aerate to the required level.
- Lighting and air conditioning efficiency in offices and control rooms

6 Energy Trust of Oregon: Water and Wastewater Treatment Energy Savings Guide, 5/14: www.energytrust.org/industrial-and-ag.

Building energy consumption within municipal water services provision is a relatively small component of total energy consumption. These areas of efficiency are looked at in more detail in the chapter on Energy Efficiency in Buildings. Major areas for consideration include:

- Use occupancy sensors to turn off lamps in unoccupied spaces.
- Upgrade lighting systems to more efficient technologies, notably T5 (high-bay) or T8 (task lighting) fluorescent lamps. This can reduce energy use by up to 50 percent. Consider installing LED lighting.

Establishing an energy management process

Institutionalising energy management within water and wastewater utilities will provide the greatest chance of successfully achieving the energy efficiency potential of this sector. An Energy Management Strategy that links water, energy and other areas of facility management into an integrated approach will provide a strong policy basis. Municipalities should develop energy efficiency targets within their strategic planning processes, and include specific targets for energy efficiency in their operations in the Water Services Development Plans (WSDPs). Energy audits should be undertaken on a yearly basis. It is anticipated that targets for the South African water sector will be developed, encouraged and regulated through the Department of Water Affairs' Blue Drop and Green Drop programs (Swartz et al., 2013[7]).

Energy efficiency should form a major criterion when planning new water supply and sanitation projects, and funding programs should use specific targets in the decision-making process. In addition to the energy efficiency measures discussed in this chapter, wastewater treatment facilities should be encouraged to implement biogas energy production projects and water supply and distribution projects should investigate the feasibility of mini-hydropower generation in water distribution systems.

As water demand management programs also result in energy savings, energy efficiency should be included in water services providers' water demand management and water conservation programs. Water supply and sanitation processes that use no energy, should be actively encouraged. Examples of these systems are on-site sanitation, slow sand filtration and rainwater harvesting (use of storage tanks).

Development of new or alternative wastewater treatment processes and systems (both centralized and decentralized) should aim towards low-energy processes, especially regarding the high energy requirements for aeration in biological systems (Swartz et al., 2013).

Energy Management Process Steps

1. Establish organisational commitment and an energy management team (EMT)

- Commitment must come from senior management to establish an EMT.
- EMT must include representation from different units within a utility (from engineering to accounting), to ensure coordination across division boundaries.
- A committed and enthusiastic champion should be identified to drive the work.
- The EMT must have clear responsibilities that are embedded within the performance management system and regular reporting of progress is required.
- The EMT must have resources to support viable initiatives.
- A training budget is important to ensure training is facilitated at all levels.

7 Swartz et al. (2013) Energy Efficiency in the South African Water Industry: A compendium of best practices and case studies, Research Commission Research Report TT 565/13.

2. Conduct a facility energy assessment: Baseline, EE opportunities and Prioritisation

- A basic understanding of energy use and cost of the utility must be obtained to help identify energy efficiency and related cost savings opportunities.
- The initial baseline analysis need only involve a walkthrough audit of the facilities, staff interviews and desk analysis of metering and billing data to reveal areas for immediate improvement and those for further investigation.
- Limited audits may be conducted to confirm key efficiency opportunities.
- Identify and prioritise opportunities based on: identified energy efficiency measures, technical feasibility, cost and rate of return, available funding. Focus on the most promising systems for quick initial wins.

3. Develop an Energy Management Plan

Once an initial set of priorities have been identified and remedies proposed (contained in an assessment report) and Energy Management Plan will facilitate translating priorities into actions. This would include:

- Goals/targets: State your goals and quantify the reductions you aim to achieve (energy and cost-wise).
- Activities based on priorities: list the interventions to be undertaken.
- Implementation arrangements: will it be done by the municipality or through contracted services, outline procurement schedules and financing plans.
- Responsibility and Time frames.

4. Implementation of planned activities, monitor, evaluate and verify results

- Implementation of projects will require the business case for each intervention to be developed and, as required by a financier, investment grade energy audits.
- Arrangements for implementation will need to be determined: will the project be done in-house, or through contracted services; will it be financed through own-funding (budget or loan), or developed as a stand-alone project, with a project developer who brings their own financing.
- Set up monitoring for ongoing visibility of the impact of interventions and measure effectiveness (savings) against the baseline. Savings may be used to finance further improvements.
- Continue with ongoing training of staff to ensure operations and maintenance continue to achieve the required efficiencies.

Identified EE Measures

- Installing VSD for large pumps
- Replacing inefficient pump sets
- Upgrading aeration blowers
- Establishing and implementing a Maintenance Regime
- Network Pressure Management

Energy efficiency should form a major criterion when planning new water supply and sanitation projects, and funding programs should use specific targets in the decision-making process

Developing the project: business models, financing and contracting

Business models

Own-executed: this would involve a municipality drawing on their own staff to design and implement the necessary changes.

Consultant with fixed payments: here a consultant would be appointed to help the municipality design and implement the project. The consultant would receive a fixed lump-sum fee for services. This is a very low risk model, but may also be low service in that the consultant is not incentivized to ensure that the systems bring maximum savings.

Range of Energy Service Performance Contracting options: a range of options (increasing in risk, but also in service level) in which a consultant or energy services company (ESCO) receives performance based or savings based payments, depending on contract terms. These contracts may involve Public Private Partnership arrangements.

Financing

Internal financing/municipal budget is an important, though given constraints, often limited funding source. With a good Energy Management Plan in place, internal funds can be used to phase in pumping station retrofits.

External financing instruments can assist with more capital-intensive projects, or projects with relatively long payback periods. The following are some financing instruments to partially or fully fund EE investments:

Deferred payment financing: also considered an internal financing source, is a short-term borrowing process where the utility makes payments to the vendor soon after receiving supplies and services. Such arrangements may allow utilities to purchase high efficiency equipment to upgrade facilities if the incremental cost can be recouped quickly through operational savings.

Energy Service Performance contracting: here the service provider covers the project cost using its own funds or arranging for third party financing. Repayment is through energy savings resulting from the project. Specifics will depend on contract terms.

Partial risk guarantee programmes, reduces risk by guaranteeing a portion of any default by the utility to the lender.

Municipal bonds: these are sometimes used for large investments. To be effective the municipality needs to have a good credit rating, but if so this can be a low-cost, tax-exempt, long-term financing option for energy efficiency investments. The City of Johannesburg has issued a successful "Green Bond" for financing of its environmental/ climate response projects.

Barriers and opportunities

Barriers range from institutional and regulatory, knowledge and know-how and accessing finance. Much however is currently underway in this area and many of these barriers are being addressed and/or new opportunities are arising.

Water and wastewater tariffs are often not based on real costs of supply and municipalities struggle to cover maintenance and infrastructure renewal. Financial ring-fencing of water services provision is a legal requirement in terms of the Water Services Act (1997: Section 20 (1)). The Blue and Green Drop initiatives are focusing more attention on this compliance parameter.

Municipal budgets are separated between capital and operational and the fiscal system emphasizes upfront cost rather than lifecycle cost. This makes it difficult to motivate for more expensive equipment, even though it will save money over its lifetime. In addition the responsibility for payment for energy consumed usually sits elsewhere in the municipality and water utility officials handling day to day operations may be entirely divorced from this aspect of management.

A well-developed business case for each efficiency remedy or technology will help to motivate to procurement officials; and those involved in procurement should be trained to select the best pumps. This approach must include lifecycle considerations.

Energy efficiency is often not a required element for assessing the performance of water utilities. Protecting public health is of such critical importance that this aspect of water management trumps most other interventions.

Municipal 'champions' wishing to take energy efficiency forward should thus start with interventions that also enhance the water treatment and distribution operations. The Department of Water Affairs 'Green Drop' and 'Blue Drop' monitoring and achievements programme have now also brought in energy efficiency as a 'point scoring' management element within the evaluation system. Undertaking efficiency interventions will enhance municipal scores.

Knowledge and Know-how of officials: Many water utility managers and officials don't have the necessary information about energy efficiency opportunities and their costs and benefits, or the capacity to undertake efficiency optimisation. This includes not having adequate access to information or skills relating to sourcing financing and engaging contractors to undertake the interventions.

The sharing of information, particularly peer to peer learning, through such portals as SALGA, the Urban Energy Network meetings and Website, SACN's Water Management Group and other forums is important in addressing this. Benchmarking status, such as the Blue/Green Drop systems, and recognition of achievements will also enhance knowledge on this area of management. Tools to support rapid assessments would also be beneficial.

Access to and availability of finance: Few municipalities have ready budget to invest in detailed audits, optimization studies and new, energy efficient equipment. Although the interventions can be shown to be financially viable, producing quick returns on investment, few municipalities have sufficiently high credit ratings to obtain commercial financing (loans) to undertake the investments.

In order to avoid piecemeal interventions a municipality should undertake an initial scan and identify priorities. Thus, even if interventions must be staggered over time in order to not exceed budget, they can be done in a synchronized manner.

Initiatives to assist this barrier include guarantee funding programmes. This helps to reduce risk to lenders through a guarantee facility that pays the lender an initial loss amount or portion of the full payment default.

It may also be possible to structure the project as a viable project separate from the finances of the municipality and could therefore attract private sector investment. The Emfuleni case study provides an example of a shared savings scheme (structured as a 'build, own operate, transfer scheme) was undertaken in the Metsi-a-Lekoa municipality.

Figure 8: Potsdam wastewater treatment plant, Cape Town

Source: Aurecon

Figure 9: Amatola Water , Eastern Cape

Source: http://www.amatolawater.co.za/gallery

Case Study 1: Polokwane Municipality energy efficiency water pumping retrofit: Matching water pumps to their duties

Figure 10: Secondary clarifiers at Polokwane Municipal WWTW

Photo: Jerome Bob

Source: Polokwane Municipality, 2014.

Polokwane Municipality, in 2013, embarked on a project of retrofitting its existing water pumps in both its bulk water supply and wastewater treatment systems. The project was funded through the fifth-round (2013/14) of the Department of Energy's EEDSM fund. Polokwane municipality has participated in the DoE's programme since its inception in 2009/10. Implementation of EEDSM programmes within the municipality is managed by the municipality's Electricity Planning and Design Department. The energy saving interventions in water pumping systems comprised of the replacement of existing, re-wound energy inefficient IE1 graded motors with more efficient IE2 and IE4 motors coupled with variable speed drives (VSDs). The addition of VSDs was aimed at controlling the speed of the motors, thereby allowing them (the motors) to be operated at the ideal speed for every load condition i.e. matching the pumps to their duties. This has an impact of reducing energy consumption by the motors instead of using other control methods e.g. use of restrictive valves, on/off control, or by-passing etc. Energy efficient motors have an impact of reducing energy consumption by 5% and a further 15% of energy savings was realised from the impact of VSDs, taking the overall energy savings per pump to over 20%.

A total of 38 water pumps were retrofitted, and these pumps are located at one of the sewer works and in 9 pump stations. The expected impact of the project is a reduction in demand (24 hour average) of 0.262 MW and energy savings of 2,404 MWh per year during weekdays and weekends. The most significant benefit of the programme is that it reduces the municipality's energy consumption. In addition the pumps are now being operated during off-peak hours resulting to significant cost saving impact within the water and waste treatment system, and overall cost saving to the municipal finances.

Case study 2: Using Energy Savings Performance Contract (ESPC) for Water Loss Reduction and EE Improvement in Emfuleni*

The municipal water utility Metsi-a-Lekoa of Emfuleni, South Africa, distributes water to 70,000 households in Evaton and Sebokeng. Due to deteriorating infrastructure resulting from many years of low investment and poor maintenance, about 80 percent of potable water was leaking through broken pipes and failed plumbing fixtures. Leakage for a well-managed system is typically below 15%. A technical investigation determined that by adopting advanced pressure management in the distribution network water loss could be reduced dramatically while also lowering pumping costs.

* This case study draws extensively from the report: ESMAP, 2010, Good Practices in City Energy Efficiency, http://www.esmap.org/esmap/ node/231. Unless referenced otherwise, information is sourced from this document.

Metsi-a-Lekoa, however, lacked the required technical expertise to prepare and implement the project and was short of funds to finance the investment. A shared savings Energy Services Performance Contract (ESPC) could help address both issues. Emfuleni engaged the Alliance to Save Energy as the technical advisor to help Metsi-a-Lekoa design and prepare the project, as well as procure engineering services, and monitor and verify savings.

Through a competitive bidding process, Metsi-a-Leoka signed a water and energy performance contract with WRP Engineering Consulting Company under a Build-Own-Operate-Transfer arrangement for a period of five years. WRP acted as an ESCO—providing turnkey services—while underwriting all financial and performance risks for which WRP was able to obtain project financing from the Standard Bank of South Africa.

Figure 11: Sebokeng/Evaton pressure management installation

Source: Mckenzie & Wegelin (2009)Implementation of pressure management in municipal water supply systems.

The project involved the design, installation and commissioning of a pressure reduction chamber with appropriate sizing, fitting and operation of the valves, pipes, meters, strainers and monitoring equipment. This consisted of cutting into existing water mains and replacing sections with smaller diameter pipes and equipment. The chamber was operated to reduce pressure during off peak periods and restore to higher pressure during high demand periods.

Under the "shared savings agreement" in this contract, WRP received remuneration for its services based on verified energy and water savings from the project over a five-year period. Twenty percent of the project's savings were to be accrued by WRP and 80 percent were retained by Metsi-a-Lekoa. After five years, operations would be transferred to the utility at no cost and the utility would keep 100 percent of the savings. The project was designed to operate for at least 20 years under this scheme.

The project achieved impressive results | 7-8 million m3 annual water savings and 14,250 MWh annual electricity savings, worth a total of US$3.8 million per year [some R30 million ZAR per year]. WRP recovered the capital cost of its investment in one year: the total return to WRP represents four times its initial investment. But the lion's share of the benefit stayed with Emfuleni Municipality.

Case study 3: Umbilo Wastewater Treatment Works, eThekwini Water and Sanitation: an Industrial Energy Efficiency Improvement Project in South Africa*

The eThekwini Water and Sanitation department of the eThekwini municipality has pioneered a number of innovations in the sector. Through their involvement in the Industrial Energy Efficiency (IEE) Project the unit embarked on the journey to establish an Energy Management System (EnMS) for each of its wastewater treatment plants. With 27 plants across the metro area, it was decided to select a pilot plant and Umbilo Wastewater Treatment Works (WWTW) was chosen as the demonstration facility.

Umbilo WWTW, located at the catchment of the Umbilo River, is made up of two distinct plants: the East Works Bio-filtration Plant and the West Works Activated Sludge Plant. Each plant has its own inlet and outlet.

* This case study draws extensively from the report: Industrial Energy Efficiency Project: Municipal Wastewater Treatment 2014/15: www.iee-sa.co.za. Unless referenced otherwise, information is sourced from this document.

In 2014 and 2015 an EnMS was implemented at a total capital investment of less than R1 000. This resulted in a total monetary saving of R280 000 and an energy saving of 287 620kWh per annum. GHG emissions were reduced by 275 tonnes of CO_2. The total payback period for the investment was less than 1 month.

Summary of energy-systems optimization interventions: Activated Sludge Plant-aerators

The major energy-systems intervention was **aerator-use pattern optimisation** within the activated sludge plant aerator system. This intervention resulted in the reduction of use of four 75kW aerators from 59h per day to 46h per day (the aeration tank at Umbilo WWTW consumes about 83% of the total energy of the West Plant).

Savings achieved, based on a 19-day trial: 11% of total plant electricity consumption (19% of aerator kWh x 83% of West Plant x 70% of Total Plant) = 287 620/annum.

Implementation of an Energy Management System

An EnMS consultant was appointed to guide the development of the EnMS, after which an energy team was appointed. The energy team, with the help of the consultant, conducted an energy review with limited access to energy data (only West Plant energy consumption data was available), to identify and understand the significant energy users, their drivers and management.

After the review the team identified opportunities to improve energy performance. They compiled an EnMS Manual as a high-level management document to define the EnMS and its rollout. An agenda for management review of energy performance was also set.

Implementation Challenges

Time and priorities had to be re-aligned. Demands on the time of top managers and prioritizing EnMS roles while at the same time attending to urgent water treatment concerns proved to be very difficult.

The appointment of an energy team where all key roles were represented was a challenge, especially as an EnMS had to be driven without regular meetings to ensure sustainable progress between consultant visits.

Data management was initially difficult because of the lack of any kWh data for the East.

Creating general awareness to support behaviour-based energy performance also had to be prioritized. Initially there was limited awareness of EnMS in the plant.

The Future

- *Confirm chemical oxygen demand (COD) impacts on quality of outflow effluent and consolidate the aeration pattern, taking cognizance of peak tariff times and provide training in operator aerator efficiencies.*
- *Install on-line dissolved-oxygen probes to enable aeration times to be COD-based and install a seasonal setting on the aerators as less aeration is required during cooler months.*
- *A new energy-efficient screw pump to be installed.*
- *Investigate the viability of routing more flow to the East Plant that is more energy efficient.*

Lessons Learnt

If energy performance is integrated into performance indicators for key management members, it increases the profile and likelihood of success. Unless energy management is integrated, there will always be other priorities that take precedence. There is need for increased ownership of energy management.

An active energy team and sound and current energy data are critical success factors.

Non-energy benefits of energy interventions should also be considered when developing energy business cases. For example, reduced maintenance costs and extended life span of the aerators if the aeration hours are reduced.

Case study 4: WRC Research Report TT565/13: Short case studies – City of Johannesburg and eThekwini Metro

Cost reflection in City of Johannesburg

Johannesburg Water operates and maintains six wastewater treatment works. Johannesburg estimated that the cost of electricity for the treatment of wastewater would have risen from R97 million per annum in 2010 to over R300 million per annum by 2020, making the existing wastewater treatment operation possibly unaffordable. Failure of the wastewater treatment operations would have a devastating effect on the economy, environment, health services and social activities of the City. Energy has been recognized as a key driver in the wastewater treatment value chain of Johannesburg and efforts have been made to reduce power consumption and produce renewable energy.

Energy efficiency improvement has been achieved by the City of Johannesburg through:

- *Power factor correction installed.*
- *Targets set for an annual reduction in power use.*
- *Automation of the aeration systems.*
- *Control of the maximum and minimum dissolved oxygen concentrations.*
- *Hydraulic balancing of bioreactor influences.*
- *Guidelines and best practices in demand side management (energy conservation) within the Utility operations.*

Off-peak pumping and pressure management in municipal water distribution systems: Durban

The Durban water distribution network is operated by Durban Metro Water Services (DMWS) and includes some 250 reservoirs, each of which has a level signal which is transmitted to a central SCADA system. Some pumps and valves in the network can be actuated remotely from this control point.

Optimisation of the operation of the distribution system by pumping at off-peak periods, while ensuring minimum emergency levels in all reservoirs, will not only effect an energy savings in terms of electrical energy used for pumping, but may also delay upgrades to the distribution system. Energy gains are entirely dependent on management of the system. Optimising the system for example to gravity feed from one reservoir to another to cater for high demand periods during peak tariff periods and then replenishing both reservoirs by pumping during low tariff periods can realize significant savings in electricity costs.

Advanced pressure management was implemented in the Durban Central Business District (CBD). The objective of this initiative was to promote responsible management and usage of potable water. The commissioning of a pressure management system in the Durban CBD reduced the water loss levels in this area by 18.7 ML/day – representing approximately 2% of the daily treated water purchases from Umgeni Water, the bulk water provider. Annual water purchase savings have been R20.8 million for a capital investment of just 10% of the annual benefit (i.e. a payback of less than 2 months).

Support organisations

Department of Energy – EEDSM Programme, including water and wastewater efficiency measures
www.doe.gov.za

Institute of Municipal Engineering South Africa (IMESA)
admin@imesa.org.za

National Cleaner Production Centre
www.ncpc.co.za

Wastewater Biogas to Energy

Overview

The organic matter in raw wastewater contains almost 10 times the energy needed to treat it. Some wastewater treatment works (WWTW) can produce up to 100% of the energy they need to operate, though more typically 60% of operational energy can be produced. Biogas is typically used to meet on site power and thermal energy needs. Export of gas to local industrial users, power producers or for use as a municipal vehicle fleet fuel is also possible.

In a wastewater treatment works (WWTW) biogas is produced when sludge decomposes in the absence of oxygen, in digesters. This process is referred to as Anaerobic Digestion. South Africa was one of the first countries in the world to utilise digesters as part of sludge management at WWTW. Digesters at WWTW were, however, not built to capture and use the biogas produced, but rather to assist in sludge management. In most cases, digesters can actually be refurbished to allow for biogas collection.

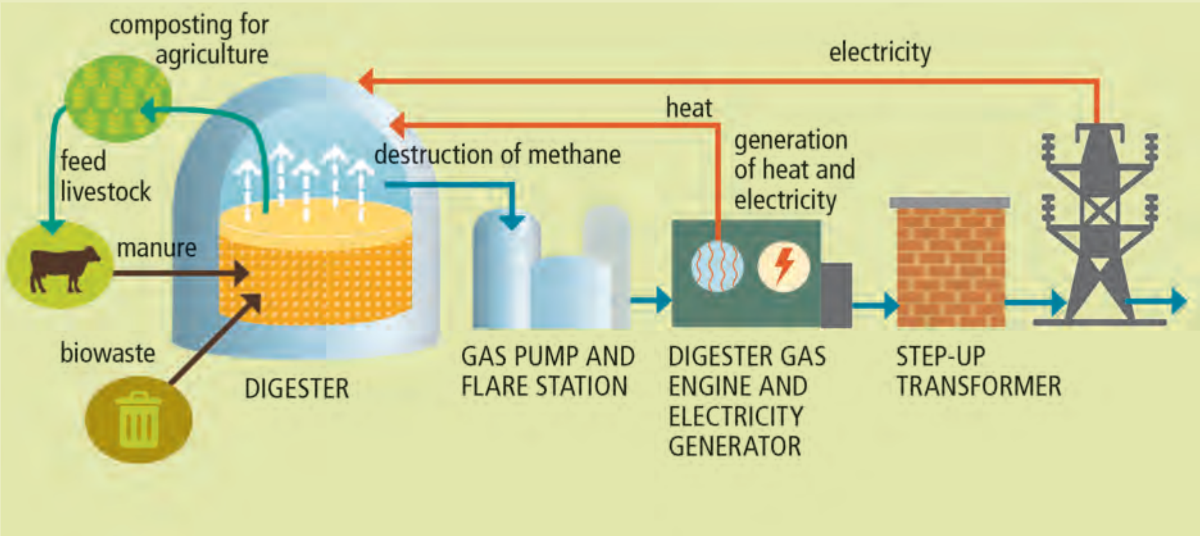
Biogas (a methane-rich natural gas) derived from anaerobic digestion and captured at WWTW plants provides a renewable energy source which can be used for electricity, heat and biofuel production. At the same time the sludge is stabilized and its dry matter content is reduced. This sludge, or digestate (remaining solid matter after the gas has been removed), contains valuable chemical nutrients such as nitrogen and potassium, and can be used as an organic fertilizer.

This intervention involves the installation of biogas digesters and CHP plants at wastewater treatment facilities to generate electricity from sludge digestion, which can be used on site to power lights, pumps, control etc. Excess heat can also be used to heat digesters or in the composting process. Pre-treating the sludge with heat produced from the CHP plant helps break down stronger chemical bonds and makes protein in organic matter more accessible for biological decomposition.

Technical aspects for consideration in a biogas to electricity project within a WWTW:

- Building or refurbishment of digesters to optimise them for biogas collection sufficient for viable electricity production.
- Gas scrubbing to remove impurities that can result in damage to the engine and affect electricity generation.
- Engine type: CHP, gas engine, fuel cells.
- Transformer selection – needs to be based on whether electricity generated will be used internally only (i.e. one-way transformer) or used internally and fed into the grid (i.e. two-way transformer).
- Heat exchange system: need an effective heat exchange system to ensure that waste heat energy from the gas engines is used to heat the digesters. This will assist in optimising biogas production and boost electricity production.

Figure 1: Biogas system



Implementation

Wastewater treatment processes contribute some 20% plus to the total municipal electricity consumption – and bill. Wastewater to energy plants can potentially contribute 60% to site electricity, offsetting what is required from the national utility. Generation engines have a lifespan of 10 – 15 years and return on investment (ROI) is usually 7 – 9 years. Studies indicate that larger plants with in excess of 15ML/day inflow are more likely to be financially viable. However, biogas production is highly dependent on treatment processes and thus varies greatly, requiring site-specific detailed feasibility studies to be undertaken. Producing energy from biogas in WWTW has multiple benefits:

- Combined heat and electricity production which results in:
  - Operational cost savings: reduced electricity bill for WWTW, buffering the municipality against steep retail electricity price increases while displacing the need to purchase power for the plant's thermal needs (heat use)
  - Improved sludge management (reduce quantity, improve quality) though use of pre-treatment heating that improves biological decomposition
- Digestate is an organic compost, offering a potential revenue stream
- Reduced methane and CO_2 emissions / carbon footprint towards municipal and national targets
- Skills transfer and green economy development (introduction of new technology, new business development)

Implementation of a WWTW biogas to energy project includes the following aspects:

- Potential feedstock and viability assessment
- Project structure and development: Project ownership and municipal participation, electricity aspects and licensing arrangements
- Financial modelling and project financing

Potential feedstock and viability assessment

Assessing viability is primarily done by looking at the anticipated Return on Investment (ROI) calculated by comparing the cost of establishing a biogas plant in relation to the potential income generated from replacing electricity bought from Eskom. Other indirect benefits such as efficient waste management, reduction in sludge, revenue from the sale of fertilizer, compliance with sludge quality requirements, carbon mitigation and local 'green' economic development provide additional motivation to the financial case within a cost-benefit analysis.

Determining the quantity and nature of sludge available is essential to determine the amount of biogas and resultant electricity which can be generated. This will provide an indication of the financial viability of such a project. The quantity of sludge produced is largely determined by the treatment processes employed by each specific WWTW. Each municipal WWTW has a unique water treatment process, which leads to highly variable biogas yields. This can result in biogas yields that are substantially different from a theoretical calculation based solely on the inflow of waste water in the WWTW. It is thus very important to understand in detail the waste water treatment processes and such expertise should be included in the project team of any biogas project in WWTW.

As a guideline, there is a strong likely viability in larger plants with inflows in excess of 15 M litres/ day; smaller plants with a flow of less than 15 M litres/day would most likely not be able to produce sufficient sludge for viable levels of electricity production under current financial conditions.

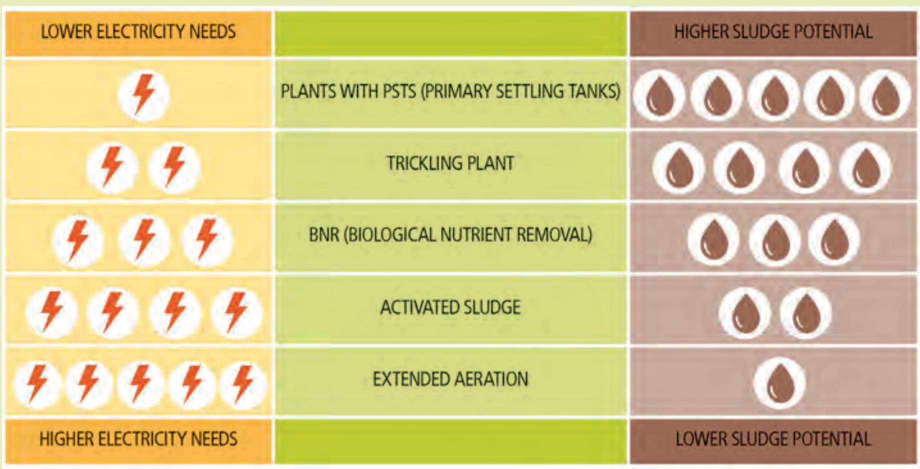
The following information is important when assessing the potential to produce biogas:

- Design capacity and current daily flow rate of the WWTW
- Plant operational and sludge generation process: whether this is biological nutrient removal (BNR) trickling, or aeration, etc. Current quantity of sludge produced
- Current quantity of biogas produced, if any
- Existing biogas capture infrastructure, if any
- Sludge disposal procedures
- Status of existing digesters (number, size, mixed and/or heated, structural integrity, etc.).

Plant treatment process, sludge management and biogas digestion

Each WWTW plant employs a different treatment process (or a combination thereof) and each process produces different quantities and quality of sludge. Sludge production is usually inversely proportional to electricity consumption, i.e. the more mechanically driven the process is, the less sludge is produced.

Figure 2: Electricity usage decreasing down the list; sludge potential increasing



Many South African WWTWs have digesters. These are operated to optimise sludge management and not biogas production. Sludge management is integrally part of the operations of the WWTW and most municipalities have drying beds which function with varying degrees of success. There normally exists some arrangement with the private sector to collect the dried sludge that is then used as compost.

Fully functional digesters will benefit the WWTW by reducing the quantity of sludge going to the drying beds and improve its quality for organic composting. There are new regulations currently under development that will specify improved sludge management in future.

Additional Organic Waste, or "Co-digestion"

A municipality may consider securing additional organic feedstock over and above the sludge from the WWTW. This could include the organic fraction of the Municipal Solid Waste or directly from agricultural or commercial organic waste. While certain benefits can be reaped through such co-digestion, including improved biogas productivity and more stable biogas production across the seasons, co-digestion can be complex and implementation of co-digestion activities would necessitate a separate, detailed assessment of sources of organic waste, necessary pre-treatment and related infrastructure, impact on retention times and operating capacities, proportions of substrate addition rates, etc.

More WTPs are adding post-consumer food waste to existing anaerobic digesters at their facilities. Food waste has up to three times as much energy potential as bio solids.

Project structure and development

Electricity (and heat) usage

WWTW use a lot of electricity for pumping and aeration. International reference indicates that around 60% of the electricity consumption of the WWTW can be offset by the electricity generated at the biogas plant. Combined with efficiency measures (enhancing pumping operations, pumping equipment, optimisation of processes and aeration equipment – see page 153 in the chapter on WWTW), offset can reach 80%. (SALGA GIZ Biogas potential, March 2015).

Although electricity could be fed into the grid, on-site consumption is preferable given that generation potential is generally less than on-site consumption and the "price" for the generation would be the full cost of the electricity purchase offset. Selling power to the private sector would only be attractive for a WWTW if the buyer was willing to buy electricity at a premium price, for example if the buyer wanted to promote its green profile. Such an option complicated and costly as long-term commitments have to be negotiated between the WWTW and the buyer as part of a Power Purchase Agreement and wheeling arrangements to transport electricity to the buyer must be concluded with the owner of the grid. Experience indicates that, given the complexity in ensuring the feedstock (e.g. if the downstream municipal WWTW breaks down), such arrangements would entail high levels of risk.

The heat produced by a combined heat and power (CHP) unit should also be used on-site, mainly to heat the digesters and thereby increase the biogas production. It could also be used for drying the sludge in order to produce fertilizer.

Business model

The most common business model utilised to date in South Africa is one where the municipality owns the plant and all of the waste streams that provide the feedstock. The model includes:

- Full ownership of the plant by the municipality
- Investment by the municipality
- Appointment, through competitive tender, of a service provider to design, build, manage and operate the plant for a period of 7 – 10 years

SAGEN-GIZ/SALGA Biogas Potential Assessment Toolkit

A Biogas Potential Toolkit has been developed to assist municipalities to determine the biogas potential of their WWTW and the viability of such a project at the early stage of decision making process. The Toolkit is intended for use by Water and Sanitation and/or Energy and Electricity departments of municipalities.

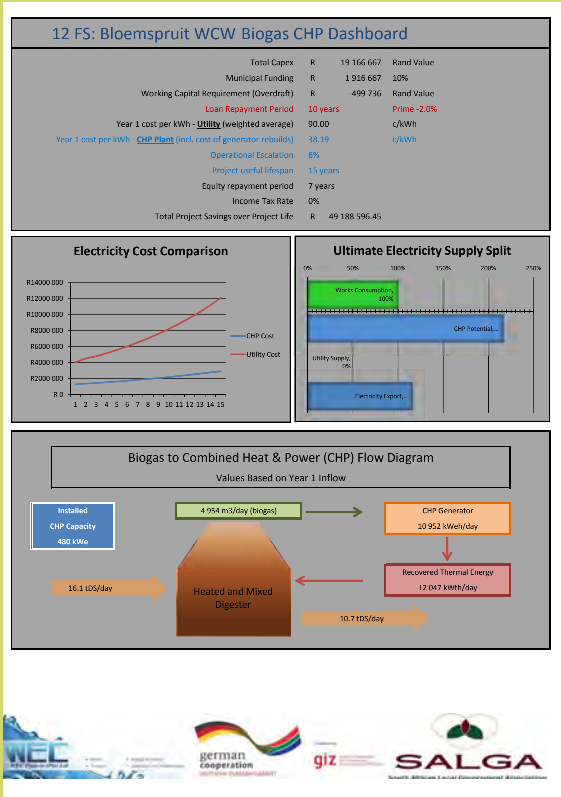
The Biogas to Energy at Municipal Wastewater Treatment Works: Feasibility EXCEL tool

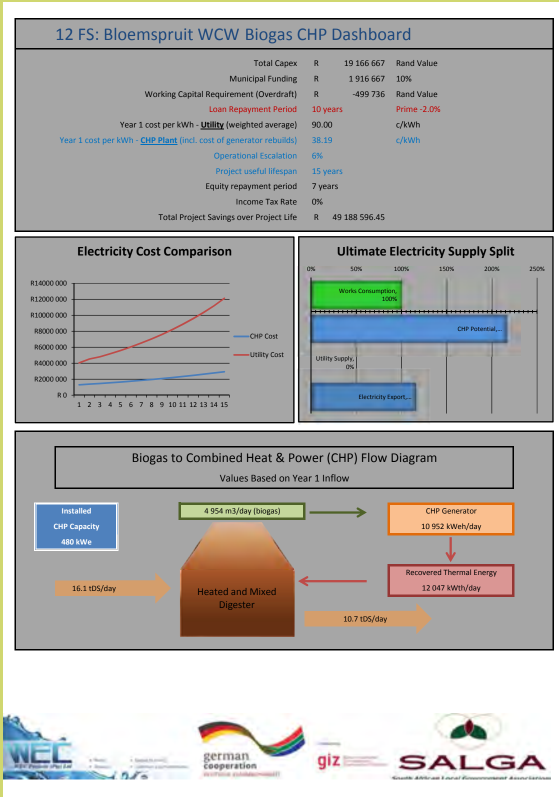
This calculation tool requires inputs from municipal officials' familiar with the WWTW processes used and from officials familiar with the municipality's finance requirements. The excel tool comprises 4 sheets:

Notes: this page if for information purposes and explains how to use the tool.

Assumption Sheet: this is the main user interface with the excel tool. Here the user inputs all process and financial information.

Dashboard Sheet: the Dashboard provides an Executive Summary of the potential project allowing the user to quickly assess the project's viability based on the information inputted in the Assumption Sheet.





Generator CAPEX Sheet: the model calculates an approximate capital cost of the complete CHP plant based on the cost of the generator set. These are rule of thumb assumptions and are for guideline purposes only. The cost of the generator set can be modified by the user.

The accuracy of the tool is only as good as the information it receives. It is also for indicative purposes only. Should the tool indicate viability, the municipality would still need to then appoint suitably qualified consultants to **undertake a full feasibility study.**

POWER POINT PRESENTATION and NOTES

The presentation and accompanying notes have been developed to assist project initiators when presenting the project to management. The notes provide a better understanding of biogas as a technology and how it applies to WWTW. The presentation can be used to:

- Explain the technology
- Outline the multiple benefits associated with such a project
- Display the results of the Excel tool in a specific waste water treatment plant.

All Tools can be downloaded on: www.cityenergy.org.za / Renewable Energy / Tools and Guidelines.

The tool was commissioned by SAGEN-GIZ/SALGA; the Excel tool was developed by WEC Projects (PTY) Ltd. The other parts of the toolkit were jointly developed by Biogas SA, CapEAPrac and WEC Projects (PTY) Ltd.

This greatly simplifies the business of plant establishment and operation as there is no need for complex public private partnership agreements, wheeling agreements, generating license applications, etc. While this model may be considered optimal in terms of simplicity, it is still very important to clarify the roles and responsibilities of those in charge of development, operation and maintenance of the plant. Key actions include:

1. Appointing a dedicated champion within the municipality to drive the project. As this is a relatively unknown technology, new to most decision makers, this person will need to equip themselves with new skills and knowledge.
2. Setting up cross-departmental teams to steer the implementation of the project and appoint consultants with the necessary experience in the biogas field to undertake the viability assessment and draft the necessary tender documentation.
3. Appointing of service providers to design, build, operate and maintain the plant for 7 – 10 years.
4. Clarifying operation and maintenance responsibilities: feedstock to the plant and biogas production is reliant on the downstream feedstock, so coordination between these municipal responsibilities and/or the contractor, is critical. The more in-house capacity is built in relation to the new activities, the better the cooperation between facility managers and staff will be, ensuring a higher likelihood of success.
5. Once commissioned the risk sharing must be clearly delineated between the municipality and the service provider ensuring good performance while not penalizing the contractor where the municipality fails to supply adequate feedstock to the power plant. This can also be assisted by a clear delineation – marked through fencing off of the power plant – of the management boundaries between the parties. This process requires complex contracting and takes time and money.

Partnering with the private sector

Private participation may be helpful to bring in specific project development expertise or to mobilise private capital. However, private capital is likely to only be interested where the ROI is high enough to make it attractive to invest. Such projects may be set up as a Public Private Partnership (PPP) or Energy Services Company (ESCO) model.

While establishing a PPP may mobilise expertise, share risk and reduce financial commitments, the process can be lengthy, cumbersome and costly. A Power Purchase Agreement (PPA) needs to be developed, either directly with the municipality or a private company, which in turn requires a comprehensive contract and possibly a wheeling agreement – all of which is time consuming and costly – requiring a high level of technical (financial and legal) skills that have to be contracted in.

Licenses

The licensing requirements for a biogas project in a municipal WWTW are not clearly stipulated under current legislation, but the following would have a bearing:

- **Environmental Impact Assessment (EIA):** either a Basic or Scoping and "Full EIA" will need to be undertaken in terms of the NEMA (No.107 of 1998) – this depending on the scale and design of the existing WWTW facility and scale and design of the biogas digester proposed, and on existing licenses.
- **Various additional authorisations will need to be obtained:** Waste Management License, Water Use License, Atmospheric Emission License, Land Use Planning Authorisation, Major Hazard Installation Regulation may also be relevant.
- **Electricity/gas related authorisation:** while a generating license from NERSA is usually only required if the project sells the electricity into the national grid and is over 1MW (Schedule 2 Electricity Regulation Act, 2006), biogas is an exception. Section 28 of the Gas Act No.48 of 2001 stipulates that NERSA registers all small biogas projects not connected to the grid.

Financial modelling and project financing

The primary financial viability factor is the potential revenue made, or cost savings derived from avoided purchases where consumption is on-site, through electricity generated from the available biogas. Secondary benefits include sludge management (reduction and improved quality), carbon mitigation and local economic development and related jobs. These secondary aspects may have a financial value that could be costed in.

The financial model will depend on whether the municipality retains sole ownership or enters a Public Private Partnership with the private sector. Private sector stakeholders may require a higher ROI compared to the municipality. Secondary benefits, such as sludge management, may also not benefit to them. Lengthy contract development processes (PPP, PPA, Wheeling agreements) in a PPP may impact on ROI due to the additional time and resources required to effect.

In general, biogas projects will require a long-term investment of 7 – 10 years or more. The initial indication is that larger WWTWs with an inflow in excess of 15ML/day show financial viability based on the amount of electricity they could generate. As emphasized, site-specific modelling would be required to confirm any estimation, given the variability of characteristics of each plant.

There are no strongly established typical costs for such projects. This was also depend on whether biogas digesters are in place and the capacity and functionality of these. The capital investment at Johannesburg Northern Works plant was in the region of R32 million/MW installed. This included investment for upgrading of existing biogas digesters. Operational costs are cited as R300/MWh. (SALGA-GIZ case study series: Municipal Wastewater Treatment Works: Biogas to Energy (Co-generation) at City of Johannesburg Northern Works: http://www.cityenergy.org.za/uploads/resource_336.pdf).

Finance for project implementation may be sourced internally from the municipal fiscus, or externally, from a commercial bank, donor funder or through Public Private Partnerships. In order to motivate for finance the Project Business Plan needs to present a favourable financial feasibility for the project. Expected financial savings and other benefits need to be clearly articulated.

Barriers and opportunities

Undertaking a sound feasibility analysis can be hampered by lack of information: an in-depth understanding of the actual operational processes at each WWTW is required in order to do a realistic analysis of the practical quantity of sludge available to serve as feedstock for the digesters at each WWTW (this informs the electricity generation potential and is thus the basis of the financial viability). This information is not readily available or recorded at municipalities.

Downstream management of the feedstock: poor gas yields due to issues relating to the sludge management component of the plant can result in lower gas production than anticipated. This aspect of the project is often managed by municipal wastewater treatment plant staff. The system they are operating within is not market related, or performance output related (for example obtaining supplies from stores for broken components may require lengthy public service procedures resulting in delays in production. This is important for spending of public money, but may not result in optimal efficiency of gas production). This can result in the engines not operating optimally and higher than expected unit costs for the electricity produced.

Opportunities and enablers that can facilitate biogas to energy projects at WWTW include:

- Many plants already have biogas digestors. While these may require refurbishment, they generally already have the requisite environmental permitting.
- If the electricity produced is under 1MW and largely used on-site, the municipality is likely to be exempt from generation license application processes, and if it is used entirely on-site, complex Power Purchase Agreement contract development will be avoided.
- Improved sludge management may result in an additional revenue stream where it meets the standards for organic compost.

Future developments

Given that this is a rapidly changing technological space, it is important to remain attentive to developments and regularly investigate new possibilities. For example, the Netherlands has introduced the idea of the NEW Factory (nutrient, energy and water factory) for wastewater treatment works. This suggests considering wastewater as a resource of nutrients, energy and clean water, rather than a waste product. New areas of technological development include:

- High-load digestion: increased concentration of solids and microorganisms inside the anaerobic digester reducing necessary digestion volume and heat required which lowers investment and operation costs. For WWTPs without digesters, and for smaller plants, this may open up a cost effective solution;
- Hydrothermal carbonization, pyrolysis and gasification and fuel cells. In addition to utilizing the methane gas from waste for combustion or heat generation, the carbon dioxide found in waste streams may offer an important source of carbon dioxide for synfuel development. Hydrogen from water – through a hydrolysis process – mixed with carbon dioxide can form hydrocarbons that can be used as transportation fuels in the future. These technologies are in theory far more efficient, but require high quality gas and there are security concerns around hydrogen;
- Phosphorus recovery from sewage sludge for nutrient recycling.

Case study 1: Johannesburg Water Northern Works Biogas to Energy*

With electricity price increases set to triple Johannesburg Water's electricity bill from R100 million to over R300 million over the next ten years they identified the need to cut back on electricity usage. Northern Works treats about 43 ML of sewage/day. It is the City of Johannesburg's largest wastewater treatment works and the site of its first biogas to energy project.

The plant produces electricity from biogas using three 376kWe (KWh equivalent = heat and power) combined heat and power (CHP) gas engines. The electricity produced is consumed on-site. Currently it produces 10% of the treatment work's power requirement. However, once all of the digesters have been refurbished, and all of the sludge is treated anaerobically, the CHP plant should produce some 56% of the on-site power requirements.

Figure 2: Generators at Northern Works

Source: courtesy of Jason Gifford, WEC

The heat energy produced by the CHP engines is used to pretreat the sludge, which increases the biogas production. Additionally, the heat improves sludge management producing lower volumes of better quality waste. Sludge will now meet the standards for organic compost and can be sold into the agricultural sector.

Business model: The biogas plant installation was undertaken by Johannesburg Water (wholly owned by the City of Johannesburg). The project is a design, build, operate and manage model whereby a private company was appointed by Johannesburg Water for an 8-year period.

Procurement and contracting: Phase 1 included the design and build of the biogas scrubbing and CHP engine installations through a 1-year contract. Phase 2 covered the operation and maintenance of the biogas plant through a 2-year 'defects liability period' contract and a 5-year operation and maintenance contract. As the latter is a contract of more than 3 years a public participation process was undertaken in accordance with the Municipal Finance Management Act (Section 33).

The greatest hurdle in the contracting arrangements was working out a fair balance of risk and responsibility between Johannesburg Water and the O&M Company. This was complex as power output (responsibility of the O&M Company) was reliant on feedstock (responsibility of Johannesburg Water). This was ultimately resolved through structuring the contract to include both a fixed (to ensure ongoing operations and maintenance despite potentially variable feedstock) and variable fee component, the latter based on actual power production (to ensure performance).

Permitting and licensing: the project was facilitated by the fact that it involved the refurbishment of existing biogas digesters within an existing plant and therefore did not require environmental permitting. In addition, as the power generated is only used on-site, for municipal 'own use', no generation licensing application procedure was required. However, registration with NERSA was required in terms of Section 28 of the Gas Act No.48 of 2001.

Lessons learnt through the process:

- *Complex contractual arrangements in terms of performance and risk sharing required substantial, and costly, legal time and knowledge. Despite mechanical availability of the plant, poor gas yields have meant lower than expected electricity production (a third of the forecast value), shifting the anticipated 9 year ROI back and severely affecting the financial viability of the project. This emphasizes the importance of detailed and accurate gas feasibility studies.*
- *A dedicated champion within the WWTW department was critical in driving the project through.*
- *Clear fencing of the electricity generation unit from the rest of the WWTW has assisted in clarifying the management boundaries between the two plants.*
- *Improved sludge management is considered an important additional benefit resulting from the project.*

* This case study draws extensively from the report: Municipal Wastewater Treatment Works: Biogas to Energy (Co-generation) at City of Johannesburg Northern Works: http://www. cityenergy.org.za/uploads/resource_336.pdf. Unless referenced otherwise, information is sourced from this document.

Support Organisation

Southern African Biogas Industry Association (SABIA)

http://www.biogasassociation.co.za

Waste to Energy: Incineration, gasification and pyrolysis

Overview

Incineration, gasification and pyrolysis can be simply described as a process whereby organic matter is decomposed by burning (heating the waste). The major differences between the three processes relate to operating temperatures (linked to oxygen volumes in the burning process) and the products that you obtain from each due to the operating temperatures at which the waste is burned. While incineration and gasification technologies are similar in principle, the energy product from incineration is high-temperature heat whereas combustible gas is often the main energy product from gasification.

These technologies offer an opportunity within the South African context, but are still relatively costly, require highly specialised skills to manage and operate , and need secure volumes of waste (security of feedstock) to ensure the viability of these technologies. Another barrier relates to enabling legislation. Land zoning issues remain a challenge for the establishment of such WtE technologies.

It is likely that in the short term, given the relative costs and skills levels, municipalities will focus on the biogas to energy projects from landfill and WWTW as detailed in other chapters. However, the private sector may well pursue such projects and this may draw municipalities in. A working knowledge of the technology is therefore useful.

Implementation

Incineration

Incineration involves the combustion of organic materials into incinerator bottom ash, flue gases, particulates, and heat that can be used to generate electricity. It is both a landfill reduction method, reducing the volume of waste by 95-96%, and a WtE technology.

The heat produced upon incineration can be used to generate steam which can then be used to drive a turbine in order to produce electricity. The typical range of net electrical energy that can be produced is about 500 to 600 kWh of per tonne of waste incinerated [1]. Thus, the incineration of about 2,200 tonnes per day of waste will produce about 50 MW of electrical power. Electricity production is thus around 0.5–0.7 MWh/t of municipal solid waste (Royal Haskoning DHV, 2014[2]).

Incineration reduces mass and volume of landfill, lightening the load of landfill management in cities. There has been concern around the health ramifications of incineration, but significant advances in emission control have occurred and strict regulations have been initiated concerning dioxin and furan emissions (both of which are highly toxic substances). By diverting municipal solid waste, incineration avoids the release of methane into the atmosphere. In addition to methane, for every tonne of municipal solid waste that gets incinerated, approximately one tonne of CO_2 is prevented from being released into the atmosphere.

Medical waste incineration is the most common application in South Africa, but there are also some industrial waste incinerators for hazardous waste. There are currently few incinerators for household waste (3SMedia, 2013[3]).

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1 https://en.wikipedia.org/wiki/Waste-to-energy_plant#cite_note-Columbia-1.

2 Royal Haskoning DHV (2014) Municipal Solid Waste Diversion and Beneficiation Opportunities at Nelson Mandela Bay Metro Municipality – Feasibility study final report.

3 3s Media (2013) Should the focus rather be on waste to energy than incineration? Sourced online at Infrastructrene.ws http://www.infrastructurene.ws/2013/05/15/should-the-focus-rather-be-on-waste-to-energy-than-incineration/

Figure 1: An example of a low capacity, mobile incinerator. These may be deployed in developing countries for health purposes, for example the destruction of medical waste or to dispose of infected animals quickly.

Source: Public Domain, https://en.wikipedia.org/w/index.php?curid=11060590

The biggest challenges for waste-to-energy mass burn incineration currently in South Africa lie in the high capital costs and air emission control requirements. Incineration produces particles containing toxic metals, dioxins, and furans that are so small that they can potentially evade pollution control devices. Incineration also produces a highly toxic fly ash that must be safely disposed of; leading to transportation and residential health concerns. Gasification and pyrolysis on the other hand are cleaner processes and do not pose toxicity threats, but remain "third generation" technologies.

Although the fuel (i.e. the waste) in a WtE incineration plant may be free, and the plant may save hugely on landfilling costs, the high capital costs of plants means that incineration is still prohibitively costly as a household waste treatment approach in South Africa.

Gasification / Pyrolysis

Just about any organic material, such as biomass, wood and plastic waste, can be converted into a gas mixture of carbon monoxide, hydrogen and carbon dioxide by gasification and pyrolysis. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam.

Unlike incineration, gasification does not produce energy from waste through direct combustion. Waste, steam, and oxygen are fed into a gasifier where heat and pressure break apart the chemical bonds of the waste to form synthesis gas (syngas). It allows the breakdown of hydrocarbons into the gaseous mixture by carefully controlling the amount of oxygen available.

Syngas may be used directly in internal combustion engines or to make products that substitute for natural gas, chemicals, fertilisers, transportation fuels and hydrogen. Pollutants are removed from syngas before it is combusted, so that it does not produce the high levels of emissions associated with other combustion technologies.

Like gasification, pyrolysis also turns waste into energy by heating under controlled conditions, but involves thermal degradation in the complete absence of air. Pyrolysis typically occurs under pressure and at operating temperatures above 430ºC (800ºF).Pyrolysis produces char, pyrolysis oil, and syngas, all of which can be used as fuels.

Gasification and pyrolysis are extremely efficient ways of using biomass to produce energy, both being more efficient than incineration. They are flexible technologies where existing gas-fuelled devices (ovens, furnaces, boilers, etc.) can be retrofitted with gasifiers and syngas can directly replace fossil fuels. Gasification is able to generate energy which is cheaper and more efficient than the steam process used in incineration.

Municipal solid waste can be reduced by as much as 75% through this process, reducing to the same degree the amount of potential emissions the waste would have created in a landfill. The process of sorting and preparing the solid waste (autoclaving) for pyrolysis is well established and the technological expertise is available in South Africa.

These technologies are cleaner than incineration and do not pose toxicity threats. However, the technology is still relatively new (or "third generation") with limited plants in operation around the world (although anticipated to grow substantially into the future).

Waste to Energy: municipal landfill waste methane gas to energy implementation

Overview

When electricity, gas or heat is generated from a waste source it is utilising waste-to-energy (WtE) technology. In addition to energy/heat generation potential, these processes may also reduce waste that would otherwise go into a landfill and help close the nutrient loop through better sludge management; they also reduce the amount of methane released into the atmosphere from landfill or wastewater treatment sites, thus mitigating climate change.

It is important to remember that the most sustainable path is one of ZERO waste. Reducing the amount of waste generated, reuse of discarded items and recycling and composting are fundamental principles in a ZERO waste approach. Municipalities should strive to achieve this goal ahead of pursuing waste for energy purposes.

A number of WtE technologies exist, with the most relevant for municipalities being that of biogas digestion at landfill and wastewater sites. Biogas digestion at landfill and wastewater treatment sites, based on mature technologies, is now taking place at within the larger metros. Located on municipally owned sites with municipal-controlled energy feedstocks, and with important waste management improvements to be gained through such projects, these are typically municipally driven. Both of these technologies are developed in detail below.

It is unlikely that Cities will pursue other WtE technologies, such as incineration and pyrolysis/ gasification in the short term, given the viability of landfill gas and wastewater biogas projects and support for these from the national renewable energy Independent Power Producer Program (REIPPPP). However, should the REIPPPP be made available to these technologies, it is anticipated that they too will enjoy mass implementation in the country. These WtE technologies will most likely be exploited in the medium term by cities in order to promote their renewable energy profiles. A brief over view of these technologies is provided at the end of the Waste to Energy chapter.

Private sector investment in WtE, particularly in the agricultural waste sectors (crop produce and animal waste), is growing in South Africa. This is of interest to municipalities as it may offer waste management opportunities.

Landfill gas (LFG) is released when anaerobic bacteria decompose organic waste at landfill sites. A landfill acts as an anaerobic digester producing gases composed of 50 – 60% methane (CH_4), 40 – 50% carbon dioxide (CO_2) and a small percentage of volatile organic compounds. Formation of methane and CO_2 commences about six months after depositing the landfill material. The evolution of gas reaches a maximum at about 20 years, then declines over the course of decades.

Methane has a global warming potential 21 times as high as that of carbon dioxide. Instead of escaping into the air, LFG can be captured, converted and used as an energy source. CH_4 is a high energy clean burning gas and is suitable for generating electricity or for direct use as a combustible fuel.

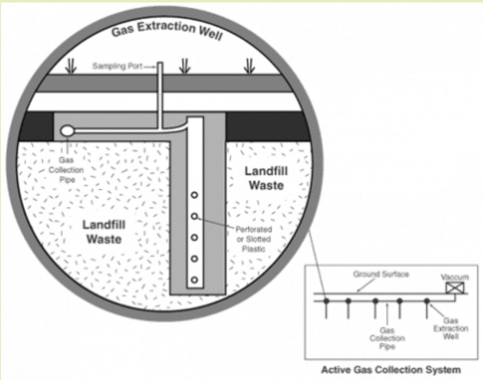
The basic idea behind the technology is that landfills are covered (e.g. by a layer of earth) and LFG is extracted from the landfills using a series of wells and a blower/flare (or vacuum) system. This system directs the collected gas to a central point where it can be processed and treated depending upon the ultimate use for the gas.

From this point, the gas can be flared (to dispose of flammable constituents safely, control odour and mitigate climate change through conversion of methane to carbon dioxide), used to generate electricity, or used directly for space and water heating. It can also be upgraded, concentrated and compressed, to pipeline-quality gas where the gas may be used directly or processed into an alternative vehicle fuel.

A LFG to energy project thus has two major technical components, often completed as two separate phases of the project:

- **Phase 1:** Gas collection and flaring: this involves the installation of a pipe network drilled into the landfill, the laying of vertical and horizontal gas wells, gas collector pipework, high temperature gas flares and continuous gas monitoring system. Results from the gas monitoring will facilitate best sizing of the electricity generation unit.
- **Phase 2:** Gas conversion to electricity or direct use for energy or thermal purposes. Detailed feasibility needs to be done on the best use (greatest financial, economic and social benefit) of the gas. If electricity is to be produced, the captured gas is fed to a modular electricity generation plant, very often a gas engine in a container. The generator combusts the methane to produce electricity. Excess gas, and all gas collected during periods when electricity is not produced, is flared.

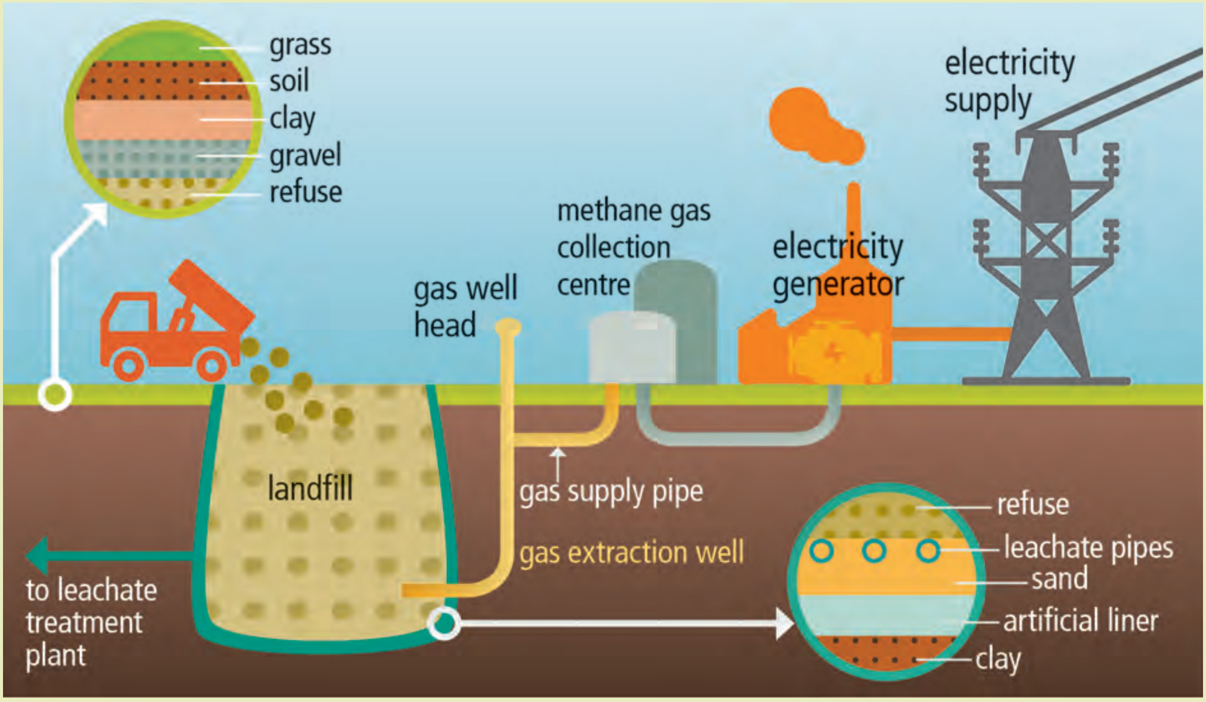
Figure 1 – Gas extraction well and well head



For a large modern landfill, useable LFG may be generated for between 15 and 30 years. However, biogas composition can vary significantly across locations as it depends on factors such as climatic, industrial and agricultural production characteristics and waste management practices.

Several options are available for converting LFG to energy. Below are descriptions of some of the typical project types. Experience from the pioneering landfill to electricity sites in the eThekwini municipality indicate that direct use of the gas may prove to be the most economical.

Figure 2: landfill



Electricity Generation

The harvested gas is burnt in spark ignition gas engines which drive generators to produce electricity. Although a variety of technologies can be used for the electricity generation, the vast majority of projects use internal combustion engines. Any surplus gas is flared via flare units. The LFG generators have an anticipated life of 10 – 15 years depending on operational conditions, fuel quality (in the form of LFG), and the maintenance regime adopted.

Direct Use

The harvested gas can be used directly in a boiler, dryer, kiln, greenhouse, or other thermal applications, offsetting the use of another fuel. Current industries using LFG include auto manufacturing, chemical production, food processing, pharmaceuticals, cement and brick manufacturing, wastewater treatment, consumer electronics and products, paper and steel production, and prisons and hospitals.

Cogeneration

Cogeneration, also known as combined heat and power or CHP, projects use LFG to generate both electricity and thermal energy, usually in the form of steam or hot water. Several cogeneration projects have been installed at industrial operations, using engines or turbines. The efficiency gains of capturing the thermal energy in addition to electricity generation can make these projects very attractive.

Alternative Fuels

Production of alternative fuels from LFG is an emerging area. LFG has been successfully delivered to natural gas pipeline systems as high and medium energy intensity fuel. LFG is also being used to produce the equivalent of compressed natural gas (CNG) for use in vehicles.

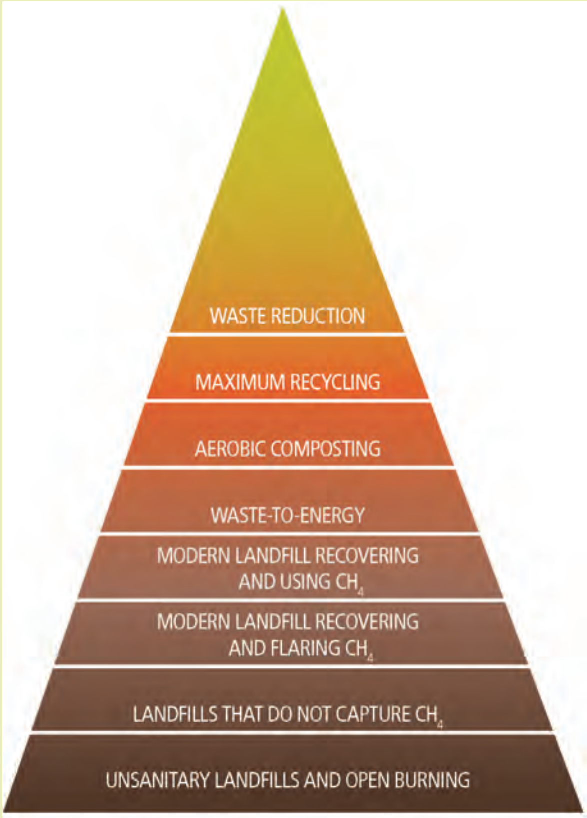
Figure 3: The Simmer and Jack landfill site, Ekurhuleni municipality: gas flare and 1MW electricity generation engine and water and gas monitor boreholes

Photo: Sustainable Energy Africa

Photo: Sustainable Energy Africa

Figure 4: Mariannhill, eThekwini Municipality, 1MW engine and LFG flare; Bisaser Road, eThekwini Municipality, 6.5MW engine and LFG flare station

Figure 6: Waste management optimisation pyramid



Waste to energy processes can only be undertaken in situations where waste is already well managed. Where waste is not yet properly managed the CH_4 will simply being emitted into the atmosphere on an ongoing basis and cannot be captured for usage as a fuel stock.

A first step in the waste optimisation pyramid is to pursue effective waste management strategies.

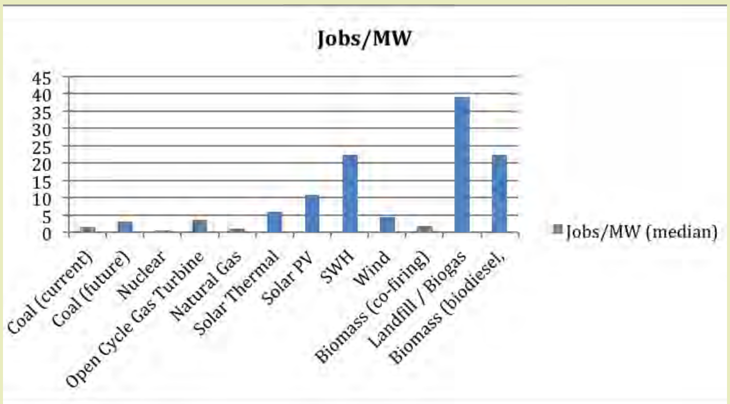
Implementation

Landfill sites, with powerful greenhouse gas emissions, offer an important opportunity to reduce GHG emissions in line with national goals and targets. At a local level, municipalities need to manage the emissions from their landfill sites in order to comply with air quality licensing thresholds and improve the safety and quality of life of local residents who live nearby to the landfill sites. A landfill gas extraction to energy project can provide opportunities to achieve these goals, while also producing energy and offsetting electricity costs to the municipality. Benefits of landfill gas conversion to electricity:

- A substantial GHG emissions reduction impact: GHG emissions are reduced through conversion of methane to water and CO_2 (which has a lower global warming potential than methane) and through displacing energy produced from fossil fuel combustion.
- Improved site management as escaping gas impairs the working of the landfill
- Improved groundwater quality as the management of the site could relatively easily be combined with leachate collection and disposal action.
- Improved local air quality, safety and reduction in odour for neighbouring communities.
- Economic stimulant and job creation: the process of designing, constructing and operating LFG capture plants creates jobs associated with such activities: engineers, construction firms, equipment vendors, and utilities or distributors; local spend on drilling, piping, construction and operational personnel.

If we do nothing differently, methane emissions from municipal solid waste are expected to increase globally by around 19% above 1990 levels by the year 2050. This increase could largely take place in developing countries (US EPA, 2005).

Figure 6: Job creation from WtE projects shows the highest potential across a range of technologies for South Africa



Source: Sustainable Energy Africa (2010) Renewable energy employment figures: A synthesis of available

Potential for rollout

The technology to generate electricity from landfill gas is mature and expertise to implement the technology in South Africa exists. With the potential for inclusion within the REIPPPP, along with the rapidly closing gap between the unit cost for landfill gas to electricity and average Eskom Megaflex tariffs, there is a very strong case for all viable landfill sites to be set up as landfill gas to energy generation sites.

Ekurhuleni Metropolitan Municipality, the City of Johannesburg and eThekwini Metropolitan Municipality have all three developed landfill gas to electricity projects. The projects were developed over two decades: eThekwini initiated exploration in 1994, Ekurhuleni in 2005 and the projects in Johannesburg are still in construction phase. Over this period of time, the regulation applicable to municipalities has changed, the electricity sector in South Africa has been transformed and most importantly, an impressive amount of knowledge, capacity and skills have been developed, within municipalities but also for the manufacturers, suppliers and service providers involved in the projects, from the designing phase to operation and maintenance.

In total, a capacity of 8.5 MW is currently installed in municipal landfills, 18.6 are being built and a further 4 are at planning stage. This should add up to a total of about 30 MW of installed capacity across the 3 municipalities. While this is small compared to the needs of the country, it is electricity generated as a base load, close to the consumption area, which decreases transmission losses and at a price which can be controlled over time. These 30 MW installed could in theory power 37,000 households (at an average consumption of 500 kW/month)

According to a 2004 DME study, Economic and Financial Calculations and Modelling for the Renewable Energy Strategy Formulation document, 57 feasible landfill sites, currently producing some 43 million m^3 of methane gas per year, were identified across the country. Potential electricity generation capacity from the sites (ranging from micro/650 kW capacity to large/4 000 kW capacity) could contribute the following:

Renewable energy capacity	75 MW*
Annual renewable energy into the grid	830 GWh
CO_2 reduction from offset fossil fuel electricity	830 000 tons
CO_2e reduction from burning methane	1 928 550 tons

* noting that experience is now indicating that smaller than 1 MW may not be readily viable (some 24 MW of the above); however, this may change over time with higher electricity prices and greater experience in the country with the technology.

As landfill sites are municipal-owned, a landfill gas to energy project needs to be driven by the municipality.

Costs and financial viability

The financial viability of a landfill gas to energy project is complex to assess because:

- There is a very significant difference between the financial and economic costs of a landfill gas to energy project. This is to do with the emissions offsets that are possible to achieve within such a project. Conventionally the financial viability would be assessed through comparing the cost of producing energy from the landfill gas vs the cost of the equivalent grid electricity available. However in a landfill gas to energy project there is the added component of the value of the gas management and emissions displaced. In this instance a project's viability must look at the cost of the landfill gas energy as compared to the displaced fossil fuel energy plus the value of the reduced methane emissions. Where such offsets have a financial value (such as through carbon credits, or avoided carbon tax) this can enormously facilitate the viability of a project, where not, the project may not be financially viable.
- In addition the municipality would need to assess the important, but often un-costed/non-financial benefits for the municipality: air quality standards adherence, climate mitigation targets and integrated waste management. Where gas capture infrastructure is installed as part of waste management and thus "off" the energy project balance sheet, the financial viability of the energy production element will be greatly enhanced.

Landfill gas to energy projects are relatively new in South Africa and investment costs and returns are still fairly variable. The City of Johannesburg development of the Robinson Deep Landfill to energy project was considered financially viable at the REIPPPP tariff rate of 1.00 ZAR/KWh, but not at the Eskom Mega Flex rate, which was – at the time of project development – R0.53/KWh (in 2014/5). With Eskom Megaflex at an average rate of R0.85 (2016) however, this gap may well be closing rapidly: the Robinson Deep developers believed that a minimum rate of R0.71 was required for viability.

The following table provides a simple payback analysis for LFG to electricity projects (no inflation, discount, interest, electricity price increases have been used). The figures are purely indicative as all costs drawn on have been in ZAR at the time of the investment (not constant ZAR).

Table 1: Simple payback analysis for LFG to electricity projects

	REIPPP Feed in Tarriff (FIT) unit rate (2015)	Eskom Avg Mega flex unit rate (2016)	Units
Average output per MW installed	7 095 600	7 095 600	KWh/year
Average capacity/load factor experienced in SA projects	81	81	%
Anticipated/global average capacity factor	92	92	%
Tariff for landfill gas	1	0.85	ZAR/KWh
Annual income/MW installed	7 095 600	6 031 260	ZAR/MW
Annual income minus op costs	4 967 600	3 903 260	ZAR/MW
Revenue over 15 year lifespan (12 – 20 years avg lifespan)	106 434 000	90 468 900	ZAR/MW
Capital cost/MW (estimated avg. including wells)	19 300 000	19 300 000	ZAR/MW
Operational costs per year (figure indicative)	2 128 000	2 128 000	ZAR/MW
Operational costs (over 15 years)	31 920 000	31 920 000	ZAR/MW
Revenue minus costs (over 15 years)	55 214 000	39 248 900	ZAR/MW
Revenue minus costs (average annual)	3 680 933	2 616 593	ZAR/MW
Payback/break even – number of years	3.89	4.94	Years

Source: Figures taken from: Ferry et al. (2016) Municipal Landfill Gas to Energy: concept and summary of lessons learnt from 3 South African cities http://cityenergy.org.za/uploads/resource_360.pdf

Although this provides a critical source of funding for projects, it must be noted that allocations for landfill are limited and not all projects may qualify within the program. The tender process is complex and requires the dedicated time of experienced project developers. The City of Johannesburg ultimately used this route to fund their LFG to electricity project (developed as a Public Private Partnership – PPP – between the City and a private developer).

Air Quality control legislation

Atmospheric release of LFG currently complies with South Africa's local and national laws. The draft "Minimum Requirements for Waste Disposal by Landfill" (published in 2005 and constituting the **most recent** legislation on landfill site management available in South Africa) does not categorically specify that it is a mandatory requirement to actively capture, flare, or destroy LFG at every landfill in South Africa.

The draft requirements provide guidelines to ensure safety on site (i.e. reducing the risk of explosions) by limiting LFG accumulation via passive ventilation. The prevailing practice in South Africa is either venting the LFG to ensure that the concentration of methane in any particular area of the landfill stays below hazardous levels, or to not install any kind of capturing system[5].

Source: City of Joburg Landfill Gas to Electricity CDM PDD, 2011

Given the likely increase in Eskom prices over the next 15 – 20 years, LFG projects offer a stable source of electricity at a stable price and would be in the best interests of a municipality to pursue.

Financing opportunities for LFG to electricity projects

The following financing opportunities can be explored:

Municipal budget:

Given that LFG to electricity (or energy) projects may offer reasonable ROI and relatively short payback periods it is worth exploring whether the municipality could undertake its own investment in the project. Ekurhuleni Municipality went this route, with budget allocated to the project through the annual CAPEX budget process.

The national Renewable Energy Independent Power Producers Program (REIPPPP):

South Africa has a target of 17 800 MW of renewable energy by 2030 under the Integrated Resources Plan (2010-2030). The Minister of Energy has to date determined a total of 13 225 MW to be procured through the RE Independent Power Producer Procurement Program (REIPPPP), launched in 2011. Landfill gas to electricity is an approved technology within the program, with a capacity allocation of 25 MW. In addition, landfill gas may qualify within the Small Projects IPP category, to which an additional 400MW has been allocated (each project may have a minimum and maximum contracted capacity of between 1 MW and 5 MW). The maximum tariff a bidder may bid is set out in each Bid Window Request for Proposals. This was set at R1.00/KWh for landfill gas to energy in the Bid Window 3 (2014).

Although this provides a critical source of funding for projects, it must be noted that allocations for landfill are limited and not all projects may qualify within the program. The tender process is complex and requires the dedicated time of experienced project developers. The City of Johannesburg ultimately used this route to fund their LFG to electricity project (developed as a Public Private Partnership – PPP – between the City and a private developer).

Carbon finance:

As noted, landfill projects have sizeable carbon 'credits'(or offsets) associated with them – from the conversion of methane gas to CO_2 and the offset of fossil fuel electricity production. However, to date the route of carbon financing has proved costly, inefficient and unproductive for South African landfill gas to energy projects. Unless the price of carbon is very good, the costs of verification may often be significantly more than the value of the credits themselves.

Registering a Carbon Credits or Cleaner Development Mechanisms (CDM) project with the UNFCCC Executive Board is a lengthy process and involves a substantial range of stakeholders, adding to project complexity. Emissions reduction monitoring is onerous and gas emissions data needs to be collected every few seconds using rigorous monitoring methods and expensive software packages. The data requires in depth analysis to explain irregularities for verification purposes and ongoing engagement with external verification teams.

CDM projects can also only be registered where a case can be made for "additionality". This means that the project must be able to demonstrate that it would not have been able to be implemented without the additional carbon monies. As South Africa's electricity prices increase to close to cost comparable with LFG to electricity prices, this may become a challenge. A further concern is that this additionality clause will deter government from implementing regulations for air quality management that would require landfill site management to bring in gas capture and flaring processes as this may inhibit CDM funding. However, carbon offset markets into the future might still mean that LFG to electricity projects can attract carbon credit finance.

Establishing project feasibility: determining the gas and electricity potential and undertaking a detailed feasibility assessment

It is necessary to have a reasonable idea of the gas yield in order to design the appropriate gas extraction schemes. The gas yield and the lifespan of the yield may limit the economic viability of the use of the gas.

Methane gas can only be harvested where landfills have been well developed and managed. Poorly designed and managed landfills will have leaked substantial amounts of gas, and the site may not have viable concentrations of gas for harvest. Where the site has been well managed, the methane gas can be produced for up to 20 years after the waste has been landfilled.

Using LFG for electricity generation or alternative fuel for vehicle fleets?

After the enormous challenges in developing the eThekwini landfill to electricity projects, the municipal project developer from within the Electricity Department, Mr John Parkin, has suggested that municipalities should strongly consider direct use of the gas in vehicles, rather than conversion to electricity.

Although direct use of the gas would involve 'cleaning' it, not having to build and manage a power station (losing 50% of the energy in the form of heat), would offer cost and time savings. A municipality could either use the gas directly in the municipal vehicle fleet, or sell the gas to industry should there be a market/buyer nearby.

However, some challenges exist that require consideration and it is recommended that a thorough analysis of cost to produce electricity vs gas be done before a municipality decides which path to pursue. A major challenge is that while use of the gas to fuel the waste collection trucks sounds a perfect solution, the experience worldwide is that municipalities struggle to maintain the vehicle conversion kits. This option would require that municipalities sort out the full supply chain story for gas-powered vehicles. If selling into industry, the municipality would need to have a very good understanding of the gas market and prices.

Currently there is limited gas around and prices are good, but as more such projects come on board the economic case may well swing back in favour of electricity production.

The following "rule of thumb" can be used for estimating biogas production and related electricity generation potential:

- 100 000 tons of domestic waste entering a landfill per year = roughly equivalent to a potential electricity capacity of 1MW
- 600 – 700 m^3/hour of gas can generate 1 MW of electricity
- 1 ton of highly organic waste will produce 6 – 10 m^3 of landfill gas per year for 10 – 15 years from placement
- 1 Mton of average city residential waste can produce roughly 500 m^3/hour (roughly 4.3 m3 of gas per year)

Sources: Eden et al.(2002) Ener-G Systems, John Parkin, eThekwini Municipality.

Although a useful indicator, a rule of thumb provides only a very crude estimation. Actual gas values and potential electricity generation do not solely depend on the amount of waste received but on a number of other factors, which may include climatic conditions, historical quantity of waste received, waste composition and landfill site management. To determine the viability of such project at a landfill site, detailed assessment studies must be conducted.

Feasibility studies done on South African landfill sites indicate a great electricity potential variability and detailed feasibility studies are critical. In addition real gas yields should be monitored, once they have stabilized, before efficient sizing of generation plants are made.

Table 1: Annual waste tonnage and electricity potential of 3 landfill sites indicating variability in electricity potential across sites

Landfill site	Tons of waste per year	Electricity potential
Linbro Park landfill, Johannesburg	360 000	3.3 MW
Robinson Deep, Johannesburg	400 000	5.5 MW
Rietfontein, Ekurhuleni	355 000	Potential doubtful

Source: GIZ case study series

Bringing all stakeholders on board

Municipal stakeholders: It is important that all municipal stakeholders – political leadership, municipal officials and affected communities are brought on board from the beginning of such a project. In terms of municipal officials this must ensure that staff related to each component of the project be included in the project planning and development from the start. This would critically include:

- Waste
- Energy and Electricity
- Air quality control
- Finance and procurement

National Department of Energy: DOE and NERSA for generation licensing, IPP office if the project is to bid within the REIPPPP, and, where carbon credits may be part of the project, then engagement with the Designated National Authority (DNA).

National Department of Environment: for permitting and authorization, Air Quality licensing processes.

Private sector: this will depend on the business model being pursued by the municipality.

International: if the project is to include a carbon credit component, then a range of accredited carbon credit stakeholders would need to be engaged. This will depend on what particular carbon market is being pursued.

Developing the project: business models, financing and contracting

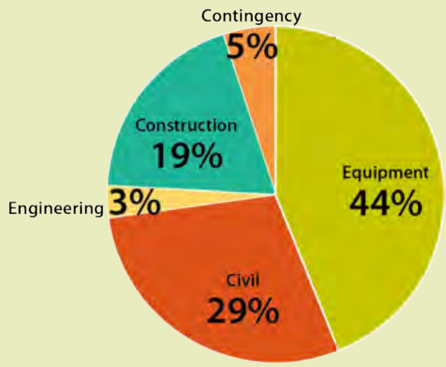
Under current conditions, it makes sense for the municipality to pursue this project 'in-house' drawing on capital expenditure budget, infrastructure grant funding or sourcing development finance/loan. The municipality must ensure that finance is sourced for both the infrastructure, or capital costs and the operations and maintenance costs. These come from different budgets, but must both be considered in the financial plan and secured and approved within the municipal budget.

Where upfront capital finance is not available a partnership with the private sector may be considered, through a Build, Own, Operate and Transfer (BOOT) arrangement. In such a project the contract would be for the full lifespan of the plant – usually 15 – 20 years. The appointed contractor is responsible for financing the project, or part of it, and is paid during the course of the project through the revenues generated from the sale of the electricity. The municipality would receive royalties or agreed upon profits. Two legal opinions obtained by the City of Johannesburg, who contracted on this basis, confirmed that landfill gas is not a municipal asset (from which a private company may not derive profit, in terms of the Municipal Finance Management Act – MFMA) and that the project was not a PPP (Private Public Partnership). However it has been contentious and any municipality pursuing such a model should contact National Treasury early on in the project development.

Where the municipality is the project developer the project is a standard procurement project with outsourcing of operations and maintenance: the municipality owns the asset and the operation of the gas capture and power plant is outsourced to service providers. Once finance has been secured, the municipality would need to consider the most suitable contracting arrangements for the design, supply, installation and commissioning of the landfill gas to electricity/energy plant. Operation and maintenance contracts can be built into the development and installation contract, through an O&M item listed under the Bill of Items. How the different elements of the project are contracted will need to be decided internally.

Figure 7: Breakdown of capital costs of a typical LFG capture plant

Equipment	44%
Civil	29%
Engineering	3%
Construction	19%
Contingency	5%



Source: World Bank, 2005

The project will likely involve a series of contract elements/contracts, potentially managed through different departments, for:

Phase 1: the (a) design and construction and (b) operation and maintenance of the gas wells and flaring site.

Phase 2: the (a) design and construction and (b) operation and maintenance of the energy generation site.

Combining service provision should be considered: there may be efficiency gains through one contract for both elements (though sequencing the phases is important given that the gas should be monitored for some time to establish optimal energy generation capacity). Risks may be better controlled where the gas production and energy generation are under the control of a single service provider.

Operation and maintenance contracts would be 3 – 5 years and thus procurement would require public participation processes in accordance with Section 76 and in line with Section 33 of the Municipal Finance Management Act (MFMA). This should not present too many obstacles given that the project is financially viable and would not place a burden on the tax payer or financial risk on the municipality. The additional benefits of job creation, local and global emissions reduction and energy security may generate additional public goodwill.

Risk sharing and performance

In a municipal-owned project the municipality would bear the risk even though part of this could be shifted to the service provider within the O&M contract – a portion of payment would be against units of energy produced. However, where gas collection and electricity/energy generation component are managed by different service providers and different departments this can be challenging as electricity cannot be generated if gas is not produced and collected.

Once decided, municipal staff must draft tender documents and go through the necessary internal assessment and approval processes to determine who will design, construct and operate the site.

Permitting and licensing

The usual building approval processes need to be followed. Since 2011 however, adjustments to the environmental regulations mean that landfill gas extraction projects of less than 10MW no longer require a full Environmental Impact Assessment (EIA) process to be undertaken.

Depending on whether the gas will be used to generate electricity or produce gas or synfuel, the respective licensing would be required. If electricity generation exceeds the municipality's 'own consumption' of electricity a generation license application would need to be undertaken; where it is only used for 'own consumption' the municipality would be exempt from generation licensing in terms of Schedule 2 of the Electricity Regulation Act, 4 of 2006. However, it is generally accepted good practice to inform the National Energy Regulator through a generation license application process. Further, it is a requirement of the Gas Act that all off-grid gas to energy projects be registered (the assumption being that on-grid will be registered through NERSA).

A useful overview of the legislative and permitting requirements can be found on: http://awtguide.environment.gov.za/content/technologies-overview-legislative-requirements

Barriers and opportunities

A landfill gas to energy project offers the municipality the opportunity to generate baseload electricity or alternative fuel at a cost that will be stable over the 15 – 20 year lifespan of the project. The unit price is now almost cost-comparable with Eskom mega flex rates, making these projects financially viable. In addition the municipality will generate benefits through climate mitigation, improved air and water quality and improved waste management. Job creation and economic benefits of local energy production are also promising.

Sustainability: It must always be remembered that zero waste is the sustainable development goal. Municipalities should ensure that this is the goal they are working to achieve and not allow WtE projects to divert resources from this, or indeed become and end in themselves.

Quality of landfill site and lack of enforcing legislation: landfill sites must be optimally managed for successful extraction of gas. As waste management is driven by municipalities with waste taxes being below cost recovery, municipalities generally generate insufficient income for environmentally sound waste management. Currently there is not legislation enforcing gas extraction.

Onerous project planning and development process: experience in South African municipalities indicate that the project development time for a LFG to energy project can take anything from 3 – 8 years. It involves complex contracting and innovative financing arrangements. Any carbon credit arrangements involve costly and lengthy registration processes, with international stakeholder engagement. MFMA requirements will necessitate a full public participation exercise for the operation and maintenance contracts. In order to meet these challenges a municipality will need buy in and drive from highest level and coordinated throughout the municipality, plus a dedicated champion/ project manager.

Institutional challenge and risk sharing: The nature of WtE projects is that they involve both waste and energy. Traditionally these two areas are managed in two separate municipal departments, involving different sets of skills, budgets and management lines. Where gas capture is undertaken as a separate project to energy generation, it may result in two sets of contracts and service providers answerable to different departments. This raises a complex issue of risk and performance based contracting: feedstock to produce energy is dependent on gas capture. Establishing who carries the risk when the feedstock cannot be supplied is vital.

Permitting and authorizing: New rulings have reduced the EIA requirements for landfill gas to energy projects, which will assist in a quicker project development process. Projects must register in terms of the Gas Act. However, 'own use' of any power generated is recommended over resale into the national grid for greater project implementation simplicity.

Technical and financial: The status of landfill gas to electricity project is rapidly changing. Until recently the financial performance of projects has generally been insufficient to attract enough investment funding from financial institutes (i.e. the project is unattractive compared to the interest rates provided by local banks). With rising electricity prices and the potential for inclusion within the REIPPPP these projects will be receiving far greater attention.

Spare parts can be difficult to source in South Africa and often need shipping from overseas. Such hiccoughs can often result in lower than anticipated production levels. However, technical experience and expertise around LFG to electricity production has grown substantially in South Africa, enhancing project implementation (time and cost reductions).

Because methane is such a large emitter carbon opportunities cannot be overlooked. However, these may be risky (market price fluctuations) and the costs of engaging in that funding stream must be assessed. The process of registering with UNFCCC is long and costly, the cost of verification is high – gas emissions data needs to be collected every few seconds using rigorous monitoring methods and expensive software packages; data requires in depth analysis to explain irregularities for verification purposes plus auditing verification costs.

Case study 1: Pioneering landfill gas to electricity in Africa: eThekwini Municipality LFG to electricity*

EThekwini Municipality launched Africa's first LFG to electricity project in Africa with the commissioning of their two major sites, Mariannhilll and Bisasar Road, in 2006 and 2008 respectively. Bisasar Road landfill site is the busiest landfill in Africa accepting 3500 to 5500 tonnes of municipal waste daily. Bisasar has stopped receiving waste in 2016, but estimations are that it will continue producing gas for another 15 years.

The project is successfully producing 45 000 MWh/year and has resulted in the creation of 15 permanent technical jobs. A driving goal of the project was the reduction of CO_2 *– and gaining of associated emissions reduction revenue streams. The carbon finance which the project had banked on, however, has proved disappointing. The collapse of the carbon market has rendered the sizeable efforts to secure Certified Emissions Reductions (CERs) meaningless.*

Although carbon money has proved elusive, significant positive effects on local air and groundwater quality and safety have been achieved. There has also been the economic benefit of additional employment, providing skilled jobs for the operation and maintenance of equipment at the landfill and at the power generation units. The project has been an invaluable 'learning by doing' site for LFG to electricity in Africa.

Overview of project

EThekwini LFGs project makes use of methane extracted from city landfill sites for the generation of electricity. The project is registered with the Cleaner Development Mechanism (CDM) and generates income from the sale of carbon credits through:

The process of flaring – burning methane to produce CO_2 *(methane is approximately 21 times more potent a greenhouse gas than* CO_2*)*

Offset of coal generated electricity through the use of methane powered generators for electricity (reduction in electricity use from coal fired power stations)

At the time of development the project would not have been considered viable without the CDM funding. In fact, the generation of electricity was considered secondary when compared to the anticipated CDM credit income from the flaring process. This changed with the collapse of the carbon price from around 15 euros to a few cents per ton of CO_2

Technical description

At both sites the gas is collected using an array of wells and a pumping system. The harvested gas is burnt in spark ignition gas engines driving generators to produce electricity which is then fed into the municipal grid. Mariannhill takes 450 tons of waste per day, peaking at 700 tons. It has 17 vertical and 6 horizontal wells. A 1 MW generator engine is installed here. Bisasar Road used to take some 3 500 tons of waste per day, peaking at 5 000 tons. The site is composed of 77 vertical and horizontal wells each, and has 38 leachate pumps. It has the potential to generate 8MW, though installed engine capacity is currently 6.5 MW – made up from six gensets of 1 MW and one 500kW engine. The organic waste component within the landfill is around 35%.

The capacity factor has been 68%. Capital costs per MW installed in the project was around R16,8 million (in 2005–8 terms). Operational costs per MWh are around R290 (2015 terms).

* This case study draws extensively from SALGA-GIZ Case Study Series: eThekwini Landfill Gas to Electricity Case Study: http://www.cityenergy.org.za/uploads/resource_340.pdf . Unless referenced otherwise, information is sourced from this document.

The project development: drivers, business model and role of the municipality

This has been a city-driven project, with added impetus from the involvement of the World Bank's Prototype Carbon Fund (PCF) post the Johannesburg World Summit on Sustainable Development. The landfill sites are all municipal owned. As a pioneering endeavour the project took a lengthy 5 – 7 years from initial contact to commissioning of the sites. Many of these obstacles have since been reduced – notably the adjustment of the EIA requirement process (a full EIA is now no longer required for LFG to electricity smaller than 10MW) and the potential to not require the additional carbon finance stream for LFG development. Complex social issues relating to communities living alongside the landfill and challenging carbon finance ethics also required substantial time and effort.

Internal championing, communication and buy in at the highest level was instrumental to getting the project implemented. A strong financial, environmental and social case was made for the project. The persistent efforts of dedicated champions from within both the eThekwini Cleansing and Solid Waste Department and Electricity Department were the foundation of the project's success. High level buy-in was also sought from the outset. The mayor (Cllr Mlaba) was involved directly in the negotiations with the World Bank around the sale of carbon credits generated by the project.

The project was designed as a procurement project, with the investment made by the Municipality, with additional finance obtained through the DTI/DOE and PCF. EThekwini Municipality thus owns the asset and the operation of the power plants is outsourced to service providers. The capital and operational costs are supported by two revenue streams: the sale of the electricity (or offset of the production cost against that of purchasing electricity from Eskom) and sale of the carbon credits.

The electricity sale was structured through a Power Purchase Agreement between the eThekwini Cleansing and Solid Waste Department (as project developers) and the Electricity Distribution Utility. Since this was an

Figure 8: Laying gas collection pipes, eThekwini

Photograph: John Parkin

Source: eThekwini Municipality

internal contract there were no obstacles encountered. The sale had to be at a rate lower than Eskom Megaflex rate, which at the time was below cost recovery rates. Thus the project required additional revenue for financial viability.

The additional revenue for project viability was to be through the sale of carbon credits. However the development of a registered and verified CDM project added substantial complexity and involved a large array of external stakeholders. Given the collapse of carbon markets and the increase in Eskom Megaflex tariffs, this route may no longer be necessary and would save enormously on time and associated costs. The experience in eThekwini was that the cost of verification is significantly more than the financial benefit of the credits. The process of CDM registration was also long and costly and monitoring for verification is a very onerous process. Municipalities would do well to understand this fully before making project finance decisions based on carbon revenue streams.

While eThekwini Municipality has a dedicated staff member assigned to managing the plants, the complexity of the process of running the facilities required the drawing in of external expertise through an O&M contract. This contract was initially in place for 3 years, but has now been extended to a 5 year contract, with due public participation processes being undertaken.

Case study 2: Ekurhuleni Municipality LFG to electricity*

Ekurhuleni Metropolitan Municipality (EMM) has installed a 1 MW LFG to electricity plant at its Simmer and Jack landfill site in Germiston. This project, commissioned in September 2014, has the potential to reduce electricity purchases from Eskom by 7 GWh/year. It is part of the Electricity and Energy department's endeavours to meet its 10% renewable energy target. Further installations are envisaged.

Technical overview

As in the case of eThekwini, the project has its roots in the initial groundwork and championship of the Waste Department who embarked on gas collection and flaring at 4 landfill sites, from 2005 – 2007. This first phase included the installation of vertical and horizontal gas wells, gas collector pipework, high temperature gas flares and a continuous gas monitoring system.

With the failure of the Carbon Development Mechanism to deliver financing for ongoing project development, the EMM council approved budget for the establishment of a LFG to electricity plant. In January 2013 a tender was published for the design, supply installation and commissioning of a LFG to electricity plant. The plant was commissioned in September 2014, due to various contracting delays. The 1 MW gas engine is installed in a container, which uses the landfill gas to generate electricity at 400V AC (alternating current). The power is then stepped up to 6.6kV AC and fed into the municipal distribution grid.

Capital cost per MW installed is estimated at R12.8 million (2015 terms) and operational costs per MWh at around R235. Payback on the electricity generation plant alone is estimated at around 4.5 years, with the lifespan of the plant around 12 years.

The site achieved a production of 594 MWh in its first month of production – around an 80% capacity factor. However production has been hampered by contractual challenges and the site has not been fully utilised to date. Gas is still flared on site as the gas production is greater than the generator can utilise. EMM has plans to increase site capacity to 2MW and to add additional electricity generation capacity on other sites.

* This case study draws extensively from SALGA-GIZ Case Study series: Ekkurhuleni Landfill Gas to Electricity: Simmer and Jack: http://www.cityenergy.org.za/uploads/resource_338.pdf. Unless referenced otherwise, information is sourced from this document.

Figure 9: A 1MW gas-to electricity generator set at Simmer and Jack landfill site

Sou

Electricity is exported to the municipal grid, for 'own use' within the municipality. Although 'own use' may be defined as being exempt from generation licensing in terms of Schedule 2 of the Electricity Regulation Act, 4 of 2006, the Gas Act will require that this project is registered. EMM has made a formal application to the national regulator (NERSA).

Business Model

As with eThekwini, the municipality is the owner and developer of this project. The finance has come through their capex and opex budgets, and the service of gas extraction and flaring and of electricity generation are outsourced to service providers – at this stage still through short-term contracts.

Gas collection and flaring remains the business of the EMM Waste Department. While no performance standards are specified in the contracts with service providers, tight conditions around maintenance of operations (such as a 24 hour period turn around on fixing breakages or stoppages) ensure smooth operation. Similarly the energy generation component is based on a flat O&M rate, rather than performance (unit output) based. The different management of these contracts – by two different departments – has posed challenges, however, as the operations are so closely interlinked.

No actual electricity sale takes place. The electricity produced is simply seen as equivalent in value to the offset purchase of Eskom electricity. The municipality has plans to account for this internally and thereby enable some return to the Electricity and Energy department for further renewable energy generation investments.

Carbon as a potential municipal revenue stream

Despite the current low value of carbon, the municipality is still pursuing the carbon market as a potential revenue stream. This is driven through the Waste Department. A first verification of credits generated in underway. Initial approval by the Emissions Board was given in November 2014, and the municipality is hoping for issuance of Verified Emissions Reduction certificates (VERs). These can be sold into the voluntary market while *the lengthy CDM carbon credit certification process is underway. The municipality intends to put these VERs out to tender to test the market for interest in the project and to gauge the value of the emissions reductions. The municipality is also hoping that the carbon offsets programme, set to be implemented in South Africa alongside the introduction of the Carbon Tax, will open up a potential ER market with a much higher value than the current carbon market. Since project inception a total of 573 494 tCO_2eq (as at 29 February 2015) has been reduced to the atmosphere.*

Case study 3: Waste diversion and electricity generation at Bronkhorstrpruit Biogas project, Tshwane*

Cattle manure has traditionally been used as a source of biomass for heating and cooking. It can also be used to produce electricity. The Bronkhorstspruit Biogas Project (BBP) is the first large scale animal waste-to-energy project in South Africa, addressing clean and secure energy needs while resolving waste issues. BMW South Africa (the electricity off-taker) has signed a power purchasing agreement (PPA) with the project developer, Bio2Watt.

A prerequisite for the PPA was the Wheeling Agreement of the City of Tshwane and Eskom, for the transfer of the power between the project developer (Bio2Watt) and the power purchaser (BMW). The project aligns strongly with the City's broad Sustainability Programme and as such the City has agreed to wheel the power and is also finalizing a plan to divert some of its organic waste to be processed directly in the biogas plant.

The process involves the Anaerobic digestion of agricultural waste in a Covered in Ground Anaerobic Reactor (CIGAR). The project is being constructed by the South-African construction and engineering company Bosch Projects. The Danish company ComBigaS (Complete Biogas Solutions) supplied the biogas technology.

Due to the size of the proposed development (a footprint of greater than 1-hectare of agricultural land), a full environmental impact assessment (EIA) had to be undertaken according to the Environmental Impact Assessment (EIA) regulation (2006).

Figure 10: Beefcor feedlot

Source: Bosch Munitech

* This case study draws extensively from Supporting private renewable development in a municipality: waste diversion and wheeling of power for biogas to electricity project City of Tshwane Metropolitan Municipality: Bronkhorstpruit Biogas: http://www.cityenergy.org.za/uploads/resource_337.pdf. Unless referenced otherwise, information is sourced from this document.

Wind Energy

Overview

Wind energy is generated when the kinetic energy of the wind is harnessed by wind turbines and converted into mechanical energy. To generate electricity, this mechanical energy is used to rotate a generator situated in the hub of each turbine. Wind turbines can range in size from small home based 50W units to large 5MW commercial units. Offshore turbines are even bigger at 8MW. A 3MW wind turbine can generate enough electricity to supply around 900 South African middle-income households with a consumption of 800kWh per month. Currently, more than 1400MW of wind turbines are producing power with another 2300MW at various stages of planning and construction.

Wind turbines for commercial power generation are generally arranged in an array, collectively called a wind farm. Wind farms are typically located in areas with a consistently high level of wind. Their performance increases exponentially with the increase in wind speed. Wind speeds are stronger at higher elevations, which is why most wind turbines are mounted on around 100m high masts. The output of a wind turbine is determined by its power rating and the load factor.

The Darling Wind farm, South Africa's first commercial wind farm that was financed through a 20-year power purchase agreement (PPA) with the City of Cape Town. It is noted that this type of municipal PPAs is no longer legally possible.

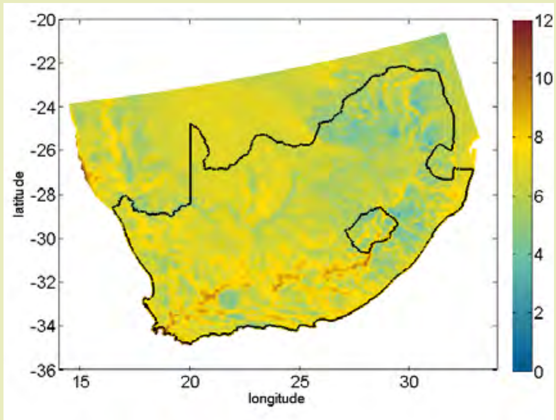
Recent research by the CSIR found that South Africa has excellent wind resources (see wind map below). If appropriate turbines for higher or lower wind speeds are selected 80% of the South African land mass has sufficient wind for turbines to achieve a load factor of more than 30% which makes them economically viable. Therefore wind turbines could be installed in many parts of the country taking advantage of different weather patterns of each area to produce more consistent output from this source of energy. Wind parks with a capacity of 50 GW would require only 0.4% of the South African land mass and could supply 150TWh/year. This is 2/3 of the current annual electricity consumption of the country[1].

Figure 1: Wind turbines at Darling wind farm near Yzerfontein

Photographer: Kalle Pihlajasaari

Source: https://en.wikipedia.org/wiki/File:Darling_South_Africa_wind_turbines.jpg

Figure 2: Map of South Africa showing the average wind speed at 100m height



Source: CSIR, Fraunhofer, Eskom & Sanedi (2016) Wind and Solar PV Resource Aggregation Study p. 10

1 CSIR, Fraunhofer, Eskom & Sanedi (2016) Wind and Solar PV.

Figure 3: Small horizontal axis turbine

Photographer: Graham Hobson)

Source: http://www.geograph.org.uk/photo/4079521

Large Wind Parks

Large wind turbines are currently the most financially feasible renewable energy technology available. Through the Renewable Energy Independent Power Producer Procurement (REIPPP) Programme several windfarms have been installed or approved. The cost of electricity generated by wind turbines as decreased from R1.42/kWh in the first bidding window of the programme to R0.62/kWh in the fourth. Wind parks approved in the first window started operating in early 2014. Approved project in the fourth window are still at planning stage. This cost per kWh is about 40% lower than the cost of electricity generated in the new Eskom coal fired power stations (Medupi and Kusile) and makes wind the cheapest new built technology for electricity generation in South Africa. Because wind generated electricity is not consistent, it needs to be paired with other generation options such as gas (which can quickly respond to decreases in supply from wind or other sources) in the national generation mix.

Large wind turbines and wind parks require Environmental Impact Assessments (EIA) to be conducted. Negative environmental impacts can be avoided through careful choice of location or can be mitigated through technical measures such switching off turbines at certain times of day or year. The Department of Environmental Affairs has published the Draft EIA Guidelines for Renewable Energy Project[2] that need to be followed.

Small Wind Turbines

In many municipalities small wind turbines will be or have already been installed by residents. Small wind turbines are used for generating electricity for a house, mini-grid or to charge batteries. They can be installed on-grid (grid-tied) or off-grid. The implications of small wind turbines for the municipality are similar to those of PV systems described in the section on Solar PV Systems below.

Small turbines do not require an EIA but they require a municipal building permit because they are structures according to the National Building regulations, and protrude more than the permitted height above the ground or above existing buildings. The chapter on municipal mandates: planning, regulation and service delivery explains the role and responsibility of municipalities in approving applications for renewable energy installations. Two types of small turbines can be distinguished: turbines with horizontal and vertical axis.

Horizontal Axis turbines

These turbines are technically similar to large turbines. Turbines available in South Africa typically range from less than 1kW to 10kW.

Horizontal turbines are most effective when installed significantly above surrounding buildings and trees to avoid turbulent flow. They can be installed on towers of 10 to 20 m height or attached to buildings. Installations on towers are generally safer because turbines cause vibrations that may cause damage to buildings. Some taller installations may not be permitted in urban areas due to height restrictions.

Large wind turbines are currently the most financially feasible renewable energy technology available.

2 DEA (2013) EIA Guidelines for Renewable Energy Projects.

Vertical Axis turbines

This type of turbines is not very common. Vertical axis turbines are less efficient than turbines with horizontal axis in converting wind into electricity, especially at high wind speed. On the upside, this turbine type better manages turbulences that occur in the vicinity of buildings and close to the ground. This is an advantage in urban areas with height restrictions or if a turbine is being installed between buildings and trees.

Figure 4: Small vertical axis turbine

Photographer: Ashley Dace

Source: http://www.geograph.org.uk/photo/3116833

Implementation

Currently, some rural municipalities have large, multi-MW wind parks installed in their areas, funded through the REIPPP programme. These municipalities enjoy significant economic development benefits such as job creation and contributions to socio-economic development. SALGA has published a brochure how municipalities can maximise these benefits[3].

Financial Aspects

Large wind turbines generate electricity at the lowest cost compared to all other technologies. The cost of electricity generated by the latest wind parks will be around R0.62/kWh[4].

Reliable data on the cost of electricity generated by small turbines is not available. The current price of a 2kW turbine alone is around R18 000 without the support pole, installation, inverter and other components. The cost of power also depends strongly on the micro location and maintenance (see case study below 1.3.2).

Barriers and opportunities

Large wind turbines are a mature and reliable technology but their installation requires comprehensive planning, careful site selection and environmental impact assessment. Municipalities cannot influence the location of large scale wind projects funded through the REIPPP. The main barrier for implementing projects over 10MW outside of the REIPPP is the very complex planning and approval process requiring a Ministerial Determination. The Minister of Energy must approve large project to be in line with the Integrated Resource Plan (IRP) that determines the mix of sources of electricity generation. At the time of writing no project outside of the REIPPP had received this approval, although some municipalities are moving in this direction. Municipalities should monitor policy developments in this regard (for details see the chapter on Power Purchase Agreements, page 374).

Municipalities can create an enabling environment for small turbines by facilitating the integration of small scale electricity generation in the municipal grid and by simplifying development application and approval of small turbines and other renewable energy options (see chapter on Municipal mandates: planning, regulation, service delivery, page 313 and the chapter on Solar PV systems, page 205). The Sherwood case study shows that small turbine installations are still quite complicated to install and operate, indicating that the technology is less mature than large turbines. An additional barrier is the uncertainty of the cost of generated electricity. These barriers will only be removed once the technology has matured.

These municipalities enjoy significant economic development benefits such as job creation and contributions to socio-economic development.

3 SALGA (2013) Local Economic Benefits of the REIPPP.

4 2017 prices.

Case Study 1: Jeffreys Bay Wind Farm*

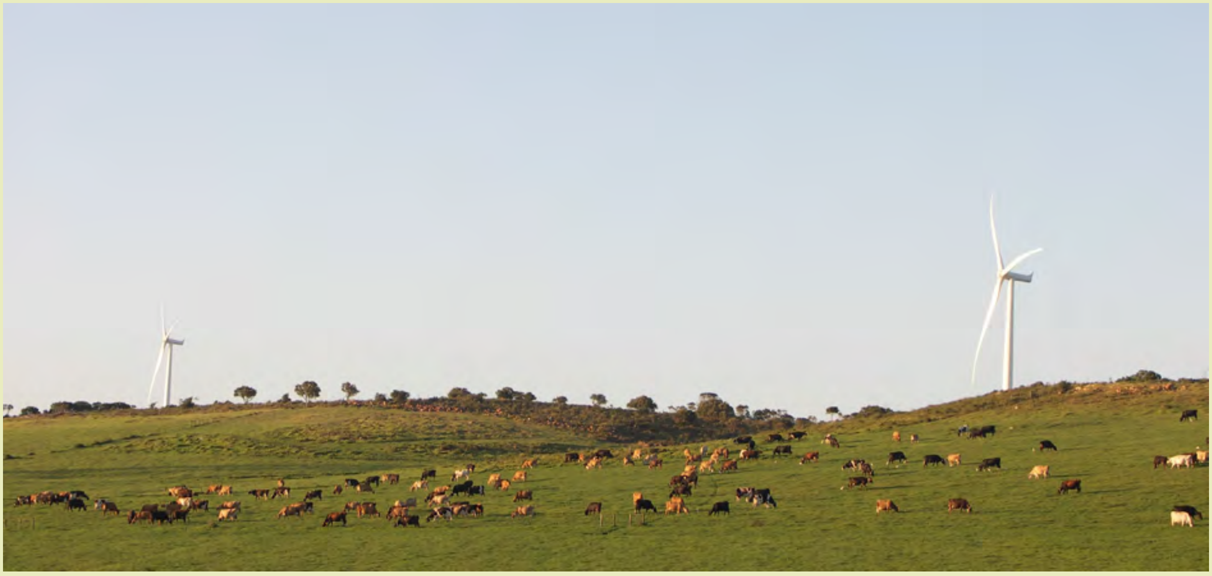
This project is one of the first and largest wind farms in South Africa funded through the REIPPP programme. The wind farm site spans 3 700 hectares on which 60 wind turbines have been erected. Construction started in December 2012 and started commercial operations by mid-2014.The wind farm supplies the Eskom 132kV grid line and generates 460 000 MWh per year. This is enough clean electrical energy to power more than 100 000 average South African households.

Each wind turbine stands 80m tall with blades 49m long and a rotor diameter of 101 metres. The average rotation of the blades is between 6 and 16 rotations per minute. Each turbine can generate 2.3 MW of electricity. The project supports socio-economic development initiatives to communities living within 50km radius of the wind farm:

- *Enterprise development includes initiatives to assist and accelerate the sustainability of local enterprises and intends to support emerging black farmers in the area.*
- *The socio-economic focus is on health programmes (HIV and Aids, and vulnerable children programmes), youth upliftment – sports programmes and education support programmes, including:*
- *early childhood development, as part of a crèche support programme*
- *numeracy and literacy interventions at primary school level*
- *support for mathematics and science programmes at secondary school level*
- *a scholarship programme for engineering related studies at tertiary level.*

Further benefits to the community include six percentage ownership of the Jeffreys Bay Wind Farm by a Community Trust. The project supports scholarship and internship programmes especially for young mechatronics and electricity engineering students in collaboration with several South African universities.

Figure 5: Turbines at Jeffreys Bay Wind Farm



Source: NJR ZA, https://commons.wikimedia.org/wiki/File:Jeffreys_Bay_Windfarm-001.JPG

* This case study draws extensively from the website: http://jeffreysbaywindfarm.co.za, accessed January 2017. Unless referenced otherwise, information is sourced from this site.

Case study 2: Small turbines in Sherwood and Westville, Durban

The owner of Breez air conditioners in Sherwood Durban intends to sell small wind turbines in the future[5]. In 2016 he set up a prototype 1kW turbine on a 10m high pole in order to test and gather experience about the product. The wind turbine is combined with a 2kW PV panel. The technologies jointly feed a battery bank and inverters that supply electricity for lighting and office machines of the business. The batteries allow the business to continue working during longer electricity supply interruptions (load shedding) provided that large loads are switched off.

The cost of the turbine is around R18 000. In addition the pole costs R20 000. The photographs show the wind turbine and PV panels in the company's car park and the inverters, batteries and switchboard in a corner of the storeroom.

Figure 6: Wind turbine in Sherwood, Durban

Photographer: S Godehart

Figure 7: Inverters, batteries and switchboard

Photographer: S Godehart

Figure 8: PV panels next to the wind turbine support pole

Photographer: S Godehart

5 Information provided in personal communication with M. Overall, 1/2017.

Figure 9: 2kW turbine in Westville, Durban

Photographer: S Godehart

Figure 10: Fixture of cable securing pole

Photographer: S Godehart

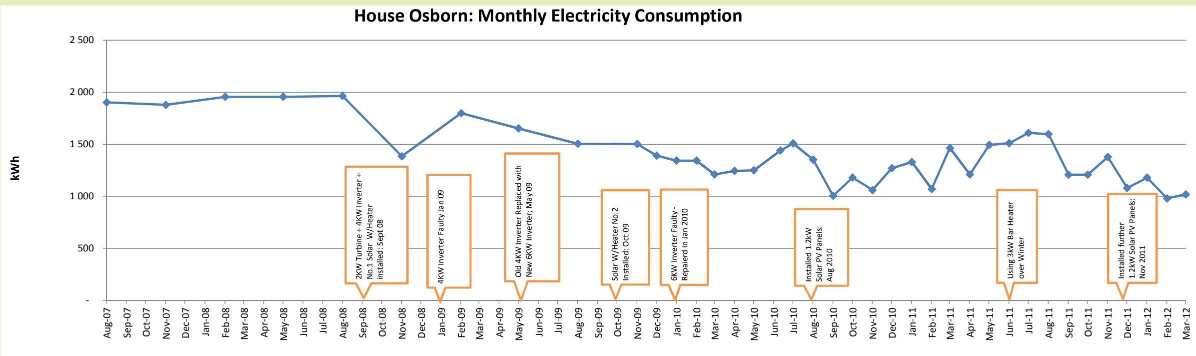
At a private residence in Westville a 2kW wind turbine has been installed that feeds a battery bank and an inverter. The wind turbine was installed in 2008, at a height of 11m above ground on a pole fixed to the garage roof[6]. The tubular pole was secured with cables to limit movements[7]. The pole is installed on a hinge so that the turbine can be lowered for maintenance. At the same time a Solar Water Heater was installed.

The owner has recorded the electricity purchased from the grid before and after the installation of the turbine and solar water heater. The graph shows a reduction of around 500kWh/month in electricity purchased after the installations. After resolving technical problems with the inverter consistent monthly savings of around 400kWh/ months were achieved. However it was not metered much the wind turbine and the solar water heater contributed to the savings.

The owners of the turbines stated the following observations:

- *Both installers are happy with the electricity generation but state that the efficiency of the turbine depends on the exposure to wind at the micro location. Both turbines are installed close to trees impacting on their efficiency. Better locations would be along the coast or at cliffs.*
- *Both are concerned about maintenance. The turbines require maintenance as the bearings of moving parts wear out. Access to the turbines for maintenance is complicated. A free standing turbine can only be accessed with a 'cherry picker'. Especially free standing poles move in the wind resulting in stress on the bearings.*
- *Worn bearings result in increased noise of the turbines.*

Figure 11: Monitoring of Monthly Energy Consumption House Osborn



Source: H. Osborn

Support Organisation

SAWEA South African Wind Energy Association

www.sawea.org.za

6 Information provided in personal communication with H. Osborn 1/2017.

7 The PV panels on the roof have only been installed in 2012.

Sustainable Solar Photovoltaic (PV) systems

Overview

How do Solar Photovoltaics work?[1]

'Photovoltaic' means the direct conversion of light into electricity. This happens at the atomic level. Some materials have photoelectric properties because they absorb sunlight and release electrons When these free electrons are captured, an electric current results. For solar photovoltaic cells, specially treated semiconductor materials are used for this purpose.

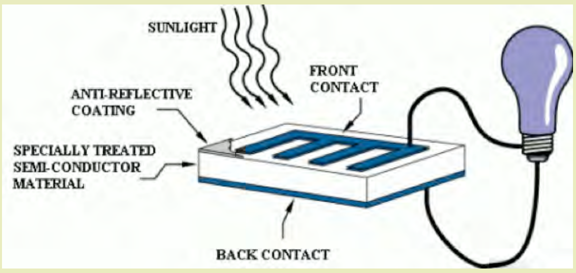
A solar module is a collection of individual cells. Multiple modules can be wired together to form a larger panel, or an array. In general, the larger the area of a module or array, the more electricity will be produced. Photovoltaic modules and arrays produce direct-current (DC) electricity. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination.

The DC current from the solar array is then often fed into an inverter to convert the power to AC – the type of power in a normal electricity network. AC power is generally preferred because most appliances are designed for AC electricity. While they are sophisticated electric systems, PV systems have few moving parts, so they require little maintenance. The basic PV module can last more than 30 years.

Where are solar PV systems used?

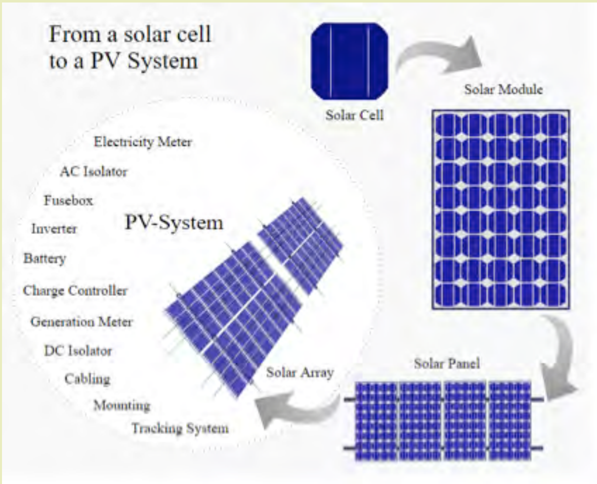
Solar PV systems can be installed on house or other building roofs to provide electricity needs, or they can be installed as ground-mounted arrays. The most common practice is to mount modules onto a north-facing roof. PV systems likewise can be blended into virtually every conceivable structure for commercial buildings. You will find PV used outdoors for security lighting as well as in structures that serve as covers for parking lots and bus shelters. It is used for rural water pumping, to

Figure 1: how a basic solar photovoltaic cell operates



Source: https://science.nasa.gov/science-news/science-at-nasa/2002/solarcells

Figure 2: From a solar cell to a PV system



Source: https://en.wikipedia.org/wiki/Photovoltaic_system

1 Sources: Wikipedia Photovoltaic System; NASA How do photovoltaics work?

Source: SEA

'Kilowatt-Peak' (kWp) rating of solar PV

Solar PV panel sizes are rated in kilowatt-peak (kWp): a 1 kWp panel will produce 1 kilowatt at midday on a sunny day (officially, the kWp rating is when solar radiation is 1000 watts per m^2 – which is roughly the sunshine power at midday in summer).

provide power to poor rural households, to power large malls, on government buildings, and for many other applications.

Systems can be grid-connected – where the inverter synchronises the PV power with the local grid and feeds PV power into the grid, or stand-alone, where there is no link to the local grid and a battery is charged by the PV array to enable electricity use (e.g. for lighting) at night and during cloudy weather.

Sunlight Requirements for PV Systems

Since solar photovoltaic (PV) systems require a significant capital outlay, it is best that they have unobstructed access to the sun's rays for most or all of the day to produce maximum output for the investment. Shading on the system can significantly reduce energy output. Most parts of South Africa have abundant year-round sunshine by world standards, enabling relatively high solar electricity output from these systems.

Different Scales of Solar PV Systems: Single house to large power station

Solar PV systems can be of any size, from one panel to charge a battery for lighting in a small rural house, through to a 'solar power station' using thousands of panels to feed hundreds of Megawatts of power into a national electricity grid. The size depends on several factors such as how much electricity is needed, the size of the roof on which it is to be mounted, available funding, and how much energy is required.

Implementation of SSEG

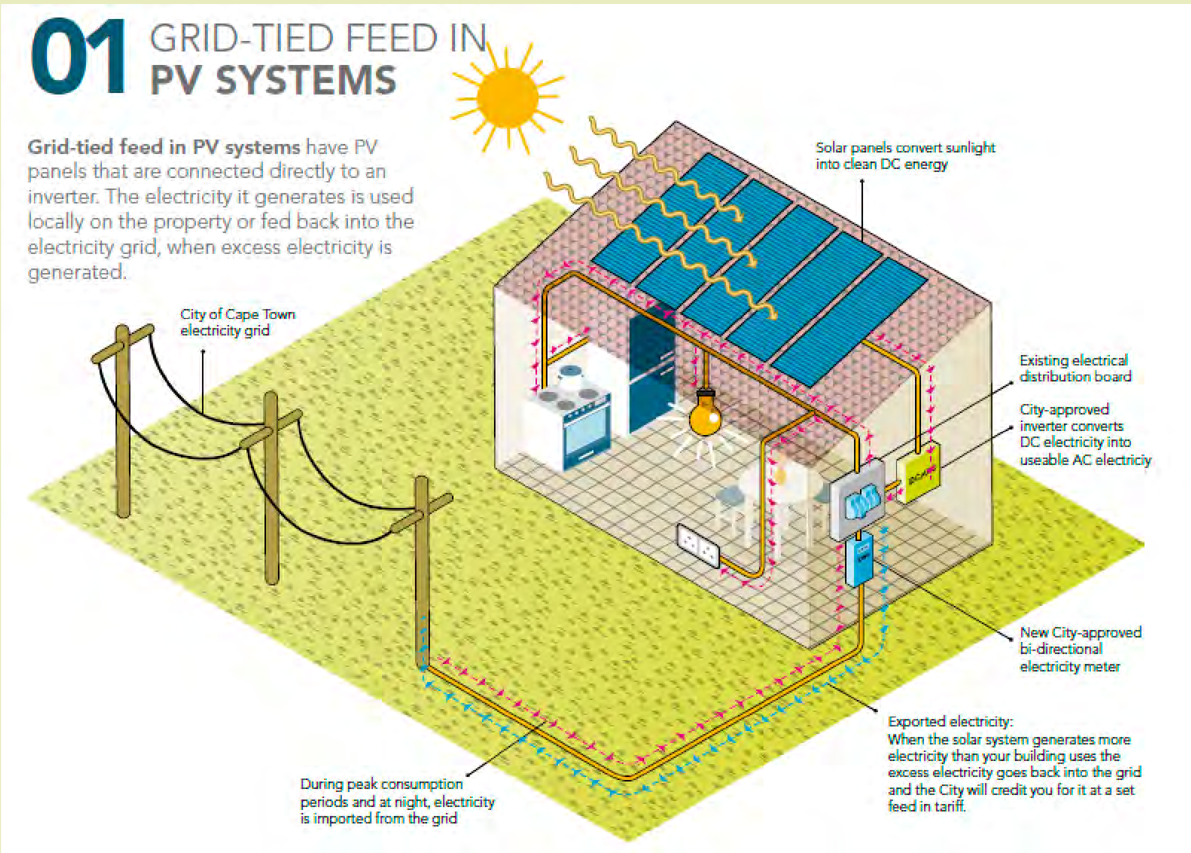
Solar Photovoltaic Small-Scale Embedded Generation Systems

Municipal distributors are facing the fact of accelerating grid-connected solar generation systems within their networks, and many have implemented processes to regulate the situation so that safety and various technical standards are not compromised. This section explains the technology, drivers and standards of relevance, as well as the impact on municipal revenue, and how the challenges can be met in a way that works for the customer and the municipality.

What is a solar photovoltaic small-scale embedded generation (SSEG) system?

A solar Photovoltaic (PV) system that is connected to the distribution grid, is called an 'embedded' generator. It is also often called a 'grid-tied' generator. 'Small-scale' generally is taken to be < 1 Megawatt (MW). SSEG systems are often installed on building rooftops. A key component in the system is the grid-tied inverter, which takes the DC power generated by the solar PV panels and converts it to AC power which is synchronized with the distribution grid power in frequency and other parameters, and feeds it into the normal building distribution board.

Figure 3: Components of a PV SSEG system



Source: City of Cape Town (2016) Safe and Legal Installation of Rooftop PV systems.

When the panels are generating less electricity than the building needs, the extra power is automatically drawn from the distribution grid as normal. At night all power needs would be drawn from the grid. When the panels are generating more than is needed by the building, the extra power is exported to the distribution grid for use elsewhere. A specially installed bi-directional meter records all power drawn from the grid and exported to the grid for billing purposes. PV SSEGs generally have no battery backup, and when the grid fails, for example, the SSEG is required to shut down operation for safety reasons.

Stand-alone solar PV systems

Stand-alone solar PV generators, on the other hand, have no physical connection to the grid and so must have batteries for night time electricity use or other periods when the solar power is not enough to meet the demand.

International trends

Solar PV panel prices have been falling steadily for at least the last decade, and this decrease is expected to continue. This has led to solar PV power becoming cost-competitive with conventional generation technologies in many countries around the world, and there has been an associated exponential increase in solar PV installations globally.

Figure 4: Price per Wp of Solar PV: 2007 – 2022

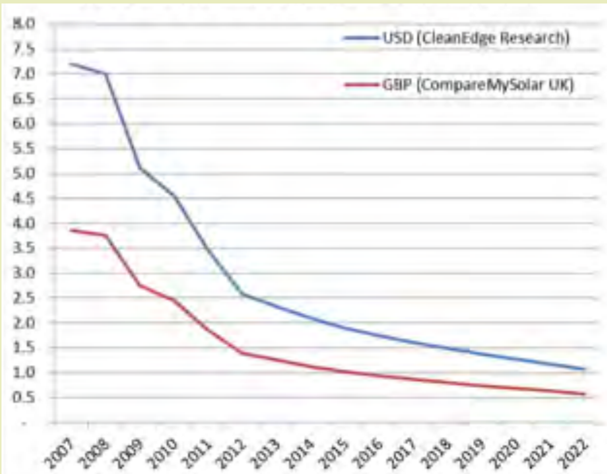
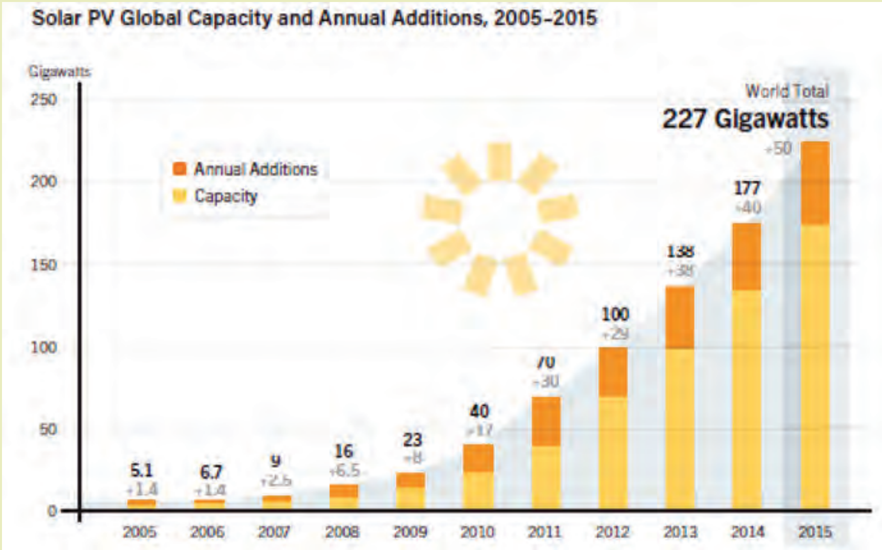


Figure 5: PV technology is developing fast – these roof tiles are actually solar generators, and are expected to be cost-competitive with conventional solar PV panels in the near future

Source: http://www.cornwallsolarpanels.co.uk/solar-panel-aesthetics/

Figure 6: Solar PV global capacity and annual additions from 2005 to 2015

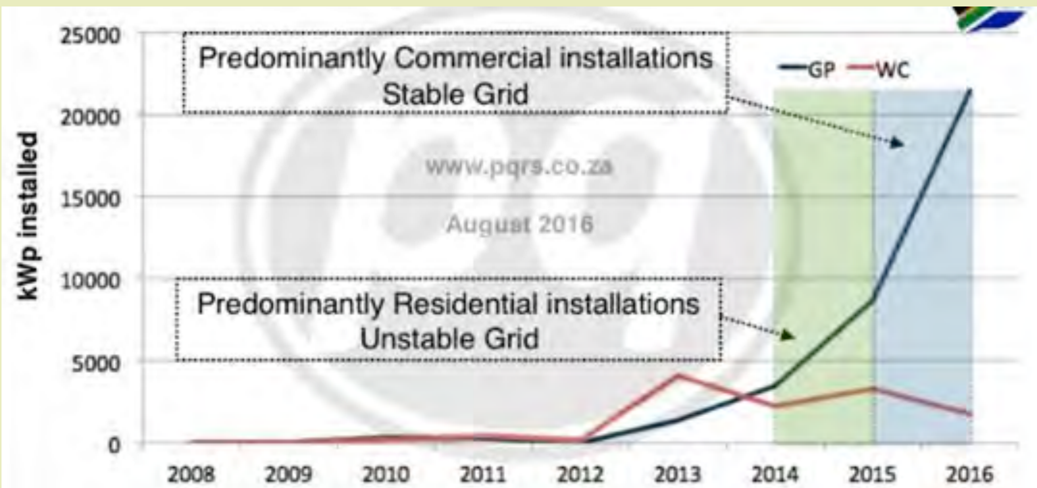


Source: REN21 Renewables (2016) Global Status Report

Local trends in urban areas

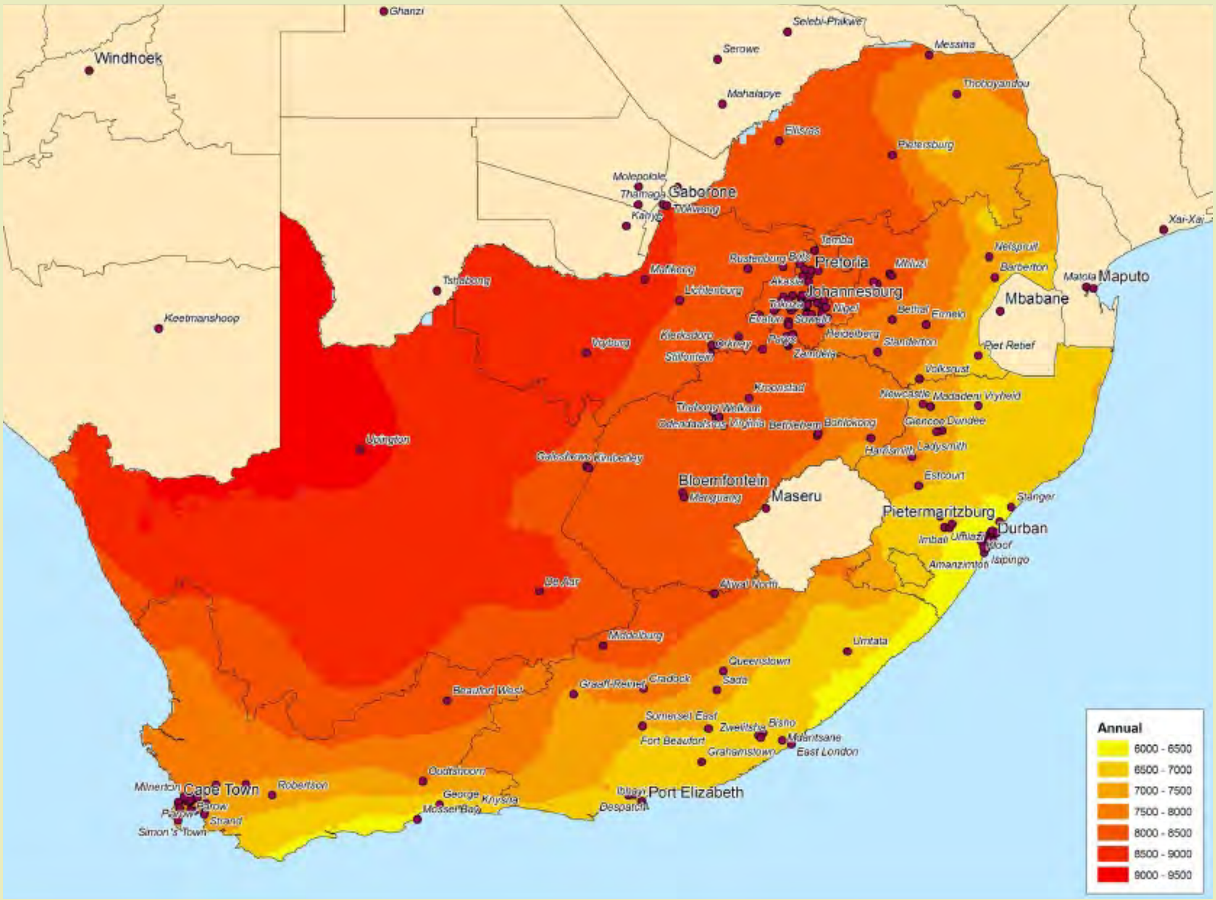
Associated with global PV price reductions as well as a strong solar radiation resource in the country, and spurred on by high annual grid power price increases as well as load shedding, SSEG installations in South African municipal areas has also been accelerating. This is taking place in residential, commercial and industrial sectors, where customers deem the investment worthwhile in the longer-term. Many of these installations have been undertaken without official approval (which is necessary to connect to the grid) often because municipal distributors have not had procedures in place to engage with to obtain permission.

Figure 7: supplier data on PV installations in Gauteng and Western Cape



Source: www.pqrs.co.za

Figure 8: Solar resource map

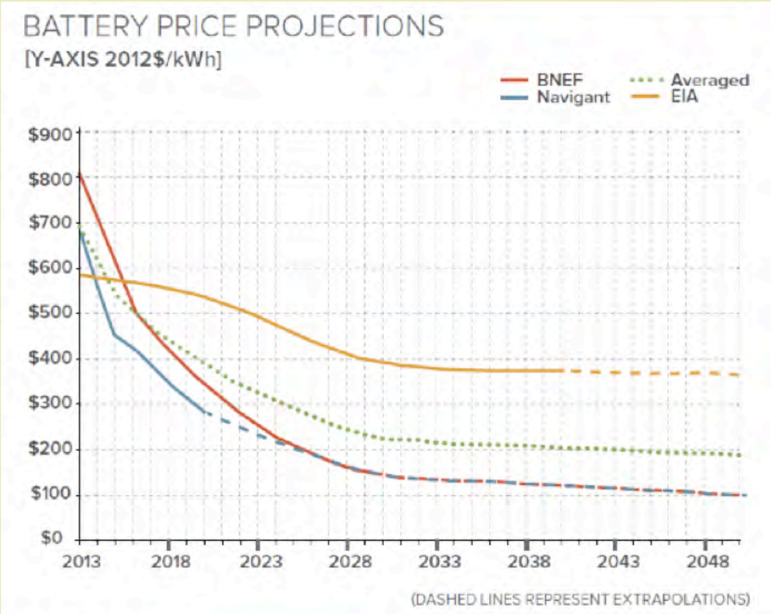


Source : http://www.aaamsa.co.za/images/Matrix/2015/TIASA/Annual%20Solar%20Radiation%20Map%20as%20provided%20by%20the%20CSIR.pdf

Battery storage price reductions: The Game Changer?

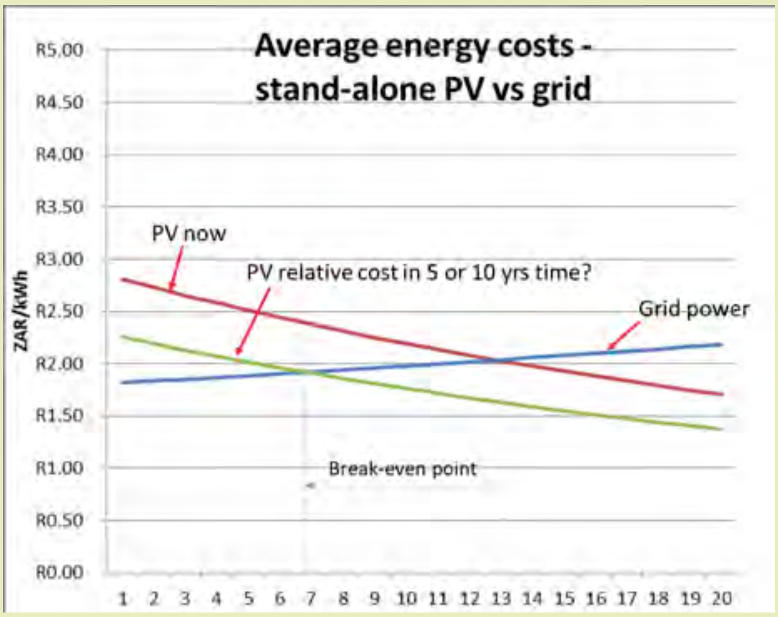
Battery storage prices have been declining fast in the recent past – with almost a 30% reduction in the past 3 years – and this trend is expected to continue (see on next page). This means that stand-alone, off grid solar generation could become viable sooner than we think, leading to potentially significant 'defections' from the grid (households and businesses disconnecting from the grid and generating all the power they need through their private solar PV-battery system). For many municipal distributors this may be disastrous: How will they obtain much needed revenue when many wealthier customers are disconnecting from the grid? How will the poor consumers be cross-subsidised? What funds will maintain the distribution grid? Unfortunately this trend is not in municipal control. The best they can do is to make user-friendly procedures and tariffs for existing customers to stay on the grid as long as possible, including for existing and new PV SSEG customers, and to adjust municipal business models to prepare for these radical shifts in the external environment.

Figure 9: Blended battery price projections



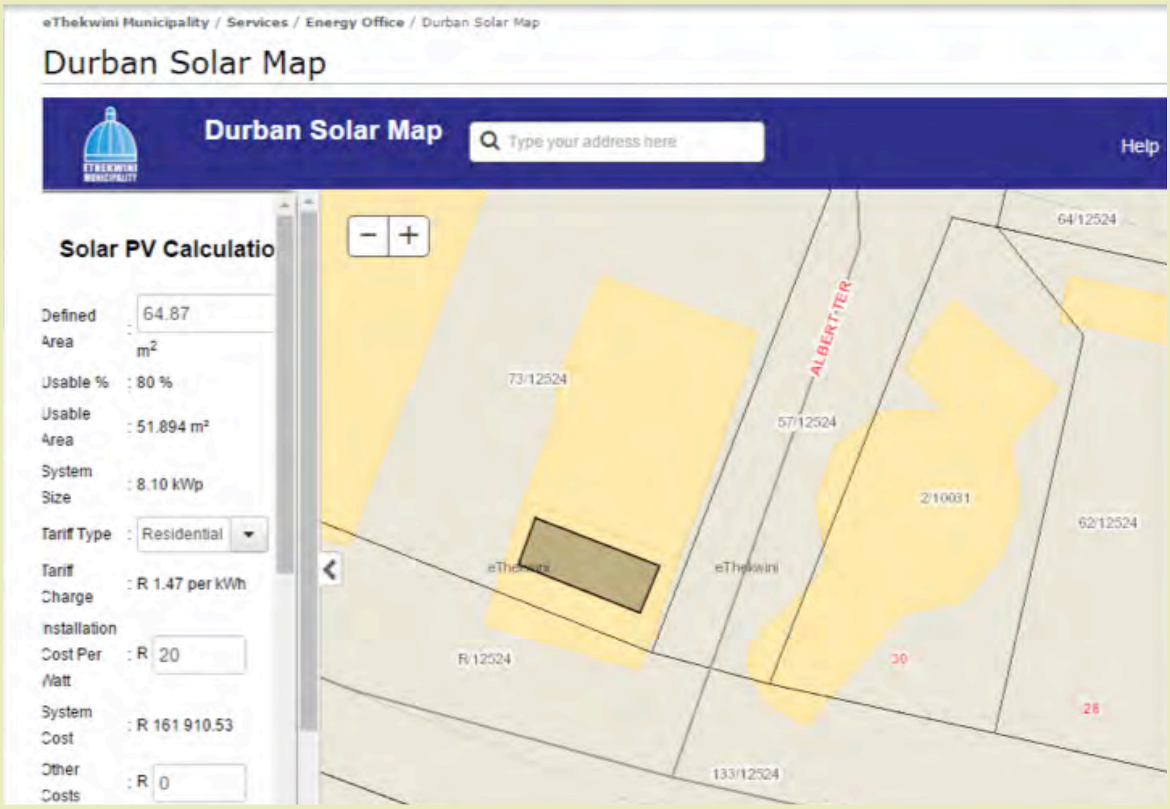
Source: Rocky Mountain Institute

Figure 10: Illustrative impact of relative reductions in stand-alone PV (panel and battery) prices on system financial viability (assuming loan financed at 13%, 8% grid tariff escalation)



Source: SEA

Figure 11: eThekwini municipality have developed an interactive map to help prospective SSEG customers assess the feasibility of such systems, and link them with installers



Source: *http://gis.durban.gov.za/solarmapviewer/*

The price and payback of solar SSEG

Typical SSEG system costs[2]

- Smaller systems <100kWp: From R20 000 to R25 000 per kWp installed
- Larger systems >100kWp: From R15 000 to R17 000 per kWp installed

Table 1: typical cost breakdown for an SSEG system *

	SMALL system (4kW)		Larger system (160kW)	
	ZAR	% of total cost	ZAR	% of total cost
PV panels	R41 430	50%	R1 656 960	56%
Inverter	R17 470	21%	R611 520	21%
Balance of system equipment	R11 900	14%	R452 350	15%
Installation	R6 900	8%	R207 000	7%
Bi-directional meter	R3 000	4%	R9 000	0.3%
Commissioning, sign-off	R2 000	2%	R4 000	0.1%
TOTAL	R82 700	100%	R2 940 830	100%

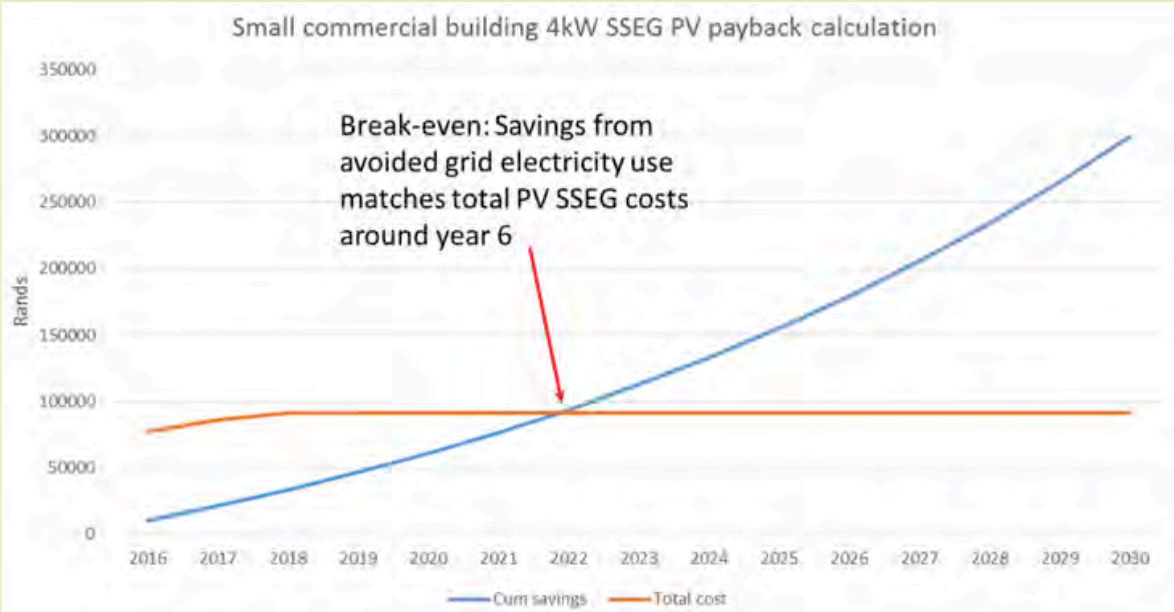
* derived from actual quotes, excluding VAT

2 GreenCape Market Intelligence Report (2016) Energy Services: Energy efficiency and embedded generation. www.greencape.co.za

Commercial and industrial system payback for the customer

Payback varies depending on the tariff the customer is on. Most commercial and industrial customers are on tariffs that have a significant fixed demand charge component. Since generally commercial and industrial customers are daytime loads, most, if not all, of the solar power generated will be used on site (i.e. there will be little export power onto the grid, and mainly at weekends if at all). Even without compensation for this, typical payback periods are in the region of 6 to 9 years currently, although this is tariff dependent. Many commercial and industrial customers currently consider a PV SSEG system a good investment with sound returns. New developments such as malls are starting to install PV SSEG as a matter of course. One mall developer noted that it provided them with an 18% internal rate of return, whereas they decide to develop malls based on a 10% rate of return.[3]

Figure 12: Example of small commercial PV system payback calculation from developer (based on a 3 year loan, not discounted)



Source: SEA

Residential SSEG payback for the customer

The residential SSEG payback is highly dependent on the tariffs. One important difference between most residential systems and commercial or industrial SSEG is that residential SSEG customer will often generate more solar energy than the household needs (i.e. when people are at work during the middle of the day and solar generation is at its maximum), so system payback usually becomes very dependent on the export tariff provided by the distributor (see more under 'Revenue impact' section).

3 Personal communication Moeketsi Thobela, SAPVIA.

Table 2: Comparing different billing principles for residential SSEG systems

Billing principle	Explanation	Comment
Net Metering	The meter does not record export power separately, but effectively 'reverses' when solar power is exported* – the customer is charged based on the total kWh consumed minus the exported power (i.e. the export power is compensated for at the same c/kWh as the power purchased from the distributor). ** Note that while some spinning-disc meters are able to reverse, they are not designed for this and municipalities therefore do not permit their use as a net meter.*	Municipal distributors would find it difficult to justify this approach as it would be cheaper to purchase power from Eskom at the Megaflex rate than purchase export power from the SSEG customer at the same rate at which they sell power to the customer. This is effectively subsidizing the SSEG customer. The only reason to follow this route would be to specifically boost PV SSEG uptake for economic or clean energy reasons.
Net Billing	The meter records power consumed from the distributor separately from solar power exported onto the grid, and bills these at different rates (e.g. grid power is purchased by the customer at R1.50/kWh and solar power export compensated at 85c/kWh).	This is considered sound practice for distributors, as they are purchasing power from the SSEG at rates comparable to Eskom Megaflex/bulk purchase rates.
No reverse feed (export)	Excess solar PV generated by the SSEG customer is not allowed to flow back onto the grid. Reverse–feed blocking is required, and no bi-directional meter is necessary. Existing meters can be retained (even prepayment meters).	Some distributors are not allowing reverse feed, although generally this is a temporary measure. This is often a significant disincentive for households to install SSEG, and is not recommended as it leads to systems being installed without the customer seeking official permission from the distributor. It also has a distinct municipal revenue disadvantage over net billing (see Revenue Impact Section).

Table 3: Typical payback periods for residential SSEG customers[4]

Net metering ('reversing' meter):	6 to 8 years
Net billing (separate export tariff):	12 to 15 years
No reverse feed or no compensation:	13 to 20 years

4 This is illustrative, as it is very tariff dependent. Values informed by the GIZ/Genesis Revenue Impact Modelling spreadsheet (available on www.cityenergy.org.za) and financial model developed by eThekwini Energy Office (available on: http://www.durban.gov.za/City_Services/energyoffice/projects/Pages/RenewableEnergy.aspx)

Figure 13: Solar energy changes for different orientations (azimuth) and tilt angles for a site at latitude 27 degrees South (Gauteng is 25-26 degrees South, eThekwini 29 degrees, Cape Town 34 degrees).

Heading / Azimuth

Tilt Angle	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
5*	-8%	-8%	-8%	-7%	-7%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-7%	-7%	-8%	-8%	-9%	-9%
10	-9%	-8%	-7%	-6%	-5%	-5%	-4%	-4%	-4%	-4%	-4%	-4%	-5%	-5%	-6%	-7%	-8%	-9%	-10%
15	-9%	-8%	-6%	-5%	-4%	-3%	-3%	-2%	-2%	-2%	-2%	-3%	-3%	-4%	-5%	-7%	-8%	-9%	-11%
20	-10%	-8%	-7%	-5%	-4%	-3%	-2%	-1%	-1%	-1%	-1%	-2%	-3%	-4%	-5%	-7%	-9%	-10%	-12%
25	-12%	-9%	-7%	-5%	-4%	-2%	-1%	0%	0%	0%	0%	-1%	-2%	-4%	-5%	-7%	-9%	-12%	-14%
30	-13%	-10%	-8%	-6%	-4%	-3%	-1%	0%	0%	0%	-1%	-1%	-3%	-4%	-6%	-8%	-11%	-13%	-16%
35	-15%	-12%	-9%	-7%	-5%	-3%	-2%	-1%	-1%	-1%	-1%	-2%	-3%	-5%	-7%	-10%	-12%	-15%	-18%
40	-17%	-14%	-11%	-8%	-6%	-4%	-3%	-2%	-2%	-2%	-2%	-3%	-5%	-7%	-9%	-11%	-14%	-17%	-20%
45	-19%	-16%	-13%	-10%	-8%	-6%	-5%	-4%	-3%	-3%	-4%	-5%	-7%	-9%	-11%	-14%	-16%	-19%	-23%
50	-22%	-18%	-15%	-12%	-10%	-8%	-7%	-6%	-5%	-6%	-6%	-7%	-9%	-11%	-13%	-16%	-19%	-22%	-25%
55	-24%	-21%	-18%	-15%	-13%	-11%	-10%	-9%	-8%	-8%	-9%	-10%	-12%	-14%	-16%	-18%	-21%	-25%	-28%
60	-27%	-24%	-20%	-18%	-16%	-14%	-13%	-12%	-12%	-12%	-12%	-13%	-15%	-17%	-19%	-21%	-24%	-27%	-31%
65	-30%	-27%	-24%	-21%	-19%	-17%	-16%	-16%	-15%	-16%	-16%	-17%	-18%	-20%	-22%	-25%	-27%	-31%	-34%
70	-33%	-30%	-27%	-25%	-23%	-21%	-20%	-20%	-20%	-20%	-20%	-21%	-23%	-24%	-26%	-28%	-31%	-34%	-37%
75	-37%	-33%	-31%	-28%	-27%	-26%	-25%	-24%	-25%	-25%	-25%	-26%	-27%	-28%	-30%	-32%	-35%	-38%	-41%
80^	-41%	-37%	-35%	-33%	-31%	-30%	-30%	-30%	-30%	-30%	-31%	-31%	-32%	-33%	-34%	-36%	-38%	-41%	-44%

Tariffs for PV SSEG[5]

Residential SSEG Tariffs

Residential SSEG tariffs are necessary because most municipalities' normal residential tariffs are based only on a c/kWh charge. Such normal tariffs become unsound with SSEG systems, as customers can end up paying very little towards the operation and maintenance of the distribution grid infrastructure, yet they rely on this infrastructure when SSEG output is low and at night. For this reason a fixed charge component is necessary with residential SSEG tariffs to ensure all customers are sharing costs more equally. A typical residential SSEG tariff is comprised of three parts:

- A fixed charge covering both service and network charges:
  - Network charges ensure that fixed costs associated with maintaining and operating the municipal electrical grid are recovered
  - Service charges are associated with providing a retail service network (metering, billing, customer call centre)
- Electricity consumption charges per kWh consumed from the grid – this may be simple (Flat or Inclining Block tariff) or complex (Time of Use or other tariff).
- An export compensation rate per kWh at which the municipality purchases SSEG excess generation exported to the grid.

5 This part of the chapter draws extensively from the report: GreenCape Requirements for Embedded Generation and AMEU Standard SSEG documentation (available from www.greencape.co.za, www.cityenergy.org.za). Unless referenced otherwise, information is sourced from this document.

Different approaches to 3-part SSEG tariff setting

Municipalities have chosen their 3-part SSEG tariffs very differently – some opting for high fixed charges and low export compensation charges (which will discourage prospective SSEG customers and increase the rate of 'unofficial' installations), while others have SSEG tariff regimes which incentivise prospective SSEG customers, both to stimulate the industry and embrace green energy, as well as to reduce the incidence of 'unofficial' installations. The spread of tariff approaches is illustrated in Table 4.

Table 4: Residential Normal and SSEG tariffs in selected Metros

(excluding VAT)	Johannesburg (City Power)	Cape Town	eThekwini	Nelson Mandela Bay
Current 'normal' residential c/kWh (high IBT)	145	200.05	129.39	170
Residential SSEG fixed charge/mth (R) (1-ph)	R440	R342	R220	R60
Residential SSEG energy charge (c/kWh)	140.65	200.05	129.39	175 peak 170 std 125 off-pk
SSEG feed-in tariff (c/kWh)	42.79	61.47	62	150

Source: 2016 tariff documents from each municipality

Commercial and Industrial SSEG Tariffs

Commercial and industrial customers are generally on tariffs which already have a fixed service charge and network demand charge as well as a variable energy charge, and therefore only an export generation tariff component needs to be added. Customers on a tariff that does not include fixed service charge and demand charge will need to be changed to an appropriate tariff.

Although Commercial and Industrial SSEG customers sometimes expect a reduced demand charge because of their SSEG system, this is usually not the case: because of cloudy days there can seldom be a long-term reduction in customer peak demand, and therefore most distributors will charge the same demand charge as previously because they still need to ensure that the supply infrastructure capacity can meet the peak demand without the solar SSEG contribution.

Time of Use tariffs are considered best practice for both consumption and export (feed-in) tariffs, and municipalities may increasingly move to such tariffs over time.

National regulatory and policy situation

The national regulatory and policy situation has catered for SSEG systems inadequately in the past, but is being amended to rectify this. Although many of the key technical standards are now in place, the relevant national acts and regulations are in the process of being finalized.

Electricity Regulation Act, Act 4 of 2006 (ERA)

The act states that no person may, without a license issued by the regulator (NERSA), operate any generation facility. The current proposed amendment of the ERA Schedule 2 exempts systems which are 1MW or smaller in generation capacity from obtaining a license.

NERSA SSEG regulations

NERSA regulations around SSEG will be developed during the course of 2017, once the ERA amendment above has been finalised.

Standards of Importance

The below standards are the most important for embedded generation, and they set the majority of regulatory requirements that municipalities need to ensure are complied with in their SSEG application and approval processes.

NRS 097-2-1 (Part 2: Small Scale Embedded Generation, Section 1)

This document serves as the standard for the interconnection of SSEG's to the utility network and applies to embedded generators smaller than 1000kVA connected to LV networks of type single, dual or three-phase. The document covers thorough all key safety concerns (anti-islanding and response to abnormal grid conditions) and power quality criteria (harmonics, over-under-voltage, over-under-frequency, DC injection, flicker etc.). Municipalities are advised to require SSEG inverters to have test certificates from accredited test houses for compliance with NRS097-2-1.

NRS 097-2-3 (Part 2: Small Scale Embedded Generation, Section 3)

This document provides simplified utility connection criteria for low-voltage connected generators. Some criteria for 'simplified utility connection' in this standard include:

- Systems up to 350KVA size
- Shared LV feeders: systems up to 25% of circuit breaker size, with a maximum of 20kVA
- Dedicated LV feeders: systems up to 75% of notified maximum demand

There are many other criteria in the standard which should be consulted. If SSEG installations comply with the criteria herein, municipal distributors are able to approve SSEG applications relatively quickly. If not, municipalities should still look to approving installations, but may consider requiring special grid impact studies before such approval.

Wiring standards: SANS 10142-Part 3: The Wiring of Premises – low voltage embedded generators (under development, due end 2017)

This standard will regulate the DC wiring on the customers side of the meter (SANS 10142-1 permits DC wiring but does not deal with it in adequate detail).

South African Renewable Power Plants Grid Code (SARPPGC)

This document is also considered a foundational standard for SSEGs, although in practice the vast majority of requirements for SSEGs are laid out in the NRS097 series of standards (which are substantially based on the SARPPGC). Systems above 1MW (and therefore not small-scale) will need to comply with the SARPPGC, as the NRS097 series does not apply.

Further information on Standards and Legislation

OCCUPATIONAL HEALTH AND SAFETY ACT, 1993

The Occupational Health and Safety Act provides for the health and safety of the people by ensuring that all undertakings are conducted in such a manner so that those who are, or who may be, directly affected by such an activity are not negatively harmed as far as possible and are not exposed to dangers to their health and safety.

NRS 097 PART 1: DISTRIBUTION STANDARD FOR THE INTERCONNECTION OF EMBEDDED GENERATION

The specification sets out the minimum technical and statutory requirements for the connection of embedded generators to **medium-voltage and high-voltage** utility distribution networks. The specification applies to embedded generators **larger than 100 kVA**. (under development)

SOUTH AFRICAN RENEWABLE POWER PLANTS GRID CODE (SARPPGC)

This document is also considered a foundational standard for SSEGs, although in practice the vast majority of requirements for SSEGs are laid out in the NRS097 series of standards (which are in fact substantially based on the SARPPGC). It sets out the technical and design grid connection requirements for renewable power plants (RPP) to connect to the transmission or distribution network in South Africa. This guideline is of concern to embedded **generators of Category A that are connected to a low-voltage (LV) network.**

Category A: 0 – 1 MVA (Only LV connected RPPs)

This category includes RPPs with rated power of less than 1 MVA and connected to the LV voltage (typically called 'small or micro turbines'). This category shall further be divided into 3 sub-categories:

> **Category A1: 0 – 13.8 kVA**
>
> This sub-category includes RPPs of Category A with rated power in the range of 0 to 13.8 kVA.
>
> **Category A2: 13.8 kVA – 100 kVA**
>
> This sub-category includes RPPs of Category A with rated power in the range greater than 13.8 kVA but less than 100 kVA.
>
> **Category A3: 100 kVA – 1 MVA**
>
> This sub-category includes RPPs of Category A with rated power in the range 100 kVA but less than 1 MVA.

SANS 10142-1 THE WIRING OF PREMISES – LOW-VOLTAGE INSTALLATIONS

This document serves as the South African national standard for the wiring of premises in low-voltage networks. The aim of the document is to ensure that people, animals and property are protected from dangers that arise during normal as well as fault conditions, due to the operation of an electrical installation. Compliance to the standards and regulations as laid out SANS 10142-1 is required and proof should be provided via an electrical installation certificate of compliance.

SANS 10142-2 THE WIRING OF PREMISES – MEDIUM-VOLTAGE INSTALLATIONS ABOVE 1 KV A.C. NOT EXCEEDING 22 KV A.C. AND UP TO AND INCLUDING 3 000 KW INSTALLED CAPACITY

This document serves as the South African national standard for the wiring of premises in medium-voltage networks. The aim of the document is to ensure that people, animals and property are protected from dangers that arise during normal as well as fault conditions, due to the operation of an electrical installation. Compliance to the standards and regulations as laid out SANS 10142-2 is required and proof should be provided via an electrical installation certificate of compliance. The implication is that a qualified electrician is required to sign off on your system.

SANS 10142-3 THE WIRING OF PREMISES – LOW VOLTAGE EMBEDDED GENERATORS (UNDER DEVELOPMENT, DUE END 2017)

This standard will regulate the DC wiring on the customers side of the meter (SANS 10142-1 permits DC wiring but does not deal with it in adequate detail).

SANS 474 / NRS 057 CODE OF PRACTICE FOR ELECTRICITY METERING

SANS 474 specifies the metering procedures, standards and other such requirements that must be adhered to by electricity licensees and their agents. It refers specifically to new and existing metering installations for the purpose of billing. It further specifies the initial calibration and certification requirements as well as compliance testing of metering installations and the subsequent procedures to ensure continued compliance. It specifies the procedures for the manipulation and storage of metering data and sets a standard format for the numbering of electricity meters.

NRS 049: ADVANCED METERING INFRASTRUCTURE (2015)

This standard ensures that AMI metering follows interchangeable protocols and features thus preventing utility lock-in to particular suppliers. It covers all devices and systems in a 'smart' metering system, including head-end, vending point-of-sale, meter, customer interface, data concentrator, auxiliary meter, and appliance control systems.

NRS 048: QUALITY OF SUPPLY

The **NRS 048** series covers the quality of supply parameters, specifications and practices that must be undertaken to ensure correct and safe operation. The NRS 048-2 and NRS 048-4 have the most relevance to the operation and connection of SSEG's to the utility network:

NRS 048-2: 'Voltage characteristics, compatibility levels, limits and assessment methods' sets the standards and compatibility levels for the quality of supply for utility connections as well as for stand-alone systems. It is intended that generation licensees ensure compliance with the compatibility levels set in this document under normal operating conditions.

NRS 048-4: 'Application guidelines for utilities' sets the technical standards and guidelines for the connection of new consumers. It also sets the technical procedures for the evaluation of existing consumers with regards to harmonics, voltage unbalance and voltage flicker.

SSEG: Challenges and concerns of municipal distributors

Municipalities are realizing that there is a need to be proactive in developing appropriate procedures and standards for SSEG integration to support the green economy as well as to avoid unregulated proliferation of installations. Some municipalities already have procedures in place to guide prospective SSEG installers regarding system criteria and standards to be followed, and have developed associated tariffs. Municipal distributors have to balance the following pressures:

- On the one hand they are obliged to ensure that the distribution grid power quality and safety standards are upheld – and are under threat of extreme penalties if they do not. This puts pressure on them to enforce demanding standards on SSEG installations, which in turn has a cost implication for SSEG installers.
- On the other hand they realise that unless they have a user-friendly framework around installation application and approval, SSEG systems will simply be installed and grid connected by one of the solar PV supply companies on behalf of customers without official approval.
- A further issue for municipalities revolves around potential revenue loss from reduced sales due to PV SSEG uptake amongst customers. The concern is that revenue losses may threaten their ability to cross-subsidise poor households and support other city functions. Current residential tariffs in particular are not designed to accommodate SSEGs, raising uncertainty about revenue loss. For this reason specific SSEG residential tariffs are generally introduced.

Municipalities may typically express their concerns as follows:

- Safety: "What about when the grid goes down and the SSEG is still powering a section thereof? What about the safety of our staff working on the lines?"
- Power quality: "We don't want all sorts of devices putting variable quality power onto our network."
- Revenue loss: "We will lose revenue because of reduced sales resulting from people generating their own SSEG electricity. And if they put power back onto the grid, it is during midday when we don't really need it."

These concerns have all been addressed through various standards and research undertaken. The first two are dealt with below, and revenue impact is covered in a subsequent section.

Safety

Concerns around safety are no longer merited as long as systems comply with the NRS097-2-1 standard and are certified as such from an accredited test house. This standard requires a range of safety disconnection responses from the SSEG inverter to protect both people and equipment. Prevention of islanding[6] is amongst these, and the

Figure 14: Example of safety labelling required by the NRS097-2-1 (at distribution board)

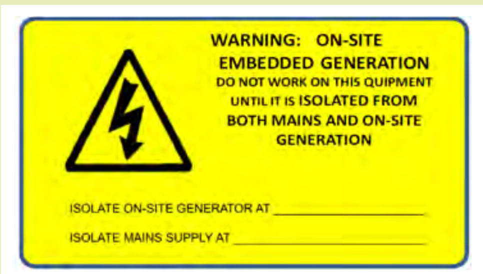
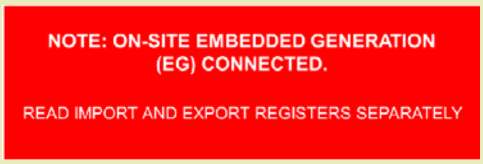


Figure 15: Example of safety labelling required by the NRS097-2-1 (at metering points)



6 Islanding: continued generation on a portion of the grid when the main grid is down due to faults, maintenance or load shedding.

inverter is required to use both passive and active detection of grid power methods (active detection involves an attempt to vary an output parameter such as voltage or frequency, which will elicit no response if the grid is powered up, and will receive a response if the grid is down).

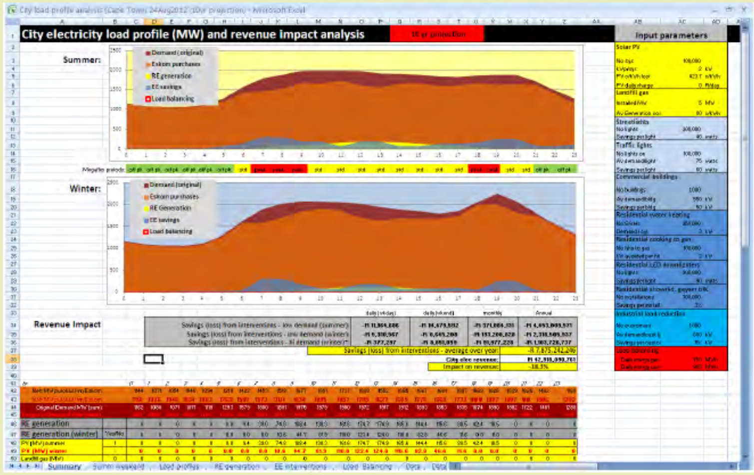
Power quality

The NRS097-2-1 standard deals with power quality thoroughly, drawing on the Renewables Grid Code as a reference. Amongst other parameters, it covers:

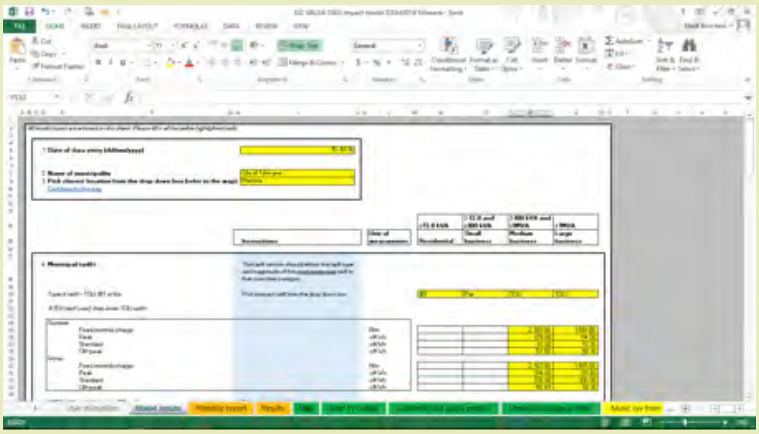
- Permissible voltage ranges, changes and unbalance
- Fault levels
- DC injection
- Frequency operating range
- Harmonics and waveform distortion
- Power factor
- Synchronization methods
- Electromagnetic compatibility

The challenge is therefore not one of poor power quality, but rather one of ensuring that inverters are compliant with the NRS097-2-1 and are certified as such. As long as this certification is in place, power quality need not be a concern.

Figure 16: Two of the SSEG revenue impact models in existence They are user-friendly and come with user manuals, and can be used for revenue assessments with specific tariffs to support tariff setting.



Source: Sustainable Energy Africa and GIZ/GENESIS respectively



Source: www.cityenergy.org.za

Revenue impact

Because it has been such a long-standing concern to municipal distributors, SSEG revenue impact assessment work has been underway since 2012.[7] Since this time detailed analyses have been undertaken in at least six major urban areas,[8] and, in spite of perceptions to the contrary, all analyses have indicated that revenue impact under feasible SSEG penetration scenarios is not a major concern. This section will outline the revenue impact methodologies and present typical results.

7 The potential impact of efficiency measures and distributed generation on municipal electricity revenue: Double whammies and death spirals. Sustainable Energy Africa. AMEU conference, September 2012.

8 Including eThekwini, Ekurhuleni, Polokwane, Cape Town and Tshwane

Factors in a revenue impact assessment

The following are important factors in assessing the revenue impact of SSEG introduction:

Commercial and industrial demand charges: Because most months have at least one cloudy day in much of the country, there is generally no consistent, long-term reduction in demand charges due to installation of PV SSEG systems. PV SSEG therefore generally has no demand charge revenue impact.

Figure 17: Demand charge reductions are negligible due to SSEG installations because of the incidence of cloudy weather most months of the year.

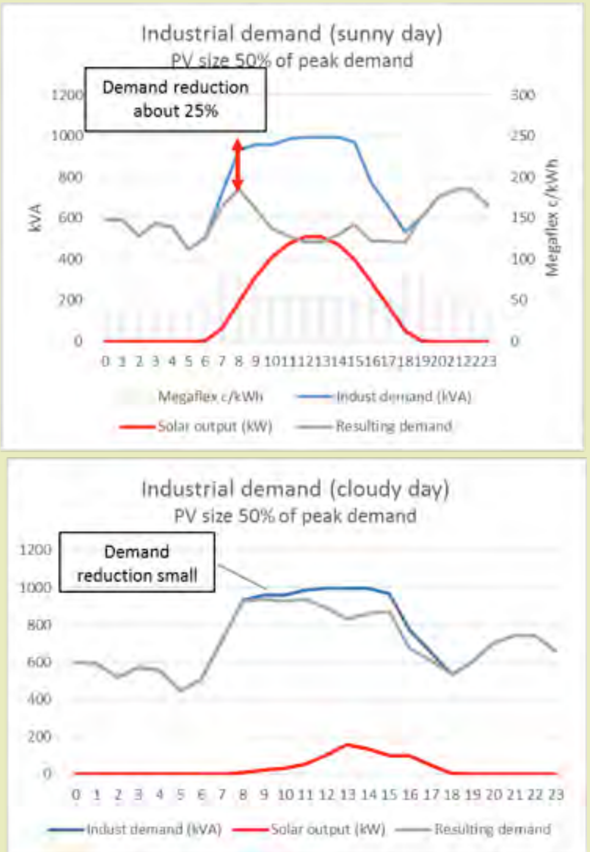


Figure 18: Revenue impact considerations for industrial SSEG customers

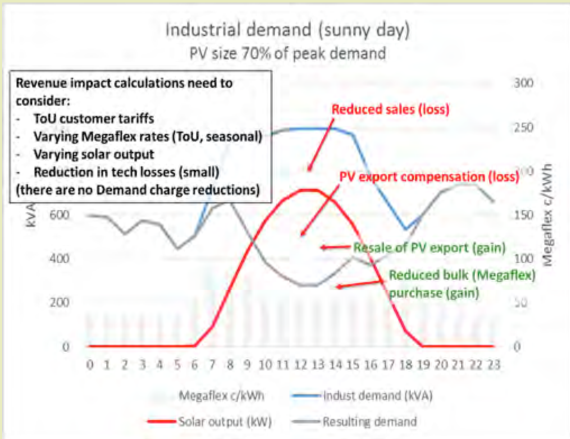
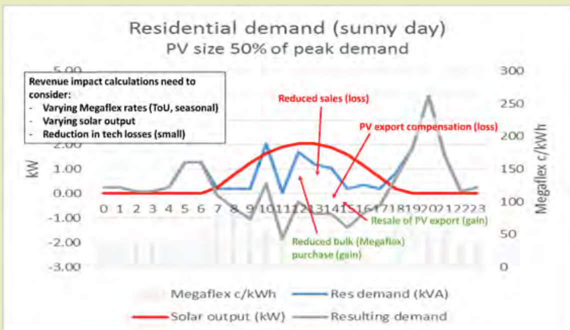


Figure 19: Revenue impact considerations for residential SSEG customers



Electricity sales reduction because of SSEG generation: this will result in a revenue loss for the municipal distributor.

SSEG export compensation: where distributors compensate SSEG customers for export power, this will also result in a revenue loss. It is sensible for such compensation to be related to bulk purchase tariffs, e.g. around 65 to 85 c/kWh currently.

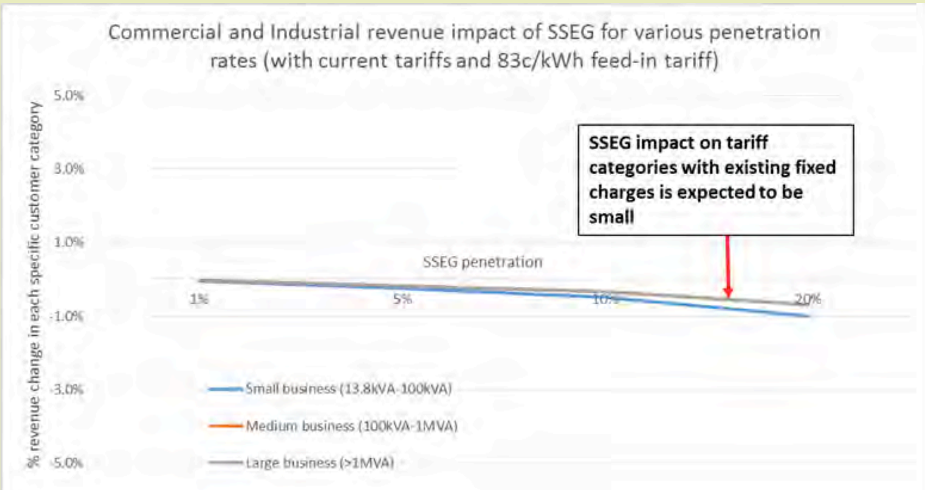
Resale of SSEG export power: SSEG export power should be resold at normal tariff rates, representing a revenue gain for the distributor.

Reduced bulk purchases: because less electricity is required by municipal customers, bulk purchases are reduced, which is a revenue gain. In addition to the above factors, a revenue impact analysis needs to consider the ToU tariffs that customers are on, the ToU and seasonal variations of bulk purchase tariffs, variations in solar SSEG generation with the weather, and the fact that decentralized SSEG generation will have some impact on reducing distribution losses, although likely to be small. Residential SSEG customers often generate a greater percentage of excess solar power for export than commercial or industrial customers whose demand is more daytime peaking (i.e. matching the solar generation profile better) than residential customers. Distributors should keep in mind that such SSEG customer export power represents a revenue opportunity for them, as they would typically compensate at a bulk purchase rate (e.g. 65c/kWh) yet re-sell at a normal midday tariff rate (e.g. R1.00/kWh).

Typical revenue impact results

Some typical revenue impact results are shown in the graphs below. Where customers are on a tariff which already has a fixed charge component, the impact is generally not significant. The more cost reflective such tariffs are (as determined by a 'Cost of Supply' study) the less revenue will be lost, as the actual fixed costs will be recovered through the tariff irrespective of SSEG penetration rates. This has been a consistent finding in all revenue impact analyses since the first such exercises in 2012.

Figure 20: The revenue impact from SSEG for different penetration rates (x-axis) for customers already on a tariff with a fixed charge is unlikely to be significant (note that a 20% SSEG penetration rate is an extreme scenario)

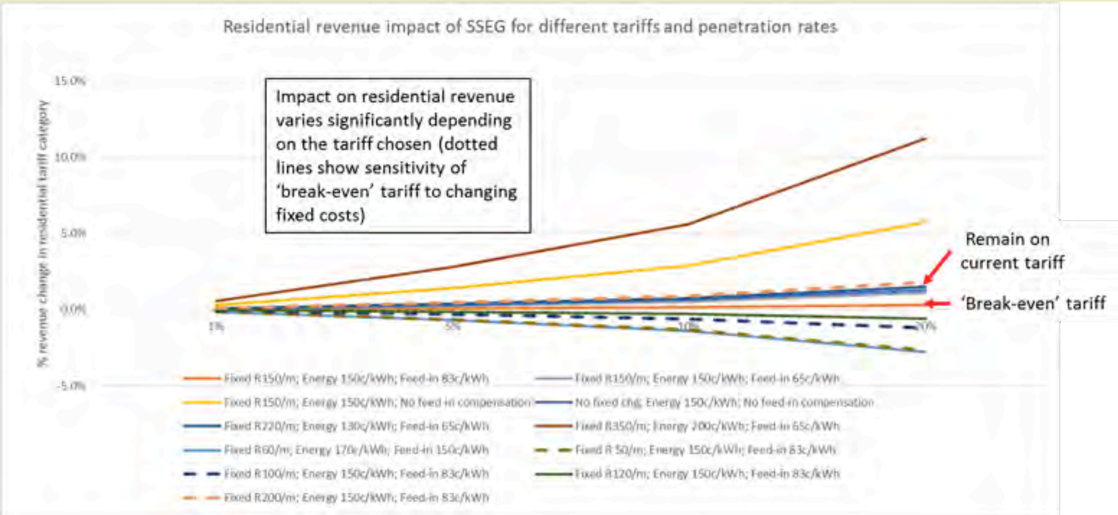


Source: SEA (2017) City of Tshwane Revenue Impact Study.

Residential SSEG revenue impact is sensitive to the SSEG tariff that is set by the municipal distributor. It is relatively easy to set a tariff that is both acceptable in terms of revenue impact and providing an adequate return on investment for the customer. As shown in the example in Figure 32, an appropriate tariff may be about R150 per month fixed charge, R1.50 per kWh electricity purchase charge, and R0.83 per kWh for export compensation. Even in the scenario where residential customers remain on current tariffs without a fixed charge, the revenue impact analyses show that the reduction in bulk purchases as well as revenue from resale of SSEG exported power will often result in minimal revenue loss for the distributor, if any [9].

9 Note that a 20% penetration rate is considered extreme. For example, in 2015 The Energy Supply Association of Australia published a report indicating that Australia was amongst the world leaders regarding residential SSEG penetration at 15%, with Belgium at 7%. A 2016 report indicates that 17% of all electricity customers (not just residential) in Hawaii have rooftop SSEG PV (Hawaii has been engaged in a programme to promote solar SSEG for over 10 years) (www.pv-magazine.com).

Figure 21: The revenue impact from residential SSEG installations for different SSEG penetration rates (x-axis) and different SSEG tariffs (coloured lines). Reasonable tariff setting can easily avoid revenue loss and still be acceptable to customers.



Source: City of Tswane Revenue Impact Study (SEA 2017).

The Business case for SSEG customers

It is important to understand the implications of their SSEG tariff on the business case for SSEG customers to avoid tariffs which weaken the financial returns on PV purchases excessively, as this is likely to increase illegal SSEG installations and encourage grid abscondment. Table 7 shows how tariffs can impact on SSEG investment payback periods, which can range from 9 years to over 20 years for residential systems. Even 9 years would be a daunting payback for many households, and estimates are that significant take-up of SSEG systems will only occur when payback is around 5 years[10]. A payback of 20 years is comparable to that for a stand-alone PV system (with batteries). It is therefore important to optimise residential SSEG tariffs so they keep payback periods as low as possible while still protecting municipal revenue. Payback for commercial systems is typically 10 years or less, which would often be considered a reasonable investment for businesses (e.g. giving an IRR of around 12-14%).

10 Sewchurran et al. (2016) See Drivers and Application of Small Scale DG on Municipal Distribution Networks, AMEU Conference.

Table 5: Payback (in years) for different customer characteristics and SSEG tariffs*

Residential	**Payback**		
SSEG Tariff	Small residential system (2kWp), 50% self-consumption, total consump 1000kWh/mth	Larger residential system (5kWp), 50% self-consumption, total consump 1000kWh/mth	Larger residential system (5kWp), 20% self-consumption, total consump 1000kWh/mth
Fixed R60/m; Energy 170c/kWh; Feed-in 150c/kWh (NMBMM)	13 yrs (cash) 20+ yrs (financed)	9 yrs (cash) 11 yrs (financed)	12 yrs (cash) 20+ yrs (financed)
Fixed R350/m; Energy 200c/kWh; Feed-in 65c/kWh (Cape Town)	20+ yrs (cash) 20+ yrs (financed)	20+ yrs (cash) 20+ yrs (financed)	20+ yrs (cash) 20+ yrs (financed)
Fixed R220/m; Energy 130c/kWh; Feed-in 65c/kWh (eThekwini)	11 yrs (cash) 19 yrs (financed)	11 yrs (cash) 17 yrs (financed)	12 yrs (cash) 20+ yrs (financed)
No SSEG tariff (and no export compensation)	12 yrs (cash) 20+ yrs (financed)	13 yrs (cash) 20+ yrs (financed)	20+ yrs (cash) 20+ yrs (financed)
Commercial	Payback		
Commercial (non-domestic 1-phase) Fixed R1102/m; Energy 130c/kWh; 100% self-consumption (no reverse feed)	8 yrs (cash) 10 yrs (financed)		

** Source: own calculations*

Assumptions for table 5:

Solar PV cost (grid-tied) /kW installed	R22,000
Solar PV O&M cost/year	1% of cap cost p.a.
Finance rate	11%
Financed over (years)	20
Grid Elec tariffs inflation (nominal)	7%*
Discount rate	0%

* Note that a 7% escalation of grid power costs is considered conservative by some, as municipal tariffs have escalated by well over 10% over the past 10 years. A higher escalation rate here would reduce system payback period.

Some key points emerging from all the revenue analyses undertaken for municipalities to date

- Solar PV SSEG revenue impact is not likely to pose a significant threat to municipal distributors, and is generally likely to be below 2% of total revenue for anticipated SSEG penetration rates.
- Expected revenue loss from substantial penetration of solar PV (even up to the extreme scenario of 20% penetration) is not significant in tariff categories where there is a fixed (R/kVA) and variable (c/kWh) charge already in existence (i.e. most commercial and industrial tariffs).
    - Note that it is important that tariffs are cost reflective such that fixed costs are recovered irrespective of SSEG penetration rates.
- An appropriate 'break even' residential SSEG tariff may be in the region of R150/month fixed charge, 150c/kWh energy charge, and 83c/kWh feed-in compensation (although an analysis of the situation in each municipality is recommended before deciding on a tariff).
- Municipalities should be careful not to reduce the business case for households to install SSEG solar PV by levying too high a fixed charge, or too low an export compensation charge, or making it difficult to obtain official approval through excessive bureaucratic hurdles. An attractive SSEG tariff and a simple application procedure guard against unofficial installations, with associated safety and power quality issues which are undesirable for a municipality. They can also guard against grid defections – 'chasing' prospective SSEG customers off grid by making stand-alone (off-grid with battery storage) solutions more feasible. As municipal operations currently stand, a trend of defections would represent a serious threat to financial sustainability.

The broader economic case: although not directly related to municipal revenue, municipalities should keep in mind that there are economic benefits to enabling SSEG rollout, such as strengthening the clean energy business sector and job creation.

PV GreenCard: SSEG PV installer accreditation

The South Africa Photovoltaic Industry Association (SAPVIA), GIZ and GreenCape are partnering around the development of a voluntary certification scheme for PV installers, called PV GreenCard. This will be a significant step in providing comfort for customers, distributors and financiers around installation integrity and compliance, as well as strengthening the credibility of the PV industry. While it is principally designed to provide residential customers with comfort and cross-checks, it can also be used for larger installations. The GreenCard initiative provides a best practice guide for installers, as well as a checklist for customers to assess the installations. If the customer is not happy with the system they can 'Red Card' the installation. The PV GreenCard covers:

- System components
- DC installation
- Ac installation (especially grid codes, NRS standards)
- Lightning protection
- Fire safety
- Rooftop installation
- Safety at work
- Commissioning, operation and maintenance

Short training course curricula have been developed and approved by SAPVIA to enable PV GreenCard certification, and these will be run by endorsed training providers. The courses are based on the national QCTO Curriculum. It is intended that electricians with PV GreenCard certification will be able to sign off residential systems in future, rather than requiring Pr Eng or Pr Tech Eng sign-off of such systems. Professional sign-off will still be appropriate for larger commercial or industrial systems. For more information see www.pvgreencard.co.za.

How to implement a balanced SSEG approval process

Municipal distributors wishing to establish systems for accepting and processing applications for SSEG installations now have significant supporting resources available to them. Most significant are the set of standard documentation and forms endorsed by the AMEU (see text box).

AMEU Standard SSEG documents and forms

A set of AMEU endorsed documents and forms is available for municipal distributors to use in establishing systems to accept and assess SSEG applications. These may be edited as necessary to suit individual municipal purposes. (available at www.cityenergy.org.za – see Electricity Services / SSEG section). The documents are:

AMEU SALGA: Requirements for Embedded Generation: This provides all the information an SSEG applicant needs. Specifies the conditions and system sizes that are acceptable, the standards that are to be adhered to, and the details of the application process to be followed.

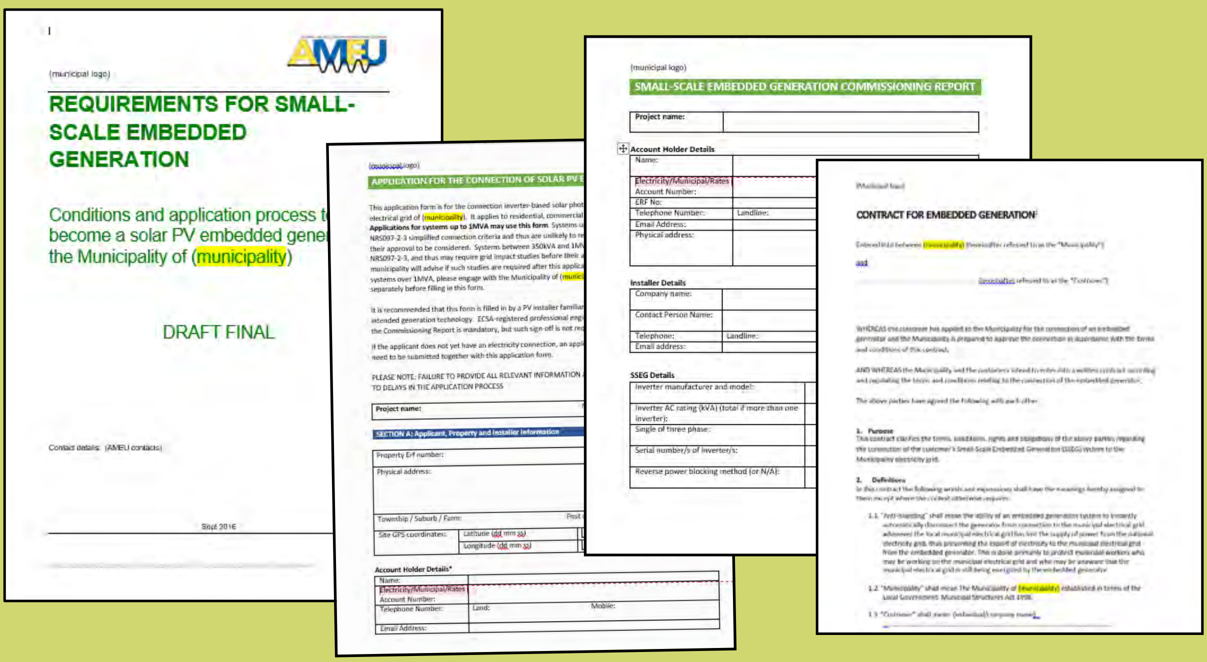
AMEU SALGA: SSEG Application Form: This form elicits all the information a distributor requires to process an SSEG application.

AMEU SALGA: SSEG Commissioning Form: This form lists the information that is to be provided on commissioning, and is to be signed off by a professional engineer or engineering technologist (this is a temporary measure until the necessary standards are in place, then a Certificate of Compliance will replace professional sign-off).

AMEU SALGA: SSEG Supply Contract: Before the SSEG can be activated, an SSEG contract needs to be signed, making the rights and obligations of both the SSEG customer and municipal distributor legally binding.

AMEU SALGA: SSEG Decommissioning form: This form requires that a Certificate of Compliance of physical disconnection be obtained for the municipality to register the decommissioning of the SSEG.

The documents were developed with input from a working group comprising all metros, and were based on equivalent documents developed by the City of Cape Town (who pioneered much of the SSEG application process) and GreenCape, who have developed a range of documents to support Western Cape municipalities.



Process within the municipality to adopt an SSEG application and approval process

Developing a procedure for approving SSEG systems may involve the following activities within municipalities:

- Review of the Standard AMEU/SALGA documentation and editing where necessary to suit individual municipal purposes.
- Capacity building workshops/meetings with management and other senior staff to provide information, allay safety and revenue concerns, and obtain buy-in.
- Tariff setting, especially for residential SSEG systems, potentially supported by revenue modelling tools (see Resources section at the end ofthis chapter).
- Some municipalities prefer to develop a policy around SSEG for political approval before activating the SSEG application system.
- Training of inspectors regarding key SSEG technical issues for compliance, and possibly participation to SSEG commissioning procedures for hands-on experience (although generally municipalities will not need to be present at system commissioning).
- Some municipal officials may want to attend short SSEG training courses (e.g. those organized by SALGA and GIZ)
- Municipal Electricity Supply by-law amendment will be necessary to adequately include SSEG systems (see text box).
- Develop a process flow (which section does what, and in what order) and associated checklist for each section specifying exactly what needs to be assessed. (examples available at www.cityenergy.org.za – see Electricity Services / SSEG section).
- Work with each section to ensure they are capacitated to undertake the tasks in the checklist.

Municipalities should note that NERSA is likely to require regular updates on existing SSEG installations (Table 6), and therefore the necessary information should be systematically recorded.

The existence of the SSEG application and approval process should be communicated to the PV industry and customers.

Table 6: NERSA is likely to require the following information on installed SSEG systems from municipalities

Information to be registered for each SSEG installation (and submitted to NERSA)
– PV system code (unique to system)
– PV system operator information (name of operator, email address)
– Location of PV system (street name, house number, city, zip code, GPS coordinates)
– Connection to LV or MV grid?
– Newly built system or extension to existing system?
– Installation includes storage system? If yes, what is the storage capacity in kWh?
– Circuit diagram and design showing major components
– Metering concept
– Type of system (Rooftop / Ground-mounted / Building integrated)
– Total nameplate capacity of PV modules
– Type/Model of PV modules installed
– Type/Model of PV inverters installed
– Day of commissioning

Amendments to Municipal Electricity Supply by-laws

Key areas where Electricity Supply by-laws generally require amendment to ensure the safe and compliant adoption of SSEG into the municipal electricity grid, are as follows:

- Require all prospective SSEG generators to obtain the written agreement of CoT to connect
- Require that the application process be adhered to, and conditions in the "Requirements for embedded generators" document by complied with.
- Require that safety and power quality issues be explicitly addressed and are the customers responsibility. This includes inverter safety and compliance certification.
- Obtain consent that the SSEG installation may be accessed by CoT staff as required.
- Assert that CoT has the right to disconnect non-compliant SSEG systems.
- Assert that CoT has the right to set norms and standards and change these from time to time.
- Assert that CoT has the right to set SSEG tariffs and billing arrangements, and change these from time to time.

More detailed by-law amendment information and text can be found in the GreenCape document *10 Questions Municipal Officials should be asking about the document titled 'Guidelines for Small Scale Embedded Generation in Western Cape Municipalities'* available at www.greencape.co.za.

Case study 1: Clearwater Mall in Johannesburg – 1.5MW rooftop PV system

Clearwater shopping mall is located in Roodepoort, western Johannesburg. In November 2014 Hyprop Investments Limited developed the first phase of the mall's grid-tied rooftop solar PV system, totaling 500kWp of capacity. Through a tender process, Hyprop contracted Solareff (Pty) Ltd, a specialist solar PV company, for the design, installation and commissioning of the system. The installation was complete in 7 weeks. Due to its success, Hyprop extended its partnership with Solareff to install a second phase of PV, adding an additional 1 000kWp of panels, making it the largest rooftop PV system in Africa at the time – 1 500 kWp. The second phase was completed over four months, finishing in August 2015. This increased the surface area from 4 000m² to an estimated 12 000m². The roof of the mall was specifically designed for the additional weight of the solar PV array. The grid-connected PV system now generates around 2 500 000kWh of power annually, and saves the mall about 10% of the electricity they would otherwise have purchased from the municipal grid. This is equal to the consumption of about 347 average households. It is also expected to result in about 2 790 tonnes less CO_2 emissions per year.

Hyprop's motivation for installing the rooftop PV system was to buffer against the rising costs of grid electricity, and reduce the mall's carbon footprint.

Solar PV installations are an ideal clean energy source for shopping malls because the energy yield from solar panels closely matches the electrical consumption curve, with the bulk of electricity being used during the daytime. Furthermore there is no wastage of solar energy over weekends as shopping malls operate seven days a week.

The performance of the system to date is above expectations, and is providing a 6% higher return on investment than anticipated. With current tariffs the return on investment is around 20%, making it a financially attractive option in current circumstances. Hyprop is embarking on a third phase of the PV system, adding another 1.4MW on the parking rooftop, taking the total system capacity to 2.9MW.

Figure 22: Clearwater Mall 1.5MW of rooftop PV panels – phases 1 and 2

Photo: Solareff

Figure 23: Clearwater Mall PV system inverter bank

Photo:Solareff

Figure 24: Clearwater Mall PV arrays

Photo: Solareff

The total system comprises 29 Kaco 60TL inverters and 5922 solar panels. It is configured in 3 x 500kWp blocks, each feeding into a different mall substation. This was done to optimize the feed-in point in relation to the PV modules on the roof and inverters. While the system output is grid-synchronised and accords with the necessary safety and power quality technical standards, there is no reverse feed into the municipal grid (the feed-in substations are the mall's, not the municipality's), as the load of the mall is consistently four times greater than the solar output.

Generation Licensing and Municipal interactions

Grid-tied PV systems require municipal permission to be connected to the distribution grid (even though not reverse feeding). At the time of project inception, City Power – Joburg's municipal distributor – did not have established processes in place to handle such applications. City Power and Solareff thus worked together to clarify necessary compliance conditions and enable the project to proceed (since this time City Power has established formal procedures for such applications, as have many other municipalities). Amongst the benefits for municipal distributors of such projects is that they bring relief to network constrained areas and enables development to proceed in places where the grid may not be strong enough to meet the power needs of the new facilities.

The National Energy Regulator (NERSA) exempted the Clearwater system from electricity generation licensing requirements because the system was purely for 'own use' – i.e. no power is ever exported back onto the national grid.

Case study 2: Embedded PV on municipal buildings in Cape Town

Gallows Hill embedded solar PV and energy efficiency project: lessons

The City of Cape Town is in the process of implementing sustainable energy measures in some of its public buildings. The first of these was the Gallows Hill Traffic Department building, which has implemented smart metering, rooftop PV systems and LED lighting. There have been clear benefits in electricity consumption reduction and interesting lessons have emerged.

One of the objectives of City of Cape Town's Energy and Climate Change Action Plan (ECAP) is to reduce energy consumption by 10% in City-owned facilities. Gallows Hill Traffic Department, situated in Green Point, is one of 90 large administrative City-owned buildings. It is very visible and has a large public interface, and was therefore selected as an ideal building to implement and showcase the renewable and energy efficiency (EE) interventions to the public. The following were installed: a 10 kWp grid-tied solar photovoltaic (PV) system; a smart meter; and LED lighting technology with occupancy sensors. The PV system was funded by

Behaviour change

A further intervention, related to behavioural change, which is being rolled out in City buildings is the Smart Living workshop and campaign series. This campaign aims to create awareness around resource conservation and provides information and energy saving tips that can easily be implemented at home and in the workplace. The campaign is based on the Smart Living Handbook produced by the City and showcases both low cost and high cost technologies and interventions that can be used to reduce energy, waste and water and to conserve and protect the environment. The Energy and Climate Change Unit also invites facility and building managers to participate in an accredited Fundamental Energy Management training course, where key technical methods of optimising energy savings are showcased in practical teachings and assignments.

the City, while the energy efficient lighting and smart metering projects were funded by the Division of Revenue Act (DoRA) through the national Energy Efficiency Demand Side Management (EEDSM) programme.

The Energy and Climate Change Unit of the Environmental Resource Management Department implemented the interventions in a three phase approach. In the realms of energy management there is a saying: "If you can't measure it, you can't manage it"; therefore the City has implemented a phased city-wide project to install smart Advanced Meter Readers (AMRs) into City operations and facilities to record and monitor consumption of electricity over time. Gallows Hill's electricity consumption is being monitored through the City's online metering system, so data can be accessed at any point in time. The historical data is stored and the amount of electricity consumed can be monitored before and after interventions have been implemented. In this way, the true savings of the interventions can be calculated.

In March 2014, the City installed a 10kWp solar system on the roof of the building through a tender process. The system consists of 42 photovoltaic panels, which feed into a grid-synchronising inverter which interfaces with the normal electricity grid power. The annual generation is around 11 900 kWh, allowing the building to provide 2% of its energy from rooftop PV.

The third intervention to be implemented throughout the building, during the 2014/15 financial year, is a complete energy efficient lighting retrofit which replaced all the existing lighting in the building with light emitting diodes (LEDs). LED lights use up to 10 times less power for the same light output and last 25 times longer than inefficient incandescent bulbs.

Figure 24: The PV array on the Gallows Hill roof

Source: City of Cape Town

Solar PV challenges and lessons

The Energy and Climate Change Unit encountered a few challenges implementing the solar PV project:

- *The main lessons learnt were around procurement – using the relatively demanding FIDIC contracting for the first time, and developing a process in Supply Chain Management framework for contracting PV systems:*
    - *Developing the Request for Quotes for the installation of the 10kWp PV project triggered Supply Chain Management to tread cautiously, as this was the first time PV had been installed and processes for this were not in place. The Unit was encouraged to use the FIDIC (International Federation of Consulting Engineers) form of contracting, which is a more complex form of contracting for construction projects and ensures that the project meets all health and safety laws.*
    - *Developing a sound tender specification was also important, and assistance from an external expert was sought in this regard.*
    - *A structural engineer should be sought to sign off on the roof loading prior to any procurement taking place.*
    - *Waterproofing needs careful attention in the specifications and guarantees provided.*
- *Pr Eng are not necessarily the correct people to sign off on PV system commissioning, as they often are new to these technologies.*
- *Due to budget constraints it was decided to procure the system first and then undergo installation separately, which resulted in the cost of the entire system amounting to more than was budgeted for.*
- *Other important lessons include the need for engagement with the Electricity Department to get clarity on guidelines for Small Scale Embedded Generation (SSEG) applications – such processes were still relatively new in the City and were reasonably demanding to comply with.*
- *It is also important to understand the IT Department's requirements to ensure that they could access the data from the PV system, and thus allow system performance and diagnostic data to be on the City's intranet to alert staff regarding faults.*
- *Training of building staff to maintain the PV system was also necessary.*

Overview of Cape Town's 'own building' solar PV projects

Since the first investigations in embedded generation, a variety of Cape Town City departments have pioneered PV rooftop installation. These are relatively small installations to date and are electricity consumption offsets rather than generation projects. However, they provide important opportunities to demonstrate leadership by the City in terms of embedded, distributed energy service development, as well as to develop skills amongst municipal staff in relation to new forms of energy provision.

Table 7: Information on early 'own building' embedded generation projects in Cape Town

	Gallows Hill	**Royal Ascot**	**OmniForum**
ENERGY EFFICIENCY			
Energy Efficiency implemented prior to PV installation	LED lighting and occupancy sensors	LED lighting and occupancy sensors	LED lighting and occupancy sensors
EE demand reduction impact	20%	32%	33%
EE financial savings per year	R 142 797	R 119 933	R 142 706
EMBEDDED SOLAR PV			
Process duration (investigation to commissioning	March 2013 – March 2015	June 2013 – June 2015	June 2013 – August 2015
Roof mounting method	Bolted on flat concrete roof (sealed waterproofing)	Bolted to concrete slabs on flat roof (no waterproofing required)	Clasped tp corrugated roof sheet with 'SolarRoof Longline Interface' type clasp
Roof area	126m2	183m2	775m2
PV kWp installed	10 kWp	20 kWp	60 kWp
% of total demand met by PV	2%	7%	20%
Total cost of system	R 276 294	R 1 713 762 (2 systems on one tender)	
R / kWp installed	R 27 600 / kWp	R 21 400 / kWp	
kWh savings per year	11 921 kWh/yr	22 976 kWh/yr	61 346 kWh/yr
Financial savings per year	R 14 306	R 27 571	R 73 615

Table 8: City of Cape Town installation of rooftop PV on own buildings and facilities to date

Installed to date	**Size (kWp)**	**Grid tied**	**Commissioned**
Manenberg Housing Contact Centre	20	Yes	2012/13
Electricity Services Department building	100	Yes	2014
Gallows Hill	10	Yes	2015
Wallacedene taxi rank	20	No	2014
Khayelitsha Environmental Health Centre	17	Yes	2014
Royal Ascot	20	Yes	2015
Omni Forum	60	Yes	2015
Civic Centre (in process)	10	Yes	2017
Total	**257**		

Support organisations & resources

Resources

- AMEU standard documents: available at www.cityenergy.org.za – Electricity Services/SSEG section
- GreenCape municipal support documents: available at www.greencape.co.za
- A range of resources to support municipalities with SSEG processes are available at www.cityenergy.org.za
- Solar radiation map by the CSIR: http://www.aaamsa.co.za/images/Matrix/2015/TIASA/Annual%20Solar%20Radiation%20Map%20as%20provided%20by%20the%20CSIR.pdf
- Durban Solar map (interactive solar feasibility assessment map): http://gis.durban.gov.za/solarmapviewer/
- SAPVIA (South African Photovoltaic Industries Association) is involved with SSEG training and installer accreditation: www.sapvia.co.z
- SALGA (South African Local Government Association): www.salga.org.za
- South African – German Energy Programme (SAGEN)

The information below represents the best level of information on the uptake of SSEG processes and tariffs by August 2016. The sector is rapidly evolving and this information may easily become out-dated.

1. Overview per province

Province	Keeping track of existing installations	Official application system	Approved SSEG tariffs	Number of installations	kWp installed	Average size (in kWp)
Eastern Cape	2	2	1	191	1,454	8
Gauteng	4	2	1	77	24,813	322
KZN	1	1	1	18*	70*	4
Limpopo	2	0	0	3	265	88
Western Cape	14	12	9	322*	9,787*	30
North West	1	0	0	10*	2,000*	200
Mpumalanga	0	0	0	-	-	
Northern Cape	1	0	0	4	183	46
Free State	1	1	0	5	1,075	215
TOTAL (Aug 2016)	**25**	**18**	**12**	**621**	**38,389**	**62**
PAST DATA to track progress						
TOTAL (Aug 2016)	23	16	12	495	17,029	34
TOTAL (Feb 2016)	10	3	5	264	9,044	34

2. List of municipalities active on SSEG

Province	Municipality	Keeps list of installations	Approved SSEG application process	Allows feed back into the grid?	Status of SSEG tariffs	Website / Contacts
Eastern Cape	Nelson Mandela Bay	Yes	Yes	Yes	Approved and operational	[illegible]
Eastern Cape	Buffalo City	Yes	Yes		No SSEG tariffs	
Free State	Mangaung	Yes	Yes	No	Under development	
Gauteng	City of Johannesburg	Yes	Yes	Yes	Approved and being rolled out	distributedgeneration@citypower.co.za
Gauteng	City of Tshwane	Yes	Under development	No	No SSEG tariffs	
Gauteng	Ekurhuleni Metro	Yes	Yes	No	No SSEG tariffs	
Gauteng	Midvaal	Yes	No	No	No SSEG tariffs	
KwaZulu Natal	eThekwini	Yes	Yes	Yes	Approved and being rolled out	http://pv.shisasolar.org.za/
Limpopo	Ephraim Mogale	Yes	No	Yes (pilots)	Under development	
Limpopo	Polokwane	Yes	No	No	No SSEG tariffs	
Northern Cape	//Khara Hais	Yes	No	No	No SSEG tariffs	
North West	Tlokwe	Yes	No	No	No SSEG tariffs	
Western Cape	Beaufort West	Yes	Yes	Yes	Approved and operational	
Western Cape	Bergrivier	Yes	Under development	Yes	No SSEG tariffs	
Western Cape	Breede Valley	Yes	Yes	Yes	No SSEG tariffs	
Western Cape	Drakenstein	Yes	Yes	Yes	Approved and operational	
Western Cape	George	Yes	Yes	Yes	Approved and operational	
Western Cape	Langeberg	Yes	Yes	Yes without compensation	No SSEG tariffs	
Western Cape	Mossel Bay	Yes	Yes	Yes	Approved and being rolled out	
Western Cape	Oudtshoorn	Yes	Under development	Yes	Under development	
Western Cape	Overstrand		Yes	Yes	Approved and being rolled out	
Western Cape	Stellenbosch	Yes	Yes	Yes	Approved and being rolled out	
Western Cape	City of Cape Town	Yes	Yes	Yes	Approved and operational	https://www.capetown.gov.za/en/cityforms/Pages/default.aspx http://savingelectricity.org.za/pages/pv_and_renewables.php
Western Cape	Saldanha Bay	Yes	Yes	No	Under development	
Western Cape	Theewaterskloof	Yes	yes	Yes	Approved and being rolled out	
Western Cape	Swartland	Yes	Yes	Yes	Approved and operational	

Small-scale and conduit hydropower

Overview

Small-scale hydropower refers to any hydropower plant smaller than 10 MW, while conduit hydropower refers to generation of electricity by placing a turbine within a man-made conduit, such as water pipes or canals. The turbine converts the mechanical energy of the pressurised water into electrical energy. The potential for conduit hydropower electricity generation exists wherever there is high water pressure due to pumping or gravity. Site examples would include:

- where dam water is released into bulk water supply lines,
- water treatment works where the inlet water source pipeline can be tapped,
- water reservoir inlets where pressure-reducing stations are used,
- water distribution networks, and
- treated effluent discharge points

Head: The vertical difference in height between the pipeline intake and the water turbine. The greater the difference, the greater the water pressure.

Conduit hydropower falls within the range of pico- to small-scale projects. As such, they may not contribute substantially to the national grid, but can contribute a significant amount towards a specific site's local electricity demand. For example, conduit a hydropower project at a wastewater treatment plant would contribute towards the electricity requirements of that plant.

Table 1: Classification of hydropower size

Category	Capacity
Pico	< 20 kW
Micro	20 – 100 kW
Mini	100 kW – 1 MW
Small	1 – 10 MW
Macro / Large	> 10 MW

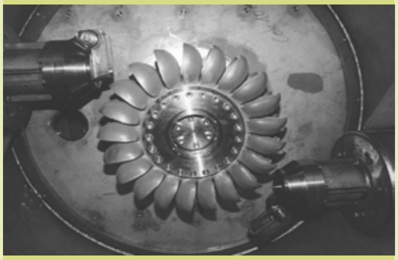
When considering a hydropower project, there are four important factors that will determine project costs and electricity generation potential:

1. Head
2. Flow
3. Penstock (pipeline) length
4. Electricity transmission line length

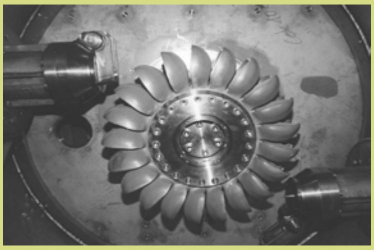
Hydropower projects are classified according to head: high (>100m), medium (30-100m) and low (<30m). In projects with a high head, penstock (pipeline) costs dominate, due to the length of the pipe. In projects with a low head, turbine costs dominate, due to larger volumes of water at high pressure.

Figure1: Main turbine types

***Impulse**: Converts kinetic (movement) energy into mechanical energy. Examples: Pelton, Turgo and cross-flow turbines.*



***Reaction**: Converts pressure energy to mechanical energy. Examples: Francis, Kaplan and propeller turbines.*



Source: Culwick & Bode (2011) City of Cape Town mini hydro feasibility design.

In contrast to conduit hydropower, **large hydropower** projects are usually **not considered as a renewable source**, due to the negative socio-economic and environmental consequences of the building of a large dam, e.g. displacement of people, loss of agricultural land, etc.

A South African scoping study (Van Vuuren et al., 2013[1]) indicated that there is significant potential for low-head hydropower in urban systems (e.g. water distribution networks), irrigations schemes and rivers (e.g. small dams and weirs).

There are multiple benefits of small-scale and conduit hydropower:

- It is considered a renewable resource.
- It is installed within existing man-made infrastructure, which means that only a basic environmental assessment is required rather than a full environmental impact assessment; and water licencing is not required, because there is already existing lawful use.
- In the case where it only generates for "own use" (e.g. electricity generated by a turbine at a wastewater treatment plant is only used in the running of that treatment plant), there are no NERSA[2] licencing requirements.
- Project payback times are relatively short, mainly due to the minimal civil works required when compared to a large hydropower projects, as well as low operation and maintenance costs, and the rising cost of conventional electricity.
- If installed in parallel to existing pressure control valves, hydro turbines can extend the operational life of these pressure control valves due to their reduced use.
- It is a proven technology with high efficiencies and a long lifespan – the standard is 20 years.

Implementation

Feasibility

Each potential hydropower site is unique, since about 75% of the development cost is determined by the location and site conditions. Only about 25% of the cost is relatively fixed, being the cost of manufacturing the electromechanical equipment. This highlights the importance of a prefeasibility study. Based on the recommendations of a prefeasibility report, a project developer may choose to undertake a full feasibility report.

A prefeasibility report will cover:

- Site description and data (e.g. flow rates)
- Design concept
- Modelled design results (e.g. plant output)
- Grid connections details (location, cost, line length, etc.)
- Infrastructure costs

1 Van Vuuren, Loots, Van Dijk & Barta (2013) Scoping study: Energy generation using low head hydro technologies, WRC Report no KV 323/1.

2 National Energy Regulator of South Africa

- Financial modelling (based on capital and operational expenditure, funding, interest, energy produced, etc.)
- Conclusions and recommendations (e.g. recommendation of sites / aspects to be investigated in a feasibility report)

Costs and contracting

The major cost components in a hydropower project are:

1. Civil, e.g. earthworks, water conveyance infrastructure, power house construction.
2. Mechanical and electrical, e.g. turbine and generator.
3. Electrical, e.g. grid connection and grid infrastructure.

Usually a construction contract is required for each of the above components, with the balance of the plant contract held with the civil contractor.

In cases where the conduit hydro technology is installed in municipal infrastructure, the generation of electricity can be carried out by a Public Private Partnership in which the municipality will own the generators, but the cost of all other equipment and the costs of operation and maintenance will be borne by a private sector partner.

Financing

Due to the very low profile of conduit hydropower development in South Africa over the last two decades, there are no defined approaches and methods for financing of these types of projects.

The easiest methods of financing are balance sheet or corporate financing, but this would require sufficient up-front funds, which is often not the case. Limited-recourse financing is an option if a project owner does not have adequate funds, or assets to provide security for a bank loan, and the project developer does not want to shoulder all the risk. It takes the form of securing a loan against an anticipated cash flow (i.e. the sale of electricity produced by the hydropower plant or the anticipated savings realised by not having to use grid electricity). This requires complex, contractual agreements, which can be expensive.

In the case of limited-recourse financing, the lender would wish to exercise tight control over the project, including contracting and insurance, amongst others. They would require an independent technical report of the project; will check any power purchase agreements (PPAs), operating and shareholder agreements; and would prefer contractors with a good track record. Risk can be reduced by using a contractor working on a turnkey fixed-price basis or signing long-term PPAs with secure off-takers. Lenders may step in to operate the project, if it is not paying its debts.

As a result of the capital-intensive nature of conduit hydropower projects, the debt-equity ratio and interest rate are very important considerations.

Useful tool

RETScreen International Clean Energy Project Analysis Software is a tool specifically aimed at facilitating pre-feasibility and feasibility analysis of clean energy technologies, including conduit hydropower. It reduces the time and cost associated with preparing pre-feasibility studies.

Risks and solutions

Risk	Solution / best practice
Water supply disruption during installation and / or disruption of water / wastewater treatment works operations.	The turbine must be flexible (large operating ranges), so as not to impact the water / wastewater plant.
	A bypass may be required to guarantee the functioning of the plant while the turbine is being installed and when the turbine is not working (e.g. when it is down for maintenance).
	The generation of electricity must never take precedence over the supply of water and must not negatively influence the cost of water to the ratepayers.
Water contamination.	Consider the corrosion and abrasive behaviour of materials used in the turbine. All parts that are in contact with the water should be stainless steel. Actuators should be electronic, rather than oil.
Potential legal and contractual repercussions when the water conduit operations are changed in the case where the hydro plant is owned by a separate entity, e.g. in the case where a private entity is the owner of the hydropower plant, they may lose out on electricity sales revenue if the city changes the operations / management of its water treatment plant.	This can be mitigated by compensation clauses in the contracts or avoided altogether if the municipality (rather than a third party) is the full owner of the conduit hydropower plant.

Case study 1: City of Cape Town

The potable water supply to the Cape Town metro area occurs principally through gravity mains. The kinetic and potential energy of the water is harnessed by four conduit hydropower sites, some of which were installed as early as the 1950s. Five percent of the City's internal operations' electricity demand is met through conduit hydropower at its bulk water treatment plants. The conduit hydropower turbines at both the Faure and Blackheath water treatment plants were designed to meet the entire plants' electricity demand. The hydropower reduces the cost of potable water supply.

Table 2: Micro-hydro electricity generation by the City of Cape Town, 2012

Location	Type	Turbine capacity (kW)	Total turbine production / annum (kWh)
Wemmershoek water treatment plant	2 x Francis	130 x 2	2,163,720
Blackheath water treatment plant	1 x Turgo	712	5,825,400
Faure water treatment plant	1 x Turgo	1,475	12,274,950
Steenbras water treatment plant	2 x Turgo	179 x 2	2,829,480
Total		**2,775**	**23,093,550**

Source: City of Cape Town, 2012

The technical and financial feasibility of additional conduit hydropower sites in Cape Town was assessed in 2011 (Culwick, L. & Bode, C., 2011[3]). The report indicated a total electricity generation potential of 35 GWh per annum at an average levelised cost of 0.38 R/kWh.

Case study 2: EThekwini Metropolitan Municipality

Durban's steep topography and resultant high water pressure in its water distribution system provide ideal opportunities for conduit hydropower. The water pressure has to be dissipated at reservoir inlets through the use of pressure control / reducing valves to avoid damage to pipe inlets. A conduit hydropower system, installed in parallel to the pressure control valves, will assist in pressure dissipation; extending the life of the valves, as they would only be in use when the turbine is not operational.

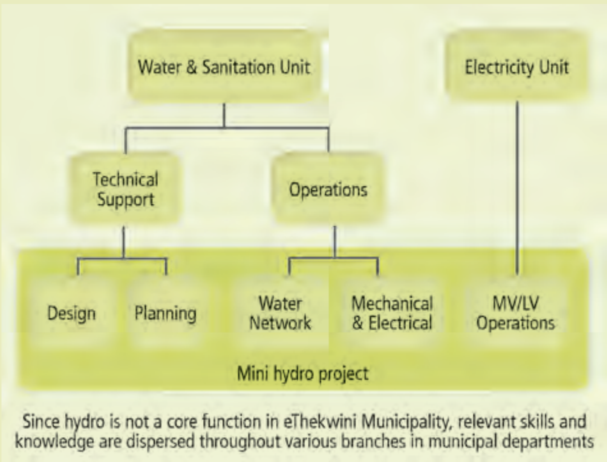
EThekwini Municipality undertook a scoping exercise to locate suitable pressure control valves and break pressure tank locations for turbines, after which an invitation to tender was sent out for the feasibility, design and installation of conduit hydropower turbines.

3 Culwick & Bode (2011) City of Cape Town mini hydro prefeasibility design: A techno-economic assessment of the potential for the development of hydroelectric plants at eight sites in the CCT Bulk Water System.

Table 3: EThekwini conduit hydropower generation potential

Name of reservoir	Size of hydro turbine (kW)
Theomore reservoir	71
Stone Bridge Drive reservoir	104
Umhlanga Rocks reservoir	Between 26 and 177
Yellowfin and Escolar reservoir	Between 26 and 177
Avocado and Pomegranate reservoir	Between 26 and 177

Figure 2: Organogram of the eThekwini Municipality's hydro team



It is envisaged that the electricity generated would contribute towards the reservoirs' electricity needs, with the remainder exported to the municipal grid. Initial indications are an expected payback of 14-15 years, with a 5.7% return over 20 years.

Given that conduit hydropower is not a core function of the City, a team was put together drawing on staff from all relevant departments across the water and sanitation and electricity units.

Case study 3: KwaMadiba, Mhlontlo Local Municipality

The Department of Science and Technology (DST) launched an initiative called the Innovation Partnership for Rural Development Programme (IPRD); aimed at value-addition to 23 district municipalities targeted by the national Department of Rural Development and Land Reform in response to the government's action plan for scaling up rural development programmes, including investment in rural areas.

The DST appointed the Water Research Commission (WRC) to showcase and test a suite of water, sanitation, micro-hydroelectric power and smart geyser technology solutions at municipal demonstration sites.

The WRC contracted the Water Division of the Civil Engineering Department of the Faculty of Engineering, Built Environment and Information Technology of the University of Pretoria to conduct research within the IPRD Programme on "Building Capacity for the Implementation of Small-Scale Hydropower Development for Rural Electrification in South Africa".

From this research the KwaMadiba small-scale hydropower plant was developed. It is a small-scale run-of-river hydropower scheme that will supply a constant electricity supply to the KwaMadiba community. The launch date was April 2017.

Table 4: Entities involved in the KwaMadiba conduit hydropower plant

Developer / funder	The Department of Science and Technology and the Water Research Commission
Designer	Water Division, Civil Engineering Department, University of Pretoria
Owner	Mhlontlo Local Municipality

Table 5: KwaMadiba conduit hydropower plant specifications

Technical	
Design flow rate	150 lit/s
Design head	48.8 m
Design power output	50.0 kW
Head race length	42 m
Penstock length	116 m
Transmission line length	1140 m
Number of household connections	51
Socio-economic	
Total cost	R 4,920,000
Internal Rate of Return (IRR)	9.7%
Levelised cost of energy	102.58 c/kWh
Households benefited	51
Persons actively involved on the project	76
Temporary employment opportunities created	32
Building material locally sourced	80%

Figure 3: KwaMadiba containerised turbine unit placed at the end of the penstock

Source: Van Dijk (2016) KwaMadiba small-scale hydropower plant (Unpublished).

Figure 4: Drilling the penstock opening

Source: Van Dijk (2016) KwaMadiba small-scale hydropower plant. Unpublished.

Challenges and lessons learnt

There were numerous stakeholders and entities on the project; posing challenges in communication, approvals and time schedules. Clear channels of communication among stakeholders need to be agreed upon from the inception phase.

The site terrain was extremely difficult for construction and there were construction access challenges at the site.

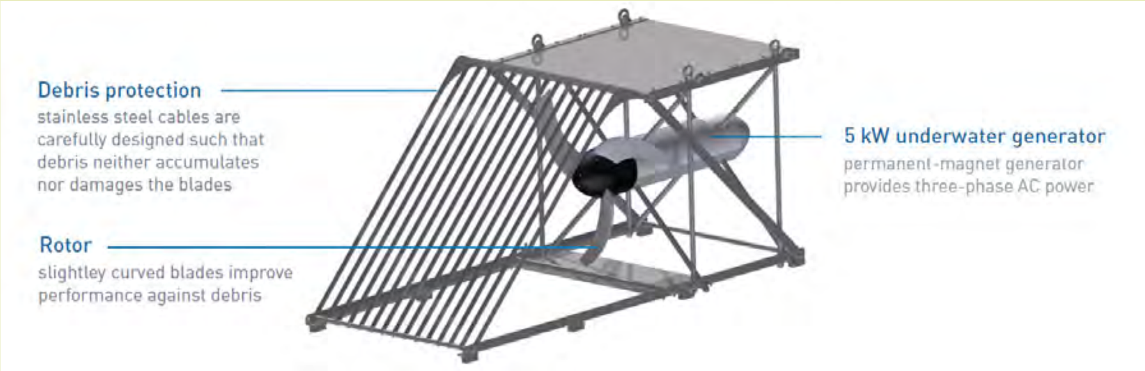
Case study 4: Boegoeberg, !Kheis Local Municipality

The Department of Science and Technology (DST) funded the University of Pretoria to develop a kinetic hydropower installation in !Kheis Municipality (ZF Mgwawu District, Northern Cape), as part of the second phase of the DST's Innovation Partnership for Rural Development Programme. The Boegoeberg irrigation canal proved a good fit for this pilot project, as existing infrastructure could be used to add value to the municipality in terms of energy production.

Table 6: Entities involved in the !Kheis conduit hydropower plant

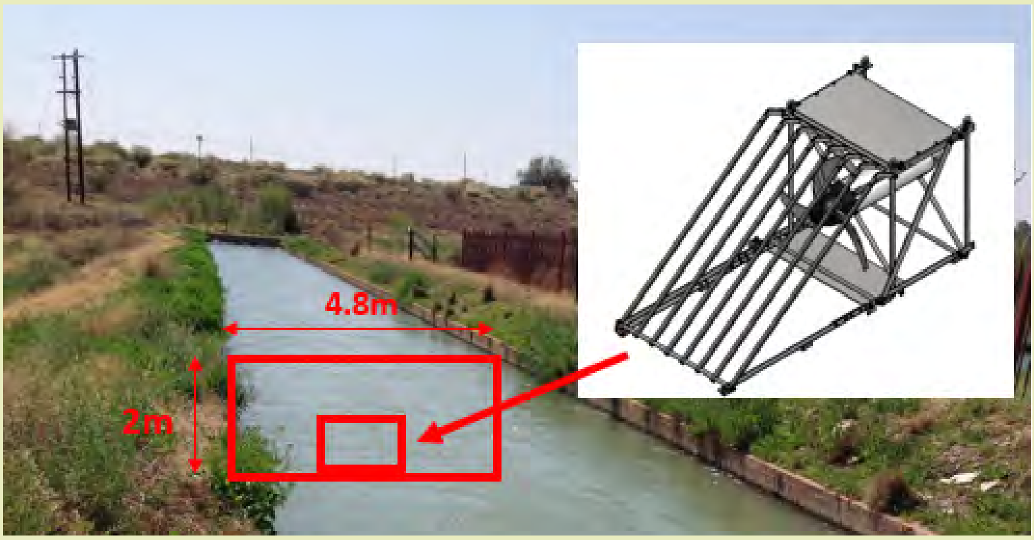
Developer / funding	The Department of Science and Technology and the Water Research Commission
Designer	Water Division, Civil Engineering Department, University of Pretoria
Owner	!Kheis Local Municipality

Figure 5: Turbine used in !Kheis Boegoeberg canal conduit hydropower project



Source: Van Dijk (2016) !Kheis small-scale kinetic hydropower plant (Unpublished).

Figure 6: Placement of hydropower turbine in Boegoeberg irrigation canal



Source: Van Dijk (2016) !Kheis small-scale kinetic hydropower plant (Unpublished).

The electricity produced will be used to power a part of the Groblershoop water treatment works, thus decreasing electricity costs for the municipality. The project will be completed and connected in May 2017. This pilot project falls in line with the newly gazetted draft policy on sustainable hydropower generation by the national Department of Water and Sanitation.

Table 7: !Kheis conduit hydropower plant specifications

Technical	
Design flow rate	11.5 m3/s
Design flow velocity	2.6 m/s
Generating capacity per unit	4 kW
Total transmission length	650 m
Total number of turbines	7
Total energy generation	28 kW
Economic	
Total Cost	R 2,184,000
Internal Rate of Return (IRR)	12.13%
Levelised Cost of Energy	84.8 c/kWh
Annual generation potential	218,500 kWh/a

Figure 7: Flow measurements at the !Kheis Boegoeberg canal

Source: Van Dijk (2016) !Kheis small-scale kinetic hydropower plant (Unpublished).

Challenges and lessons learnt

- Receiving approval from stakeholders and entities slowed the project significantly.
- The importing costs were high, as products were not available in South Africa.
- Implementation is fairly straightforward, but legislative procedures and bylaws (and the incurred costs and time thereof), may create a challenge to small-scale project feasibility.
- Major issues included the prevention of theft and the prevention of possible injuries to children swimming in the canal section.
- The support from the !Kheis Municipality was essential for the success of the project.

Household energy access

Overview

South Africa has done remarkable work since 1994 to ensure that all households, from the wealthiest to the poorest, have access to modern energy. Its universal access goal for all households by 2025 is to achieve 97% grid access plus 3% solar home systems. The intention of the South African government to electrify all South African households is to ensure that everyone's basic energy needs are met and to further ensure economic growth and social development in the country. For the poor and vulnerable, access to clean, reliable and affordable modern energy is essential for:

- Income generation possibilities.
- Improved human welfare well-being.
- Building resilience to the impacts of extreme weather events such as heat waves, cold and decreases the household's dependency on natural resources such as firewood which will become unreliable.

Table 1: Access to electricity in South Africa

	Population without electricity (millions)	National electrification rate (%)	Urban electrification rate (%)	Rural electrification rate (%)
South Africa	8	85%	88%	82%

Source: International Energy Agency (IEA) (2014) Africa Energy Outlook Special Report, OECD/IEA, Paris.

For women and children access to electricity has a significant impact to their lives. For example, having access to electricity allows women and children to have lighting at night which allows women to work into the night and/or socialise allowing flexibility. While for children (of which there are more females) in particular are able to benefit as electrical lighting allows them read and do homework at night. Additionally, access to electricity results in significant time and labour savings for women with regard to cooking, water heating and ironing due to the greater convenience, cleanliness and speed of electrical appliances (compared to paraffin) (Thom, C. and Mohlakoana, N. 2000[1] ; Goldenberg et al., 2004[2]).

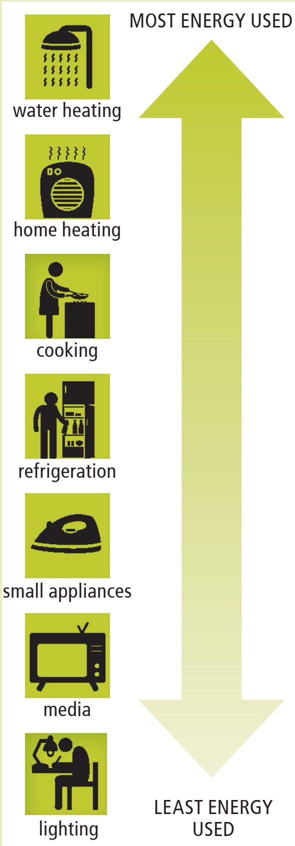
At the household level, energy is used for the following services notably cooking, lighting, water and space heating, and powering media appliances. In the South African context since the national electrification programme, many households use electricity to fulfil these energy services. However, many South African households also use other fuels such as gas, paraffin, wood, coal and candles among other fuels. The table on the next page illustrates how fuel use patterns differ according to the economic status of households.

Figure 1: Women and children are the primary users of energy at home

1 Thom & Mohlakoana (2000) The use and impact of electricity in Garagopola-Legabeng. EDRC, University of Cape Town.

2 Goldenberg et al. (2004) World Energy Assessment. New York, NY : United Nations Development Programme, Bureau for Development Policy.

Figure 2: Household appliances and their use of energy



Source: Ward, (2008) The new energy book for urban development in South Africa, Sustainable Energy Africa, Cape Town, South Africa.

Table 2: Typical energy use patterns for different kinds of households in South Africa

	High – mid income households with electricity	Low income households with electricity (formal & informal)	Low income households without electricity
Lighting	Use electric lightbulbs e.g. incandescent, LED	Use electric lightbulbs – low penetration of energy efficient lightbulbs, paraffin lamp or candles	Use candles, paraffin lamps
Cooking	Mostly use electrical appliances; hot plates, microwaves, ovens. A small percentage use gas cook stoves.	Combine electric appliances with paraffin, gas, wood and coal appliances	Mostly use paraffin and wood appliances with coal, gas sometimes used when available
Water heating	Mostly either use electric or solar water geysers	With installation of SWH these are used or they use electric stoves or kettles	Generally use cooking stoves for heating water
Space heating	Most households have ceilings but also use either electrical or gas heaters	Generally use electrical appliances or they use paraffin heaters or coal/wood mbawula	Generally they do not use anything any fuels otherwise they use paraffin stoves/ heaters, wood/ coal mbawula

The South African national government has been providing qualifying households (households with a monthly income of R0 – R3500) with state subsidised housing since 1994. This was to ensure that everyone has adequate housing and to improve the lives of vulnerable communities. However, one of the key challenges with the state housing was that it did not have insulated ceilings and weather proofing. This meant that houses have fluctuating temperatures between seasons i.e. hot in summer and cold in winter which makes the home uncomfortable to live in for the residents. Also homes without ceilings increase the occurrence of condensation which is conducive to respiratory illnesses for the household residents. 20 years later, in 2014, the Department of Human Settlements (DHS) improved the national norms and standards for the construction of stand-alone residential dwellings to current low cost housing in an effort to improve the quality of low cost houses built by government. The new norms and standards include installation of ceilings in low cost households, as well as plastering of all internal walls of the homes to ensure that the household is energy efficient through improved thermal performance. The new additions to the low cost houses will increased the budget for household from R64 000 to R110 947.00.

Barriers to household energy

Although the government has done an impressive job of electrifying households, there is still a backlog. This is mostly in rural households and informal settlements due to distributor grid limitations and/or the households, particularly informal settlements, which are located on privately owned land or unproclaimed land. Furthermore, the rate of urbanisation (1.2%pa) in the country has also led to a growth in informal housing at a faster rate than the government can electrify households.

While the government has had challenges in electrifying some households, there are also other challenges where electrified households are not utilising electricity to fulfil their energy needs. Below are some reasons:

- Poor households still cannot afford electricity for the entire month.
- Poor households often experience irregular and erratic sources of cash flows, giving rise to expenditure patterns that do not allow for large amounts of income to be spent on energy such as paying an electricity bill at the end of the month or buying a large quantity of fuel for the month. Thus energy is procured in small amounts (e.g. a bucket of coal, a litre of paraffin, or a prepaid electricity card for the minimum amount of R10), enabling the household to spend smaller amounts at a time, given their available income.

This results in households resorting to other forms of energy such as wood, candles, paraffin, etc. (which are sometimes perceived to be cheaper because they can be bought in smaller quantities than electricity) when they cannot afford to buy electricity.

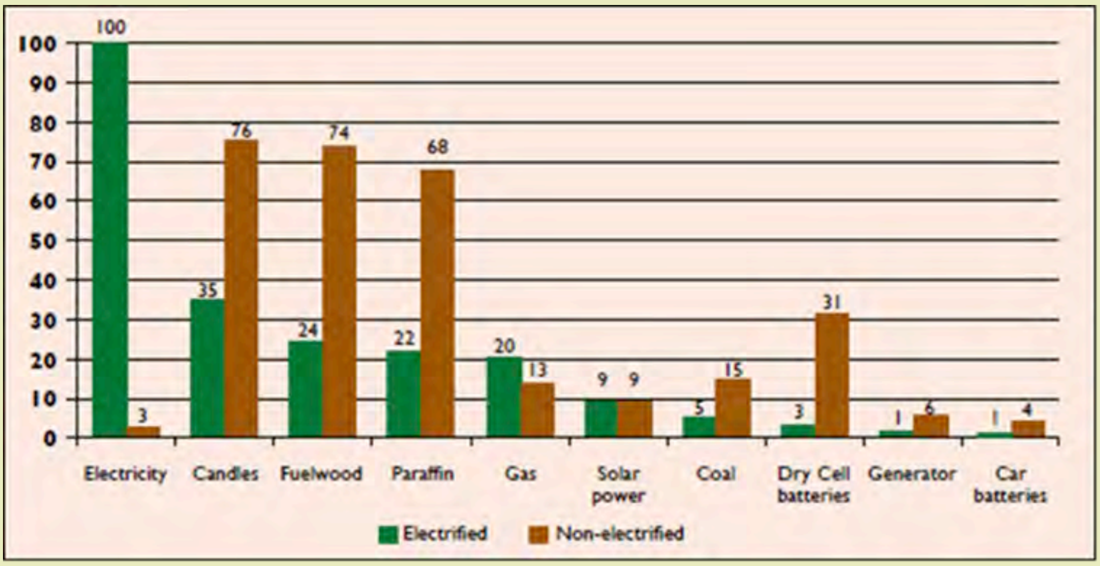
Figure 3: Examples of open fires using coal and wood used for heating purposes

Photo: Bablu Virinder-Singh

Figure 4: Examples of open fires using coal and wood used for cooking purposes

Photo: Bablu Virinder-Singh

Figure 5: Multiple fuels used by electrified and unelectrified poor households in South Africa (%)



Source: Department of Energy (DoE). (2013). A survey of energy-related behaviour and perceptions in South Africa, The Residential Sector, Pretoria.

The use of firewood and paraffin for cooking and lighting respectively, are generally not cost efficient compared to using modern fuels for the same end uses (Barnes et al., 2005[3]). As a result poor households tend to spend a higher proportion of their income on energy services than those households with more resources. Close to 50% of households in South Africa use electricity in combination with other fuels such as firewood, paraffin and gas for cooking (DoE, 2012[4]). These fuels however are associated with indoor air pollution arising from the combustion and severe health implications which are particularly detrimental for women and children, who spend the largest amount of time around chimneyless cooking fires and in poorly ventilated spaces.

Source: Tackling Urban Energy Poverty in South Africa (SEA, 2014)

What is energy poverty?

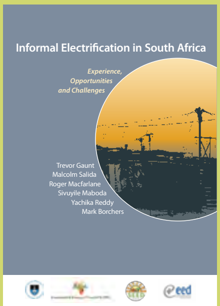
Multiple fuel use by households is an indication of energy poverty. This is because the type of fuels that are used are unsafe and unhealthy. Energy poverty is particularly prevalent in informal settlements and includes those households living in backyard shacks. This informal sector largely falls through the cracks of municipal service provision and nationally allocated poverty alleviation subsidies. Services and associated subsidies predominantly cover a formal house and/or formal plot of land. Poor households are burdened with relatively high energy costs, often in excess of 10%1 of their income compared to wealthier households, who typically spend 2-3%. This energy expenditure approach to define energy poor households is common in the United Kingdom. Households exceeding this 10% threshold are often considered to be confronted with difficult choices between meeting basic energy needs and satisfying other competing household spending priorities. On average South Africans spend 14% of their total monthly household income on energy needs (DoE, 20122). However, there is a strong gradient based on income levels with the poorest quintile spending about four times as much on energy, than those with higher living standards (27% of monthly income as compared with 6% for richer households). If this 'energy poverty' definition is applied, then close to 47% of South African households are classified as energy poor as confirmed by the Department of Energy 2012 survey on energy related behaviour.

Close to 50% of households in South Africa use electricity in combination with other fuels such as firewood, paraffin and gas for cooking

3 Barnes, et al. (2005) The urban household energy transition – social and environmental impacts in the developing world. Washington DC: Resources for the Future.

4 Department of Energy. (2012) A survey of energy-related behaviour and perceptions in South: The Residential Sector.

Informal electrification



Source: Informal Electrification in South African cities: Experiences, opportunities and challenges (SEA, 2012).

When the national government first decided to electrify all households, this only involved formal and excluded informal. This meant that informal settlements did not benefit from the social programme of Free Basic Electricity. This decision was based on the fact that informal settlements are typically considered temporary housing by government and are not recognised as permanent features of the urban landscape. However, cities like Cape Town realised the burden informal settlements have to face without electricity. They were thus one of the pioneers in electrifying informal settlements. This led to national government developing national guidelines for informal electrification that will ensure that government will be able to reach universal access to everyone. In addition, informal settlements are the fastest growing household sector in South Africa and formal housing programmes have not been able to keep up, often resulting in alarming informal household growth rates in cities. At least 10% of South Africa's population live in urban informal settlements – i.e. over 4.4 million people or 1.2 million households, although these figures are difficult to establish with any certainty and are likely to be higher in reality. Informal household figures quoted by the larger metropolitan municipalities commonly indicate over 300 000 households or more in each city.

Today informal settlements are recognised in official documents such as the "Policy Guidelines for the Electrification of Unproclaimed Areas" as a long-term feature of the South African landscape. They are now explicitly included in the Integrated National Electrification Programme, which intended to meet a national target of 92% access by 2014. Traditionally, the Integrated National Electrification Programme (INEP) focused only on electrifying formal housing in rural and urban areas. However, due to the growing trend in the increasing informal settlements and the Constitutional right of all citizens to basic services, the Department of Energy is obliged to ensure electrification of informal settlements as well. In line with the White Paper on Energy Paper (1998), Government supports the electrification of residential and unproclaimed areas. (Policy Guidelines for the Electrification of Unproclaimed Areas – DoE 20 Jan 2011 rev6, p3)

Figure 6: The structures of informal settlements

Photo: Trevor Gaunt

Photo: Bablu Virinder- Singh

Source: Gaunt. et al. (2012) Informal Electrification in South African cities: Experiences, opportunities and challenges

Figure 7: Cape Town's informal settlement electrification at Nyanga

Photo: Trevor Gaunt

Photo: Mark Lewis

Implementation

Local government in South Africa is centrally organised to achieve the objective of progressive service delivery (Constitution of RSA, Chapter 7, 152. (b)). The developmental mandate of local government requires it to prioritise the needs of the poor and participate in national development programs.

The first Priority Objective of national White Paper on Energy (1998) is that of access to affordable energy services. This is further discussed within the demand sector of Households where it is articulated that government will have to consider:

- Appropriate appliance/fuel combinations.
- Pricing and affordability.
- That grid electricity may not meet all the needs of households.
- The opportunity of thermal efficient low cost housing.

The major programmes of energy access coming out of this policy direction include the Integrated National Electrification Programme (INEP) and the Free Basic Electricity (FBE) and Free Basic Alternative Energy (FBAE) Programmes. INEP aims to address physical access to modern, clean energy and intends to reach 100% of households; while FBE and FBAE address affordability, providing a basic amount of energy 'free' to poor households. As it has become clear that the 100% access to grid electricity target is unlikely to be reached, the alternative energy subsidy was brought in. See National policies overview about all the pro poor policies that have been put in place.

Figure 7: Joe Slovo housing

Photo: Bablu Virinder- Singh

NATIONAL POLICIES OVERVIEW

National pro-poor energy policies

In recognition that many households earn below a certain income bracket and unable to afford electricity cost. The South African government has put in place a number of pro-poor policies specifically targeted at energy which began with the adoption of the White Paper on Energy Policy in 1998. The policy paper provided guidelines on how the country was to increase energy security for all through affordable energy sources, improved governance and a better economy. Subsequent sub-policies have been developed to assist in the implementation of the White Paper. These have been implemented and revised over time and meet international best practice (PDG, 2010)[1]. These policies are discussed below:

Integrated National Electrification Plan (INEP)

The INEP is a programme aimed at providing universal access to electricity. The INEP programme has been remarkable, increasing electrification from 36% in 1994 to 87% in 2014 (DoE, 2014)[2]. Most of electrification success was in the early years and was concentrated in the urban areas. By 1996, 77% of urban households were electrified, increasing to 89% by 2011 (Stats SA, 2011)[3]. Most of the historic urban households now have electricity connections, but government now faces challenges with keeping pace with new households resulting in universal access targets being amended to 2025.

Free Basic electricity (FBE)

During the INEP programme, government realised that affordability of newly electrified low-income households was a barrier (ERC, 2002). In response to this, in 2005 the Free Basic electricity (FBE) subsidy was introduced to assist households to shift from using inefficient and unsafe fuels to electricity (DME, 2005)[4]. The FBE subsidy allows for free monthly amount of 50kWh. This amount of free electricity enables the poor to meet some of their basic energy needs namely lighting, powering a radio and TV and some water-heating (Winkler, 2006). The impact on FBE on those households who have received the subsidy has been extremely positive as it has enabled the transition to electricity which is now the dominant energy fuel in the home (StatsSA, 2011)[5]. While municipalities are mandated to implement this subsidy, not all municipalities are able to afford this and therefore cannot provide the subsidy. Together with this, and the divergent methods of implementation of the subsidy between municipalities, many poor households do not benefit from the subsidy. There are also gaps in the data which make it difficult to determine how many people receive the subsidy and if this subsidy is indeed effective (SEA, 2014[6]). According to the DoE (2013)[7], 69% of poor households are benefitting from free basic energy policies.

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1 Palmer Development Group (PDG) (2010) A study into approaches to minimise the impact of electricity price increases on the poor. Report for Trade and Industry Chamber. Cape Town.

2 Department of Energy (DoE) (2014) Presentation on the Integrated National Electrification Programme made to the Parliamentary Portfolio Committee on Energy on 26 August 2014. South Africa.

3 Statistics South Africa (StatsSA) (2011) Municipal Factsheet. South Africa.

4 Department of Minerals and Energy (DME) (2005) Free Basic Electricity Policy. Department of Minerals and Energy. Republic of South Africa.

5 Statistics South Africa (StatsSA) (2011) Municipal Factsheet. South Africa.

6 Sustainable Energy Africa (2014) Tackling Urban Energy Poverty in South Africa. Research funded by Heinrich Böll Foundation Southern Africa, Cape Town.

7 Department of Energy (2013) A survey of energy-related behaviour and perceptions in South Africa: The Residential Sector 2013.

This policy was also meant to address gender equity by avoiding the need to collect firewood, a task mainly carried out by women (CURES, 2009)[8]. Studies have found that FBE has alleviated energy poverty in households that collect firewood for cooking and water heating (Thom and Mohlakoana, 2000[9]).

Free Basic Alternative Energy (FBAE)

While some households wait to be electrified, the Free Basic Alternative Energy (FBAE) policy was introduced in 2007 to assist unelectrified households with subsidised alternative energy (DME, 2007). Although initially targeted at rural municipalities, some metros have adopted it due to the growing number of unelectrified informal settlements. Nevertheless, adoption of this subsidy remains low and only 10% of informal unelectrified households nationally receive the subsidy (StatsSA, 2014[10]). According to the Stats SA Non-financial Census of Municipalities (2016d), in 2015, some households received the subsidy in the form of safe fuels i.e. solar home systems (75 000) and fire gel (19 000) but the majority received it for paraffin. There were no subsidies for coal or LPG.

Inclining Block Tariff IBT

The Inclining Block Tariff (IBT) subsidy was introduced in 2010 to further mitigate low-income households from increasing electricity prices (Eskom, 2011[11]). The subsidy is designed to take into consideration consumption levels, where the price of electricity is subsidised to lower consuming households, with the price steeply increasing the more one consumes. It is assumed that low-income households consume smaller amount of electricity than other households however it is very common for several low-income households to be on one meter (through informal connections), as well as for these households to have large families living under one roof (PDG, 2013[12]; SEA, 2014[13]).

National Solar Water Heater social programme

The National Solar Water Heater Programme was a direct outcome of the White Paper on Renewable Energy. In 2009, the Department of Energy developed the National Solar Water Heater Programme and set a target of one million solar water heaters (SWHs) by 2014. The programme began as a load reduction programme in response to environmental sustainability and electricity challenges, but shifted to a Social Programme with job creation and household services as a central objective over time. The programme has suffered staggered implementation since 2010 when it started due to a variety of institutional, financial and technical challenges, which has resulted in only a negligible number of households in the country having the technology. In 2014, the Department of Energy reported to parliament, that a total of 395 088 systems had been installed (PMG, 2014[14]).

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8 CURES (2009) Exploring Energy poverty in South Africa, A CURES Discussion Document. Citizens united for Renewable Energy and Sustainability, Southern Africa Region.

9 Thom & Mohlakoana (2000) The use and impact of electricity in Garagopola-Legabeng. EDRC, University of Cape Town.

10 Statistics South Africa (StatsSA) (2014) Poverty trends in South Africa, an examination of absolute poverty between 2006 and 2011. South Africa.

11 Eskom (2011) Incline Block Tariffs (IBT) Available from: http://www.prepayment.eskom.co.za/IBT.asp.

12 Palmer Development Group (PDG) (2013) Review of the impact of inclining block tariffs for electricity on poor households. Report for BUSA. Cape Town.

13 Sustainable Energy Africa (SEA) (2014) Tackling Urban Energy Poverty in South Africa. Research funded by Heinrich Böll Foundation Southern Africa, Cape Town.

14 Parliamentary Monitoring Group (PMG) (2014) Rollout of National Solar Water Heater Programme: briefing by Department of Energy. 25 February 2014; and November 2014. Cape Town.

Of this, only 30 000 were delivered to income households via the social component of the programme (SEA, 2015[15]). More recently, the programme was halted due to localisation content reviews. According to SAGEN, the DoE will resume the programme again with procurement and installation functions centralised, but with strong support from municipalities that are interested in participating in this programme (SAGEN, 2016). Under the new plan, municipalities will be responsible for identification of areas for implementation, and community engagement. The clear advantage of the central institutional setup of this programme, is the low cost at which the SWHs can be procured due to economies of scale, as well capacity to rollout the programme i.e. implementation and management. Municipalities are however concerned about how the community will respond to potential defective products, and maintenance issues.

15 Sustainable Energy Africa (SEA) (2015) Review of best practice solar water heating implementation by local government. Cape Town.

In terms of Schedules 4 and 5 of the Constitution, local government is tasked (although at different levels) with the functions of electricity and gas reticulation, housing delivery, water reticulation. Municipalities are therefore important partners in the national energy access programmes and have been administrators and implementers of INEP and FBE and FBAE. In addition municipalities are beginning to extend their duties into the areas of thermally efficient housing delivery (or retrofit) and concepts of 'energisation' – sustainable combinations of appliances/ fuels – are emerging, in line with the White Paper.

In addition it is worth noting that the 'Objects of local government' set out in Section 152 specify that service provision must be done in a sustainable manner and local government must promote a safe and healthy environment (152 (1) (a) and (d)).

When delivering services municipalities are also required to take into account health and the environment, the impact on development and job creation, and developing trends in the sustainable provision of municipal services generally (MSA (2003), Section 78 refers). As metros in South Africa become increasingly capacitated within the energy space and as improved technology increasingly pushes towards more distributed energy services, the range of activities undertaken by municipalities may change.

Mandates, Powers and Functions of Local Government in relation to Access to Energy

Electrification within municipal areas is within the mandate of municipalities who are electricity distributors, and this includes informal electrification. However funds for such electrification are provided largely by national government. Some municipalities also draw on their own funds for this purpose. Where municipalities are not distributors, Eskom undertakes all electrification.

Free Basic Alternative Energy (FBAE) is also intended for implementation by municipalities, although the capacity and resources to implement this service must be sourced from within the municipality and the existing Equitable Share fund.

Subsidised housing delivery is a provincial function, although larger municipalities also may implement housing projects.

Constitution of RSA (1996): Chapter 7: Local Government

Section 152: The objects of local government are -

a. to provide democratic and accountable government for local communities;

b. to ensure the provision of services to communities in a sustainable manner;

c. to promote social and economic development;

d. to promote a safe and healthy environment; and

e. to encourage the involvement of communities and community organisations in the matters of local government.

Section 153: Developmental duties of municipalities

A municipality must

a. structure and manage its administration, and budgeting and planning processes to give priority to the basic needs of the community, and to promote the social and economic development of the community; and

b. participate in national and provincial development programmes.

Ongoing challenges to energy access for all

While these policies are sound in their concepts, they still fall short in implementation as energy poverty still persists due to the following (non-exhaustive) reasons:

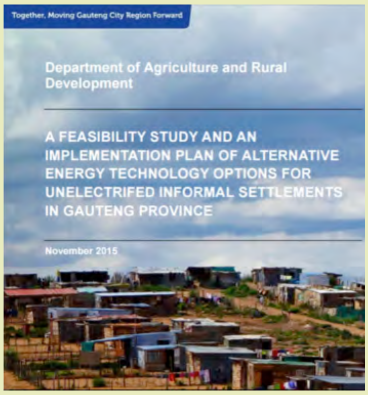
- There is lack of coordinating between housing and electrification programmes which has resulted in electrification backlogs.
- Although municipalities are mandated to implement FBE and FBAE, they can only do so if they are financially capable.
- There is no definitive method for municipalities to implement the roll out of these policies resulting in a range of implementation approaches (SEA, 2014[5]). This has meant that not all households deserving of receiving these subsidies have received and/or benefited from these subsidies.
- Illegal and informal connections mostly in informal settlements and in backyarders' households render these subsidies irrelevant as these households cannot access them. The absence of these subsidies place a burden on these households especially in the face of the recent price hikes. Households that do not have a formal connection resort to electricity theft or use other sources of energy like paraffin, charcoal and candles etc. which are often expensive and unsafe.
- Households that are connected informally succumb to exorbitant electricity prices from illegal third party electricity resellers.

NERSA, DoE, SALGA and COGTA have been working together to overcome these challenges.

5 Sustainable Energy Africa (2014) Tackling Urban Energy Poverty in South Africa, Research funded by Heinrich Böll Foundation Southern Africa, Cape Town.

Energisation as an approach to energy service delivery

Tackling energy poverty in urban South Africa is a complex issue and thus requires a range of solutions to cater to differing needs of those living in low-cost housing, backyard dwellings and informal settlements (SEA, 2014[6]). Globally, there seems to be a growing acceptance of the need to provide energy services which meets the needs of people rather than merely connecting households to electricity. It is understood that energy is not consumed for itself, but for what it can do – i.e. the services it provides – such as cooking, lighting, heating, cooling and the production of goods and services (UNDP, 2000[7]). Therefore, households should receive energy in the most appropriate form for its use. Of the United Nation's Sustainable Development Goals (SDG) adopted worldwide, the energy SDG (SDG 7) aims to ensure universal access to affordable, reliable, and modern energy services by 2030 (UN, 2015[8]). In South Africa, the National Development Plan (NDP) makes reference to the wider energy needs of poor households and the need for an integrated programme to address energy poverty (South African Government, 2012[9]).



Source: Department of Agriculture and Rural Development (2015)

Access referring to the provision of modern energy forms such as electricity and a range of renewable energy sources and excluding health and environmental-related harmful energy sources such as paraffin, candles and firewood. The electrification programme itself has not alleviated multiple fuel use and energy poverty substantially. Even for households that receive and depend on the FBE, research shows that households use the full allocation and then revert to the previously used source of energy (candle, paraffin, wood) or are forced to use "less official solutions". This mismatch between consumer demand and supply strategies needs to be addressed to the benefit of low-income households. The focus needs to shift from electrification at all costs, to include all of South Africa's energy sources.

Provided that clean and safe fuels are used, multiple fuel use is not a bad practice, as no one fuel is best for all energy uses.

In the interim, some municipalities are exploring alternative options to provide energy services to households, in the longer term, in a financially and environmentally sustainable manner. For example, the City of Joburg, City of Cape Town, and Polokwane Municipality are all investigating alternative energy technologies which supplement electricity (see case study session). The Gauteng Department of Agricultural and Rural Development (GDARD), has also recently undertaken a feasibility study investigating alternative energy technologies for unelectrified informal settlements in the province.

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6 Sustainable Energy Africa (2014) Tackling Urban Energy Poverty in South Africa, Research funded by Heinrich Böll Foundation Southern Africa, Cape Town.

7 United Nations Development Program (UNDP) (2000) Overview. In J Goldemberg (Ed) 2000.World energy assessment: energy and the challenge of sustainability. New York: United Nations Development Programme: 3.

8 United Nations (2015) Transforming our world: the 2030 agenda for sustainable development A/RES/70/1.

9 South African Government (2012) The National Development Plan. Vision for 2030. http://www.gov.za/documents/national-development-plan-vision-2030.

Findings highlighted affordability as a key challenge for majority of households. The use of affordable alternative technologies such as solar lights, hot boxes and solar hot water boxes could reduce household energy consumption as well as energy costs. These alternative technologies are energy efficient, cleaner, safer and more affordable to households as they only require once-off/upfront, relatively low cost, payments (GDARD, 2015[10]).

However, given the long history of service delivery protests and the expectation of electricity as the prime source of energy for all needs, there needs to be extensive awareness raising programmes on new technologies/fuels to attain buy-in from communities, as well as undertake thorough community consultation needs assessments to ensure that the appropriate technologies are supplied. Furthermore, while developing the integrated household energy packages, gender aspects of energy use and challenges need to be taken into account. The interventions should ensure that solutions are tailored to address the needs of both women and men. Considerations such as who chooses which energy carrier, how electricity and other energy fuels are used, who the main beneficiaries are, and preferable fuel choices need to be asked.

When developing an integrated household energy services strategy the following need to be considered:

- Energisation is often misconstrued as the provision of technologies. However it is about providing a bundle of energy services and taking into consideration long term sustainable use and maintenance of a utility that will continue to fulfil the basic energy needs of the communities.
- Different services are needed to meet different needs. No ‘one size fits all’. Need flexibility in technologies and models of delivery.
- Social acceptability and willingness to pay are critical. Awareness raising and involvement of communities is thus important. Often energy services are developed for communities but they are rarely involved or consulted during negotiation and stakeholder engagements.
- The service must be financially sustainable – municipality can provide reliable delivery over time and the community can afford it and is willing to pay for it.
- Alternative energy services are not only for off-grid systems and grid-connected households, from all social categories, can benefit from them. This also ensures greater benefits for the municipalities and the system as a whole. Awareness raising along these lines can also ensure that alternative energy solutions are not perceived as “sub-standard”.
- New energy service delivery approaches need to be aligned with the need for municipalities to change their business models and become energy companies, i.e. providing energy services instead of only selling kWh.
- Also should be gender inclusive.

Alternative energy technologies and energy options

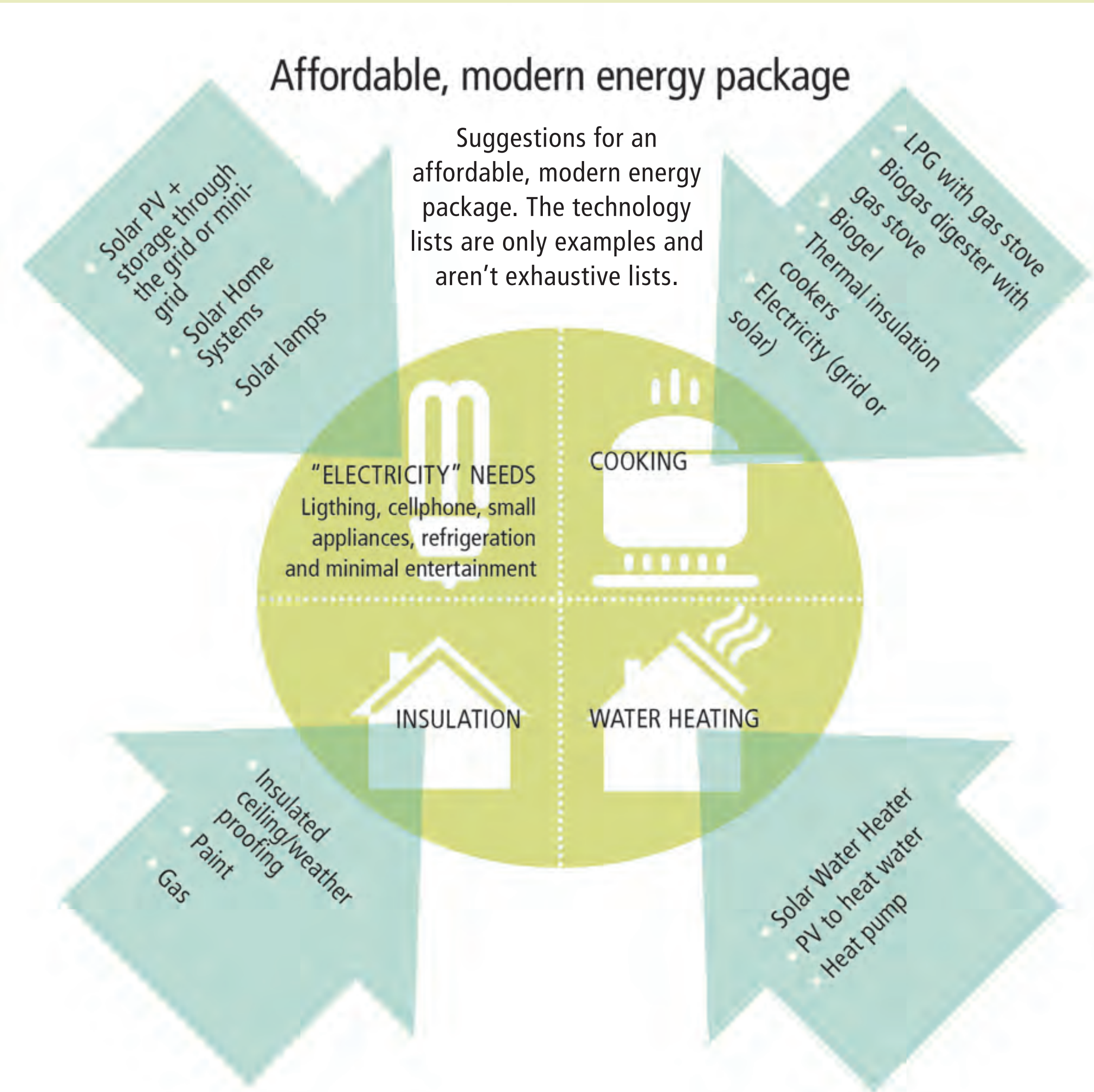
There are many technological options to provide for each of the energy needs i.e. cooking, lighting, water and space heating. However, there is no “one size fits all” solution and no clarity around the optimal mix. Additionally, technology is evolving rapidly. As such, distribution utilities and policy makers need to stay informed about development and be open to changes. In order to cater for innovations, it is important that the technology provided remain mobile and flexible (no locked-in solution).

10 GDARD Department of Agriculture and Rural Development (2015) A feasibility study and an implementation plan of alternative energy technology options for unelectrified informal settlements in Gauteng province November 2015.

The use of energy efficient solutions need to be maximised to ensure optimal demand side management. Solutions to provide for lighting, charging and entertainment include Solar lamps, Solar photovoltaic panels combined with batteries, which could be provided either as stand-alone systems for individual households (Solar Home Systems) or through the grid, depending on electricity access in the area. In an area where it is not possible to install a mini-grid, individual solutions need to prevail and community centres could be equipped to provide energy services. Also solutions for thermal needs are very varied and range from LPG gas, biogas digesters, solar stoves or biogel for cooking needs or solar water heaters for hot water needs (Figure 9: Energy options for households below).

The selection of specific technologies for specific households and dwelling need to be made on an area per area basis. A scoring system could be to develop several options and criteria could include: safety, accessibility and practicability of "re-stocking" (for electricity pre-payment, tokens or gas), affordability, potential business creation opportunities, amongst others.

Figure 8: Energy options for households



Energy options for households

The tables below examine energy options available in the market that households can utilise for their domestic requirements. The table examines risks, pro's and con's associated with the energy option as well as costs for each of the energy options, and fuel options are highlighted. It should be noted that the financing and delivery mechanisms for alternative energy service delivery are not discussed here.

The overview includes the following energy service areas:

1. Cooking
2. Lighting
3. Space heating
4. Thermal insulation
5. Water heating
6. Solar home systems

Table 3: Assumptions for monthly operating cost calculations

Appliances	Hours operated per day	Electricity demand Watts
Incadescent light bulbs	6	60
CFLs	6	14
LEDs	6	5
Stove	2	2000
Heater	4	1600
Kettle	0.5	2200

Formula used for electric appliances (Ward, 2008[11]):
*Wattage of the appliance * number of hours it is operated* 30 days * cost per kWh*
The cost per kWh is based on the City of Cape Town lifeline tariff 97.09 c/kWh exluding VAT (2016/2017)

Cooking

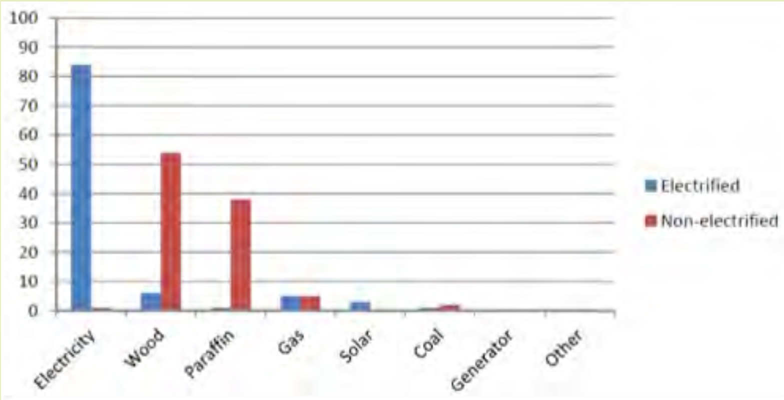
Cooking is a major energy consumer in the household as it is conducted more often than other energy needs (DoE, 2013[12]). For most households in South Africa, electricity is used for cooking. However, there are still households that use mainly firewood for cooking while unelectrified households use both firewood and paraffin as their main energy sources to meet this need (DoE, 2013[13]). This presents an opportunity for the introduction of clean cook stoves that households can use and are cleaner and more efficient. Clean cook stoves are designed to reduce air pollution as a result of improved combustion rates compared to traditional biomass cook stoves. Furthermore, they are designed to consume less energy for cooking. This increased efficiency results in improved health for household members particularly the primary cooks of the household e.g. women and children and requires less time with regards to fuel collection. The cook stoves, although slightly more expensive, have pay back periods based on the number of times they are used. This also includes health benefits, safety and convenience of use as well over time, as cook stoves reduce household energy cost.

11 Ward (2008) The New Energy Book for urban development in South Africa. 2nd Edition. Sustainable Energy Africa, Cape Town, South Africa.

12 Department of Energy (2013) A survey of energy-related behaviour and perceptions in South Africa: The Residential Sector 2013.

13 Department of Energy (2013) A survey of energy-related behaviour and perceptions in South Africa: The Residential Sector 2013.

Figure 9: Percentage households using different energy sources for cooking



Source: Department of Energy (2013) A survey of energy-related behaviour and perceptions in South Africa: The Residential Sector 2013.

Table 4: A list alternative and traditional energy options for household cooking

	Hotbox	Solar cooker	Efficient biomass cook stove	Ethanol cook stoves	LPG cook stoves
Fuel type	none	sun	Charcoal, wood or other biomass	Ethanol or methanol	LPG
Capital cost	R260 – R360 per bag	R650	R450	R500 – R1200	R700 – R1100
Monthly operating costs	0	0	R0 – R270	R180	R125 per plate

Increased efficiency results in improved health for household members particularly the primary cooks of the household e.g. women and children and requires less time with regards to fuel collection.

	Hotbox	Solar cooker	Efficient biomass cook stove	Ethanol cook stoves	LPG cook stoves
PROS	• Free to operate, therefore saves on energy costs • Safe and convenient • In the many households where paraffin or coal is used for cooking, a direct improvement in indoor air quality can be expected as does not emit any health damaging pollutants. • Needs little supervision • Low capital cost • Reduces the amount of fuel needed for cooking (estimated to save up to 30% of total fuel costs associated with cooking with paraffin alone) • Good for food that takes long time to cook, such as beans, samp, tripe, rice, stews. • Safe to use • Easy to use • Meals can be safely prepared ahead of time • Hotboxes are relatively easy to make, and thus lend themselves to decentralised small business production in low-income areas, and can be made using low-cost, recycled materials. • Saves on cooking time and energy but can be only be used to complement another form of energy.	• Free to operate, therefore saves significantly on energy costs. • Safe • Needs little supervision • Can cook entire meal at once • Provides better air quality indoors, reduces carbon monoxide emissions and cooler temperatures indoors can be enjoyed.	• More efficient use of fuels therefore reduces costs and air pollution. Compact and mobile.	• Safe, clean and more efficient than paraffin • No odours • High calorific value compared to more traditional fuels like paraffin and wood • Sustainable supply of the technology and the fuel • Potential for Small Medium and Micro-sized Enterprises (SMME) development for fuel distribution in canister, since refuelling is on the basis of exchange of canisters that are in easily-manageable sizes • Stove is easy to use	• Convenient, clean and relatively safe • High calorific value reduces cooking time significantly. • LPG is a clean burning fuel and reduces indoor air pollution by as much as 90% in comparison to burning traditional fuels • LPG stoves quickly supply heat and work more efficiently than wood and paraffin stoves. The simple and precise regulation simplifies the cooking process and can save time. • Good existing distribution
CONS	• Cannot cook all food types, such as steamed bread, pap, and food that require stirring.	• Relies on the sunlight for cooking (not predictable, can only cook during the day), and also makes it difficult to use during winter months or rainy days • Cooking takes significantly longer than conventional methods • Bulky appliance • Cannot be used indoors. • Unlikely to provide all the cooking services needed by households. A backup appliance that operates on another fuel source will be needed when weather is unfavourable or whenever the sun is hidden. • Perceived as slow and unreliable.	• Cannot be used indoors • Uses "dirty" fuels that negatively affect air quality and use of wood may impact on the environment.	• Due to the recent introduction of this fuel on the market, there is a great need to raise awareness of this fuel for household cooking. • The fuel is sometimes felt to be a 'slow' fuel, not cooking with much power.	• Reliance on distributor and distribution network – does not promote enterprise development through SMMEs/cooperative • LPG tank management is difficult (storage, transportation) due to their sizes. • LPG operating costs are high and are more suitable for the middle- to high-income earning households. • May not be user-friendly. • Gas is not regulated so the costs can vary over time making this difficult to include in a municipal programme.

RISKS	• No known risks.	• Food cannot be cooked using this appliance on days that are not sunny – therefore does not allow flexibility as to what part of day household can cook. • There is the risk of food being stolen while it cooks outdoors.	• Is a fire risk if not used safely • Can have significant health impacts if used indoors.	• Ethanol/methanol fuels still an emerging market reliant on government financing. Security and affordability of fuel supply is not guaranteed.	• Risk of gas tank explosions in the informal settlements that may lead to fatal shack fires IF not properly used. • Distributer cost recovery • Assurance of LPG supply

	Electric stove (two plate)	**Protostar one plate methanol stove**	**Ecozoom versa rocket cookstove**	**Wood/coal mbawula**	**Wood/coal Cook stove**
Fuel type	• electricity	• Methanol	• Charcoal, wood or other solid biomass	• Charcoal, wood or other biomass	• Charcoal, wood or other biomass
Capital cost	• From R179	• R400	• R505	• R0	• R450
Monthly operating costs	• R116	• R135 – R315	• R0 – R210	• R0 – R280	• R0 – R280
Pros	• Efficient • Safe, easy and convenient • Clean fuel at the source	• Compared to paraffin: • it is safer and more efficient • no dour • high calorific value • Because the stove remains under 40C when being used, there is no risk of fires • There is low risk of child poison through ingestion because the fuel comes in pre-packaged plastic capsules	• Efficient • Uses fuels that are easily accessible • Compact and mobile	• Easy to use • Uses fuels that are easily accessible • It is cheap to manufacture	• Uses fuels that are easily accessible • Can also be used to heat up the household during cold times
Cons	• The electricity used comes from coal power stations cause air pollution	• Reduced time to cook as it is one single plate stove	• Cannot be used indoors as the fuels used cause indoor pollution and has potential health risk problems for users	• Inefficient – takes longer to cooker compared to electricity or LPG • Cannot be used indoors as the fuels used cause indoor pollution and has potential health risk problems for users	• Cannot be used indoors as the fuels used cause indoor pollution and has potential health risk problems for users
Risks	• Electricity can cause fire or electrocution if illegally connected	• Potential ingestion by children	• Uses burning fuel, thus a potential fire risk	• Uses burning fuel, thus a potential fire risk • Smoke inhalation can result in severe respiratory health impacts	• Uses burning fuel, thus a potential fire risk

Lighting

Lighting is the lowest energy consumer in the household, thus, most households that are electrified use electricity as the main source of energy for lighting. Unelectrified households on the other hand mostly utilise candles with some households using paraffin as an alternative. The table below lists various options that households are using, or could use, for lighting including efficient and inefficient energy sources. Solar lights, CFLs and LED lighting are efficient options for households to use that last longer and reduce energy consumption in the household.

Table 5: A list alternative and traditional energy options for household lighting needs

	Solar lighting	A litre of light	Compact Flourescent Lamps (CFLs)	LED lights	LPG lamp
Fuel type	sun	sun	electricity	electricity	LPG
Capital cost	R150 – R1500	R100	+R30	+R30	R230
Monthly operating costs	0	R2	R2.44	R0.87	R225
PROS	• Free to operate • Safe to use • Needs no supervision • Safer, cleaner and brighter than candles and paraffin lamps • Simple to use • Children can do homework and study at night • Zero emissions • Low maintenance costs (after lifespan, only battery needs to be replaced).	• Free to operate, therefore saves on energy costs where daylighting is required • Safe to use • Needs no supervision • Safer, cleaner and brighter than candles and paraffin lamps • Low maintenance costs • Can be used in shacks that are not well lit, during the day, given that shacks usually do not have windows to allow natural light to stream in.	• Last up to eight times longer than incandescent lamps • Save up to 80% on energy use than incandescent lamps	• Last over 100 times longer than filament bulbs • Produce almost no heat • Don't contain any potentially hazardous material such as mercury • Low maintenance • Low light pollution due to high directional light • Low rates of lumen depreciation and can handle cold temperatures and on/off switching • Cost efficient	• High light output, better than candles and paraffin, roughly equivalent to a 100W incandescent lightbulb • Good calorific value • Convenient and relatively safe • LPG is a clean burning fuel and reduces indoor air pollution (health damaging air pollutants like particulate matter) • Good existing supply distribution network.
CONS	Much higher capital cost compared to candles and paraffin lamps Needs sunlight, therefore charging time limited during winter Operation/management required – to move apparatus indoors at night for lighting and outdoors during the day for charging.	Use is limited to daytime only and cannot be used at night.	Limited lumen output, high heat build up in self-contained ballast Low life/burnout due to frequent cycling (on/off) of lamp, become dimmer/ fail to start in cold weather and/or moist environments Not very durable – glass or filament can break easily Takes time to warm up		Reliance on distributor and distribution network – does not promote enterprise development through SMMEs/cooperative LPG tank management is difficult (storage, transportation) due to their sizes LPG operating cost are high and are more suitable for the middle- to high-income earning households May not be user-friendly. Fossil fuel, therefore contributes to Greenhouse Gas Emissions (GHG) emissions.

	Solar lighting	A litre of light	Compact Flourescent Lamps (CFLs)	LED lights	LPG lamp
RISKS	• Risk of theft if left unattended or solar panel installed on the roof.	• There is the risk of falling from the roof and possibly injuring occupants, if not well installed.	• Contain a small amount of mercury – less than 5mg • Electricity can cause fire or electrocution if illegally connected	• Electricity can cause fire or electrocution if illegally connected	• Risk of gas tank explosions in the informal settlements that may lead to fatal shack fires IF not properly used. • Distributor cost recovery • Assurance of LPG supply.

	Candles	Paraffin lamp	Incandescent
Fuel type		Paraffin	Electricity
Capital cost	R2.50	R25	
Monthly operating costs	R37.50	R91	R10.50
Pros	• Easy to use • Easily accessible	• Easy to use • Easily accessible	• Easy to use • Safe and clean fuel • Contains no mercury • Short-term life span • Cheap
Cons	• Low light output – thus limits night activities e.g. children doing homework • Polluting • Leaves soot deposits inside dwelling	• Low light output – thus limits night activities e.g. children doing homework • The glass shield easily breaks • Leaves soot deposits inside dwelling • Polluting	• Not very durable – glass or filament can break easily
Risks	• Poses a fire risk	• Poses a fire risk • Potential ingestion by children	

Space heating

Space heating consumes a lot of energy in households, however unlike other energy services such as water heating and cooking, space heating is seasonal and often occurs in winter. While a large majority of people use energy sources such as electricity, gas and paraffin among others for space heating purposes, some households cannot afford to use heat their homes and thus opt to wear warm clothes and use blankets to keep warm.

Table 6: A list alternative and traditional energy options for household's space heating needs

	LPG heater	Paraffin heater	Electric heater
Fuel type	LPG	Paraffin	Electricity
Capital cost	R1200	R350	From R200 depending on the brand
Monthly operating costs	R225	R260	R186
PROS	• High calorific value which heats efficiently • LPG is a clean burning fuel and reduces indoor air pollution (health damaging air pollutants like particulate matter) • Good existing distribution. • Very efficient for space heating provision.	• Can also be used for cooking purposes • Fuel easily accessible	• Easy and safe to use • Clean fuel • Efficient

	LPG heater	Paraffin heater	Electric heater
CONS	• Reliance on distributor and distribution network – does not promote enterprise development through SMMEs/Cooperative • LPG tank management is difficult (storage, transportation) due to their sizes • LPG operating cost are high and are more suitable for the middle- to high-income earning households • May not be user-friendly	• Requires adequate ventilation • Paraffin emits health damaging air pollutants and negatively affects indoor air quality • Leaves soot deposits inside dwelling	• The electricity used comes from coal power stations cause air pollution
RISKS	• Risk of gas tank explosions in the informal settlements that may lead to fatal shack fires IF not properly used. • Distributor cost recovery • Assurance of LPG supply.	• Poses a fire risk • Potential ingestion by children	• Eletricity can cause fire or electrocution if illegally connected

Thermal insulation

Increased requirements for space heating energy sources is caused by poor household thermal efficiency. Households that are not properly insulated have greater heating requirements and particularly houses that do not have ceilings result in poor indoor health conditions for families. The table below introduces the variety of thermal insulation options available for low income households.

Table 7: Thermal insulation – ceilings and insulation in low income housing

Technical Description: Reducing the flow of heat into and out of the house is one of the best ways of making a house more energy efficient. As most heat is gained and/or lost through the roof, the best way of reducing this heat transfer is by installing a ceiling. This creates an air gap between the living area and the roof and the air acts as an insulator. The effectiveness of a ceiling can be further improved by adding an additional insulating material above the ceiling or using a ceiling material, which is also a good insulator.

Costs: The financial case for ceilings in low-income houses is clear cut due to the relatively low cost of the intervention and the massive savings on both heating and cooling energy. The prices below show the relative retail costs of the materials mentioned above. Costs would vary with bulk orders. Note when comparing costs that Isoboard is a ceiling material and insulation material built into a single product.

Product	Cost per m^2
Gypsum Board	R42.00
Insulation 40mm	R15.50
Aerolite 50mm	R22.00
Aerolite 100mm	R30.00
Isoboard 25mm *low income	R52.00
Isoboard 25mm *high income	R65.00
Isoboard 30mm	R73.50
Isoboard 40mm	R98.00

Pros	Cons	Risks	Energy Impacts	Remarks
• Energy costs for heating and cooling are drastically reduced, which frees up money for other purposes. • Ceilings last for the life-time of the structure and require little to no maintenance. • Indoor environment is healthier through reducing condensation in winter (which can lead to respiratory illness) and due to decreased heating needs, there is also an improvement in indoor air quality where coal and paraffin were used for heating.	• Currently the national housing subsidy does not include an amount for ceiling and insulation and therefore these costs need to be raised in addition to the current subsidy for any developments outside of the SCCCA.		• Achieve a 70% improvement in thermal performance of the house: warmer in winter and cooler in summer.	• This technology is very mature as it is widely used in almost all mid-hi income housing.

Water heating

Water heating is also energy intensive like space heating and can increase energy peak demand. Most households that do not have solar water geysers use electric stoves or kettles to heat water for bathing, washing and cooking. To increase household energy efficiency, reduce peak demand and reduce energy costs, solar water heaters are recommended as the best option for households. The table below introduces the options available to households for water heating purposes.

Table 8: A list alternative and traditional energy options for household water heating needs

	Hot water boxes	Solar water heater	Electric kettle
Fuel type	sun	sun	Electricity
Capital cost	R200 – R300	Low pressure system: R5000 – R6000 High pressure system: R17000 – R25000	From R70
Monthly operating costs	0	R0 (no cost if no electricity backup) – minimal	R32
PROS	• Only heats a small amount of water at one time	• Free heating of water • Reduce peak load where electricity has been used for water heating by electric geyser or kettle or stove. • Reductions in water heating energy requirements of over 50% can be expected with SWHs in mid-high income houses, particularly when used in conjunction with a timer which regulates when the backup electrical element is switched on.	• Efficient and fast • Easy to use • Clean at the source
CONS	• May not work in sunny, but windy conditions.	• The initial costs of SWHs are considered prohibitive. Adequate long-term financing is essential for any chance of mass rollout. • The benefits of using SWHs are not widely enough known in the residential sector, contributing to slow uptake (along with the absence of financing mechanisms)	
RISKS		• System maintenance must be catered for	

Solar Home System (SHS)

Solar home systems (SHS) present options for unelectrified households to power small appliances in the household such as lights, radio and TV. The table below provides a description of a typical SHS.

Table 9: Solar home systems

Solar Home Systems

Technical Description: There are a range of solar home systems emerging. This overview is based on typical entry-level solar home systems specifications.

Solar home system Composition:

- Distribution Box (DB) Box fused with a cell phone charger socket, 20A input capacity
- 1no. 100Wp Solar Panel and roof-mount bracket
- 1no. 96Ah 12V SLA Battery
- 2no. 3W Internal LED lights with cable and pull switches
- 1no. 2.4W External Security light with motion sensor and cable
- External plug box for TV, Hi-Fi, Radio and DVD
- Optional 15" TV and radio

Operation: The solar panel charges the battery via the DB Box/charge controller that manages the generation and supply of electricity flowing to and from the battery. All loads are connected to the DB box and the system will cut off if the battery voltage drops to a set point. The system will automatically turn on again when the battery has been recharged.

Figure 10: Solar Home System Components

Source: iShack Project, 2016

Fuel: The Sun

Lifespan: Panel 10 years ; DB box 10 years ; Battery 2-3 years

COST:

Capital Cost: +-R6000

Monthly Operating Cost: Operating costs can vary depending on user behaviour which will determine the maintenance requirements. End-users can pay a monthly service fee to cover maintenance and replacement of battery costs. The system can be remotely turned off which is the response to default in payment. End-users will also have to pay for a new battery every 2-3 years.

SAFETY FOR USERS: SHS should only be installed by qualified individuals to ensure safety. Users should be made aware of the basic operations of the SHS as well as battery safety and maintenance.

ACCEPTANCE/ADOPTION:

Off-grid, solar home systems have been deployed in many countries to rural areas with varying levels of success. SHS technology has become more sophisticated over recent years and is able to provide affordable, basic electricity services due to the reduction in costs of solar panels, improved efficiencies of appliances and battery technology/longevity. Viable business models need to be implemented to ensure sustainability.

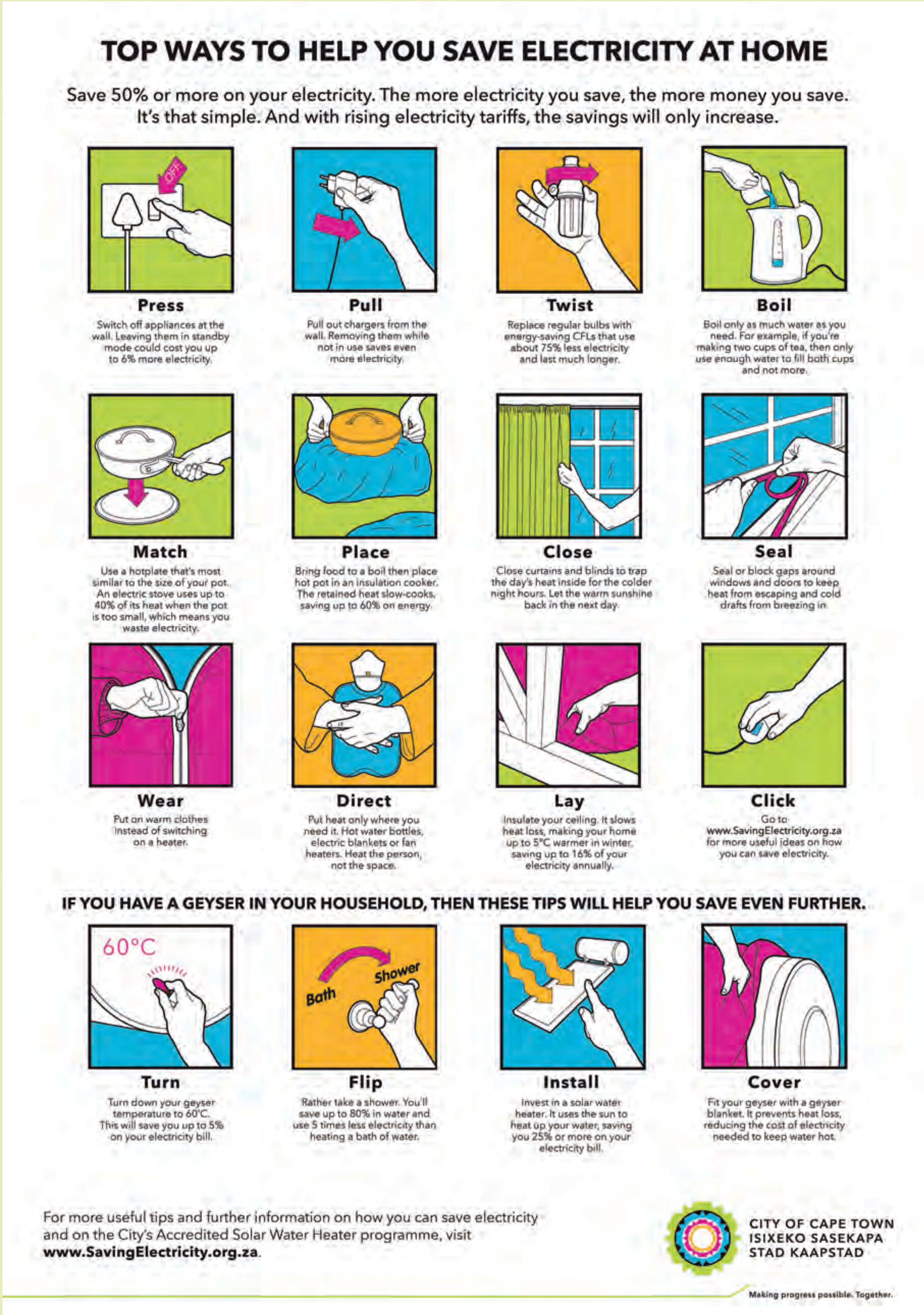
Pros	Cons	Risks	Energy Impacts	Remarks
• Stand-alone system • Modular design • Renewable fuel source • Provides basic services • Low cost	• Battery life • Requires maintenance • Users need to manage their energy use	• Battery overuse • Theft of components • Tampering / Misuse	• Decentralised electricity generation • Reduction in use of paraffin and candles • Lower CO2 emissions	Solar Home Systems are suitable for off-grid residential and small business applications. Viable business models need to be coupled with implementation

Household energy efficiency

Energy efficiency in the home saves money and is also good for the environment as it specifically addresses climate change. Saving energy reduces not only household energy consumption but reduces the overall demand for resources needed to generate energy. The image below from the City of Cape Town's electricity saving campaign demonstrates how households can reduce household energy use. The image illustrates quick, easy and practical tips for households to save energy, ranging from ceiling insulation to appliances and lights.

For more information please refer to the energy efficiency in buildings chapter (p63).

Figure 11: Tips for households to be more energy efficient and reduce energy consumption



Source: City of Cape Town, 2015 http://www.savingelectricity.org.za/

Case study 1: Exploring alternative energy solutions for low income households: Ga Dikgale, Polokwane

Polokwane Municipality has an Energy and Climate Change Strategy that has identified 5 Goals that address key energy issues in the municipality. Goal 3 of the strategy is to:

> *"Reduce energy poverty by meeting the energy needs of residents with safe, clean, affordable and reliable energy services".*

Thus, the municipality in partnership with Sustainable Energy Africa and the University of Limpopo started to investigate an alternative energy services model approach that involves the municipality procuring energy services from small scale community based energy services enterprises to address energy poverty in the municipality.

Ga-Dikgale a sub-district of Polokwane was used as a case study. Ga- Dikgale was chosen as it is representative of most of the sub-districts of Polokwane in terms of infrastructure and development. The population live in dwellings that range from shacks and mud houses, to brick houses. The majority of the population is economically disadvantaged in an area characterised by high unemployment rates, poor road infrastructure and service delivery.

This project started by conducting a detailed survey in order to develop an understanding of household energy use and household energy service "gaps" amongst the most vulnerable households. Affordability of electricity emerged as a key challenge. Although 93% of Ga Dikgale is electrified, households run out of electricity half way through the month and revert back to using firewood and paraffin to meet their energy needs.[14] The survey was conducted by the local young women from the area.

This prompted an investigation into affordable alternative energy solutions that households could use along with electricity to ensure that households do not run out of electricity and revert back to "dirty" fuels. Five alternative energy solutions were demonstrated to the community by the same young women who conducted the survey, in the local language of the area. This was done so the community members understand how these alternatives work and also to ensure that once the households receive these alternatives they are able to use them. The

Figure 14: Community workshops in Ga-Dikgale

Photographer: Sustainable Energy Africa (2016)

14 SEA and University of Limpopo (2016) Household Energy Use and Supply Survey of Dikgale Sub District of Polokwane, http://cityenergy.org.za/uploads/resource_403.pdf

alternative energy solutions were: solar cookers, hotbox, Tshisa hot water boxes, solar lights and energy efficient light bulbs. While all the alternatives appealed to the community members, the hotbox was the favourite with all the community members.

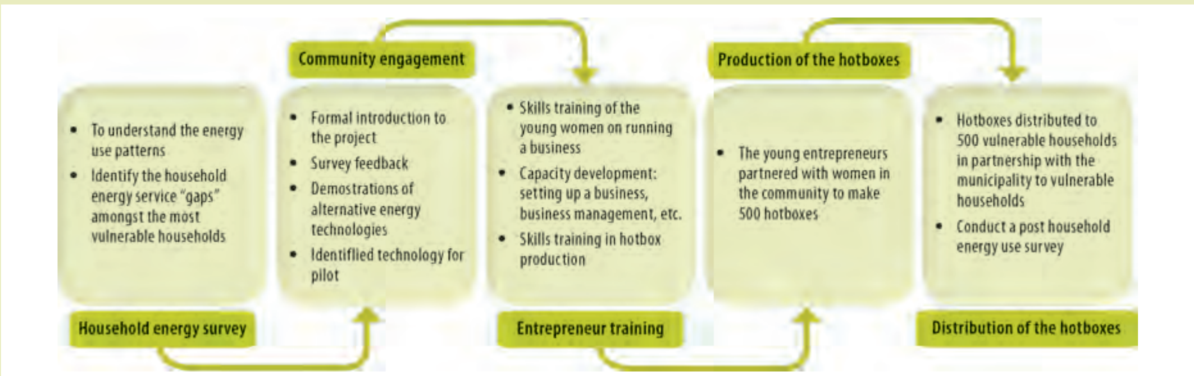
While the project could have opted to buy hotboxes from large corporate organisations and distribute them to the community, it was decided to empower young people in the Ga Dikgale area and create job opportunities. Thus, the same young women that had been involved in the project from the beginning were provided training on how to run a business and also how to make hotboxes. This training was not once off but is on-going with continuous support from SEA and the municipality.

The young women were thus able to start a hotbox production business and they were contracted to make 500 hotboxes that will be distributed to vulnerable households of Ga Dikgale. To date (May 2017) the young women have produced 325 hotboxes and the municipality will start distributing the hotboxes to the vulnerable households with the young women providing further demonstrations on how to use the hotbox before the households receive them. A post-rollout survey will be conducted amongst the households that have received the hotbox, to investigate if the households are using, and benefitting from, the hotboxes.

Figure 15: The young energy entrepreneurs with their hotboxes

Photo: Sustainable Energy Africa

Figure 16: Summary of the process undertaken in Polokwane



If there are positive results and households are using the hotboxes, the municipality plans to adopt this project as their own funded project and include it into their annual budget. The plan is that the municipality will then continue distributing hotboxes to other communities in Polokwane.

This work is part of a project called "Pioneering energy service delivery models to reduce poverty and improve social and environmental climate resilience" funded by Bread for the World.

Case study 2: Low income energy efficient housing programmes: Joe Slovo*

The Joe Slovo settlement is situated on municipally owned land off the N2 highway, a few kilometres from the Cape Town International Airport in the suburb of Langa, 10 km east of the Cape Town CBD. This used to be an informal settlement which existed for almost 2 decades on the site. Now it is an established community and the housing project has accommodated all community members. It is a national flagship housing project of the Department of Human Settlements (DHS), showcasing a new approach to sustainable housing delivery in the country under the Reconstruction and Development Programme (RDP) initiative.

The project was developed following the sustainable settlement principles which include, among others:

- *high density dwelling achieved by double storey attached housing structures instead of stand-alone structures;*
- *reduced service infrastructure, material use and costs (water, storm water drains, sewage, electricity) per household due to densification,*
- *improved thermal performance of buildings through insulated ceilings, roof overhangs and duplex block design (i.e. reducing external wall exposure); and improved energy services through energy efficient water heating via gravity-fed solar water heaters (150 litre low-pressure evacuated tube solar water heating systems).*

Figure 17: Housing units in Joe Slovo. Houses are partitioned by the wall which is in-between the back doors

Source: SEA (2014) Tackling urban energy poverty

A survey of community perceptions was undertaken once the residents had moved into their homes. This showed an overwhelmingly positive response to their new homes and substantial improvement in overall quality of life. Households in addition expressed great satisfaction with their reduced energy cost burdens relative to when they had been living in shacks. For instance, the hot water that is supplied by the solar geysers has reduced their electricity costs. The ceilings that were installed are appreciated for aesthetic reasons and for providing thermal comfort, which reduces the need for space heating except on extremely cold days.

* This case study draws extensively from two documents: Sustainable Energy Africa (2014) Tackling Urban Energy Poverty in South Africa, Research funded by Heinrich Böll Foundation Southern Africa, Cape Town, and SEA (2014) Joe Slovo, Cape Town: Sustainable low-income settlement densification in well located areas. Research funded by SAMSET Project.

Case study 3: Aganang Municipality Free Basic Energy provision model

Aganang local municipality is situated 45km west of Polokwane. It is comprised of 105 villages and divided into 19 wards. Aganang municipality is a rural area, and has four traditional authorities. Households in this municipality face the following challenges:

- *No electricity*
- *Deforestation*
- *Use of unsafe fuels such as fire wood, paraffin and cow dung*
- *High poverty levels*

To provide the solution to this and following the motto a "A better life for all", using the Free Basic Alternative Energy allowance, the municipality looked to provide low income households in the indigent list with free basic energy that is low risk and is easily accessible/available for the households. The FBAE allowance is currently[15] +\-R106 per month under equitable share per household and in 2015 the municipality allocated +/- R2.4 million budget.

The municipality started the programme in 2010, providing 100 households with free basic energy. In 2015 the municipality was supporting 500 households under the indigent list with:

- *1 Biogel cook stove*
- *10L of biogel per month*
- *2 Lamp oils*
- *2L oil per month*

The stove and lamps are replaced once they are damaged but are estimated to last longer than 1 year. The stove cost R240, 5L biogel R100, lamp R65 and oil R60. The amount of biogel provided to the households was calculated under the assumption that households only cook one main meal per day. These energy services are cleaner and safer than previously used fuels such as paraffin and cow dung. The lamp oil has no odour and is not poisonous. All the energy sources have been SABS approved.

The municipality issued tenders to local entrepreneurs to supply the households with the energy fuels every month. The local entrepreneurs fetched the products from the main suppliers in Tshwane and delivered to the households on the 7th day of each month.

Figure 18: The fuels distributed to Aganang Municipality residents

Photo: Sustainable Energy Africa (2015)

After reviewing the programme, the municipality decided replace the oil lamps with solar lights. Each household was provided with two solar buddies. The initial price of the solar lights was expensive compared to the monthly lamp oil as it cost R220 each, however the solar light is a once-off payment compared with the need for a monthly expenditure on oil.

As of 2016 after the local government elections, Aganang has been amalgamated to different municipalities. Parts of the municipality were amalgamated to Polokwane municipality, which has decided to continue with the programme.

15 2015 prices

Case study 4: iShack: Solar home utility model to deliver basic electricity services to urban informal settlements

iShack (improved Shack) has tested a model to deliver basic electricity services to urban informal areas through a pay-for-use Solar Home System (SHS). The project has been running for 3 years at Enkanini, an informal settlement in Stellenbosch, and has adopted a trial and error approach, leading to a vast amount of lessons learnt. The project has been able to deliver SHS to 1 500 households to date. The project has so far received funding from the DBSA Green Fund.

Figure 19: Enkanini informal settlement in Stellenbosch with home solar system

Source: iShack, 2016

The objective of the project is incremental in-situ upgrading of energy access in informal settlements – seen as 'interim relief' rather than replacing grid electrification. The SHS consists of 100 W solar panels, battery and DC appliances (lights, phone charger and TV). The table below summarises some elements of the business models tested. The systems are incremental and can be upgraded when additional income becomes available. As an example, some houses have now connected a fridge to their systems.

Initial funding for the systems, the local support office and training of installers and maintenance technicians has been provided through external grant funding including the DBSA Green Fund. In order to move towards achieving a financially viable business model iShack negotiated with the Stellenbosch Municipality for beneficiaries to receive the Free Basic Alternative Energy (FBAE) grant. It took 18+ months to finalise an agreement as it involved fairly complex service procurement contracts to be developed between the

Municipality and iShack. This FBAE money is paid directly to iShack where it is used to reduce household fees by roughly a third, significantly improving demand and acceptability of the 'interim relief' service.

The following benefits have been noted by Enkanini residents:

- *Increased safety for women at night because of the solar lights*
- *Reduced fire accidents in the area*
- *Reduced exposure to respiratory disease and fire risks.*
- *Improved quality of life, dignity, access to entertainment, news and current affairs.*
- *Additional stimuli and support for children to development literacy and language.*
- *Improved ability to communicate via readily accessible cell-phone charging*

Figure 20: iShack Agents are busy marketing and contracting new clients

Source: iShack (2017)

Table 9: Enkanini informal settlement with solar home system elements of the business models tested

Type of housing	Unelectrified Informal housing (urban)			
Energy needs	Previous energy usage and costs (before projects)	Initial model* Fixed monthly fee	New models being tested	
			Pay as you go	FBE** + maintenance
Lighting	R3.00/day paraffin = +/- 90 rands/month	R80.00/month	Solar home system	Payment of a system's deposit + R20.00 call out fee for required maintenance + R700.00 battery replacement when needed
Type of housing	**Unelectrified Informal housing (urban)**			
Phone charging				
TV		+ R50.00/ month		Optional
Cooking	Paraffin		Optional (alternative cooking fuels)	

** these costs include maintenance and free battery replacement*
*** in this new model, the service provider receives the FBAE payment of around 60R/household/month from the municipality.*

Case study 5: Providing integrated services in Thembelihle, City Power*

Figure 19: The proposed two plate gas stove

Source: Paul Vermeulen, presentation (16 February 2017)

The City of Johannesburg is committed to improving energy service delivery to households in informal settlements. Thus, the City decided to undertake a pilot project in two informal settlements (Thembelilhe and Lawley Station). The pilot projects seek to provide an affordable package of innovative alternative energy options to the two settlements, and ensuring that the basic services meet the expectations of the residents and improve living standards.

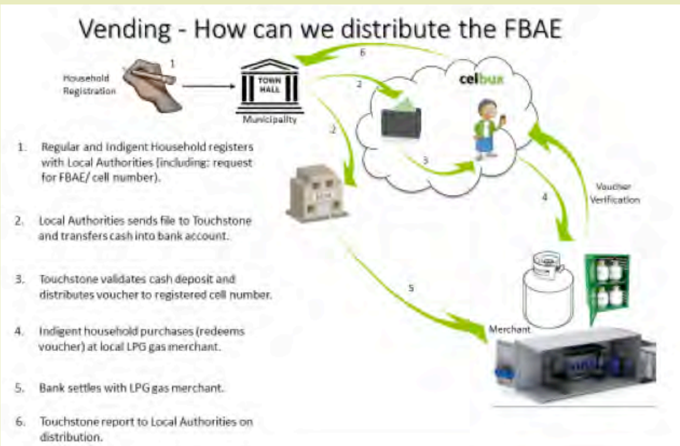
The sites selected are also constrained in terms of the grid – although grid connected they are at the end of the distribution line and there is not sufficient power within the substation to service the households. To address this, the city decided to provide households with grid electricity supplemented by with solar PV (a 3kW micro grid tied PV system with storage that will serve a cluster of six to twelve houses), and gas stoves. These options are intended to support the grid particularly during peak demand when the grid has limited capacity on the municipal bulk distribution network. A 20A ready board will allow lights to be connected and cell phones to be charged, but it is expected that gas will provide for water heating, cooking and space heating needs. Using an eVending system, households will be able to redeem their FBAE and purchase gas from a local business, making it easily accessible, while also creating local jobs.

The electricity connection will be restricted or partitioned into essential and switchable non-essential circuits to prevent overloading. Part of the pilot will include raising awareness around how to use the multiple fuel system as well as LPG safety. The cost of maintenance will be paid from a percentage of the income generated by the sale of electricity.

The main benefits, from a municipal perspective, of this approach are:

- *Partial avoidance of the usual need within the grid electrification service for cross subsidy from business or higher tariff customers to support O&M in low tariff customer areas, through low O&M costs of the PV panels*
- *High electricity savings during peak hours due to use of battery storage and LPG use*

Figure 20: The proposed vending system by City Power



Source: Paul Vermeulen, presentation, 16 February 2017

Solution to grid constraints in the area: boosting of the transmission stations would have been very costly; this energy service package solution provides a more flexible and cost effective option.

Table 10: Thembelilhe elements of the business models tested

Type of housing	**Non-Electrified Informal housing (urban)**		
Energy needs	Technology options chosen for the project	Upfront costs	O&M source of funding
Lighting	Grid electricity + PV connected to the grid (3kW + storage for 6 households)	40,000 ZAR/ HH	Prepaid electricity with FBE if indigent HH**
Phone charging			
TV			
Refrigeration			
Small appliances			
Thermal needs	LPG (Equipment supplied by the municipality)		HH will pay for the gas supply

** * this will only partially reduce the need for cross-subsidy and the risk of theft*

* This case study draws extensively from a presentation made by Paul Vermeulen, City Power on the 16th of Februaray 2017. Unless referenced otherwise, information is sourced from this document.

Case study 6: City of Cape Town ceiling retrofit programme

In 2014, Cape Town estimated that 40000 state subsidized homes did not have ceilings. To address this challenge the City of Cape Town decided to retrofit all the state subsidized housing that did not have insulated ceilings. The city secured R116 million in funding from the City's Separate Operating Account and the Development Bank of Southern Africa's Green Fund to be able to start retrofit the state subsidized homes.

So far the city has ran pilot projects in Kuyasa, Khayelitsha and Mamre, and this involved in installing insulated ceilings and weatherproofing and the city has plans to expand this programme to other areas of the city. Homes that have been retrofitted have gained significant health and comfort benefits. For example the households have improved thermal and energy efficiency which has reduced the need for cooling or heating the household during summer and winter respectively.

This has created significant social, economic and environmental local benefits. These include employment and the increased capacity of local artisans as well as environmental benefits such as mitigation of global climate change.

Figure 22: Installations of ceilings at Mamre

Source: The Kuyasa Fund, 2010

Figure 21: House with a ceiling at Mamre

Source: The Kuyasa Fund, 2010

Mamre Ceiling Insulation Evaluation, (Phillips, Silver, & Rowswell, 2011).

Resources

Urban Energy Resource Portal

Urban Energy Support is an information portal of relevant documents and resources, with an emphasis on practical tools and guides to support the transition towards sustainable local energy development and a low carbon trajectory for the country in the context of global climate change.
www.cityenergy.org.za

Documentary: Your Piece of the Sun Energy, Gender and Poverty in Urban South Africa (2016)

This is a captivating film (25 minutes long) produced by Lloyd Ross and Joelle Chesselet for Sustainable Energy Africa, explores the challenges of energy, gender and poverty in urban South Africa. Through illuminating case studies and interviews with people on the ground, new approaches and innovative solutions to energy service delivery for low-income households are illustrated. This film is intended to raise discussion and awareness and inspire innovative work in improving energy service delivery and access for low income households and in turn improve socio-economic development.
https://www.youtube.com/watch?v=1hGPui9ls3s&t=5s



Macro developments





Source: Georgia Tech Research Institute http://www.gtri.gatech.edu/history/media/237

Concentrated Solar Power

Overview

Concentrated Solar Power (CSP) plants generate electricity by collecting solar radiation and concentrating it into a small area to generate very high temperatures. The heat is then used to drive conventional (usually steam) generators in much the same way as coal and gas fired power plants do. A CSP plant consists of two basic components: 1) the Collector, which collects the incoming solar radiation and converts it to heat and 2) the Generator, which converts the heat into electricity. Most CSP technologies use very similar generators but there are different collector technologies. In South Africa, Parabolic Trough and Power Tower technologies are being used.

Parabolic Trough

A solar trough consists of a linear parabolic collector, which tracks the sun on a single axis to focus the light onto an absorber tube, which runs along the focal length of the troughs. The collectors hold a carrier fluid, which transfers the heat to the storage medium or generator. The Parabolic Trough technology is used in the KaXu Solar One (see case study 1) and the Bokpoort CSP plants both located in the Northern Cape.

Figure 1: A Parabolic Trough

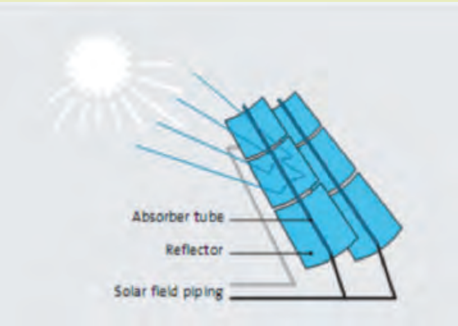
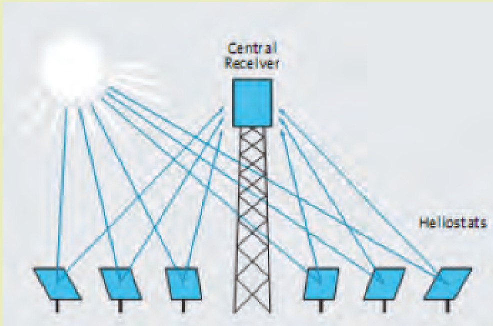


Figure 2: A Power Tower



Source: SEA, (2009). How to implement renewable energy and energy efficiency options. *Cape Town: SEA. Ch11 pg.2*

Power Tower

The power tower uses an array of mirrors, which track the sun on multiple axes to focus sunlight onto a central receiver, which is placed on the top of a tower. Like the parabolic trough, the receiver holds a carrier fluid, which transfers the heat to a storage medium or directly to the generator. The Khi Solar One plant uses this technology also located in the Northern Cape.

An advantage of CSP is the relative ease of energy storage. As the concentrated solar energy is used to generate heat, this heat can be stored (often as molten salts) in insulated containers and then used to generate electricity on demand, when there is no sunshine. This means that CSP is dispatchable[1] and can be used for both base-load power generation as well as peak load power generation.

1 Dispatchable electricity means that it can be used when needed. Wind and Solar PV generate non-dispatchable power because it depends on availability of wind and solar radiation.

Implementation

CSP is one of the technologies funded through the Renewable Energy Independent Power Producer Procurement Programme (EIPPPP). 600MW have been allocated to CSP of which 200MW have been built. All CSP plants are located in the Northern Cape that has optimal solar resources. The storage of molten salt allows for the electricity to be dispatched at any time including evening peak. This makes the technology a very valuable addition to the electricity system.

Despite the excellent solar resources in the Northern Cape CSP is still an expensive renewable energy technology. One reason for this is that not many plants have been completed worldwide compared to other renewable energy technologies where mass production has radically reduced costs.

The current REIPPPP tariffs of CSP generated electricity are between R2 and R3/kWh and therefore much higher than for solar PV and wind. However, if CSP generated power is fed into the grid during the evening peak, when power price is at a premium, its costs compare favourably to the cost of diesel for open-cycle turbines.

Only very few municipalities in the Northern Cape benefit directly from the large scale CPS projects funded through the REIPPPP and built in their area. The benefits will be in terms of local economic development and social upliftment funds which each project developed needs to allocate in the area. Municipalities cannot influence the location of REIPPPP projects. Other municipalities could only benefit if CPS projects are developed outside of the REIPPP programme.

Figure 3: 20 hectare Expansion Project, Port Augusta, South Australia

Source: Mansouraboud68, Wikimedia

Case Study 1: KaXu Solar One

KaXu Solar One is a 100MW CSP plant constructed on a 1,100ha site near Pofadder in the Northern Cape Province. It is the first CSP plant in South Africa to use parabolic trough technology. The project was officially opened in March 2015. It has the capacity to supply clean energy to approximately 80,000 homes while offsetting 315,000t of CO_2 *emissions a year. KaXu Solar One has storage of molten salt for 2.5 hours of electricity supply.*

Figure 3: Parabolic power troughs at KaXu Solar One

Source: power-technology.com http://ww.power-technology.com/projects/kaxu-solar-one-northern-cape/

Case Study 2: Khi Solar One

Khi Solar One is a 50 MW CSP plant. It is only the third plant using the solar tower technology worldwide, and the first outside of Spain. The tower plant is close to Keimoes outside Upington, in the Northern Cape Province.

The Khi Solar One plant uses a technologically advanced dry cooling system, which dramatically reduces water consumption by two-thirds.

The plant has thermal storage for 2 hours of electricity generation outside of solar radiation times.

Khi Solar One prevents approximately 183,000 tons of CO_2 *emissions per year, and has the capacity to supply clean energy to approximately 45 000 households.*

The plant has created an average of 600 jobs during construction, and approximately 35 permanent, full-time jobs during operations[2].

Figure 4: Power tower at Khi Solar One

Source: ©AbengoaSolar http://www.gicafrica.diplo.de/Vertretung/suedafrika-dz/en/pr/2013/04/04-Kopp-visit.html

2 http://www.abengoasolar.com/web/en/plantas_solares/plantas_propia/sudafrica/#seccion_2

Source: Creative commons CC BY 3.0
WaveRoller wave energy farm installed in Peniche, Portugal, in August 2012.

Ocean Energy

Overview

Ocean energy is a term for different technologies including:

- Ocean current energy;
- Wave energy;
- Ocean Thermal Energy Conversion (OTEC);
- Tidal energy; and
- Energy derived from differences in the salinity of seawater.

The technologies are at different stages of development but none of them is advanced enough to be financially viable.

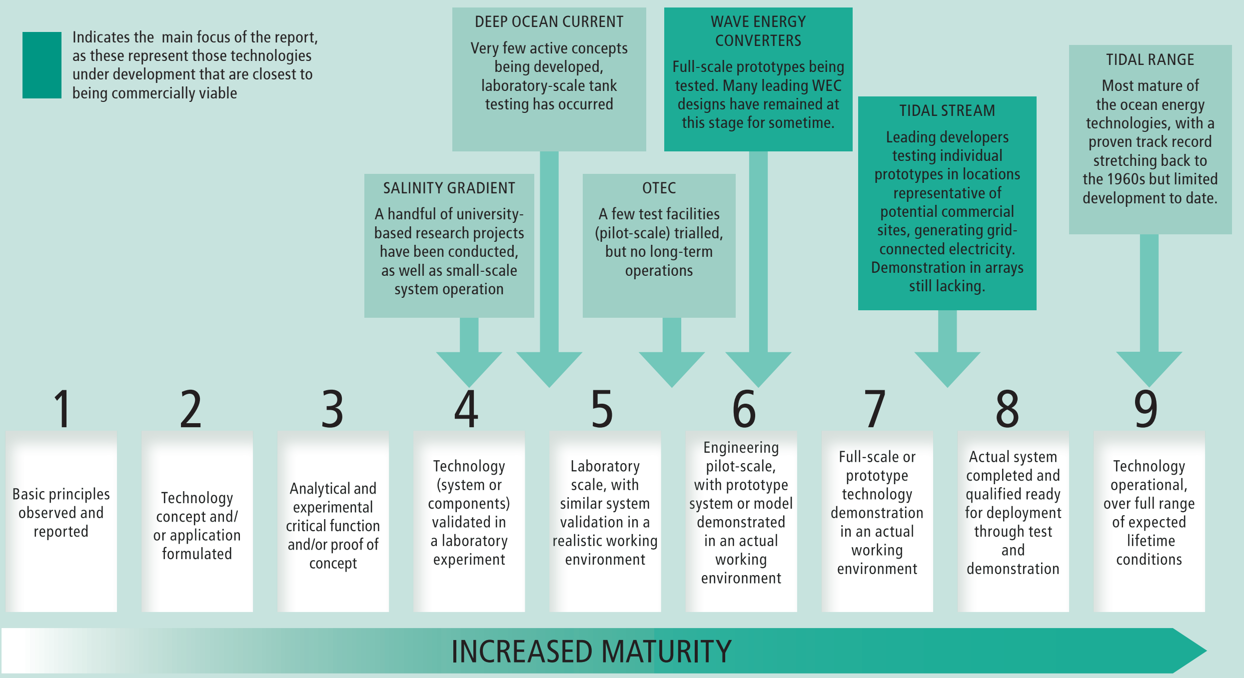
Only the first three technologies are explained on the next page because they have been considered in South Africa. For the other technologies no sufficient resources exist in South Africa.

Ocean current energy

The oceans contain several steady currents such as the Benguela and the Agulhas currents. Turbines fixed or suspended to the ocean floor can harvest the kinetic energy of currents and convert it to electricity that is brought to the coast through underwater cables. The technology can be used in locations where a current is close to the coast such as the Agulhas current along the east coast of South Africa. This technology has been piloted in the Gulf Stream off the coast of Florida in the USA and in Norway as indicated in Figure 2 on the next page.

An assessment of ocean currents off South Africa's coast[1] found that the Agulhas current travels swiftly enough for harvesting energy. It is also relatively close to the surface at less than 200m depth. The study estimates the overall power of the current as between 21 and 27GW but cautions that the useable power is significantly less e.g. due to ship traffic

Figure 1: Ocean energy technology readiness



Source: IRENA (2014) Ocean Energy – Technological Readiness, Patents, Deployment Status and Outlook. p.8

1 Meyer et al. (2013) Assessment of the Ocean Energy Resources off the South African Coast. CRSES Stellenbosch University (ed.)

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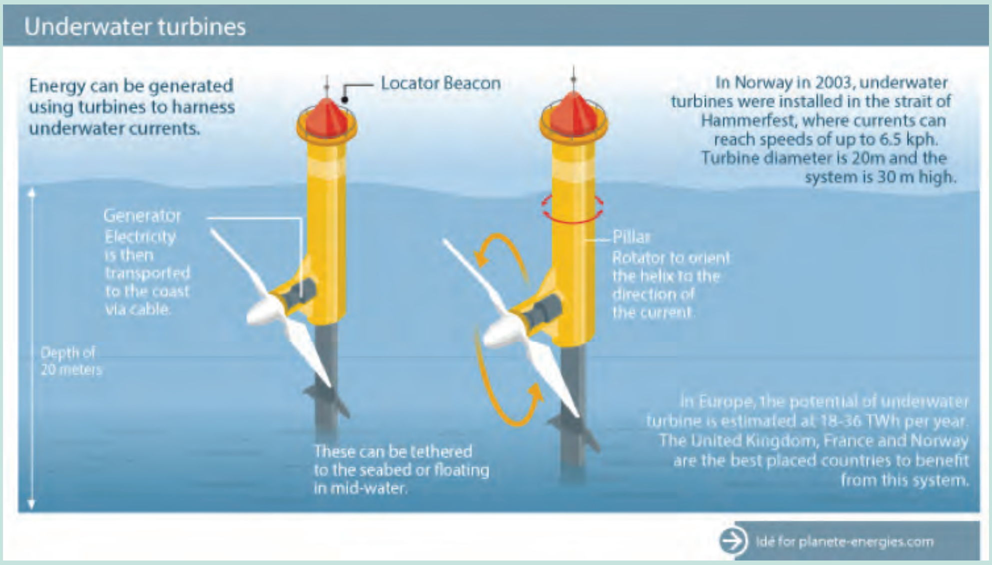
and technology inefficiencies. However, based on modelling the study found that the Agulhas current's strength and position varies more than was anticipated e.g. four to six times per year the current moves off course for a few weeks.

There is clearly a significant amount of energy available in the Agulhas Current but harnessing it remains a technical challenge. The variability of the current, which was greater than what was expected, will also reduce the amount of electricity that can be generated and the attractiveness of the current as a constant [base-load] source of energy." (Meyer I. et al, 2013)

The study further investigated suitable locations to install a pilot turbine in order to conduct further research into the best technology and the economic viability. The study proposes Cape Morgan at the mouth of the Kei River as the most suitable site.

Figure 2: Underwater turbines are turned by the current and generate power similar to wind turbines



Source: www. Planète-energies.com

Wave energy

Special buoys, turbines, or other equipment are used to capture the kinetic power of waves and convert this into clean, pollution-free electricity. Like wind and solar resources, wave energy is variable in nature.

The photograph shows the Pelamis Wave Power Project in Portugal using segmented tubes to absorb the wave power and convert it into electricity. This project was built in 2008 as the first commercial wave power project but has been dismantled after less than two years of operating because the equipment was damaged in the harsh marine environment making the project financially unviable[2]. Another technology to capture wave power is Oscillating Water Columns.

> "Oscillating Water Columns are conversion devices with a semi-submerged chamber, keeping a trapped air pocket above a column of water. Waves cause the column to act like a piston, moving up and down and thereby forcing the air out of the chamber and back into it. This continuous movement generates a reversing stream of high-velocity air, which is channelled through rotor blades driving an air turbine-generator group to produce electricity"[3]

2 Pers. comm. with Luis Castanheira, Environmental Defence Fund, Porto, January 2014.

3 IRENA (2014) Wave Energy Technology Brief.

In hot climates, oceans absorb a very large amount of heat from the sun and store it in the upper layers of water. OTEC uses the temperature difference between deep cold water and warmer water close to the surface to run a heat engine and produce useful energy, usually in the form of electricity.

The technology is being installed close to the shore and has been tested in Scotland, Spain, Australia and other countries. It appears to be simple and reliable but its performance is low.

The South African resources for wave energy have been assessed for five locations indicated in the map on the right.

The assessment was based on numerical modelling and found the highest wave power resources at Slangkop and Cape Point, followed by FA platform and Port Nolloth. The lowest wave power was found in Durban.

The study concludes that South Africa has a significant wave energy resource along the southwest coast that could be exploited as a source of renewable energy. However more detailed research is needed into larger sections of the coast to assist developers of wave energy technology to identify best suited locations.

Ocean Thermal Energy Conversion (OTEC)

In hot climates, oceans absorb a very large amount of heat from the sun and store it in the upper layers of water. OTEC uses the temperature difference between deep cold water and warmer water close to the surface to run a heat engine and produce useful energy, usually in the form of electricity. The exploitation of this resource requires a temperature difference of at least 20˚C. In tropical locations this can be found between around 1000m depth and the sea surface. The technology can only be used in locations with a steep drop in water depth close to the shore, such as in South Africa. Figure 6 shows the functioning of an OTEC plant of 100kW that was commissioned in Hawaii in 2015.

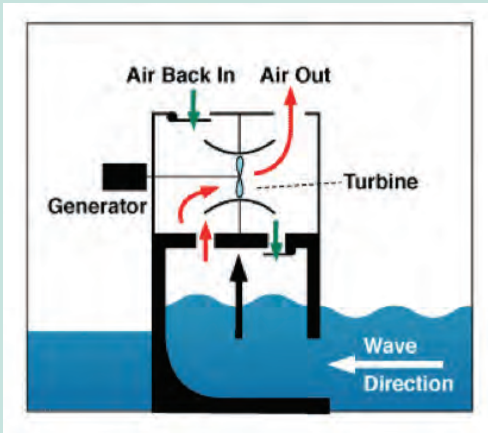
The potential of ocean thermal energy at the KZN south coast has been explored for a proposal to do more detailed research[4] into this resource. Depending on technology this

4 Gumede & DÁlmaine (2016) The Extraction of Power and Fresh Water from the Ocean off the Coast of KZN Utilising OTEC Techniques, Durban University of Technology (ed).

Figure 3: Segmented tubes absorbing wave power at Pelarmis Project in Portugal

Source: Wikimedia commons https://commons.wikimedia.org/wiki/File:Pelamis_at_EMEC.jpg

Figure 4: Semi-submerged chamber to capture wave energy

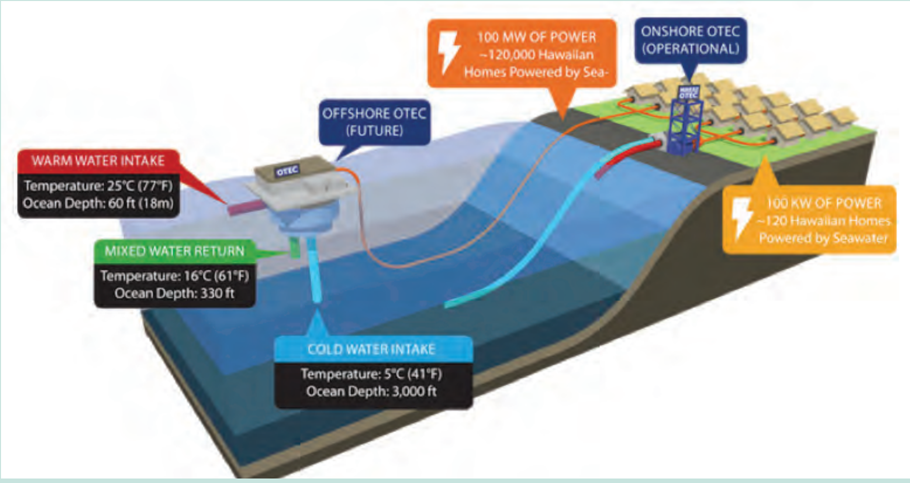


Source: By government [Public domain], via Wikimedia Commons http://www.energyquest.ca.gov/story_oldimages/chap14_wave_2007.gif

Figure 5: Locations of Ocean Energy Assessments

Source: Joubert & van Niekerk (2013) South African Wave Energy Resource Data. CRSES Stellenbosch University (ed.)

Figure 6: Ocean Thermal Energy Conversion (OTEC) plant in Hawaii in 2015



Source: http://www.makai.com/makai-news/2015_08_29_makai_connects_otec/

Figure 7: Key hurdles on ocean energy becoming commercially viable

resource could be used for electricity generation, and other applications such as desalination, seawater air-conditioning and marine culture. The authors propose Port Shepstone as a suitable location for testing an experimental design of OTEC because of the steep drop in water depth to 3 000m.

Implementation

Figure 7 indicates the key hurdles that any technology must overcome towards implementation. Ocean energy technologies have been tested or are being tested with different levels of success. The other aspects still need to be tested and addressed in similar detail.

The technologies used to harvest ocean energy and their potential electricity outputs are very site specific. This makes it difficult to predict performance and potential to reach economies of scale. All ocean energy technologies operate in a harsh marine environment. Most prototypes have operated for one or two years only and no conclusions can be drawn on the design life that determines their financial viability.

Current costs of ocean energy are estimated at around R5/kWh[5]. It appears unlikely that ocean technology will be able to compete in the near future with wind and solar PV that generate electricity at costs of just above R0.60/kWh in South Africa.

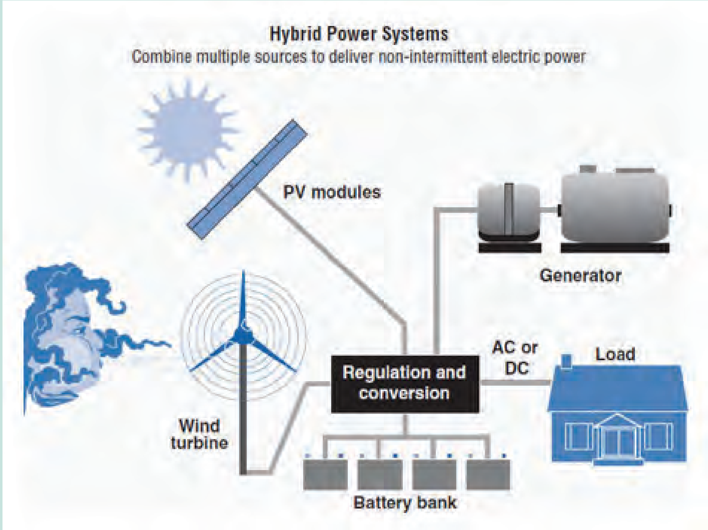
As the ocean energy technologies are not mature and viable yet municipalities cannot invest in them. Coastal municipalities with high ocean energy resources should try to attract research or pilot projects.

Overview

A hybrid system is an energy supply system that uses more than one source of energy. The term is used for vehicles and electricity supply systems. Examples of vehicles are hybrid cars that can operate alternatively on electricity or petrol, and hybrid busses that can operate on petrol or natural gas.

There will be a specific focus on decentralised hybrid systems to generate electricity. They include grid connected systems combining solar PV and wind turbines. Both sources generate electricity intermittently. Combining the technologies in a hybrid system expands the time during which electricity from renewable resources is available and minimises the need to draw electricity from the grid.

Figure 1: Off-grid hybrid systems supplied by solar PV, wind, batteries and back-up generator



Source: US Department of Energy http://energy.gov

Many hybrid systems combine variable renewable resources such as solar PV with diesel or gas powered generators and/or batteries for storage to balance the variable supply. These systems can supply electricity at any time and are typical off-grid solutions. They are used for mini-grids or single properties in remote areas not connected to the electricity grid.

Figure 1 shows an off-grid hybrid system consisting of solar PV panels, a wind turbine, generator and battery bank (see case studies 1 and 2).

Implementation

In South Africa hybrid systems have been piloted in a private public collaboration[1] in two mini grids in the Eastern Cape, one for the Hluleka Nature Reserve (see case study 1 below) and the other for neighbouring Lucingweni village consisting of 220 rural dwellings. The pilot projects were initiated by the Department of Minerals and Energy (DME) in 2003. They were implemented jointly by the National Energy Regulator of South Africa (NERSA), CSIR, Shell Africa and the Eastern Cape Provincial Government. The projects have been evaluated by the DME in 2008[2] and by the DEA and the South African National Energy Development Institute (SANEDI) in 2012[3] with rather negative reviews (see case study 1) and no further mini-grid projects have been developed in South Africa. However valuable lessons have been learnt and the DEA / SANEDI evaluation concludes that:

1 www.energy.gov.za/files/esources/renewables/r_hybrid/html

2 DME (2008) Mini-grid hybrid viability and replicability potential.

3 SANEDI DEA (2012) Sustainability of decentralised renewable energy systems report.

> "… this service delivery alternative should continue to be considered […]. This is in part due to the ability of mini-grids to supply energy for productive use, which is a necessary input for economic growth and job creation in rural areas. The mini- and micro-grid concept is making something of a comeback as solar PV prices continue to fall and grid extension process continue to mount. […] Yet, in order to achieve positive outcomes, more attention needs to be invested in developing mini-grid technologies in terms of the design and business model, as well as ensuring community buy-in."
> (SANEDI, DEA 2012 p. 44)

Another example of hybrid energy solutions is mines that are complementing diesel generators with renewable energy such as solar PV. These have proven to be financially viable as case study 2 shows.

Hybrid systems are more likely to play a role in municipalities that incorporate remote areas not connected to the electricity grid. In these areas hybrid systems powering micro grids may be more viable than the extension of the national electricity grid. In these cases the local electricity supplier – Eskom or the municipality – can promote and facilitate the installation of hybrid systems to power micro-grids. Experiences of the pilot projects covered below should be carefully considered.

Grid connected hybrid systems require the approval by the electricity distributor (Eskom or the municipality). In addition, grid-connected systems need a NERSA generation license if they are larger than one MW. Off-grid systems do not require a generation license or approval by the electricity distributor. However all installers of hybrid systems must approach the municipality to establish the need for a development application and approval according to the town planning legislation and building regulations (see section: Municipal mandates, powers, functions and regulatory responsibilities).

Financial Aspects

Off-grid hybrid systems are relatively expensive. As their components vary according to local resources and demand it is not possible to provide cost estimate. The financial viability of hybrid systems is expected to improve with the reduced capital costs of the renewable components such as PV panels.

These systems are being considered for rural electrification but the costs of power are often prohibitively high for poor users. However, they have proven to be financially viable in remote locations such as small islands or mines where they replace or complement expensive diesel generated electricity.

Barriers and Opportunities

The main barrier for hybrid systems supplying rural communities is cost.

Another barrier is the technical complexity of the systems due to their many components that need to work together seamlessly. Local trained personal to operate and maintain the hybrid system is necessary to manage a hybrid system successfully and over a long time.

A further barrier is the imitations of the system that cannot provide the same level of service as the power grid, e.g. the capacity of a hybrid system is limited and overloading will result in its collapse. Very clear communication to manage the expectations of the user community is needed to overcome this problem.

Case Study 1: Hluleka Nature Reserve*

The Hluleka Nature Reserve is located 20km south of Port St. Johns at the Wild Coast. Before installing the hybrid system the nature reserve had strongly reduced its electricity consumption by replacing electric stoves with gas stoves and electric geysers with solar water heaters. Energy saving light bulbs were also installed.

The hybrid system consisted of two 2.5kW wind turbines mounted on 6.5m high poles, 56 PV panels of 100W each (5.6kWp), inverters, a battery bank to provide 5 days reserve electricity, and a diesel generator as back-up. The system was designed to carry the household load of chalets as well as the load of the water pumping and purification system.

The DME evaluation states that the design and construction of the system was sound but proved to be too small for the load. The evaluation criticises the high cost of electricity estimated at R5.35/kWh (compared to around R0.30/kWh for grid electricity in 2007). They also critique the lack of monitoring that should have been central to a pilot project and made the project difficult to evaluate. At the time of the DME evaluation one wind turbine was not functioning and some solar panels had been stolen as shown in the photograph below. The reason for theft was that the system was installed far away from the reserve where it was not properly secured. The electricity supply relied strongly on the diesel generator

The main concern raised in the DME evaluation was the lack of a maintenance budget and trained staff to operate and maintain the system. The components of the system were imported and when an inverter broke down a technician had to be flown in from Germany. The limited sense of ownership and lack of management were the principle causes of the poor performance.

Figure 2: Renewable energy components of hybrid system at Hluleka Nature Reserve

Source: Ortiz et al. (2009) Potential for Hybrid PV Systems for Rural South Africa, in: Proceedings of Solar World Congress 2009: Renewable Energy Shaping Our Future.

Figure 3: Vandalised PV panels at Hluleka Nature Reserve

Source: DME 2008 p.18

Recommendations focus on involvement of the beneficiaries of the electricity and management. This should start with an accurate assessment of electricity demand. It is recommended to then use a modelling tool for sizing the system. A financing and revenue model must be developed that covers costs of operations and maintenance. The recommendations also state that a mini-grid in a rural area generally involves the following role-players whose responsibilities must be clearly defined. These are:

- *Regulatory authority (licensor)*
- *Project developer*
- *Engineering consultant*
- *Contractor*
- *System operator*
- *Maintenance contractor*
- *Training provider*
- *Users*

The evaluation by DEA and SANEDI found that the hybrid system was relying wholly on the diesel generator at the time of their evaluation in 2012.

* This case study draws extensively from Ortiz, B. et al. (2009). Potential for Hybrid PV Systems for Rural South Africa, in: Proceedings of Solar World Congress 2009: Renewable Energy Shaping Our Future. Unless referenced otherwise, information is sourced from this document.

Case study 2: Thabazimbi Chrome Mine in Limpopo*

The Thabazimbi Mine uses a hybrid system supplied by solar PV and diesel generators. The Thabazimbi area is remote with only limited grid connection and high transportation costs for diesel. The area has high solar irradiation making it ideally suited for the use of PV. Since 2012, a solar PV system with a capacity of 1MW complements the diesel generated electricity. The PV system generates up to 1.8GWh per year and minimises the fuel consumption during the day. It saves the mine up to 450 000l of diesel and reduces CO_2 emissions by up to 1200t per year.

Considering the estimated installation costs of R20m and the estimated annual savings for diesel of R4m, this hybrid system is financially viable.

Figure 4: PV installation at Thabazimbi Mine

Source: Paul Robert Stanka http://en.sma-sunny.com/en/first-pv-diesel-hybrid-system-in-the-megawatts-goes-into-operation/

* www.SMA.de/en/products/references.htm

Geothermal Energy

Overview

Geothermal energy is heat or coolness sourced from the earth. It's clean and sustainable. Either the heat from the earth or the coolness of the ground is used in geothermal energy systems. As a source of heat, sources of geothermal energy range from the shallow ground heat to hot water and hot rock found a few kilometres beneath the Earth's surface, and down even deeper to the extremely high temperatures of molten rock called magma.

Figure 1 shows the average temperature from the core to the crust of the earth. Due to geological formations in some places heat from the earth is available in relatively shallow depth or even at the surface e.g. in the form of hot springs. In these locations geothermal energy can be used for electricity generation or directly for heating.

Geothermal energy for electricity generation

Geothermal power plants use steam produced from reservoirs of hot water found some kilometres below the Earth's surface. The steam rotates a turbine that in turn powers an electricity generator. This technology is only feasible at large scale.

Figure 2 shows that hot water or steam is extracted from the earth and used to generate electricity. The cold water is pumped back down to balance the hydrology.

Electricity generation is only feasible at locations where sources of hot underground water are available at 3 to 5 km below the surface. However depth and usability depend on the local geology.

Figure 1: Origin of geothermal power

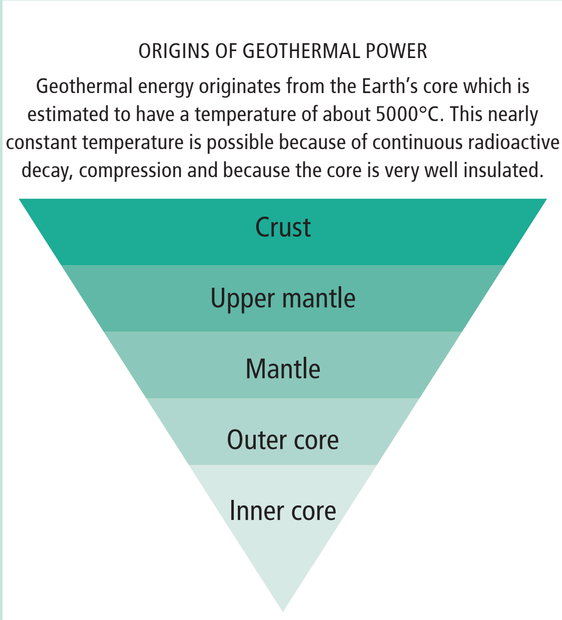
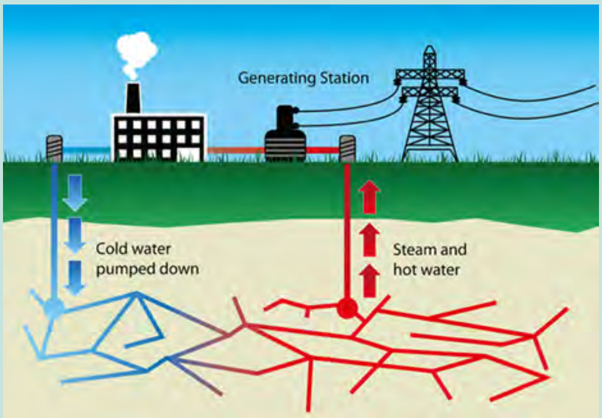


Figure 2: Principles of electricity generation from geothermal energy



Source: Wikimedia commons https://commons.wikimedia.org/wiki/File:Geothermal-energy.png

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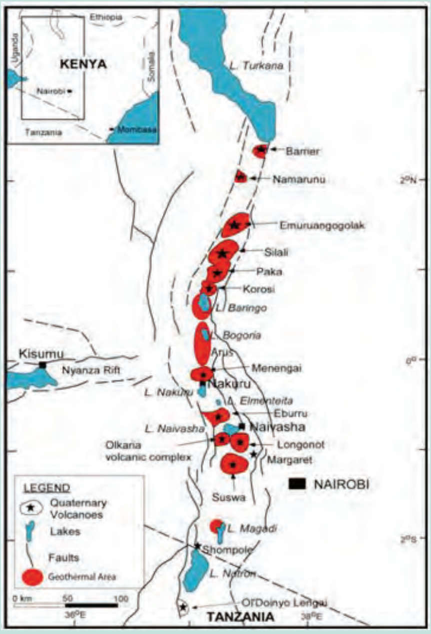
Figure 3: Olkaria geothermal power plant in Kenya

Photo: Lydur Skulason

Source: https://commons.wikimedia.org/wiki/File:Worker_in_Olkaria_Kenya.jpg

Figure 4: Geothermal potential in the Rift Valley



Source: www.akiiraone.com

Figure 5: Greenhouse in Kenya supplied by geothermal direct heat

Source: Owory, 2016 www.standardmedia.co.ke https://www.standardmedia.co.ke/business/article/2000204628/gdc-to-go-big-on-direct-uses-of-geothermal-energy

In Africa such conditions exist in the Great Rift Valley. Kenya uses this geothermal energy to generate electricity and as direct heat (see below) along the Rift Valley as shown on the map. So far 500MW[1] electricity generation has been installed, and a further 2000MW[2] are planned.

Geothermal direct heat

The same geothermal heat can be used directly for heating purposes. In modern direct-use systems, a well is drilled into a geothermal reservoir to provide a steady stream of hot water or steam. The water or steam is brought up through the well, and a mechanical system – piping, a heat exchanger, and controls – delivers the heat directly for its intended use. The cooled water is then re-injected into the ground.

1 wikipedia.org/wiki/Geothermal_power_in_kenya

2 www.euronews.com>NEWS>World_news 5 August 2016

Geothermal hot water can be used for many applications including the heating of buildings or greenhouses or several industrial processes. These systems are viable at large to medium scale. In Kenya direct heat is used for heating of greenhouses.

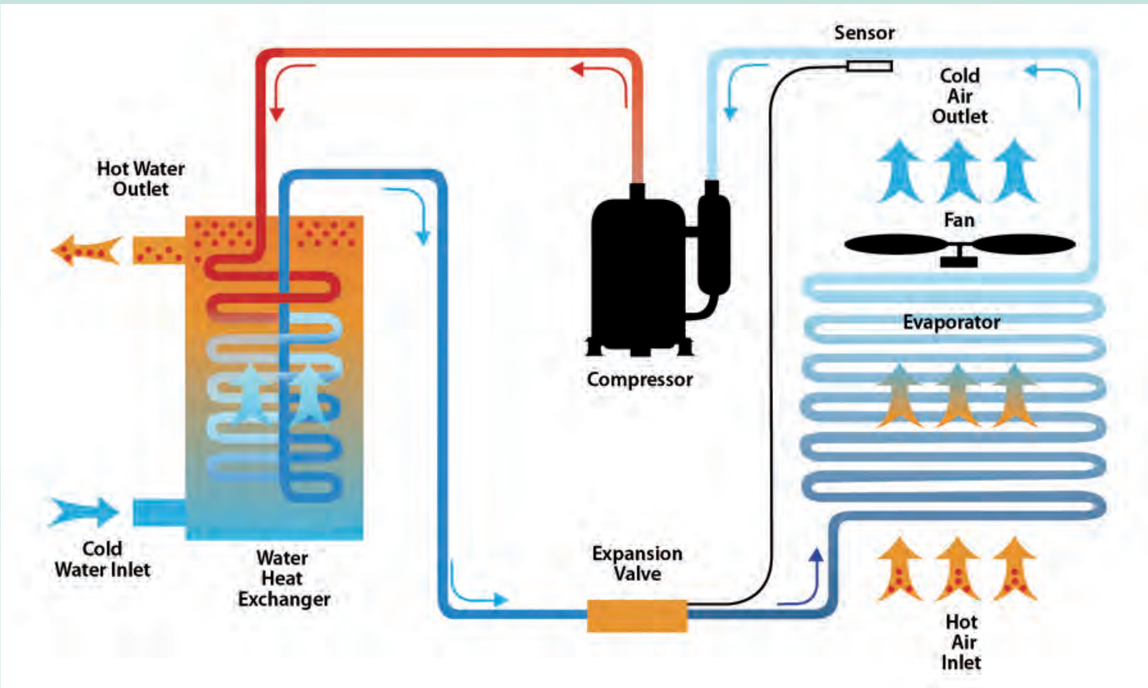
Heat pumps using the ground or ground water

This technology is very different from that described above. It works at small scale, typically for one or a small group of buildings. Its viability depends on the local requirement for heating and cooling, the local climate, and the cost of installation that differ according to the geology.

The shallow ground, around 2m below the surface, maintains a temperature between 10°-16°C all year, which is far more constant than the air temperature above the surface. In greater depth the temperature is even more constant. In many areas during winter the ground is warmer than the air above it and in summer the ground is cooler than the air. Ground and ground water heat pumps take advantage of these temperature differences to heat and cool buildings.

Heat pumps use a similar technology to refrigerators. They move heat from a source (such as the ground or ground water) to a destination (such as a water tank). A heat pump consists of an evaporator a compressor, refrigerator gas, a valve and a condenser, all operating in a closed circuit as shown in the diagram below. The technology uses a small amount of electricity to extract heat from the source medium and uses it to heat water or the air inside a building. The system can also run in reverse to cool a building.

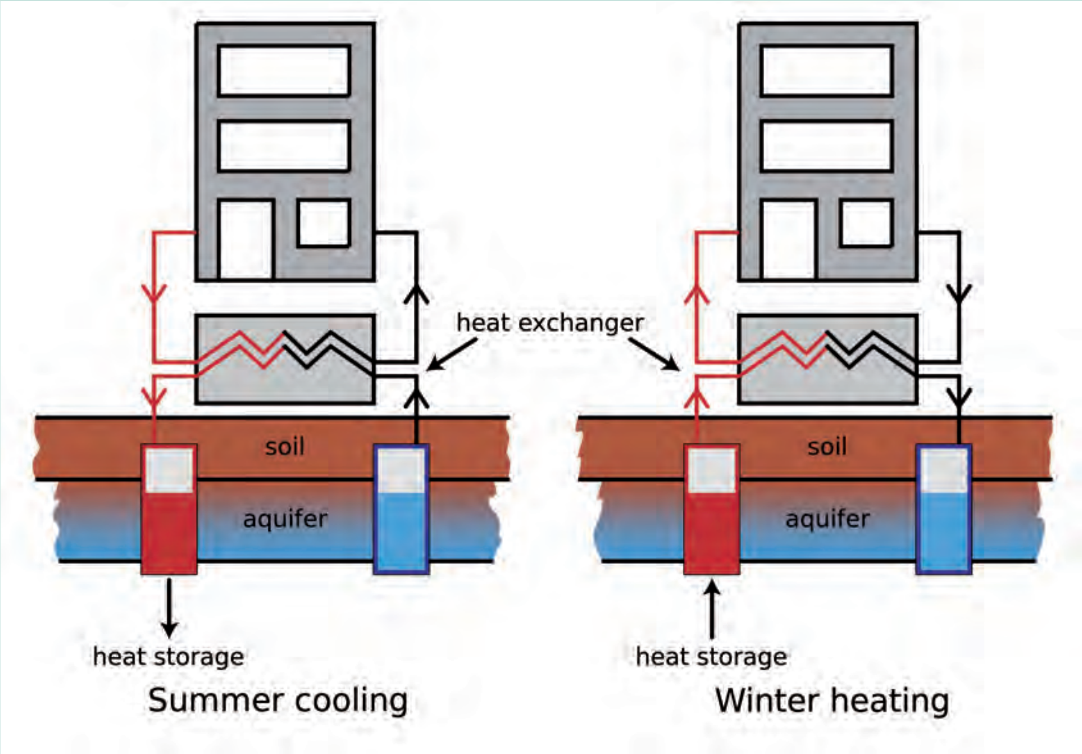
Figure 6: Components of a heat pump



Source: eThekwini Municipality Energy Office (2016), Technologies for renewable energy and energy efficiency – how do they work?

There are many types of heat pumps. They are distinguished by the medium from which they extract the heat. In South Africa the most common type is the air-water heat pump, extracting heat from outdoor air to heat water in a tank. These are described in detail in the section on Solar Water Heater. Such water heating systems are used in commercial (e.g. hotels), hospitals and residential applications, and efficiencies match those of solar water heating.

Figure 7: Ground source heat pump in cooling and heating modes



Source: Wikimedia commons https://commons.wikimedia.org/wiki/File:HeatAndColdStorageWithHeatPump.svg

Heat pumps extracting heat from the ground or from ground water are principally more efficient than those extracting heat from air because water and the ground carry a much higher amount of thermal energy than air. In order to extract heat from the ground a system of pipes is buried near the building. A fluid (usually water) circulates through the pipes to absorb heat from the ground.

In winter, the heat pump removes heat from the heat exchanger and pumps it into the building. In summer, the process is reversed, and the heat pump moves heat from the building into the heat exchanger and pumps it into the ground. The system can be extended to also supply hot water.

The efficiency of a heat pump depends on the quality of the equipment and more importantly on the differentials of the

- Temperature of the ground or ground water (source),
- Required temperature in the building (destination), and
- Outside air temperature.

The quality of the heat pump is measured by the Coefficient of Performance (CoP) that describes the ration of thermal energy output to electrical energy input. A high CoP indicates high efficiency and it should be higher than 3. However, the same heat pump will perform differently in different locations. The real efficiency is location specific and needs to be calculated for the specific temperature conditions as the Seasonal Energy Efficiency Ratio (SEER).

For hotels and hospitals with balanced heating and cooling demands payback periods of five to seven years can be achieved.

Heat pumps work most efficiently if the demand for heating and cooling is balanced because a similar amount of heat is extracted from the ground than is pumped back. In a case of only demand for cooling the heat pumped into the ground will eventually raise the underground temperature and reduce the efficiency. Highest efficiency is achieved when cooling and heating demands occur at the same time and direct heat recovery is possible. An example of this is a case when the demand for space cooling is matched by the demand for hot water.

Implementation

South Africa does not have large scale geothermal resources to generate electricity or use for direct heat. Only heat pump technology can be viably used depending on location and demand for heating and cooling. Currently, ground or ground water heat pumps are very rare in South Africa.

In most parts of South Africa the demand for space heating is much lower than for cooling because winters are short and mild. The demand for hot water depends on the use of the building e.g. it is high in hotels or hospitals but low in commercial buildings.

Ground and ground water heat pumps are expensive due to the underground installation of pipes, and their financial viability must be tested for each situation. For hotels and hospitals with balanced heating and cooling demands payback periods of five to seven years can be achieved (see case study Hotel Verde). Financial viability is not likely for domestic buildings. However, for them air heat pumps for hot water are a viable alternative to solar water heaters.

Municipalities can use the heat pump technology in their own buildings if viable (see sub-section on heat pumps in Solar Water Heater section). However, the technical and financial viability depends on the local conditions and the use of the building and must be modelled on a case-by-case basis. Some financial implications are presented in the Case Study Hotel Verde below.

If developers intend to install heat pumps the municipalities are responsible for the development application and approval process. The SANS 10400-XA requires that in new buildings and in buildings after major refurbishments at least 50% of the heat demand is met by means other than electrical resistance heating. Heat pumps are a suitable option to supply thermal energy.

Case Studies Hotel Verde in Cape Town*

The Hotel Verde has received six stars, the highest rating by the Green Building Council South Africa (see case study 4 in section on Energy Efficient Buildings) for Existing Building Performance it is also LEED (Leadership in Energy and Environmental Design by the US Green Building Council) Platinum certified for both Design and Construction as well as Existing Building: Operation and Maintenance.

Its sustainable features include energy efficient building design, renewable energy generation through wind turbines and solar PV, water saving and waste minimisation measures. It also has an energy-saving heating and cooling system using ground source heat pumps.

This Heating Ventilation and Cooling (HVAC) system achieves extraordinary efficiency through a geothermal loop field coupled to ground source heat pumps for central heating/cooling and domestic water heating. The geothermal field consists of 100 boreholes, each approximately 65m deep. Each hole contains a U-bend pipe. Combined, there is approximately 13 km of piping beneath the footprint of the building. Water passes through these pipes to either dump heat (in summer) or gain heat (in winter) from the constant ground temperature at this depth of around 19.4°C, thus using the earth as a huge thermal battery.

This system is well suited for a hotel project in the Cape Town climate as the heating and cooling loads are reasonably balanced over an entire annual cycle and the ambient-, heating-/cooling- and ground-temperatures are such that in winter one can extract energy out of the ground and in summer one can reject energy into the ground.

The hotel is about 12000 m² usable surface area and the plant has a capacity of 304kW in cooling, 364kW of heating only or 182kW for heating plus 167kW for hot water generation.

At the time of construction (2013) the costs of the system were approximately:

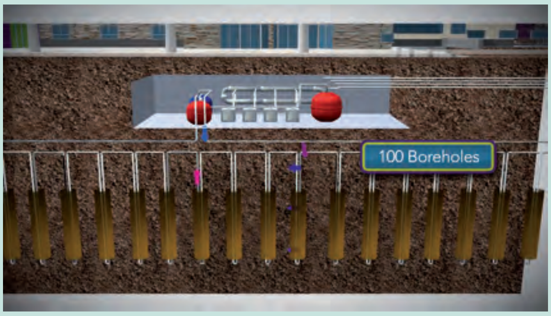
- *Geothermal installation (incl. extra earthworks, P&G, fees etc.): R6m*
- *Plantroom: R9m – R10m (incl. equipment, logistics, installation, delayed commissioning, variation orders, fees etc.)*

The system saves around 50% of the electrical energy that a conventional HVAC system would require. The expected payback period is 5 to 7 years.

Figure 8: Aerial view of Hotel Verde, Cape Town

Source: www.hotelverde.com

Figure 9: Geothermal field of 100 boreholes extracting or dumping heat



Source: André Harms

* Information provided by André Harms, director and principal sustainability engineer at Ecolution Consulting, Cape Town in January 2017 and www.hotelverde.com/static/green-showcase

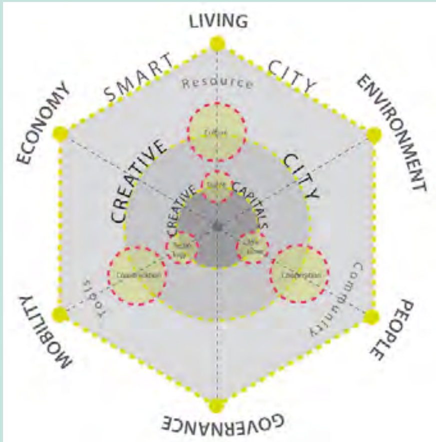
Overview

Poole, 2014[1] argues that the 'Smart City' concept dates back to the early 20th century with the invention of automated traffic lights (robots) and that in the last decade the concept has been driven by giant technology companies aided by increased internet connectivity and the miniaturisation of electronics. The concept has also been appropriated by a broad range of sectors with a common indicator that information and communication technologies (ICT) are central to modern infrastructure development and improved governance in cities.

Wikipedia defines a Smart City as:

> "an urban development vision to integrate multiple information and communication technology (ICT) and Internet of Things (IoT) solutions in a secure fashion to manage a city's assets – the city's assets include, but are not limited to, local departments' information systems, schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other community services. The goal of building a smart city is to improve quality of life by using urban informatics and technology to improve the efficiency of services and meet residents' needs. ICT allows city officials to interact directly with the community and the city infrastructure and to monitor what is happening in the city"[2]

Figure 1: Representation of components of smart city concept



Source: Maurizio Carta

Implementation

The smart city concept is very diverse and internationally, cities have taken different approaches towards it. In South Africa experiences with the concept are still limited.

A key precondition for smart city initiatives is access to the internet and availability. In South Africa this is constrained by high cost of data that exclude especially poor people. Therefore, a first step of municipalities to enable smart city initiatives could be the provision of free Wi-Fi services in public spaces as for example implemented in the City of Tshwane.

The concept has also been appropriated by a broad range of sectors with a common indicator that information and communication technologies (ICT) are central to modern infrastructure development and improved governance in cities.

1 Poole (2014) The truth about smart cities: In the end, they will destroy democracy The Guardian [online] available at https://www.theguardian.com/cities/2014/dec/17/truth-smart-city-destroy-democracy-urban-thinkers-buzzphrase

2 https://en.wikipedia.org/wiki/Smart_city

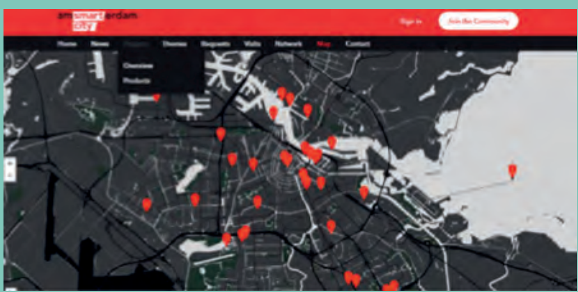
Case Study 1: Benefits and experiences – a European perspective

In 2011 the European Commission initiated the Smart Cities and Community Initiative that initially focused on energy. The focus was extended to include transport and ICT sectors after the launch of European Innovation Partnership on Smart Cities and Communities (EIP-SCC)[3].

The Partnership combines Information and Communication Technologies (ICT), energy management and transport management to come up with innovative solutions to the major environmental, societal and health challenges facing European cities today. With the aim of coming up with scalable and transferable solutions to contribute to the EU's 20/20/20[4] climate action goals, it looks to reduce high energy consumption, green-house-gas emissions, bad air quality and congestion of roads.

The Partnership aims to overcome bottlenecks impeding the changeover to smart cities, to co-fund demonstration projects and to help coordinate existing city initiatives and projects, by pooling its resources. The partnership supports the collaboration of cities, industry, SMEs, banks, research and other smart city actors to develop urban systems and infrastructures of tomorrow[5].

Figure 2: Project map of Amsterdam



Source: https://amsterdamsmartcity.com/map

Figure 3: Shared bicycles in Milan

Photo: Daniel Case

Source: https://commons.wikimedia.org/wiki/File:Shared_bicycle_rack_near_Milan_Stazione_Centrale.jpg

Examples of initiatives in European Partnership cities:

- *Milan promotes sharing and has introduced initiatives of shared bicycles, electric cars, free public wifi and shared office and production spaces for small businesses[1];*
- *Amsterdam[2] has set up a website as a space to present and promote innovative projects and their initiators in many fields. The website allows citizens, businesses and municipal officials to connect and promote their projects. Energy related projects include using seawater for the cooling of buildings and promoting e-mobility.*
- *Helsinki is establishing 'Smart Energy Kalasatama'[3], an urban neighbourhood with a smart grid connecting all residents and businesses. They can use a dynamic electricity tariff to save money and reduce*

1 http://www.eurocities.eu/eurocities/projects/SHARING-CITIES&tpl=home

2 https://amsterdamsmartcity.com/

3 https://fiksukalasatama.fi/en/smart-city/

3 https://eu-smartcities.eu/about

4 In 2011 the European Union set itself targets for 2020 to reduce GHG emissions by 20%, increase energy efficiency by 20% (compared to 1990) and generate 20% of electricity from renewable sources.

5 http://ec.europa.eu/eip/smartcities/about-partnership/what-is-it/index_en.htm

peak time demand. Another objective in Kalasatama is to increase the share of renewable energy in the energy mix and provide charging stations for electric vehicles.

- *Milton Keynes in the UK is a fast growing city that uses big data collected by a network of sensors to manage transport, energy and water systems to cover the increasing demand without expanding the systems.*[4]

Figure 4: Kalasatama, Helsinki

Photo: Timo Newton-Syms

Source: https://commons wikimedia.org/wiki File:Kalasatama_(7764252308).jpg

Figure 5: Milton Keynes data hub visualisation

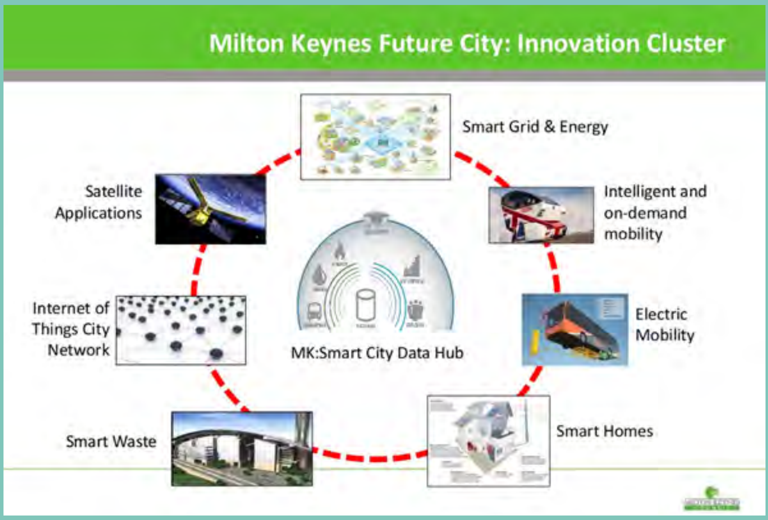


Photo: Sarah Gonsalves

https://www.slideshare.net/LocalDigitalGov/building-iot-solutions-in-milton-keynes-sarah-gonsalves-june-2015

4 http://www.createtomorrow.co.uk/en/live-examples/milton-keynes

A recent study commissioned by the European Union (EU) into Smart Cities and Communities[6] examined 300 smart city and smart community initiatives in the EU and in developing countries. All initiatives are using integrated ICT for several functions. The study found that city-wide smart solutions are still rare. Most initiatives seek to establish smart districts or focus on energy efficiency and mobility projects. Commonalities of many initiatives are summarised in the table below:

Table 1: Common types of projects and their value propositions in smart cities and communities

Type		**Value Proposition**
Sustainable Urban Mobility	Real-time road user information	Enable people to take informed decisions about their mobility, saving time and energy.
	ITS-based enhancement of public transport	Reduce waiting time as well as emissions, and facilitate intermodal commuting.
	ITS for traffic monitoring, management and enforcement	Optimise fleet management and route scheduling.
Sustainable Districts & Built Environment	Smart technologies for the built environment	Pursue better living, resource efficiency and waste reduction
	Sustainable districts	Reduce emissions and resource consumption by embedding integrated energy efficiency technologies.
	Place making	Create communities of interest that can be key to support integrated SCC solutions.
Type		**Value Proposition**
Integrated Infrastructure & Processes	Smart City Platforms	Allows real time monitoring and preventive steering of cities.
	Intelligent City Services	Co-ownership of local matters and outcomes. Efficiency savings for city administrations. Stimulate involvement at local level.
	Smart Grids	Collected information and insights may serve planners and managers, but are often also shared with users, who can take more informed decisions and can also become prosumers, i.e. users that can switch from being energy consumers to becoming producers based on the circumstances.

Source: EU Directorate-General for Energy (June 2016)

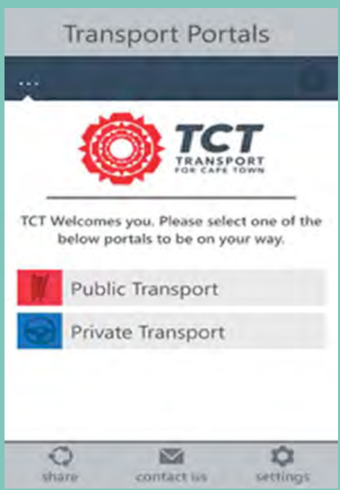
In South Africa the Smart City concept features in many planning documents but project implementation has mostly focused on the installation of smart meters in several municipalities (see below). However, often ICT supported projects are implemented in several municipalities without being labelled 'smart'.

6 EU Directorate-General for Energy (June 21 2016) Analysing the potential for wide scale roll out integrated Smart Cities and Communities solutions https://ec.europa.eu/energy/sites/ener/files/documents/d2_executive_summary_en.pdf

Examples of 'smart' projects in South African cities

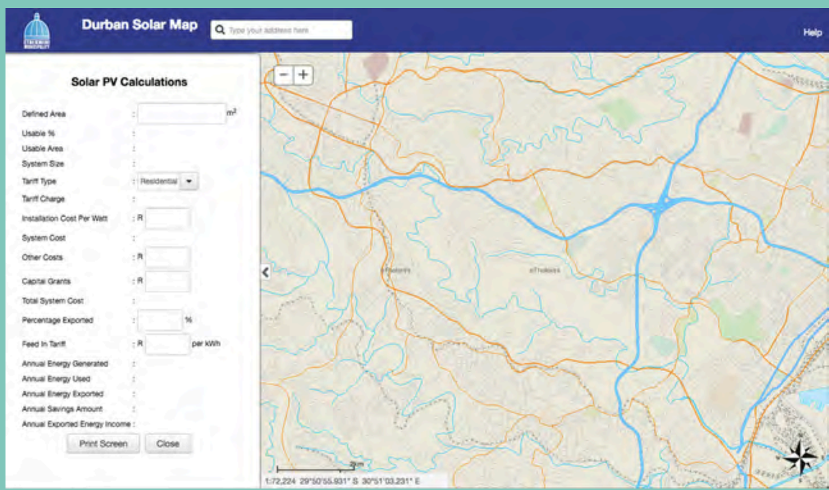
- Smartphone app to navigate the Cape Town public transport system[1];
- Provision of free Wi-Fi services in several hundred public spaces in Tshwane[2]; and
- Solar Map in Durban[3] that allows residents to plan a Photovoltaic Installation on their roofs and gather information regarding power generation, investment costs and electricity savings.

Figure 6: Cape Town Public Transport App



Source: https://www.microsoft.com/en-us/store/p/tct/9wzdncrdxk1x#

Figure 7: Durban Solar Map screenshot



Source: http://gis.durban.gov.za/solarmapviewer

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1 www.tct.gov.za/en/tools-and-resources/tct-app

2 http://www.tshwane.gov.za/Pages/WIFI.aspx

3 http://gis.durban.gov.za/solarmapviewer/

What are Smart grids?

A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart grids co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimising costs and environmental impacts while maximising system reliability resilience and stability. (EIA 2011)

Rationale for smart grid technology

The world's electricity systems face a number of challenges, including growth in demand, the integration of increasing numbers of variable renewable energy sources and electric vehicles, the need to improve the security of supply and the need to lower carbon emissions. Smart grid technologies offer ways not just to meet these challenges but also to develop a cleaner energy supply that is more energy efficient, more affordable and more sustainable. (EIA 2011)

Overview

The smart grid is a component of the smart city concept related to electricity distribution. In 2011, the International Energy Agency (IEA) published a roadmap for the deployment of smart grids [1]. It defines the smart grid and its rationale (see textbox).

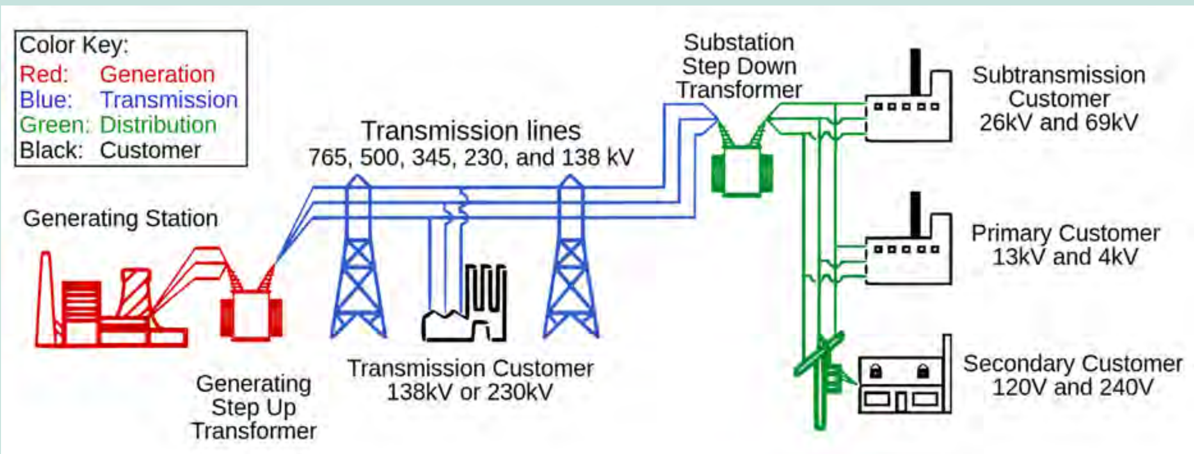
Basic technical aspects

A principle of electrical grids is that the power supply must always match the demand. If the supply exceeds the demand, electricity is wasted. If the demand exceeds the supply power outages can occur.

A conventional electricity grid is characterised by the one-directional flow of power from a few large power stations through transmission and distribution grids to the consumers. The grids have substations that reduce the voltage of the electricity gradually to the needs of the consumers (see Figure 8 below). The one-directional flow in the grid requires only simple metering of consumed power. The grid operators balance supply and demand on the basis of their practical experience.

1 EIA (2011) Technology Roadmaps Smart Grid

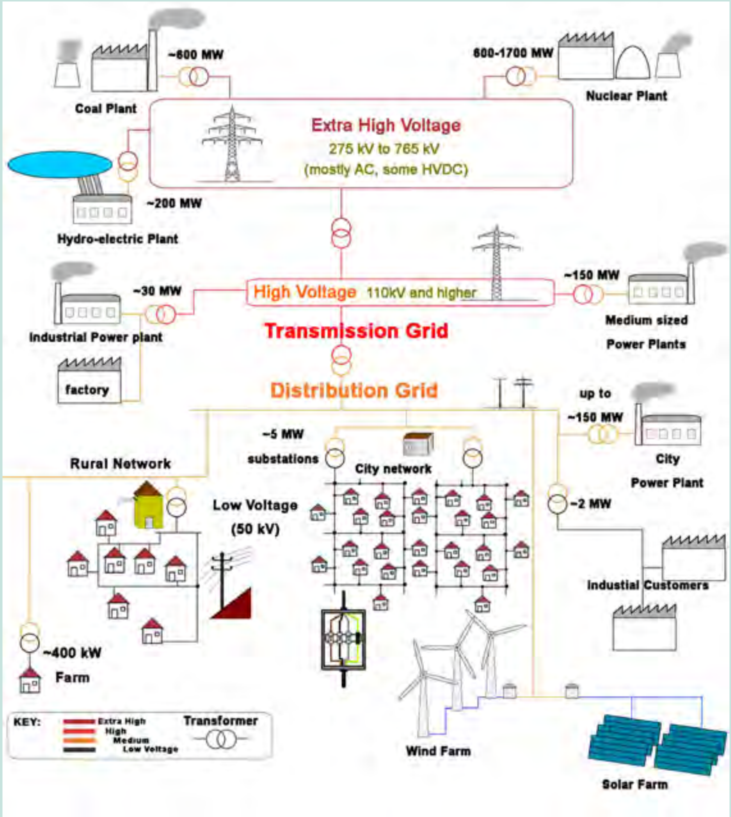
Figure 8: Conventional one-directional grid from large power generator to consumers



Source: US Department of Energy https://commons.wikimedia.org/wiki/File:Electricity_grid_simple-_North_America.svg

The introduction of electricity generated from renewable sources (wind and solar) makes it more difficult to balance supply and demand in the grid. Renewable energy from wind and solar is variable and provided by many large and small suppliers who are often at the same time consumers of electricity. The management of a grid with many variable suppliers is more complicated and requires timeous information on the performance of the power generators and the demand of customers. Information is gathered by linking the electricity grid to the ICT network that provides supply data from generators and demand data from customers at short time intervals. A smart grid is therefore a combination of the electrical grid and the ICT network.

Figure 9: Smart grid integrating small and large power generators



Source: Stefan Riepl https://commons.wikimedia.org/wiki/File:Electricity_grid_schema-_lang-en.jpg

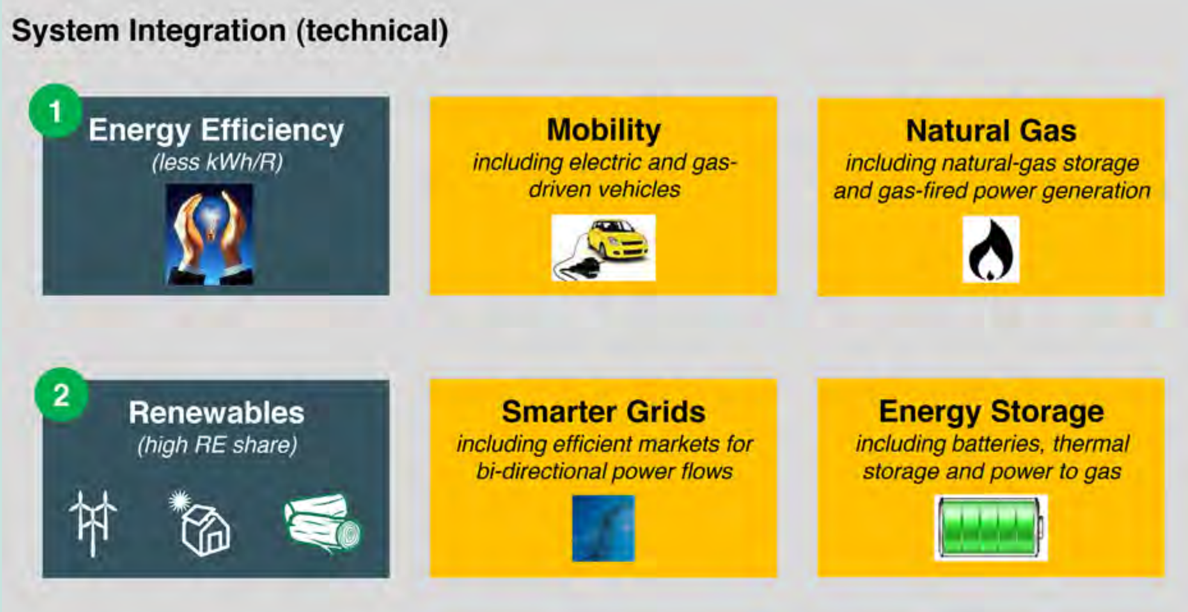
In addition to integrating renewable energy, smart grids have advantages such as enabling demand side management by the electricity grid operator, increasing efficiency in power use and in turn reducing greenhouse gas emissions. A Smart Grid is characterised by:

- Integration of the electricity grid with an ICT network;
- Decentralised power supply through many large and small generators;
- Bi-directional and smart meters transmitting data on the flow of electricity at short intervals;
- Different types of storage for electricity, including battery banks and electric cars;
- Ability to quickly respond to changes in supply and demand, e.g. through switching on additional suppliers or demand side management;
- Network grid instead of hierarchical grid; and
- Steering the gird with the assistance of a powerful IT system.

The transformation of a conventional grid to a smart grid is costly and typically implemented incrementally when the need arises or when the benefits exceed the costs.

Although the smart grid has many benefits, the technical need for it arises when many decentral power generators using variable sources of energy and storage facilities are integrated into the electricity grid. Figure 10 shows 'smarter grids' as a component of an electricity supply system with a high share of renewable energy. Other components of such a supply system are gas-fired power station and energy storage to complement variable power supply through wind and solar sources.

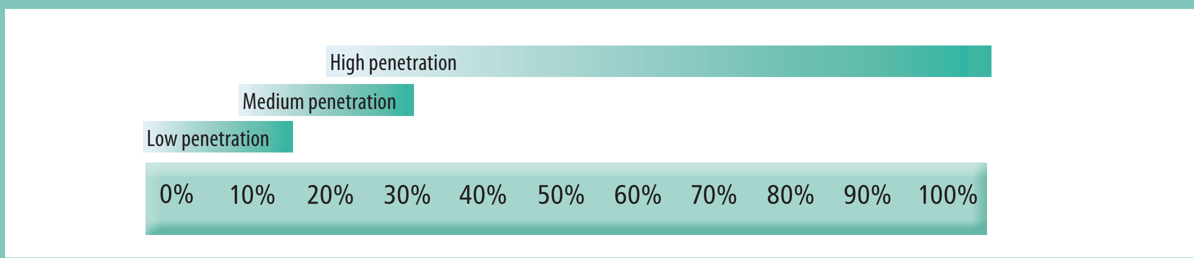
Figure 10: Technical integration of different components in electricity grid



Source: Tobias Bishop-Niemz (27 March 2014) Presentation at Africa PVSEC Conference in Durban

In 2013, the International Renewable Energy Agency (IRENA) published a study on Smart Grids and Renewables[1]. It found that at low penetration of up to 15% capacity no smart grid technology is required. At medium level penetration of up to 30% some smart grid technology is needed, while at higher than 30% penetration smart grid technology is necessary for reliable grid operations.

Figure 11: Levels of penetration of variable renewable energy in electricity grid



Source: IRENA, 2013

An example in the study is Denmark where in 2013, more than 30% of power was produced by wind. Smart grid technology was needed to integrate weather forecast data into grid operations.

Another example is Germany that has achieved 25% renewable energy penetration (mainly wind and solar PV) before starting major investment into the grid[2]. In order to move towards 50% penetration substantial investments into upgrading the grid are under way[3].

1 IRENA (2013) Smart Grids and Renewables – A Guide for Effective Employment
2 Pers. comm. with Tobias Bischof-Niemz, head of CSIR Energy Centre, Pretoria
3 Heinrich-Boell-Stiftung (ed.) (2014) Energiewende 2.0

What is a Smart Meter?

- A smart meter is a type of electricity meter that can record when and how much electricity is consumed. Smart meters are required for Time of Use tariffs.
- Smart meters can separately record bi-directional flows of electricity. This is necessary if power is exported to the grid by embedded generators.
- Smart meters can ensure more accurate electricity bills.
- Smart meters come with monitors, allowing customers to better monitor their electricity usage.
- Smart meters are capable of two-way communication between the meter and the utility. This enables the utility to remotely read information off the meter, detect power outages and meter tampering and to send information to the meter and customer.[2]
- Smart meters can be integrated in advanced metering infrastructure (AMI), which is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers.

Figure 12: Smart meter

Source: EVB Energy Ltd https://commons.wikimedia.org/wiki/File:Intelligenter_zaehler-_Smart_meter.jpg

Figure 13: Prepaid smart meter in Sandton

Source: www.iol.co.za

What is Advanced Metering Infrastructure (AMI)?

Advanced metering Infrastructure (AMI) is the collective term to describe the whole infrastructure from a smart meter to the two way-communication network to control centre equipment and all the applications that enable the gathering and transfer of energy usage information at short time intervals. The installation of an AMI is looked upon as a bridge to the construction of smart grids, and smart meters are an integral part of the AMI.

An AMI is required to capture the full benefits of smart meters. It requires setting up a communication network and IT infrastructure at the utility that can handle large amounts of data submitted by the smart meters.[3] Costs associated with hardware, software, installation, training and vendor deployment support for an AMI system need to be considered.

2 www.eskom.co.za/CustomerCare/SmartPrepayment/Pages/default.aspx

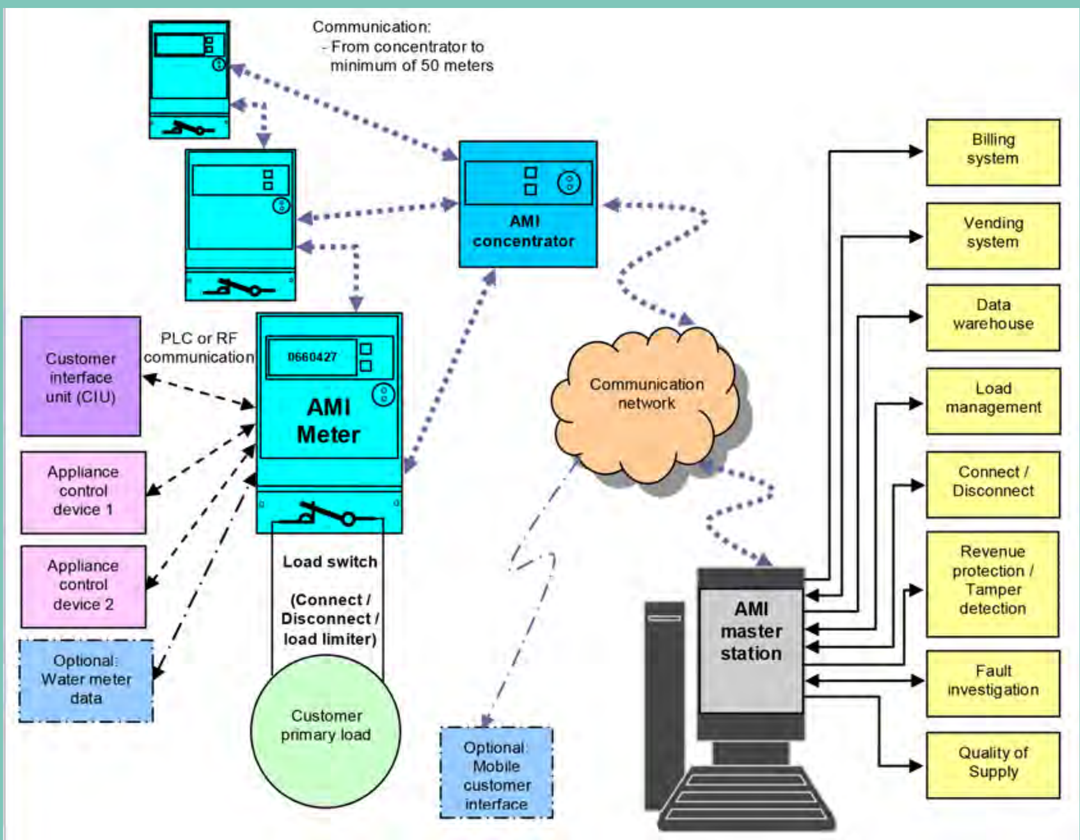
3 For more details on smart meters and AMI see: SEA (2015) Smart Metering: Overview and Considerations for South African Municipalities

A study by GreenCape[4] noted that municipalities that are already implementing smart metering are paying anything between R1 500 and R8 500 per meter compared to a conventional meter[5] that can cost them as little as R400 for a post-paid or under R1 000 for a pre-paid meter.

The NRS 049:2008 – Advanced metering infrastructure for residential and commercial customers, specification has been drafted and published to create a standard specification for advanced metering infrastructure (AMI) systems in South Africa. An NRS 049 compliant smart metering system essentially has the following characteristics:

- Bi-directional communications from the central server to meters and devices and from these devices back to the central server.
- Customers are able to have a portable customer interface unit in their premises that can read information off a meter and receive information from the utility.
- The ability to control up to two relays for load control (such as hot water cylinder and a swimming pool pump).
- Be capable of remote load disconnect for revenue protection of the utility[1].

Figure 14: Typical AMI system complying with the NRS 049-1



Source: Calmeyer (2012) quoted by Eskom (2015) Eskom Response to the Department of Cooperative Government (COGTA) Request for Information: Smart Meter Systems for Revenue Management Systems

1 SEA (2015) Smart Metering: Overview and Considerations for South African Municipalities

4 GreenCape, Economically Viable Smart Grids within Western Cape Municipalities, Summary Report 2013/14

5 Conventional meters include the currently common meters such as disc meters for billed customers and prepaid Standard Transfer Specification (STS) meters.

Smart Grid and Smart Meter Policies

In 2013 the South African National Energy Development Institute (SANEDI) drafted a Smart Grid Vision 2030[6] that was developed as part of the South African Smart Grid Initiative (SASGI).

> 'An economically evolved, technology enabled electricity system that is intelligent, interactive, flexible and efficient and will enable South Africa's energy use to be sustainable for future generations.'[7]

The SASGI sought to address challenges of the aging South African electricity infrastructure to achieve policy objectives set out in the National Energy Act (34 of 2008) and in the National Climate Change Response Policy White Paper (Department of Environmental Affairs, 2011). These objectives included:

- Ensure uninterrupted supply of energy to the country;
- Promote diversity of supply and energy resources;
- Facilitate effective management of energy demand and its conservation;
- Promote appropriate standards and specifications for the equipment, systems and processes used for producing, supplying and consuming energy;
- Ensure collection of data and information relating to energy supply, transportation and demand;
- Provide for optimal supply, transformation, transportation, storage and demand of energy that are planned, organised and implemented in accordance with a balanced consideration of security of supply, economics, customer protection and a sustainable development.[8]

Government Regulation (GN) 773, published in terms of section 35 of the Electricity Regulation Act, became effective in 2008. It established norms and standards for electricity reticulation services in order to:

- 'Maintain the quality of electricity supply;
- Ensure the stability of the electricity network, and;
- Minimise electricity load shedding and avoid blackouts.'[9]

The Regulation stipulated the roll out of smart metering to all customers with a monthly consumption of 1,000 kWh and above, and for a time of use (TOU) tariff to be applicable to these customers by 1 January 2012. The TOU tariff is very high at peak consumption time motivating customers to shift consumption to other times of the day. The main objective of this Regulation was demand-side management at a time of anticipated electricity supply shortages but it also demonstrated the intent to move towards smart grid infrastructure. The timeframe of the regulation has not been met.

Implementation

Some municipalities have embarked on the procurement and installation of smart meters. Smart meters are commonly used by large industrial and commercial customers that are being billed on a time-of-use (TOU) tariff. Residential smart metering is not common but some municipalities plan to introduce residential TOU tariffs that require smart metering.

Smart metering projects have been implemented in Johannesburg, the City of Tshwane, and the Nelson Mandela Bay Municipality. EThekwini Municipality is piloting smart meters for customers that are small scale electricity generators (SSEG) e.g. have roof top PV installations.

6 SANEDI (2013) Draft Smart Grid Vision 2030.

7 SANEDI (2013) p. 21

8 SANEDI (2013) p. 15

9 SANEDI (2013) p. 16

The main drivers of smart meter initiatives have been to improve collection of revenue for electricity and addressing electricity theft in low income areas. Eskom and a number of municipalities have responded through the installation of smart meters. However, as this is linked to social problems it is questionable if expensive technology is most effective in addressing them. Research by Eskom (Eskom 2015) and GreenCape[10] make a compelling case for a strategic approach to these issues before investing in expensive technology.

Eskom has reported the results and lessons of several of their own pilot projects and research in a report to COGTA (Eskom 2015)[11]. Important aspects and recommendations to municipalities are summarised below.

In South Africa smart meter initiatives have been undertaken to address the growing revenue challenges of electricity utilities (municipalities and Eskom) due to:

- A culture of non-payment;
- Dissatisfaction with service delivery, which may include electrical utility related services;
- Alternative energy supply options;
- Rising electricity tariffs;
- Lack or inefficient utility processes to effectively manage revenue collection; and
- Aging infrastructure and lack of maintenance on low voltage (LV) networks.

Utilities are therefore looking for innovative and technological solutions that could assist them reverse the negative trend. It is apparent that the revenue management problem needs to address people, process and technology aspects. The initial step of any project must be a thorough analysis of the problem that includes the root cause.

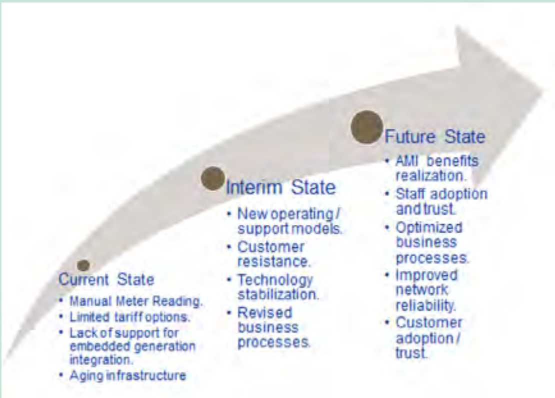
Immense gains can be made with revenue management without buying a single smart meter just by reviewing and tweaking existing processes and practices. Identifying and addressing people and process related shortcomings provides a critical foundation on which to successfully deploy smart metering. There is no technological solution that can resolve people (culture and attitude) and process related problems. In addition a utility should conduct an open smart meter readiness assessment of its organisation and network.

Eskom has developed a Smart Strategy for the installation of AMI infrastructure in its networks. Its implementation needs to be incremental because of high costs and flexible because of complexity, anticipated technological changes and risks, such as customer resistance and revised business processes.

Any smart meter project needs to consider the following aspects for successful implementation

- Customer change management;
- Staff training and buy-in;
- Automated data capturing process linked to billing system;
- Established and verified customer, meter and network data;
- Assessed and if necessary repaired infrastructure;
- Trained and competent installation teams;
- Calibrated and tested devices (meters need to be recalibrated every 10 years); and
- IT, telecommunications infrastructure and back-end integration.

Figure 15: Eskom advanced metering infrastructure journey



Source: Eskom, 2015

10 GreenCape, Economically Viable Smart Grids within Western Cape Municipalities, Summary Report 2013-14, GreenCape, Developing Smart Grid Business Cases, Guidelines for Western Cape Municipalities, 2013-14.

11 Report was compiled in collaboration with GreenCape and SEA.

A range of smart meters exists with different capabilities and prices. The meters should be carefully matched to the communities' needs and the capabilities and skills of the municipality to support the meters post the initial go-live. The Figure 16 indicates types, capabilities and costs of smart meters.

Figure 16: Types, capabilities and cost of smart meters

Offer	Type					1P Meter ONLY Price Point At Volumes	Expected Commissioned Solution Cost per 1P Meter
1	Split Meter					R 500	R1000
2	Split Meter with coms					R1000	R3400
3	Intermediate Smart					R1200	R4500
4	Advanced Smart					R2100	R6500
		Measure consumed energy, STS(Credit in kWh), Tamper Resistant	Bidirectional Coms, Tamper Alerts, PrePaid & PostPaid Meters & Concentrator in Secure Kiosks	Options for Customer Interfaces, Loadlimit, PrePaid & PostPaid TOU, Bidirectional energy Flow	Appliance Control, Integration to HEMS		

Source: Eskom, 2015

Based on their analysis of several pilot projects, recommendations to municipalities planning the roll-out of smart meters include:

- Municipalities need to conduct a thorough smart metering readiness assessment prior to commencing any roll-outs. Municipalities will need assistance in developing their smart grid visions / roadmaps and these should be guided by the high level national Smart Grid Vision.
- The project should invest significant effort into planning, designing, testing, integrating with the existing systems, processes and pilot meter rollouts. Only once a level of confidence has been obtained then a more aggressive rollout strategy should be executed.
- A smart meter programme should include demand response capabilities on the meter itself to reduce the maximum load during periods of stress on the national grid.

Generally it is recommended that a national smart grid strategy should be developed and supported by updates to the Grid Code.

Support Organisations

SANEDI

www.sanedi.org

GreenCape

www.greencape.org

Eskom

wwww.eskom.co.za

Governance and legislation

Photograph: Bablu Virinder-Singh

Overview

There is growing global, national and local awareness of the role of urban and local management as being key to many areas of sustainable energy development and climate change mitigation.

However, grasping how sustainable energy and climate change mitigation intersect with municipal mandates and regulatory powers requires an understanding of the broad objectives of local government and the nature of cooperative government. It also requires understanding how the areas of governance can influence and impact energy outcomes. These are discussed below.

This chapter will detail the 'case' for municipalities to engage in sustainable energy development and climate mitigation. It will then look at some of the key regulatory and planning instruments and processes towards executing these sustainable energy related municipal powers. The further chapters in this section will outline steps towards institutionalising this new area of work within a municipality, leading by example through implementing energy efficiency and renewable energy in municipal operations, and influencing the broader constituency towards these energy objectives.

The figure provides an overview of the principal actions municipalities can take around climate change mitigation. Strategic measures include the development of climate change strategies and action plans; the setting of targets for greenhouse gas emissions reduction, joining of energy-related city networks for lessons sharing; and the institutionalisation of climate change mitigation responsibilities in the municipality, through dedicated staff and/

Figure 1: Overview of the principal actions municipalities can take around climate change mitigation

or units and all the way through to the level of senior staff job descriptions and KPIs. Concrete Initiatives and Actions include both Municipal operations and influencing the broader community.

Municipalities typically only use around 2% of the energy consumed in the municipal area. However the municipality has direct control over actions to reduce its own energy consumption or increase the use of renewable energy. Such projects also offer opportunities to lead by example and to showcase new technologies, while also assisting staff to learn new skills relating to the adoption of new technologies.

Ultimately, if a municipality is going to have an impact on the energy consumption and climate mitigation in the area under its jurisdiction it must influence change amongst its broader constituency – the residents and businesses of the city or town. There are principally two ways of influencing the behaviour of citizens and businesses: through regulations and policies, and by providing support and information.

Constitutional objectives and mandates of local government

The objects and developmental duties of local government are set out in Section 152 and 153 of the Constitution of RSA. In terms of this, local government must pursue sustainability, environmental protection, access to services for all and social and economic development. Local government is also called upon to be the 'delivery arm' of national programmes where required:

152. (1) The objects of local government are—

(a) to provide democratic and accountable government for local communities;

(b) to ensure the provision of services to communities in a sustainable manner;

(c) to promote social and economic development;

(d) to promote a safe and healthy environment; and

(e) to encourage the involvement of communities and community organisations in the matters of local government.

153. A municipality must—

(a) structure and manage its administration and budgeting and planning processes to give priority to the basic needs of the community, and to promote the social and economic development of the community; and

(b) participate in national and provincial development programmes.

Powers and functions of local government, listed in Section 156 (1) and Schedules 4B and 5B of the Constitution, assign authority over and administration of (amongst others):

1. Air pollution
2. Amenities and facilities
3. Building regulations
4. Electricity and gas reticulation
5. Municipal planning
6. Municipal public works
7. Municipal roads
8. Streets and traffic lighting
9. Traffic and parking, vehicle licensing

10. Refuse removal and solid waste disposal
11. Water (potable), wastewater treatment

Local government has legislative and executive authority over these areas. Few of the functions of local government can be described as exclusive as these are nearly always contained within a national legislative framework, however, municipalities may exercise a high degree of autonomy when making by-laws or executing these functions (Section 156 (3)), though these by-laws or actions must not conflict with national or provincial legislation.

In the dynamic context of cooperative governance, the Constitution also provides for the assignment of powers and functions relating to areas within Schedules 4A and 5A to local government, wherever the decentralization of the administration of a function to a municipality would more effectively enable service delivery (Section 156 (4)). An example of this is the delegation of housing delivery to metros.

Section 156 (5) also gives a municipality the right to 'exercise any power concerning a matter reasonably necessary for or incidental to the effective performance of its functions'. This clause implies that cities can implement interventions not specifically listed in Schedules 4B and 5B, provided they support these functions. This provides still further support for cities to drive and/or facilitate renewable and energy efficiency implementation projects within their jurisdiction.

Lastly, the developmental duties of local government require it to prioritise the needs of the poor and participate in national development programs. For example, the Energy White Paper of 1998 articulated the policy goal of access to affordable energy services for all (3.2.2.1). The major departmental programme in this regard has been the Integrated Electrification Programme (INEP). Tasked, in terms of Schedule 4B of the Constitution with Electricity and Gas reticulation, Local Government is a critical partner in delivery of the national policy goal. Relevant national strategies and/or programmes that identify a key role for local government in implementation include:

- The White Paper on Energy Policy (DME, 1998)
- The National Climate Change Response White Paper (DEA, 2011): this identifies local government as an important partner in meeting national mitigation and adaptation targets (Section 10.2.6)
- The National Energy Efficiency Strategy (DRAFT-post 2015) (DoE, 2016): the role of municipalities is extensively mentioned throughout the strategy and municipalities are identified as a vital partner.
- National White Paper on Transport Policy, (DoT, 1996)
- Department of Transport Strategic Plan 2014/15 – 2019/20. This includes programmes such as Integrated Urban Space and Public Transport Programme.

Table 1: Intersection between municipal objects, mandates and regulatory responsibilities and sustainable energy and climate mitigation interventions

Sustainable energy and climate mitigation intervention	Local government powers and functions	Endorsement of sustainable energy/climate change mitigation approach through national mandate
Access to affordable, modern energy for all, including: Electrification Affordable energy Alternative energy services Thermally efficient low income housing	Electricity and gas reticulation (connections, tariff setting, subsidisation) Air pollution Human settlements (metros) Building regulation	Constitutional objects and duties White Paper on Energy DoE INEP National Building Regulations new energy efficiency standards
Energy efficiency, including: Efficient building regulations Retrofit of municipal buildings and operations Public transport and low carbon transport development requiring interventions in spatial planning and densification Solar water heating (or efficient)	Electricity and gas reticulation Development control Building plan approval Human settlement Amenities and facilities Street and traffic lighting Municipal public transport Municipal roads Parking and traffic Municipal Planning: spatial, transport and economic Water and Waste	Constitutional objects and duties White Paper on Energy National (Draft) EE Strategy National Building Regulations new energy efficiency standards National transport plans and programmes National Climate Change Response Strategy
Renewable Energy, including: Municipal waste and wastewater to energy Municipal mini hydro Private renewable energy development: small-scale embedded to large scale Renewable energy source electric vehicle development	Electricity and gas reticulation Water and Waste Building regulation Municipal public transport Municipal roads Vehicle licensing	Constitutional objects and duties White Paper on Energy National (Draft) EE Strategy National Building Regulations new energy efficiency standards National Climate Change Response Strategy

In terms of the Municipal Systems Act that further details the constitutional responsibilities of municipalities, municipalities are also required to take into account, when selecting service delivery options, 'developing trends in the sustainable provision of municipal services generally' (MSA (2003), Section 78 refers).

As metros in South Africa become increasingly capacitated within the energy space and as the technology change increasingly pushes towards more distributed energy services, the range of activities undertaken by municipalities may change.

It should also be noted that in addition to local obligations some of the metros in South Africa are also engaging in global networks and making global commitments in relation to climate change mitigation.

Barriers and opportunities

Barriers

- Fear of taking on unfunded mandates: this can be addressed through lobbying for political support and utilising funding opportunities such as the EEDSM, and other national and international grant funding for energy efficient infrastructure.
- Energy issues are cross sectoral and difficult to institutionalise: some good practice is emerging and presented in more detail in the chapter on Institutionalising Sustainable Energy and Climate Change Mitigation Commitments.
- Worry of additional work load such as reporting requirements to national and international funders: this issue can be addressed on a case by case basis but also in collaboration with other municipalities using the same funding sources.

Opportunities

- Initiate innovative developmental approaches: this is envisaged in the constitution
- Attract additional funding to the municipality
- Saving of energy costs
- Local economic development including job creation

Powers and functions of municipalities relevant to energy efficiency and renewable energy

- Planner
- Regulator
- Distributor of services
- Facilitator/communicator/ citizen engagement
- Procurer of goods and services
- Building owner/user
- Facilities and operations manager

Implementation

Municipalities have a range of 'tools', powers and functions, through which to address the areas of energy efficiency and renewable energy. Each of these will be detailed below and illustrated in some case studies.

In their own operations and service delivery processes, municipalities have a sizeable role to play in building and operations management and procurement. This municipal engagement in renewable and energy efficiency is detailed in the section on Municipal Initiatives.

Municipalities have the right to create by-laws in their jurisdictions in line with the objectives and development duties of local government and in line with national legal frameworks and policy directions.

Development Planning

Municipalities are empowered to shape the development direction of the area within their jurisdiction. This includes spatial/land use planning, economic development, transport planning, and infrastructure and service planning. All these sector planning processes feed into the Integrated Development Plan of the municipality and ultimately move through the budget cycles of the municipality. Some metros and large towns are

Planning questions cities and towns should be asking

- How fast is my city/town growing, and how is that growth distributed spatially?
- What might be the energy, transport, welfare and cost implication of this future?
- What is the direction (policy) we need to follow for a more efficient future that supports the welfare of citizens?
- What do we need to do now (actions), and what barriers do we need to address to achieve this?

undertaking long-term modelling exercises, or scenario planning, in order to establish how different decisions taken today will influence longer term outcomes. New information and understanding is being fed into decision making.

It is increasingly apparent that the spatial form of a city or town greatly influences the transport systems and volumes and associated energy requirements. Global studies indicate that a particular level of compaction or densification is necessary to make public transport systems financially viable. Research also indicates that compaction must be accompanied by mixed land use to ensure a settlement structure that does no longer generates one-directional peak-hour travel between residential and business areas but limits the need to travel and shifts to multi-directional trips throughout the day (see chapter on Sustainable Transport).

Indications from a City of Cape Town growth scenarios study indicate that for a 20 year planning horizon some 50% of plans are already 'locked in', i.e. determined by past decisions and investments that can no longer be changed. This shows that structural change is slow. However, without determined decisions now a more resource efficient and lower carbon city will remain a challenge[1]. Municipalities need to:

- Include energy and climate change mitigation into the scope of all municipal planning;
- Prescribe development conditions that contribute to resource efficiency, such as permission of mixed use, development that reduce the need to travel and, encourage modal shift such as improved public transport and NMT facilities and limiting parking; and
- Create incentives that encourage development in areas identified for densification, e.g. waving of height restrictions alongside public transit corridors.

Regulator

Municipalities have various regulatory responsibilities that impact on energy efficiency and renewable energy. The two major areas are that of land use management /development control and regulating the electricity grid.

Electricity: Municipalities that are electricity distributors must ensure the safety and proper functioning of their electricity grid. They must therefore ensure that grid connected local electricity generation such as roof-top PV is safe and adheres to electricity buy-laws, standards and grid-codes. In municipalities that are not electricity distributors this is the responsibility of Eskom.

1 E-mobility will contribute to a healthier environment but does not address congestion and therefore cannot replace the modal shift from individual vehicles to NMT and public transport. It is noted that currently the emissions of e-vehicles powered by Eskom generated electricity are slightly higher than emissions of vehicles with combustion engines. To be sustainable e-mobility must be powered by renewable energy.

Municipalities also set tariffs, which can influence electricity consumption and the uptake of efficiency and renewable energy.

- Consider a time of use tariff for mid and high income residential consumers.
- Ensure small-scale embedded generation regulations and associated procedures, including tariffs, are in place for grid-tied small-scale renewable electricity development. This is a complex area and detail on SSEG processes is provided in the Chapter on Solar Photovoltaic (PV) Systems.

Land use management and development control: Municipalities are responsible for land use management and development plan approval. They must ensure that developments and buildings adhere to the municipal town planning scheme and to the National Building Regulations and Standards Act 103 of 1977 (NBR).

The requirement to comply with building regulations ensures a safe and healthy living environment. It is also a prerequisite for residents to get bonds from banks and to sell their properties. New buildings and major refurbishments of old buildings must adhere to the national building energy efficiency standards (SANS 10400-XA). The municipalities must assess their compliance as part of the building plan approval.

In terms of the NBR, renewable energy installations such as PV panels and solar water heaters are defined as buildings requiring approval. Installations on buildings that are older than 60 years also require permission by the provincial institution responsible for heritage resources according to the Heritage Resources Act 25 or 1999 (HRA).

- Ensure that the new energy efficient building regulations are being enforced and where necessary source training for building planning officials in support of this (build capacity).
- Consider bylaw development to extend efficiency interventions in existing building stock, for example, solar water heating could be a requirement of property sales.
- Wave, or simplify, development application approval processes for energy efficiency interventions, such as solar water heating, and small-scale renewable energy interventions, such as roof-top PV.

Air Quality Control: Municipalities are responsible for Air Quality Control, issuing permits, monitoring emissions and enforce that emissions do not exceed permitted limits.

- Use the permitting and monitoring process to leverage energy efficiency within industry, e.g. around process heat.

Water and Waste: Municipalities regulate water supply and waste disposal. Both of these carry energy implications. Lower water consumption reduces the energy required for pumping and water purification. Lower waste volumes and greater levels of recycling of waste reduce the embodied energy in materials and products.

- Consider regulations that enforces lower consumption of water;
- Consider regulations to reduce waste such as higher charges or recycling schemes.

Renewable Energy Application Processes

Application and approval processes are often complicated and constitute barriers for renewable energy installations. All renewable energy installations must comply with the legislation below for which different institutions are responsible.

- Electricity buy-laws, standards and grid codes (responsibility of electricity department or Eskom);
- Town planning legislation and regulations – compliance with the relevant regulations for the zone within which a development falls (responsibility of municipal town planning department);
- National Building Regulations (responsibility of municipal development control department);
- Heritage legislation – applies to building older than 60 years (responsibility of the provincial heritage authority); and
- Environmental legislation – for large scale renewable energy development (responsibility of provincial or municipal environmental management department.

Large-scale embedded generation installations require environmental authorisation (EA) in terms of the NEMA 2010 EIA Regulations if they generate > 10 MW electricity. In addition the electrical transmission infrastructure that may be associated with a large scale embedded generation system requires EA if it has a capacity of 275 kV or more within an urban area, or more than 33kV outside urban areas.

Too much regulatory red tape can result in people undertaking connections without obtaining proper approval. This can compromise safety and the quality of power supply. In order to promote legal renewable energy connections, municipalities should make it as easy as possible for developers to comply with regulations by simplifying application and approval processes.

Some municipalities have already taken steps to simplify application and approval processes. Examples are presented in the case studies. Some general comments are:

- The best method to ensure that installers apply to the electricity department for approval is the introduction of a feed-in tariff as a financial incentive (see chapter on Solar Photovoltaic (PV) Systems) for feeding electricity into the grid.
- Renewable energy installations require applications to the electricity and to the development control departments. In municipalities that are electricity distributors these should be combined into a single municipal application process.
- Municipalities should collectively approach the DTI to amend the NBR to exempt renewable energy installations from the building application and approval process. SALGA could facilitate this process.

Distributor of services

Municipalities provide services to households, business and industry. This includes electricity and (where applicable) gas reticulation, water reticulation, wastewater and solid waste disposal. The function of human settlements, i.e. the provision of low income housing, has also been delegated to metros. Municipalities also provide non-motorised and public transport infrastructure and services in their area of jurisdictions. In terms of their developmental duties municipalities must ensure that service delivery is environmentally and financially sustainable, universal, and affordable for all citizens.

As provider of services municipalities should consider the following actions towards achieving greater energy efficiency and renewable energy outcomes, with the added benefit, of increased local economic development and job creation:

- Alternative energy service rollout, including solar water heating (see chapter on Solar Water Heating), hotbox delivery, gas for cooking applications, solar PV, solar-charged lights, biogel for cooking for low income or off-grid households (see chapter on Household Energy).
- Retrofit of ceilings into low income houses (see chapter on Energy Efficient Building).
- Energy efficient lighting technology rollouts (see chapter on Energy Efficient Lighting).
- Tariff structures that encourage efficient use of resources.
- Introduction of waste recycling schemes.
- Development of safe and accessible non-motorised transport infrastructure, i.e. bike lanes and walkways (see chapter on Sustainable Transport).
- Development of safe public transport systems, including school busses.
- Explore 'smart' applications e.g. to enhance public transport usage, such as an app that provides information on bus and train times, delays, linkages, etc. (see chapter on Smart Cities).

Facilitator and communicator

The municipality is the level of government 'closest to the people'. There is scope to bring parties together and provide information to support behaviour change amongst citizens.

- Running behaviour change campaigns to promote energy efficiency and safe energy usage amongst citizens and business/industry.
- Create consumer confidence through endorsement programmes and reliable technical information on which basis consumers feel confident to take decisions.
- Provide a platform for knowledge exchange, such as a business energy efficiency forum.

Municipal operations

As stated, a municipality is a sizeable institution and often the single largest energy consumer in an area. Through facilities and operations management, building management and procurement of 'green' goods and services, including electricity, the municipality can influence energy consumption and emissions in its area of jurisdiction. How to move in this direction is discussed in the section on Municipal Initiatives.

Case Study 1: Planning – Corridors of Freedom City in Johannesburg*

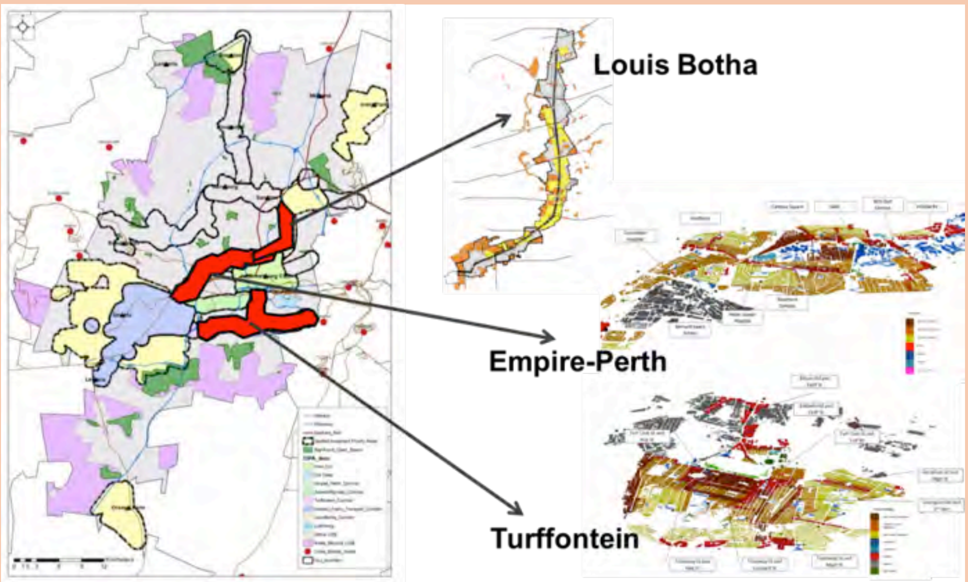
The City of Johannesburg has developed the Corridors of Freedom programme in response to the challenge of driving a city transformation agenda. The concept goes beyond a plan of simply tackling the physical environment, by addressing issues such as liveability, urban efficiencies, social cohesion and economic inclusion, sustainability and adaptability. The intention is to unfold the plan in an inclusive and participatory manner:

> *"Over the decade we will introduce transport corridors connecting strategic nodes through an affordable and accessible mass public transit that includes both bus and passenger rail. Along these corridors we will locate mixed income housing, schools, offices, community facilities, cultural centres, parks, public squares, clinics and libraries." (COJ, Corridors of Freedom).*

Three corridors have been selected within the Medium Term Priority Objectives of the City. These were Louis Botha, Empire-Perth and Turffontein. The idea is to create activity corridors. The planning approach seeks to enhance:

- *An urban system and network*
- *Access to opportunity by reducing travel distances*
- *Provision of meaningful destinations*
- *High density developments*
- *Mixed use development*
- *A vibrant people centred city that connects communities*
- *Sustainable travel alternatives*
- *Attractive environments for walking and cycling*

Figure 2: Corridors of Freedom Medium Term Development Goals, City of Johannesburg



Source: City of Johannesburg 2014

* This case study draws extensively from Herman Pienaar, Director: City Transformation and Spatial Planning.City of Johannesburg, from presentation given at the Urban Energy for development CPD course, 2014. Unless referenced otherwise, information is sourced from this document.

Movement transformation aims to reduce carbon emissions through investing in non motorised transport infrastructure focussing on 'the last mile' to enhance the use of public transport. It also aims to develop 'complete streets' – where side walks and building edges improve pedestrian access, and foster a mix of office, retail, entertainment and residential spaces.

Economic transformation *considers how to improve access to economic opportunities through access to capital and retail space (accommodating the informal 'second economy'), as well as efforts to bring factors of production and innovation together in high efficiency hubs. A special purpose vehicle has been set up to broker deals between land owners, developers, business and industry. Spatially, the plan works to create urban efficiencies and quality public environments.*

Quality public spaces aere seen as a prerequisite for social cohesion. In addition, ***social transformation*** *seeks to develop new standards in response to high density environments, such as for high density schools sharing facilities (sport, libraries), and for clustering services and amenties. Inclusive design contributes to safety and improved access to services.*

Much greater levels of ***densification*** *are proposed along the BRT and complementary transport routes. This will be achieved through zoning, subdivision and redevelopment, higher density infill and consolidation or redevelopment towards multi-storey buildings and row houses.*

In addition the process envisages sustainable innovations to buildings, infrastructure and services. Possibilities to increase efficiency and sustainability in new high density environments have been explored, such as public and citizen collaboration around waste separation.

The Medium Term Expenditure Framework focuses on an implementation agenda that works to:

- *Improve the existing bulk infrastructure to support increased development;*
- *Improve public environments and social facilities; and*
- *Spatial targeting to establish building blocks.*

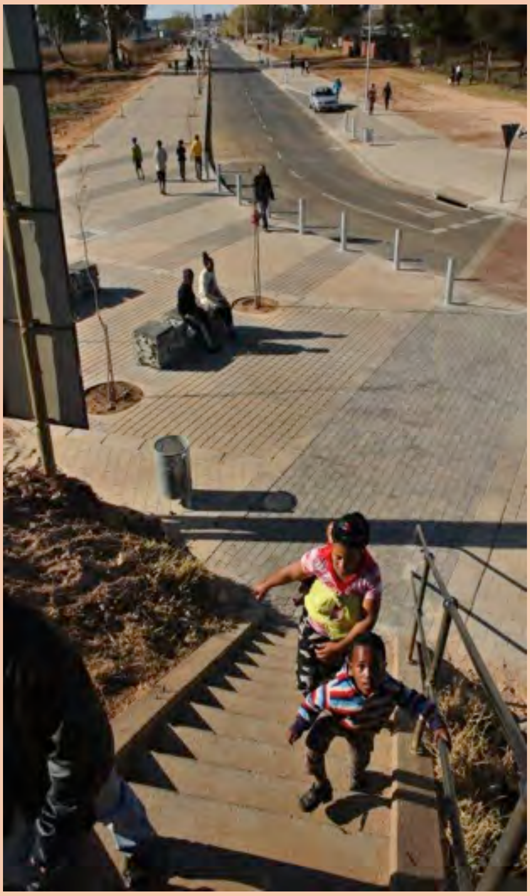
Figure 3: The Watt Street Interchange design proposal

Source: City of Johannesburg 2014

Figure 4: Construction of walkways and cycle ways in Thokoza Park/Soweto

Source: City of Johannesburg 2014

Figure 5: Completed work at Nancefield station



Photographs: City of Johannesburg

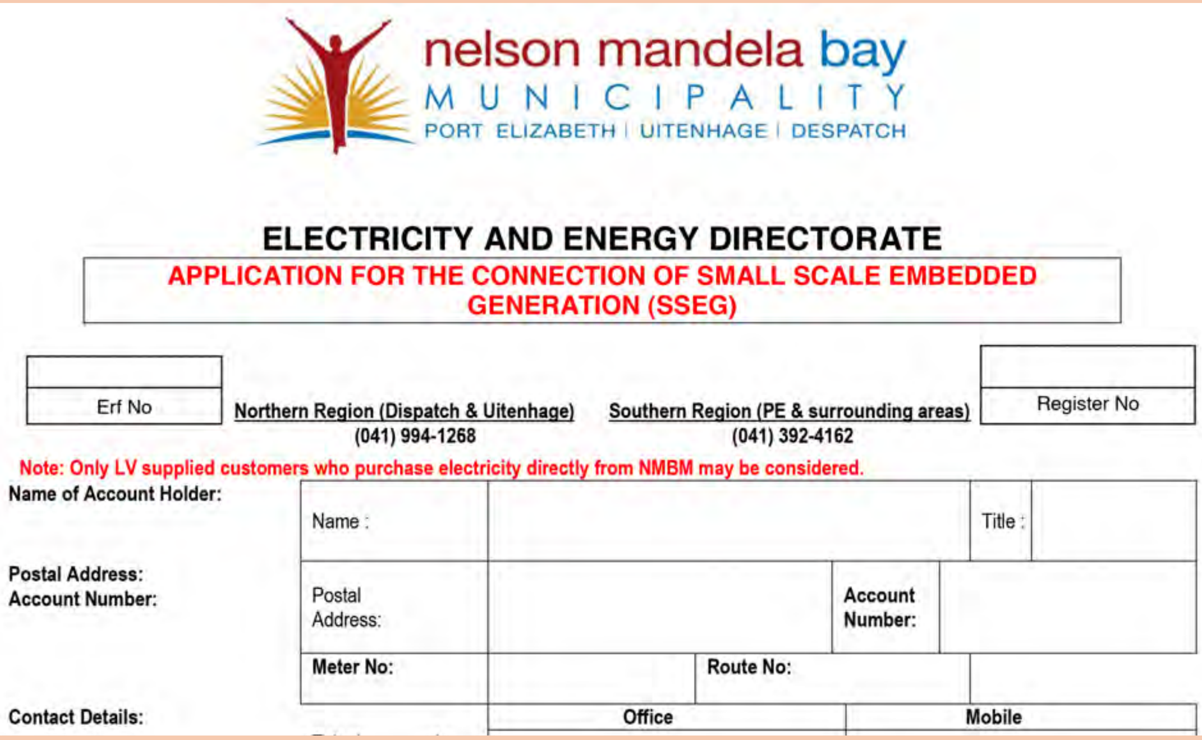
Case study 2: Regulation – Small Scale Embedded Generation

In 2013 the Nelson Mandela Bay Municipality (NMBM) Electricity and Energy Directorate introduced conditions for small scale generators of renewable electricity and a standard application form. Other municipalities offer similar services to customers who want to generate electricity from renewable sources and connect the installation to the municipal grid. Most supply the relevant information on the municipal website.

In doing this NMBM, amongst others, has created a regulatory environment which not only allows small scale embedded generation, but also ensures that it does not violate safety and power quality parameters. It has done this through the provision of technical requirements and the development of by-laws.

A generic set of requirements and supply contracts, as well as application forms and other information, is available through AMEU and SALGA[2].

Figure 6: SSEG installations form


nelson mandela bay
MUNICIPALITY
PORT ELIZABETH | UITENHAGE | DESPATCH

ELECTRICITY AND ENERGY DIRECTORATE

APPLICATION FOR THE CONNECTION OF SMALL SCALE EMBEDDED GENERATION (SSEG)

Erf No

Northern Region (Dispatch & Uitenhage) (041) 994-1268

Southern Region (PE & surrounding areas) (041) 392-4162

Register No

Note: Only LV supplied customers who purchase electricity directly from NMBM may be considered.

Name of Account Holder:

Postal Address:
Account Number:

Name :		Title :	
Postal Address:		Account Number:	
Meter No:		Route No:	

Contact Details:

	Office	Mobile

Source: http://www.nelsonmandelabay.gov.za/datarepository/documents/1-application-form-small-scale-embedded-generation-sseg.pdf

2 The document can be found at http://www.cityenergy.org.za/uploads/resource_410.pdf.

Case study 3: Regulation – Waiving of building applications for renewable energy Installations in Cape Town

In response to an increased number of applications for roof-top PV installations some metros have taken the step of waving the building application process. For example, the City of Cape states in relation to roof-top PV installations:

- *"All roof top installations: No building plans are required to be submitted provided the panel(s) in its installed position does not project more than 1,5 metres, measured perpendicularly, above the roof and/or not more than 600mm above the highest point of the roof.*
- *Full building plans, including engineer's endorsement, are required if the panel(s) in its installed position projects more than 1,5 metres, measured perpendicularly, above the roof and/r more than 600mm above the highest point of the roof. Note that a relaxation in terms of the Zoning Scheme Regulations is also required.*
- *Installation on the ground: No building plans are required to be submitted provided the panel(s) in its installed position does not project more than 2,1 metres above the natural/finished ground level. Full building plans are required where any part of the installation projects more than 2,1 metres above the ground."*[3]

Case sudy 4: Regulation – Simplifying building applications for renewable energy in eThekwini Municipality

The National Buildings Regulations and Standards Act 1977 (NBR) define renewable energy installations as buildings in its Definitions. According to Section 4 of the NBR all buildings require development approval. However, municipalities are permitted to define certain structures such as pergolas and private swimming pools as Minor Building Works (MBW) for which the application and approval process is simpler because less documentation is required. Also fees for MBW are by far lower than for a full building application. In eThekwini Municipality the fee for a MBW is about R200.

In 2015, the eThekwini Municipality has included solar water heaters, solar PV systems and small wind-turbines into its schedule of MBW. The table shows the renewable energy (RE) items in the eThekwini Municipality Schedule of MBW.

Building applications are assessed according to their adherence to the Town Planning Scheme and cording to the NBR. To simplify the assessment according to the Town Planning Scheme it has been proposed that the installations defined as MBW are treated as ancillary to the land use on site and no planning application should be required in eThekwini Municipality other than a building plan.[4]

3 City of Cape Town, Planning and Building Management, Memorandum: Dealing with applications for the installation of PV panels, 16.1.2013

4 City of Cape Town, Planning and Building Management, Memorandum: Dealing with applications for the installation of PV panels, 16.1.2013

Table 2: eThekwini Municipality Minor Buildings Works Schedule

MINOR BUILDING WORK (MBW) Schedule and Application Requirements

AS CONTEMPLATED IN SECTION 13 OF THE NATIONAL BUILDING REGULATIONS AND BUILDING STANDARDS ACT NO. 103 OF 1977 – wef: 01/09/2015

1 **MBW SCHEDULE as DEFINED BY NBR&BS ACT** [refer to notes contained in this schedule for additional clarity on requirements]			**2** **FEE TYPE**	**3** **DOCUMENTION** [refer to notes]
G	(xv)	Any solar photovoltaic system where such installation is free-standing, or where attached to the roof of a building the installation does not exceed a height of 1.2m above the top of the flat roof or 500 mm above the apex of the pitched roof; [Any supporting structural system shall be screened appropriately to integrate with the aesthetic of the building on which erected. Compliance required with NBR&BS Act, Part-L Roofs and additional loading will need to be accounted for]	MBW	MBW + Form 2
	(xvi)	Any solar water heating system where such installation is free-standing, or where attached to the roof of a building the installation does not exceed a height of 1.2m above the top of the flat roof or 500 mm above the apex of the pitched roof; [Any supporting structural system shall be screened appropriately to integrate with the aesthetic of the building on which erected. Compliance required with NBR&BS Act, Part-L Roofs and additional loading will need to be accounted for]	MBW	MBW + Form 2
	(xvii)	A wind turbine attached to a building (NOT free-standing) with a swept turbine blade area not exceeding 3.8m2; [Compliance required with NBR&BS Act, Part-L Roofs and additional loading will need to be accounted for]	MBW	MBW + Form 2

Source: EThekwini Municipality, Development Applications and Approvals, Minor Building Works Schedule and Application Requirements

Case study 5: Service delivery – Polokwane hot boxes for vulnerable households pilot project

The Polokwane Energy and Climate Change Strategy identifies access to energy and addressing energy poverty as a challenge to be addressed by the municipality. A partnership project is underway to explore the possibility of delivering hot boxes for cooking to vulnerable households. The project is training young women in the community to produce hot boxes that will then be handed out to vulnerable households. The idea is that this will alleviate energy poverty in households, while also creating jobs. If the impact of the first, pilot rollout is positive, the municipality will consider including such a 'service' as part of its service delivery.

Figure 7: Energy entrepreneurs demonstrate the hot box to community members and are trained to produce hot boxes

Source: SEA

Case study 6: Service delivery – City of Cape Town ceiling retrofit programme

In Cape Town an estimated 40000 state subsidised homes do not have ceilings. To address this challenge the City of Cape Town secured R116 million in funding from the City's Separate Operating Account and the Development Bank of Southern Africa's Green Fund for a retrofit programme. The City is exploring whether such a programme can become an established part of the energy service delivery package of the City. Homes that have been retrofitted have gained significant health and comfort benefits. The project also creates a significant number of jobs and develops skills.

Figure 8: Mamre ceiling retrofit, City of Cape Town

Source: City of Cape Town

Facilitator, communicator, citizen engagement

Below are snapshots of a couple of municipal programmes and campaigns aimed at influencing citizen action or behaviour towards sustainable energy outcomes. These include web based tools and campaigns that provide citizens with reliable information and enabling them to take informed decisions; forums for information exchange amongst business and industry, and programmes of action for behaviour change.

eThekwini Municipality: Shisa Solar Programme

The Shisa Solar programme aims to promote the use of energy efficient hot water devices throughout the city of Durban. The focus of the Neighbourhood Programme is on the middle to high income market segment in the city. Key barriers to solar water heaters (SWH) in South Africa are concerns about inexperienced suppliers and the costs of SWH units. The eThekwini Municipality has developed a programme that allows participants to liaise with experienced pre-approved suppliers and pay less for solar water heaters through a discount.

By registering on the municipal website Durban residents wanting to 'go solar' can participate in the programme. The residents enter their details onto a database which is then sent through to a panel of pre-approved suppliers who will then contact the resident and provide a no obligation quotation.

The quotations supplied to the home owner will be less a R500 Shisa Solar discount. So far over 4 000 people have registered on the site, with the numbers increasing every day.

Figure 9: Screenshot of Durban Solar City Map

Source http://gis.durban.gov.za/solarmapviewer

Figure 10: Ecomobility Festival in Sandton 2015

Source: City of Johannesburg 2015

Figure 11: Website of Energy Efficiency Forum

Source: http://www.capetown.gov.za/en/EnergyEfficiencyForum/

City of Johannesburg: Ecomobility Campaign

In 2009 the City of Johannesburg has issued a Declaration on Eco-mobility in Cities.

> *"Eco-mobility means traveling through integrated, socially inclusive and environmentally friendly transport options, giving priority to walking and cycling, public transport and shared mobility." (Johannesburg Declaration on Eco-mobility 2009)*

In doing so the City of Johannesburg has joined forces with other cities committed to sustainable and low carbon development. Associated with this global alliance, the City participates in an annual World Eco-mobility Festival that includes shutting off areas of central Sandton to vehicles and hosting of a variety of events and exhibitions, including the Freedom Ride, which celebrate and inform in relation to the concept and possibility of eco-mobility.

In 2015 an Eco-mobility Festival took place in Sandton encouraging citizens to use public and motorized transport for the month of October and to leave their cars at home. In October 2016 councillors and municipal officials re-emphasized their commitment to eco-mobility focussing on public transport systems such as the BRT[5].

City of Cape Town: Commercial Energy Efficiency Forum

In 2009 the Energy Efficiency Forum for the commercial sector was established by the City of Cape Town, in partnership with Eskom and South African Property Owners Association (SAPOA). It is supported by several other organisations and has over 1000 members.

Commercial consumers use an estimated 44% of all electricity in Cape Town. This makes them a key stakeholder in the City's campaign to save electricity. The commercial sector is feeling the impact of tariff increases and seeks to reduce costs. The aim of the initiative is to help maximise energy efficiency for economic, environmental and energy security reasons.

The Forum shares practical knowledge with owners and managers of commercial and public buildings and operations. The main Forum meets about 3 times a year, offering case studies, an annual award programme and updates on financing options, innovations, policies and training/support opportunities. A series of site tours keeps the learning alive between meetings.[6]

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5 http://www.joburg.org.za/index.php?option=com_content&view=article&id=11196&catid=88&Itemid=266

6 For more information visit http://www.capetown.gov.za/en/EnergyEfficiencyForum/

Institutionalising Sustainable Energy and Climate Change Mitigation

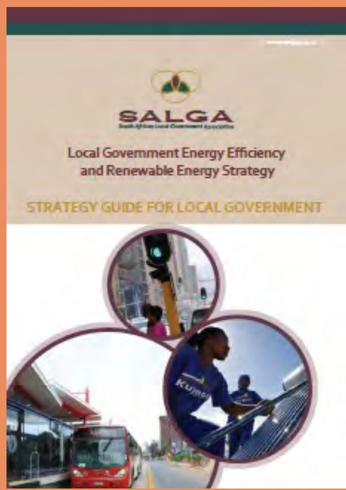
Overview

Cities and towns increasingly acknowledge the risks associated with climate change and are seek to mitigate them. An increasing number of South African municipalities are compiling annual greenhouse gas (GHG) inventories for their area of jurisdiction and have developed strategies to respond to climate change. Some municipalities have set targets for reducing GHG emissions, for increased energy efficiency and for the use of renewable energy (see Introduction Chapter). Implementing these strategies and commitments, keeping them up to date and monitoring their impact all requires an effective institutional set-up and allocation of responsibilities and resources.

As detailed in the previous chapter a strong case exists for local government to address sustainable energy and climate mitigation within their responsibilities. Cities are economic centres using large amounts of energy and contributing strongly to the greenhouse gas emissions of the country. The National Government of South Africa has made commitments to contribute to the international efforts to curb GHG emissions. These commitments cannot be met unless emissions are addressed, placing an obligation on municipalities to do so.

Managing these new fields, or new approaches to existing activities, is challenging. Energy and emissions-related activities are located across a spectrum of municipal departments. Municipalities typically face resource constraints – financial and human – and additional demands can place new pressures on municipal administrations. Achieving targets also requires strong engagement with citizens and the private sector. Thus a new way of operating, one that is cross-sectoral, partnership or network based, is important. This requires vision, strong leadership and political support.

The SALGA Strategy Guide for Local Government on Energy Efficiency and Renewable Energy provides a comprehensive overview of steps to be taken by any municipality wishing to move towards a more sustainable, inclusive and developmental future. The full document, which was developed through the active engagement of municipal officials across all nine provinces, plus the Status Quo report can be accessed on: http://www.cityenergy.org.za/uploads/resource_291.pdf.



Implementation

The particular interest of a municipality will determine who leads the work on sustainable energy and climate change mitigation. Often the work will be framed as Environment or Energy. Environmental departments usually undertake the policy development side of leading this work. In Cape Town the Environmental Resource Management Department has led the energy and climate change direction; whereas this may also be held in the Electricity and Energy Department, as is the case in Nelson Mandela Bay Metro and the City of Johannesburg. In these cities the environment departments often focus more on climate change adaptation.

In eThekwini Municipality the Energy Office has been established as a section within the Treasury. The Municipality's strong Climate Change thrust was established by the Environmental department and has culminated in a comprehensive Durban Climate Change Strategy that was developed jointly with the Energy Office. The City of Tshwane has set up a Sustainability Unit in the office of the Executive Mayor where policy has been developed around the Green Economy.

In many cities the institutional arrangements are dynamic and may change as the work grows and develops. The City of Cape Town has recently set up an Energy Directorate under which will fall two divisions (formed from the old Energy Office and Electricity Services Department): the Sustainable Energy Markets and Electricity Generation and Distribution.

Climate change mitigation actions may impact the local economy. The Department responsible for Economic Development is therefore another institutional option that is being considered by some municipalities.

It is important to align the work on climate change mitigation with existing high level municipal policies and strategies. If for example the political focus is on job creation and economic development, the energy and climate mitigation work should be framed in these terms.

Institutional Arrangements

The institutionalisation of sustainable energy and climate change mitigation in the political and administrative structures is necessary to ensure proper planning, budgeting, implementation and monitoring of initiatives. The choice of institutional set-up and allocation of responsibilities is often influenced by individuals, 'the champions', who actively promote the cause. As climate change mitigation and sustainable energy are cross-cutting functions and require actions of many departments, effective collaboration and sufficient capacity are more important for the successful implementation of initiatives than the choice of lead department.

Despite different framing and/or locating of the work, experience indicates that institutionalising the work requires addressing both the political and the administrative levels. At the administrative level cross-sectoral institutional arrangements are vital, as well as a dedicated unit with staff, to drive the work. The following institutional structures should be considered to develop this area of work in a municipality:

1. Political Committee

Options for political leadership include:

- Tasking an existing Council Committee e.g. in charge of Development Planning or Infrastructure, additionally with the responsibility for sustainable energy and climate change mitigation. This is being done in eThekwini Municipality.
- Establishing a special Council Committee (or sub-committee) on Energy and/or Climate Change, as has been done in the City of Cape Town and City of Johannesburg (see Case Study on types of Political Committees).

2. Cross Sector Executive Management Team

A formally constituted administrative committee (Executive Management Team) that draws in all relevant departments must support the political committee. This needs to involve the senior management of relevant departments such as

- Environmental Management
- Housing and Human Settlements
- Transport and Roads
- Services Infrastructure (Electricity, Water and Sanitation, Solid Waste)
- City Planning and Development
- Economic Development
- Financial Services
- Communication and Marketing Services

This high level management team is important to ensure the effective cross-sectoral work lower down the administration. The new responsibilities should be included in the Job Descriptions and KPIs of Senior Management.

3. Working Groups or Steering Committees

For specific areas of work, tasks or lead projects working groups or steering committees may need to be established. These groups involve the relevant people from different departments and must have clear terms of references determined by the municipal climate change strategy or action plan. They ensure the necessary cooperation on projects across municipal departments.

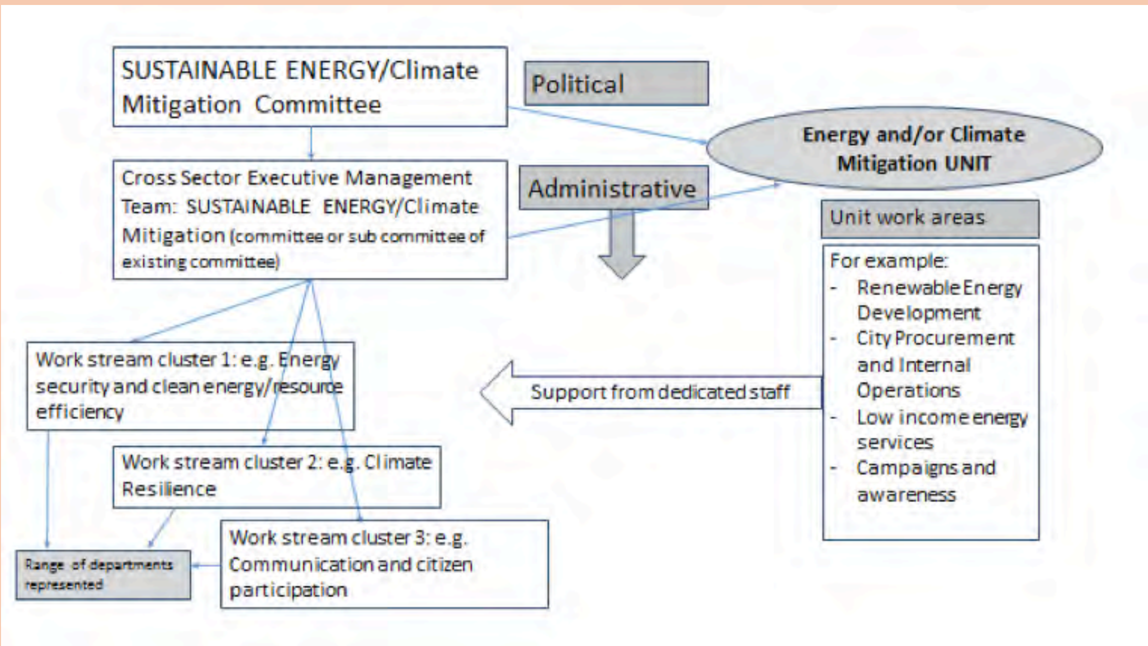
The working groups / steering committees report to the Executive Management. Senior management must assign staff to the groups and include new responsibilities in their KPIs.

4. Lead Department and Dedicated Unit

- A department should be identified that will assume the lead responsibility for sustainable energy and climate change mitigation. In this department a dedicated energy, climate or sustainability unit should be set up that supports the development and implementation of a municipal policy/strategy on energy and climate change mitigation. This unit would report to the head of the lead department but would also be the secretariat and information resource of the political and administrative committees. Critical tasks of this unit include:
- Collecting, collating and analysing energy and emissions data
- Developing and managing the GHG inventory and reporting
- Strategy, policy and action plan development, review and monitoring
- Proposal development for flagship projects
- Research and technical direction on new technologies or approaches
- Raising finance
- Engaging partners

The figure below illustrates the described institutional architecture.

Figure 12: Key elements of institutional integration of sustainable energy into municipal operations



Source: Sustainable Energy Africa, developed for Tshwane Energy and Climate Change Strategy

Dedicated Unit

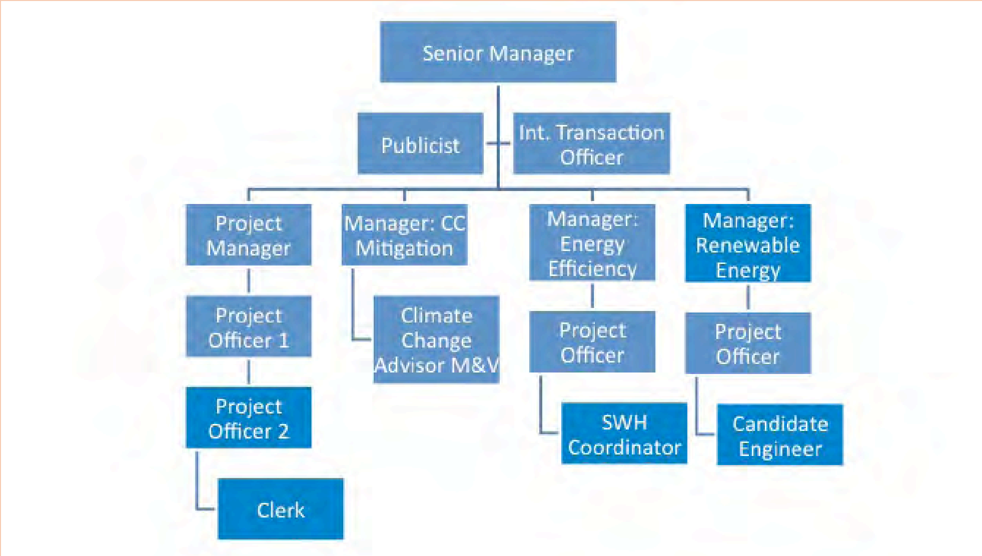
A dedicated unit to drive and coordinate the work ensures that capacity – both human and financial – is directed into the new field of work. The work of such a unit is guided by the municipal energy or climate change mitigation strategy. The table below, drawing on work of the City of Cape Town's Energy and Climate Change Unit, provides an overview of its core functions.

Table 3: Overview of work areas and themes of the Energy and Climate Change Unit of City of Cape Town

WORK AREAS	City procurement and operations	Low income household energy services	Energy efficiency	Renewable energy development	Low carbon development
PROJECT AREAS	• Supporting municipal retrofit projects; • Monitor internal energy consumption; • Training internal building and facilities management	Developing city strategy and implementation mechanisms for integrated household energy services	• Communication and campaigns; • Monitoring of city's Green Building regulations	Support sector departments to facilitate private sector RE development and pilot municipal RE projects.	Facilitating link between City Planning and Transit goals
CROSS CUTTING THEMATIC AREAS	Policy and regulation	• Developing policies for Internal Resource Management, Green Procurement, Development Planning; • Engagement (with the relevant sector department) in national planning and regulation that may have an impact on local energy objectives.			
	Finance	• Seeking additional funding to drive the new area of work, e.g. climate funds, green economy funds; • Exploring revenue models and engaging with City Finance around new, resource efficient-oriented revenue models.			
	Partnerships	• Ongoing engagement in national and international forums relating to climate mitigation and sustainable energy; • Developing partnerships for implementation with the private sector and with academia in relation to innovation.			
	Data	• Holding and developing the data bases that relate to the energy and GHG mitigation indices and targets and undertaking the necessary reporting to global and national platforms.			
	Green economy	• Align with the Green Economy initiatives in the City, as well as in the province and nationally; build and enhance the economic/job creation dimensions of the sustainable energy strategy.			
	Research	Unlocking location specific implementation barriers and developing innovative approaches relating to the legal, financial and technical aspects of sustainable energy implementation.			

This work requires a range of competencies including technical, scientific, managerial, and communication skills. Staff profiles and related job descriptions will depend on the particular priorities of each city. The figure below shows the organogram of the Energy Office in eThekwini Municipality.

Figure 13: Organogram of the Energy Office in eThekwini Municipality



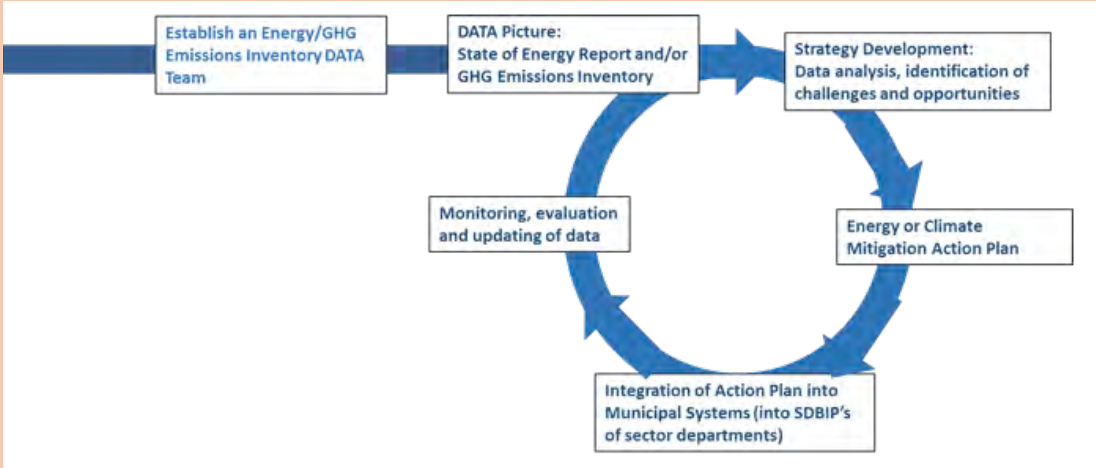
Strategy Development – Purpose, Process and Components

An energy and climate change mitigation strategy and action plan is necessary to detail the municipality's priority actions and guide the staff working in the new field. As with any strategy development process, this involves collating information in order to analyse challenges and opportunities; generating a vision that responds to the challenges, opportunities and municipal priorities; and finally developing a plan of action towards achieving this vision. The strategy should be developed and updated in a continuous cycle of engagement and progressive improvement.

The following stages and components are required

- A State of Energy and/or Greenhouse gas (GHG) Emissions Inventory with the status quo of energy use and related emissions. It is used for analysis, planning, monitoring and reporting;
- Energy or Climate Change Response Strategy stating vision and mission and identifying priority objectives and long-term targets;
- Action Plan detailing work streams and short-term targets.

Figure 14: Outline of key steps in developing an energy baseline and/or GHG emissions inventory, strategy, action plan and integrating them into municipal systems



Local State of Energy and GHG Inventory

Municipalities need to develop a GHG Inventory or Energy Status Quo report. This is usually done periodically about every 5 years. Inventory updates and monitoring should be undertaken on an annual basis. This does not involve detailed data gathering but updating data necessary to measure key indicators.

The Global Protocol for Community Level GHG Emissions Inventories (see text box on International Protocols and Tools on page 347) provides a standard approach to reporting on GHG emissions at the local level. Energy reporting follows the same protocols. The standard practice is to obtain data for all energy/emissions activities and order these by sectors: Residential, Commercial, Industrial and Municipal.

A GHG inventory is principally a simple account recording what, where and by whom energy and emissions-generating activities take place in the municipal jurisdiction. Municipalities should analyse the data further to allow municipal decision-makers and communities to understand local challenges such as sectors of high energy consumption and opportunities to address them. The analysis informs priorities action and the setting of emission reduction targets. The inventory updates are used to monitor progress towards achieving.

Data collection and collation for GHG inventory

When embarking on an emissions/energy data collection process an individual or team must be appointed who collect data on energy use from the different sector departments and from outside of the municipality. This new task must be included in KPI's and job descriptions if done in-house. Data collection processes should be institutionalised so that they happen routinely and regularly. The internal team may need to be supplemented by consultants every few years when new data collection and an in-depth analysis take place.

The Case Study on City of Tshwane provides an overview of the data required and data sources for typical data requirements of South African cities. A detailed, step by step guide for collection and collation of a greenhouse gas inventory (Sustainable Energy Africa, 2017) can be found on: http://cityenergy.org.za/uploads/resource_422.pdf.

The Urban Energy Website: supporting your municipality

The Urban Energy Website: www.cityenergy.org.za has been developed by Sustainable Energy Africa and is a jointly held platform with SALGA and the SA Cities Network. The website is designed to house documents that support municipalities with energy and emissions data collection, planning, policy and strategy development and with implementation. Documents are from South African cities and towns.

The 'First Steps' button on the home page will take the user to a page that outlines the process. If scrolling the mouse along the various steps, it will direct the user to key resources, including 'Energising South African Cities & Towns' which is a valuable resource for initiating energy management in a municipality. The guide can be directly downloaded on:

http://www.cityenergy.org.za/docs/Energising-SA-Cities.pdf

Figure 15: the Urban Energy website

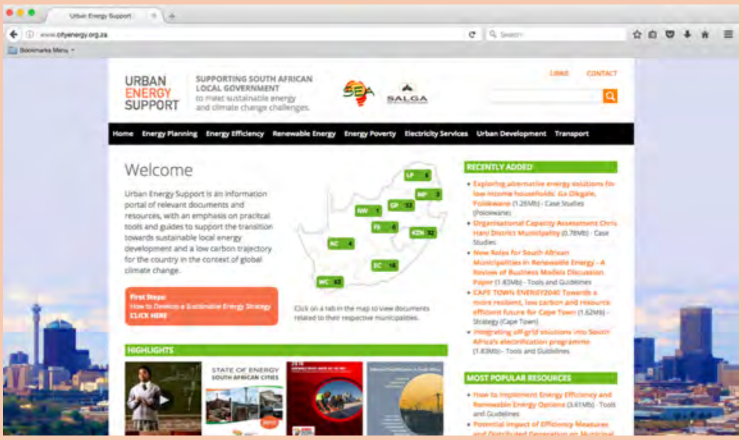
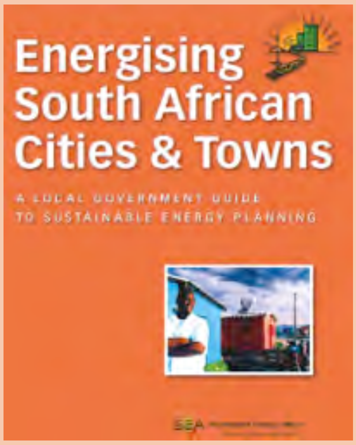


Figure 16: Energising South African Cities and Towns

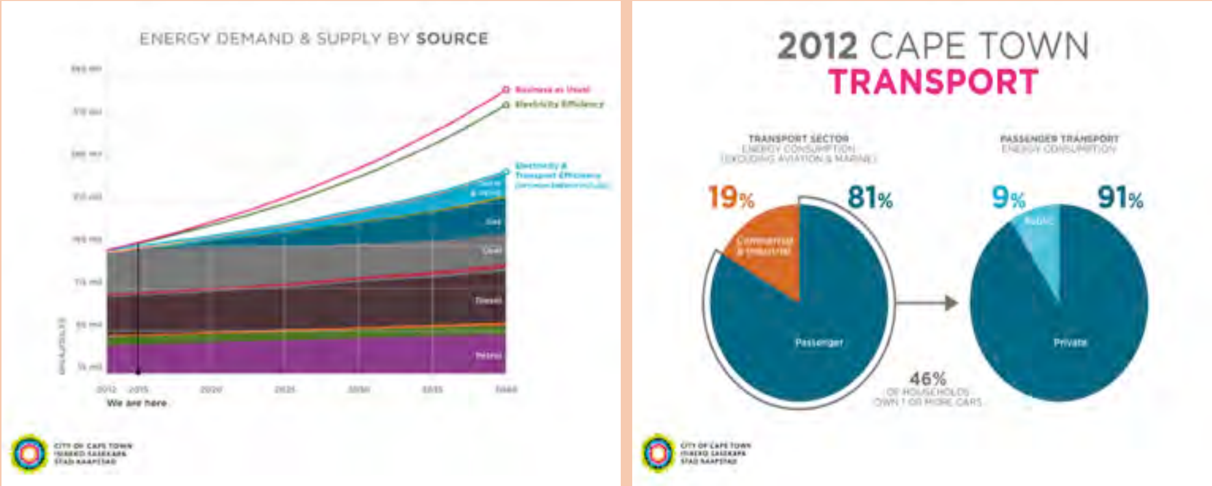


Energy and Climate Change Mitigation Strategy

The strategy development process must engage internal stakeholders from relevant departments and external stakeholders such as community organisations, business organisations, environmental NGOs, and academia.

The State of Energy report and GHG Inventory informs the strategy development. It is important to analyse and represent the data in a visibly interesting way to communicate it to stakeholders in the strategy development process. Presenting key indicators can also be helpful. The figure on the next page shows how large volumes of information can be represented in an accessible way.

Figure 17: Examples of energy and emissions data representation



Source: City of Cape Town, Energy climate action plan, 2016

The purpose of the strategy is to guide the municipal activities around climate change mitigation. It will typically state a vision and objectives that should reflect the energy profile of the municipality and should be aligned to the municipal development priorities. The strategy should set long-term targets to reduce GHG emissions through energy efficiency and the use of renewable energy. In addition the strategy will set targets to provide access to modern forms of energy for poorly or non-serviced communities. Targets need to be ambitious, but achievable and measurable. The achievement of the targets will be monitored using the data in the GHG Inventory and other simple to access information (see: Targets and Indicators below).

Vision and objectives of the strategy are to be achieved by a target date that is typically 20 or more years in the future. It is helpful to undertake a future scenario modelling exercise in terms of energy use and emissions. Scenario modelling is based on estimating the future demand, the energy efficiency potential and the use of renewable energy. The modelling establishes a Business as Usual Scenario (if nothing is done differently) and compares it with scenarios with improved energy efficiency, increased use of renewable energy, and other emission reductions. A number of South African cities have done such modelling and examples of these can be found on the www.cityenergy.org.za website.

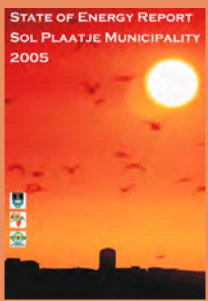
The Long-Range Energy Alternatives Planning system (LEAP) has been found to be the most appropriate tool for local, or municipal level futures planning (see an analysis of different tools done by the Energy Research Centre at the University of Cape Town on: http://africancityenergy.org/uploads/resource_27.pdf). New tools particularly related to Emissions projections are under development and may also prove useful and user friendly (see International Protocols and Tools below).

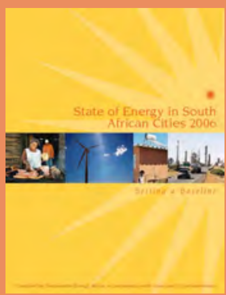
The stakeholder engagement process should result in a strategy towards achieving the most optimal future scenario. This needs to be guided by the existing Municipal Vision and Goals. Once in place, the strategy must be submitted to council for adoption. The strategy must be reviewed periodically to respond to a rapidly changing environment (technologically and politically).

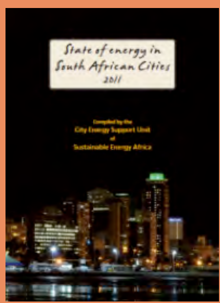
South African Cities' Energy and Emissions Baseline Reporting and Strategy Development

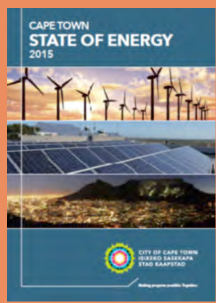
The first State of Energy report was developed for Cape Town in 1998 and Africa's first City energy strategy was completed and adopted by the City of Cape Town in 2003. Since then at least sixteen more South African cities and towns have developed State of Energy Reports, Energy and Climate Change Strategies and/or GHG Emissions Inventories.

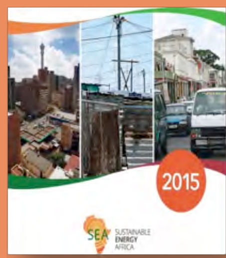
The State of Energy in South African Cities is a report undertaken every five years by Sustainable Energy Africa. This report measures progress towards sustainable energy transition at the local level across South African's metro and secondary cities.











Action Plan and integration into municipal systems

The strategy need to be translated into a detailed Action Plan. This plan requires working with each relevant department and ensuring that the energy and climate mitigation activities are integrated into their sector strategies and plans. The Action Plan will specify projects, responsibilities, time frames and targets for a 5-year period. It should be approved by council and reviewed every 5 years.

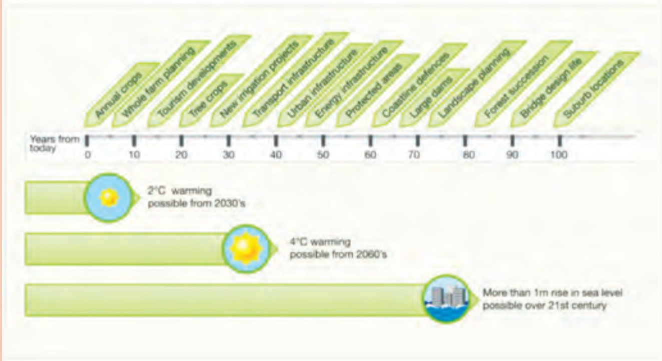
The energy efficiency or climate change mitigation strategy and action plan must be included into the municipal Integrated Development Plan (IDP) and Spatial Development Framework (SDF). Projects need to be reflected in the Service Delivery Budget Implementation Plans (SDBIP) and associated municipal budget.

Once projects are included in the SDBIPs, the targets and indicators set in the energy and climate strategy and action plan will be reflected in the performance management system of all key staff (through KPIs). Staff members from Performance Management should be included in the process of target development as this can be a complex institutional process.

"Let's Respond": Integrating climate change response into municipal IDPs

The National Climate Change Response Strategy identifies municipalities as important partners in implementing the national climate change mitigation commitments. SALGA and the Department of Environmental Affairs have developed guidance and tools to assist municipalities to integrate municipal climate response strategies and commitments into the municipal IDPs.

Figure 18: The lifespan of today's development decisions



Source: Let's Respond, Toolkit

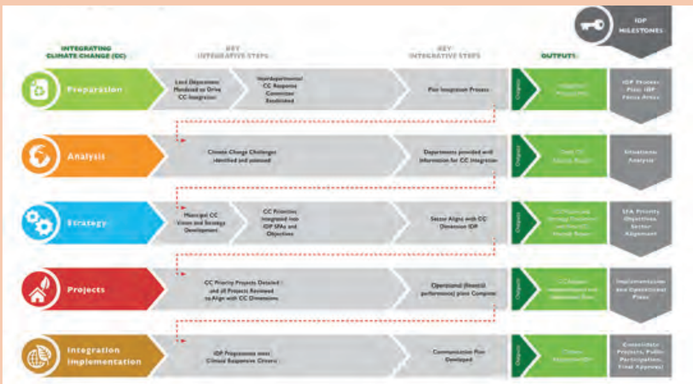
This is not only a precondition for budgeting for projects but is also necessary to introduce and sustain climate change mitigation as a work stream in the Council and the municipal administration. The rationale is that development decisions made today have a long lifespan (particularly on bulk infrastructure and spatial planning) and need to be designed with a changing climate in mind.

The approach encourages municipalities to:

- Align climate change response with existing development challenges and deepen existing response capacity.
- Develop links with research institutions and community structures to improve the flow of information, in particular early warning systems, such as information about potential drought.
- Incorporate climate change information into sector planning and plan for a wide range of longer-term changes in weather conditions (rainfall and temperature).
- Improve cross-sector integration of management and development planning.
- Move more decisively and faster on core development objectives, which will provide immediate benefits and long-term climate change response benefits.

The guide provides a five phase process, aligned with the IDP process: preparation, analysis, strategy, projects, integration. Each phase includes steps to integrate climate change response into municipal systems and structures. For each step of the process support tools are provided, found in the toolkit, which will facilitate the process.

Figure 19: The Let's Respond Guide and Toolkit



Source: http://cityenergy.org.za/uploads/resource_143.pdf.

Targets and Indicators

An energy scenario modelling process provides guidance for strategic long-term targets for energy efficiency and the use of renewable energy. For the Action Plan the long-term targets must be broken down into specific, shorter-term targets for different sectors and departments. These targets inform the projects and interventions. Indicators need to be developed to monitor the achievement of the targets.

Below are examples of templates for targets and indicators. Municipalities should set locally appropriate targets and identify indicators that can be monitored through easily accessible data.

Table 5: High level sustainable energy/carbon emissions targets

	2020	2030	2040
Total GHG emissions from energy (CO_2e)			
GHG emissions per capita (tonnes)			
Renewable/cleaner energy as portion of electricity supply			
Electricity efficiency (fraction of electricity reduced off BAU)			
Transport efficiency (fraction of liquid fuel consumption reduced off BAU)			

Table 6: Examples of 5 year sector targets required to achieve the high level targets

Sector Target	Municipal Actions	Monitoring
Residential Sector		
10% of households have efficient water heaters (and give it in numbers)	Develop Solar Water Heater (SWH) strategy and implementation plan; consider mid to high income endorsement of local SWH companies;	GIS based mapping; Industry figures; Implementation project figures.
80% of residential lighting is efficient	Partner with Eskom to run another efficient lighting rollout.	Industry figures
Commercial Sector		
80% of lighting is efficient	Establish a Municipal-Commerce EE Forum; Partner with Eskom to run another efficient lighting rollout.	Industry figures
Electricity generation		
120 MW of rooftop PV is installed	Develop SSEG policy and application guidelines and tariff	Application documents; Industry figures
100MW of large scale renewable energy capacity is developed in the city-region	Municipal projects on gas to energy; Facilitate IPP development	Industry figures
Transport		
4% decrease in fuel consumption off BAU	Congestion charging and/or incentive schemes to increase vehicle occupancy; use public or non-motorised transport	DoE liquid fuel figures;
Doubling of BRT passenger-kms	Zoning and development approval enhances public transport usage	BRT occupancy data

Table 7: Proposed Indicators for monitoring sustainable energy and emissions reduction

City profile indicators	
Population: total and local (city)	Poverty levels: households under the poverty line (< R3 200/month)
Number of households	Average household size
Economic growth	Population and Household growth
Economic	
Total energy consumption (GJ)	Energy use per unit of GDP
Energy consumption per capita	Expenditure on energy: net energy import expenses
Energy mix (and fuel quantities); including proportion of mix made up by renewable source energy	Local energy production (quantity and value); including locally produced renewable energy
Energy per economic sector	Electricity distribution system maximum demand (MW)
Electricity supply efficiency: distribution losses	Energy use per unit of GDP
Environment	
Total GHG emissions from energy (CO2e)	Waste per capita
GHG emissions per capita	Quantities of air pollutant emissions (SO_2, NOx, particulates)
GHG emissions per capita (including Waste and AFOLU if available)	Water consumption and system leakages
Environmental protection expenditure	Wastewater treatment
Proportion of waste minimised/production of reusable waste	
Spatial and development planning and Mobility	
Functional density (person per km2)	Share of households that own a car and total number of light passenger vehicles registered
Non-motorised transit as a fraction of all trips and as fraction of passenger kms	Modal split within transport sector by fuel use and passenger km
Social development	
Access to modern, safe energy (electricity)	Households receiving the national energy grant
Households using 'clean and safe' fuels for cooking	Fraction of disposable income spent of fuels (total population, 20% poorest)
Governance	
Institutional mechanism for SE management (existence of a political and admin SE committee)	Internal energy management strategy and implementation
Dedicated and capacitated SE staff	Existence of forum or campaigns for citizen engagement and awareness raising
Regulations and Guidelines across the SE work areas (Green procurement, building, water, waste, electricity generation, efficient resource use	

Implementation of Action Plan

Translating the plan into action is often the greatest challenge. Below are typical activities and initiatives of municipalities.

1. Integration into existing municipal plans and activities while also undertaking 'showcase' projects

- 'Mainstreaming': Engage with relevant departments to ensure a thorough understanding of how energy issues intersect with their areas/services and how they can integrate sustainable energy objectives into their line department functions and SDBIP. This process can be time consuming.
- 'Showcasing': While working on integration and mainstreaming, it is worthwhile to identify projects to showcase the new approach and to provide motivation and incentives to council to continue to support this work.

2. Develop an enabling policy and regulatory environment

A strong and enabling regulatory environment will encourage investment by the private sector in new areas of sustainable energy and climate change mitigation. Key policy and regulatory areas to address include:

- Municipal Procurement
- Integrated Household Energy Services and related tariffs
- Small-scale embedded generation
- Third party wheeling
- Green building
- Densification and Zoning
- Traffic/parking management and non-motorised transit.

Detail on all of these areas is provided elsewhere in the manual.

3. Develop a communications platform

Publicise commitments and new approaches to provide citizens and potential partners with information that will enable them to engage in new projects. This can take the form of energy forums, rollout programmes, websites and campaigns.

4. Develop monitoring and reporting system

Draft and publish an annual update report on key indicators. Targets need to be monitored in terms of the performance management process. Once an area of work is regularly measured and monitored ('seen'), it starts to **receive attention and budget.**

5. Ongoing skills, knowledge and capacity development

New areas of work require a continuous updating of skills and knowledge. This can be achieved through:

- The employment of new staff with the required skills;
- Training and continuing professional development e.g. through courses and peer learning exchange;
- Engagement in learning networks such as the Urban Energy Network of SEA-SALGA-SACN, or the SACN Transport Working group, ICLEI, etc.; and
- Utilisation of resources, such as this manual or the City Energy Website.

Numerous examples of policies, regulations and tools relating to, for example, cost of supply studies, revenue impact, as well as case studies can be found here: www.cityenergy.org.za.

6. Secure funding for project implementation

Identify, secure and coordinate funding streams. Expand funding streams particularly for pilot or priority projects. 'Seeing is believing' and showcasing projects generates momentum. Attracting funding will build council support for this new field of work.

Figure 20: Municipal officials attending a site visit at Alexander Solar Water Heater rollout project of the City of Johannesburg, 2015, organised by the Urban Energy Network, a partnership between SEA, SALGA an SACN.

Photo: Sustainable Energy Africa

Figure 21: Municipal officials and related stakeholders attend the University of Cape Town Engineering Faculty Continuing Professional Development course on Urban Energy for Development convened by Sustainable Energy Africa and the Energy Research Centre.

Photos: Sustainable Energy Africa

International Networks of Cities

Increasingly South African cities are joining the global community of cities responding to climate change.

Transnational network of municipalities emerged in the 1990s, with the advent of Local Agenda 21, following the Rio Earth Summit (1992). These noted that while political commitments were negotiated by nation states, much of the implementation towards achieving these emissions reduction and sustainable development objectives required local action. Following the 2015 Paris Climate Agreement the world's two largest global coalitions of cities (the Global Compact of Mayors and Covenant of Mayors) merged to form the Global Covenant of Mayors for Climate and Energy.

The global Covenant requires specific commitments from its members to emissions reduction and associated monitoring and reporting. Covenant supporters include organisations such as Energy Cities, Climate Alliance, ICLEI, C40 Network of Global Cities and EUROCITIES, as well as a number of national networks and support programmes. The network organisations provide project implementation support, best practice guidance, access to funding and tools to assist reporting and monitoring of commitments.

A number of South African metros are signatories to the global covenant and must report according to their requirements. Even if municipalities are not obliged to report on these platforms, it is useful for all to align with the well-developed protocols of these networks; and to benefit from the support tools generated through these initiatives. The text box provides an overview of reporting protocols and tools.

International Protocols and Tools

A range of protocols and tools have been developed to ensure comparable, robust and transparent accounting of GHG Emissions. In addition, tools for scenario modelling and Action Planning are presented.

1. The Global Protocol on Community-Scale GHG Emissions Inventories

The Global Protocol for Community-Scale GHG Emissions Inventories (GPC) offers cities and local governments a robust, transparent and globally-accepted framework to identify, calculate and report on greenhouse gases at a local level; allowing for consistent and comparable reporting across cities. This framework is in line with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and was developed as a collective effort among a variety of stakeholders (World Resources Institute, C40 Cities Climate Leadership Group, ICLEI, Cities Alliance, World Bank, UNEP and UN-HABITAT).

2. GHG Emissions Reporting Platforms for Local Governments

Carbonn (cCR): The Carbonn Climate Registry (cCR), launched in 2010, is a global platform used to report local climate actions. It is the reporting platform of various pacts/agreements, such as the Mexico City Pact, the Compact of Mayors, the Compact of States and Regions, the Durban Adaptation Charter, the Earth Hour City Challenge and others. The cCR was developed with support from ICLEI and the Government of Mexico City, under the auspices of the World Mayors Council on Climate Change and with the endorsement of United Cities and Local Governments (UCLG) and the Club of Madrid.

Carbon Disclosure Project (CPD): CDP is a World Bank-led global disclosure system for companies, cities, states and regions to manage their environmental impacts. It is used by investors or traders to access environmental information to inform their decisions.

3. Data/action Reporting, Monitoring and Inventory tools

City Inventory Reporting and Information System (CIRIS) (developer: c40): This is a comprehensive inventory calculator and excel-based tool based on the GPC. It is freely available for download from the C40 website: http://www.c40.org/other/gpc-dashboard.

ClearPath (developer: ICLEI): ClearPath is an online software platform for completing greenhouse gas inventories, forecasts, climate action plans, and monitoring at community-wide or government operations scales. The tool is internet based and oriented to US cities. Non ICLEI-members can purchase ClearPath Pro annual subscriptions from ICLEI.

SECAP Reporting template (developer: Covenant of Mayors): this is a reporting tool rather than a calculating tool that focuses on energy. It is still in the process of becoming a global GPC-compliant, emissions reduction tool.

4. Project level emissions calculator and accounting tools

Tools to standardise the carbon savings potential of projects are being developed by ICLEI and C40. Recognised tools can enable project developers to assess the carbon savings potential of individual projects (including complex transport or spatial planning projects). This information can be used in financial assessments for projects towards 'bankable' status.

The Clean Energy Emission Reduction (CLEER) tool was developed by the USAID Resources and USAID Global Climate Change Office (GCC). CLEER is also designed to enable 'stacking' of project emissions reductions for national and/or global reporting. It can be found at https://www.cleertool.org/.

5. Scenario modelling and action planning tools

CURB (Climate Action for Urban Sustainability) (developer: C40 and World Bank) tool evaluates low carbon actions. As an Excel-based tool, CURB can be used offline and allows for transparent modelling. Cities can use CURB free of charge with technical support available upon request. The tool is not yet available online, will be free of charge, once available.

LEAP (The Long-range Energy Alternatives Planning System) (developer: the Stockholm Environment Institute (SEI)) is a software tool for energy policy analysis and climate change mitigation assessment. In addition to tracking energy and GHGs, LEAP can also be used to analyse emissions of local and regional air pollutants, and short-lived climate pollutants (SLCP) making it well-suited for studies of the climate action co-benefits to reduce local air pollution. LEAP has developed a reputation among its users for presenting complex energy analysis concepts in a transparent and intuitive way. LEAP is free to any user.

HEAT (Harmonized Emissions Analysis Tool) (developer: ICLEI) is an online tool to build an emissions inventory based on local energy use, transportation demand, and waste practices. The tool will also help a user/city to develop simple emissions forecasts, set targets for emissions reduction, and quantify emission reductions and their co-benefits.

Case Study 1: Political committees – Section 80 Energy Committee in the City of Cape Town and Climate change Section 79 committee in the City of Johannesburg

Council committees may be established in terms of the Municipal Structures Act to enable smaller groups of councillors to meet to discuss specific issues. Councillors then get a chance to dedicate time to specific issues and to become experts in those. Committees make recommendations to council and saves council from having to deal with all matters in detail. Committees do not make final decisions since most decisions need approval by council as a whole.

In addition to Portfolio or Ward/geographic committees the Structures Act permits a municipality to establish additional committees (Section 79) committees deemed necessary 'for the effective and efficient performance of any of its functions or the exercise of any of its powers'. If a municipality has an Executive Council or Executive Mayor it may appoint committees (in terms of Section 79) to assist the Executive Council or Executive Mayor (Section 80).

Section 79 committees are usually permanent committees that specialise in one area of work and sometimes are given the right to make decisions over small issues. Outside experts as well as councillors can be included on Section 79 committees.

The City of Cape Town established a Section 80 Energy and Climate Change Committee in July 2008. The committee was established in response to the power crisis and the new inclusion of energy security and climate change mitigation and adaptation within the IDP. An EMT (Executive Management Team) Sub-Committee on Energy and Climate Change was set up concomitantly to support its political counterpart. The work streams of the committee included Energy security and carbon mitigation; Communication and education; and Adaptation and Climate Resilience. This committee has since been disbanded and most of the responsibilities now fall within the Section 79 Portfolio Committee for Utilities and Energy (this committee has special delegations to oversee Energy2040 Vision and the Energy and Climate Action Plan); with some falling into the Portfolio Committees of Sustainability & Resilience and Economy & Environment.

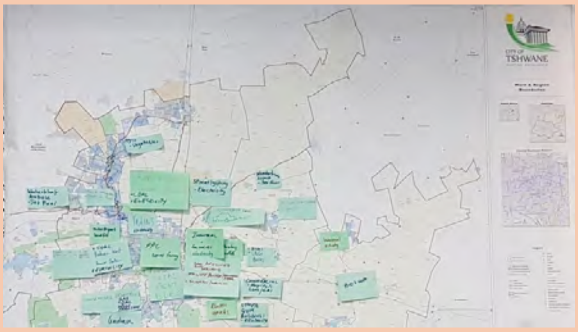
In the City of Johannesburg a Section 79 sub-committee on climate change was set up to facilitate high level political decision making on climate change. Its administrative counterpart is the Joint Coordinating Committee on Climate Change, comprising a technical team of officials drawn from all the relevant departments and led by the Environmental Management Department. A team of dedicated support staff are located here. The Section 79 committee on climate change ensures that every decision coming before council has been viewed through a climate 'lens' prior to presentation at council for decision making.

Case study 2: Establishing a GHG Inventory in the City of Tshwane

The City of Tshwane has had its latest inventory declared as GPC-compliant. This helps Tshwane complete one of the key milestones of the Global Covenant of Mayors (formerly known as the Compact of Mayors) to which it is a signatory. The GHG Inventory update was undertaken with the support of the C40 Technical Support Team. Data from C40 cities around the globe can be found on the C40 website: http://www.c40.org/other/gpc-dashboard.

The following steps and data sources, followed by Tshwane and drawing on years of South African city data collection, have been developed to guide any South African municipalities undertaking such an exercise.

Figure 22: Various energy and emissions-related activities are 'mapped out' by members of the Tshwane Sustainability Unit and key sector department representatives



Source: Max Jamieson, Programme Manager, Technical Assistance, Measurement and Planning Initiative, C40

Step 1: Identifying Energy and Emissions-related Activities

A first step is to list all activities taking place within the municipality that either consume energy and/or emit greenhouse gases. These are then ordered into sectors such as Stationary energy use (in Residential, Commercial and Industrial sectors), Transport, Waste, Industry, Agriculture and Land Use Change.

The types of energy used for each activity are then identified (e.g. lighting could be from electricity, candles or paraffin) and a source of data on the quantity of each fuel type per activity must then be identified. If no data is available a method to estimate the quantity must be used.

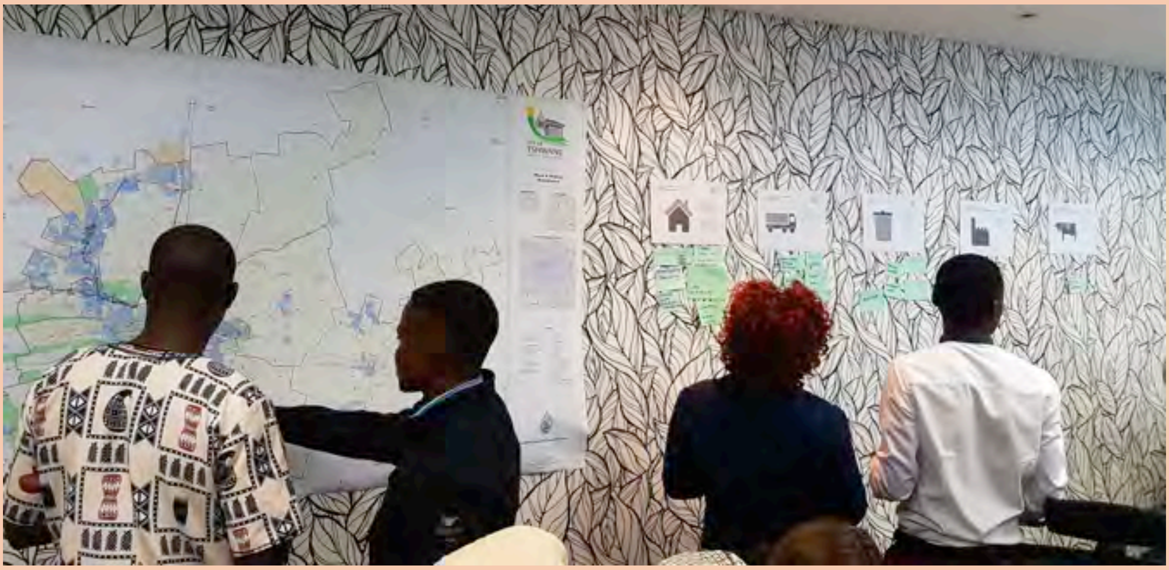
Step 2: Data Gathering

Types and quantities of fuel and other emissions of activities (this could be waste or livestock) are the foundation of the data inventory. Much of this data is being held within the Municipal records, such as electricity accounts, service accounts, waste statistics, etc. However, some data requires engaging with external agencies, such as StatSA (household stats and energy use), Department of Energy (liquid fuel), Eskom (electricity), private gas and coal suppliers, local industries, etc.

Some of the data is supply–side data and needs to be allocated to the sectors where it is consumed. Often the total supply to a municipal area can be obtained, but it is difficult to apportion it to different sectors, such as the use of liquid petroleum Gas (LPG) which is used in the residential and commercial sectors. Often other studies provide clues to disaggregate data by sector. Detail on this is provided in the Guide document referred to above.

Where no supply data exists, or where the allocation of the supply data to sectors is unclear, the consumption picture is being built on the basis of the activities. For example, finding supply data on coal in South Africa is very difficult as the sector is deregulated. It is therefore necessary to establish or estimate the amount of coal required for certain activities. A summary table of data sources is provided below.

Figure 23: Activities are then grouped according to sectors; C40 Emissions Inventory Development Workshop, City of Tshwane, 2016.



Source: Max Jamieson, Programme Manager, Technical Assistance, Measurement and Planning Initiative, C40

Table 8: Summary table of data sources

Data	Source(s)
INTERNAL DATA SOURCES	
Electricity sales by tariff (municipal distribution areas)	Local municipality (Electricity and Finance Department)
Coal use at municipal power stations	Local municipality (Electricity Department)
Solid waste landfilled (municipal)	Local municipality; private landfill site operators
Wastewater volume and treatment method (municipal)	Local municipality, sanitation department
Types of industries and industrial processes taking place in Tshwane	Local municipality, economic development department
EXTERNAL DATA SOURCES	
Electricity sales by tariff (Eskom distribution areas)	Eskom
Energy (electricity, diesel) use by rail	Eskom; PRASA; Transnet
Liquid fuel sales by fuel type by magisterial district (by trade category)	Department of Energy (www.energy.gov.za)
In-boundary aviation fuel use	Flight schools (any local flying schools, private aerodromes)
Residential coal and wood use	Local studies; StatsSA (www.statssa.gov.za)

Data	Source(s)
EXTERNAL DATA SOURCES	
Commercial and industrial coal and wood use	Relevant licencing authority (air quality)
Emissions factors	Department of Environmental Affairs; Eskom Integrated Report (www.eskom.co.za); emissionfactors.com (www.emissionfactors.com)
Gas (pipeline length, volume and purpose of gas use)	Sasol
Solid waste landfilled (private)	Private landfill site operators
Solid waste incinerated	DEA Air Quality department
Wastewater volume and treatment method (private)	Private operators
Number of livestock	Industry annual reports (Beefcor, etc.)
Industrial processes (volumes of cement, glass, etc., produced)	Industry annual reports (PPC Cement, Consol Glass, etc.)

Step 3: Converting energy consumption data into GHG emissions

Emissions from each activity are calculated by multiplying the quantity of fuel or emitted gas by its emission factor. An emission factor is the amount of carbon dioxide equivalent that is emitted into the atmosphere as a result of one unit of the consumption of that fuel, or gas emission. Default emissions factors are provided by the International Panel on Climate Change (IPSS) along with a list of country-specific factors. They can be found at www.emissionfactors.com. The latest Eskom emissions factors can be found in their annual / integrated report on their website: www.eskom.co.za.

A detailed, step by step guide for collection and collation of a greenhouse gas inventory has been developed by Sustainable Energy Africa (2017) and can be found on: http://cityenergy.org.za/uploads/resource_422.pdf.

Case study 3: Durban Solar City project – encouraging citizens and businesses to install solar PV

Municipalities can implement sustainable energy projects to reduce the energy consumption of their internal operations. However, most energy is consumed in the commercial, industrial and household sectors. It is critical to engage these sectors to support the municipality's energy and climate change mitigation commitments.

The eThekwini Municipality has implemented the Durban's Solar City project. The project aims to develop the solar PV market by overcoming barriers such as the lack of a clear regulatory framework and information of PV potential, costs and benefits.

The project has developed

- *Five pilot solar PV installations on municipal roofs to gather experiences and showcase the technology.*
- *The Durban Solar Map which is a web-based roof cadastre that provides residents and businesses with information about the potential to install solar PV on their roofs and generate electricity. It also allows potential investors to estimate costs and benefits of an installation on their buildings. The website is linked to the municipal GIS.*
- *The building application and approval process for solar PV installations has been simplified by defining it as Minor Building Works with strongly reduced municipal fees.*
- *The Electricity Department permits solar PV installations to feed into the grid. A simple application process is in place.*
- *A feed-in tariff for embedded generators has been approved by NERSA and will be activated once it has been linked to the municipal revenue system.*

Figure 24: Solar Roof cadastre - an internet based solar website

Source: eThekwini Energy Office, www.gis.durban.gov.za/solarmapviewer

Support organisations

SALGA

https://www.salga.org.za/

SEA

www.sustainable.org.za

ICLEI Africa

africa.iclei.org/

Processes and finances for implementing municipal projects

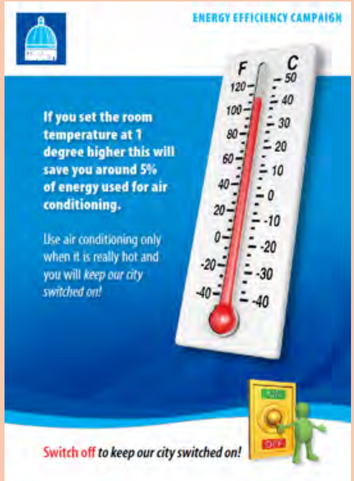
Overview

This chapter focusses on implementing municipal projects to make operations more energy efficient or to utilise energy from renewable sources. Technical aspects are not covered here, but are discussed in other sections of the manual. Depending on the local priorities and available resources a broad range of projects can be implemented including:

- Investment projects into energy efficiency in municipal buildings and facilities;
- Introduction of an Energy Management System;
- Pilot projects of renewable energy systems; and
- Staff campaigns to reduce energy consumption.

All such projects require budgets and expertise that is often not available within the municipal administration.

Figure 1: Energy Efficiency staff campaign posters



Objectives and benefits

The principle goal of such projects is to reduce the carbon emissions of the municipality and to contribute to achieving sustainable energy targets that several municipalities have set for themselves. The municipal operations only use a fraction of the energy consumed in a municipality. Large scale reductions of GHG emissions can only be achieved if communities and businesses implement GHG reduction projects. It is therefore important to use municipal projects as learning opportunities for both municipal officials and the public; and for showcasing the municipality as leading by example. An additional objective of projects is stimulating the local economy by establishing or strengthening a sustainable energy sector, as well as creating jobs.

To maximise learning, municipal officials must be involved at all stages of the project planning and implementation process. Lessons learnt should feed into policy development with the objective to stimulate sustainable energy interventions by private and public investors in the municipal area.

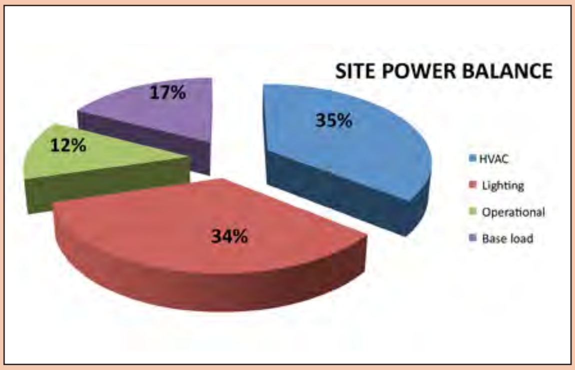
Typical learning opportunities for energy efficiency projects include:

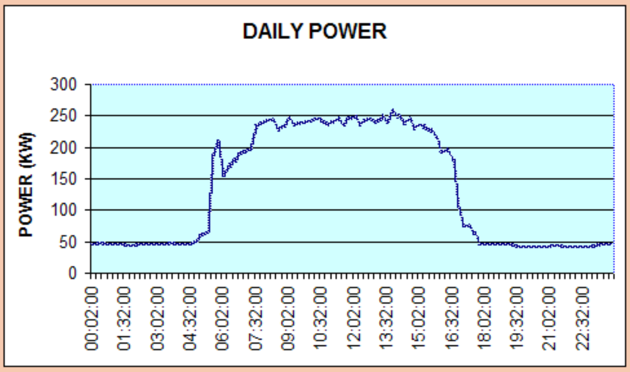
- Baseline assessment of energy consumption of a building or facility,
- Identification of measures to reduce energy consumption,
- Drafting of Business Plan for the measures;
- Procurement and implementation of measures; and
- Monitoring and validation of energy savings.

HEINRICH BÖLL STIFTUNG SOUTHERN AFRICA | SEA SUSTAINABLE ENERGY AFRICA | SAMSET | USAID | SOUTH AFRICA Low Emissions Development Program | Brot für die Welt

The graphs below show typical graphs that are part of the baseline assessment of a building.

Figure 2: Analysis of electricity demand in municipal office





Source: eThekwini Municipality EEDSM 2013-14, Baseline Report: City Health Building

For renewable energy installations typical learning opportunities include:

- Identification of suitable technologies;
- Drafting of Business Plan for the measures;
- Specification and procurement of renewable energy installations;
- Integration of generated electricity into the municipal grid;
- Operating and maintenance of installations; and
- Monitoring of electricity generation that can be variable as in case of solar PV.

The images below show a photograph of the roof of a municipal building for which a roof-top solar PV installations is planned and the proposed PV panel layout.

Figure 3: Roof of EWS Customer Services building in eThekwini Municipality

Showcasing that a municipality is leading by example requires that projects are visible and accessible to the public. Visibility and accessibility can be enhanced through explanatory tools such as displays or public guided tours. In order to promote renewable energy installations like roof-top solar they must be aesthetically pleasing and improve the physical appearance of buildings they are attached to.

Implementation

Energy efficiency and renewable energy projects require investment by the municipality. Projects can principally be funded from the municipal budget, grants or loans. The projects typically result in saved costs of electricity purchased from Eskom. These savings can be used to finance further projects.

It can be difficult in municipalities to quantify electricity savings because internal use of electricity may not be recorded. Even if internal electricity bills exist reduced costs may not motivate for capital budget allocation because electricity does not appear as a budget item. Therefore the first step is often to bring cost of electricity to the attention of managers and council.

When embarking on an energy efficiency or renewable energy project a rough Business Plan must be drafted indicating capital costs, operating costs, avoided costs of electricity and pay-back period or Return on Investment. The avoided electricity costs are the direct financial benefits to the municipality. They depend on the tariff charged internally for electricity. Municipalities that are electricity distributors purchase electricity from Eskom at wholesale (Megaflex) tariffs that are lower than the retail tariffs of private and business customers. Municipalities that are not electricity distributors purchase electricity from Eskom at a retail tariff similar to private and business customers. Therefore their avoided costs of electricity are higher than of municipalities that are electricity distributors.

The table below shows a financial model for a grid-connected roof top Solar PV project. The Model can be downloaded from the eThekwini municipal website. It can be customised to draft Business Plans for other renewable energy and energy efficiency projects[1].

The example shows that for Solar PV installations investment costs are still relatively high, compared to avoided costs of electricity resulting in a relatively long pay-back period, especially if the project is funded through a loan at commercial interest rate. However, the ratio between investment costs and electricity savings and the resulting payback period differs for different technologies and project types, e.g. for energy efficient lighting projects payback periods are typically 2 to 3 years. Generally, sustainable energy projects have long-term benefits and their financial viability improves with declining investment costs and increasing costs of electricity. The projects have additional benefits such as reduced greenhouse gas emission, learning and stimulating the local economy. These should be highlighted in business plans to motivate for funding.

Many municipalities are not in a position to fund projects from their own budgets. Project business plans are necessary for submission to Council and to outside funders. Current grant and loan funding opportunities for municipal projects are listed below.

A range of funding options and incentives are available for businesses and private households including tax rebates. Some detail on funding options can be found at SALGA (2014)[2]. The resource has been published in 2014 and while most information is still accurate, some funding mechanisms have changed. It is necessary to confirm information for each planned project as government and donor programmes are frequently being reviewed. An example is the introduction of the Carbon Tax that will make projects more viable but has been postponed several times and is now expected to be introduced in 2018.

1 Similar models can be found on the RETScreen website.

2 SALGA (2014) Local Government Toolkit: Financing Energy Efficiency and Renewable Energy, http://cityenergy.org.za/uploads/resource_263.pdf

Table 1: Example calculation for 10 kWp Rooftop PV

FINANCIAL MODEL FOR ROOFTOP PV		
Output		
Total capacity	10	kWp
Annual insolation	1 890	kWh/m^2
Performance ratio	83.0%	
Yearly production	15 687	kWh
Income and rates		
Customer tariff (avoided electricity)	1.35	R/kWh
Inflation adjustment	7%	per annum
Investment & installation		
Capital cost	20 000	R/kWp
Project development	1 000	R
Operational costs		
Upkeep (first year)	400	R/kWp/annum
Allowance for component change (first year)	1 000	R/annum
Insurance premium	0.8%	of initial invest
Finance structure		
Total investment	201 000	R
Senior Debt Leverage (% bank finance)	10%	
Total debt	20 100	R
Cost of Debt Funding	11%	
Maturity	10	years
Equity	40%	
Total equity	80 400	R
Ratios		
Project Return Post Financing	9.4%	
Payback period	11	years

Source : http://www.durban.gov.za/City_Services/energyoffice/Pages/Durban-Solar-Financial-Model.aspx

Municipal Financial mechanisms (loans and grants)

Municipalities have major operational and investment budgets. The 2017 Budget Review provides for R366.3 billion to be transferred directly from national to local government and a further R23 billion allocated to indirect grants for the 2017 MTREF.[1] Access to conditional grant funding for national government's service delivery priorities is based on compliance with conditions stipulated in the Division of Revenue Act (DoRA).

A series of grants, loans and other financial mechanisms for infrastructure projects are listed with different conditions and eligibility criteria. Funders include government, development finance institutions (DFI) and donors. Although most mechanisms can fund a range of infrastructure projects they can be used for specific energy related projects or other infrastructure projects should be designed in an energy conscious manner.

Energy Efficiency Demand Side Management Grant (EEDSM) by Department of Energy

The Energy Efficiency Demand Side Management (EEDSM) programme of the DoE is the only national government grant especially for energy projects. It funds energy efficiency projects in municipal buildings and facilities, such as street lights, pump stations and waste water treatment works. The funding scope has been expanded to include co-generation. Municipalities must apply for the EEDSM grant. One of the conditions is such projects must have a maximum payback period of 7 years.

Municipal Infrastructure Grant (MIG)

The Municipal Infrastructure Grant (MIG) is a consolidated grant mechanism, introduced in March 2003. It is managed by the Department of Cooperative Governance and Traditional Affairs (CoGTA). The MIG fund is allocated according to a formula to all municipalities that fulfil three categories of conditions: (a) conformity with the Division of Revenue Act; (b) cross-cutting conditions (e.g. compliance with the IDP, infrastructure development with economic spin-off for poverty alleviation and job creation, basic service coverage, among others) and (c) sector specific conditions.[2]

The purpose of MIG is funding of basic infrastructure such as roads, water, sanitation and electricity. Projects funded through the MIG must be in the municipal IDPs and approved by council. Once sustainable energy objectives are included in the IDP MIG funded projects must contribute to achieving them.

National Treasury's Cities Support Program (CSP)

The National Treasury's (NT) Cities Support Program (CSP) has the goal to make cities function more efficiently, to ensure economic growth and reduce poverty. Grants are provided to metros by the NT, but channelled through different departments. Scope of funding includes land management, urban regeneration and integrated urban transport.

In 2017, Climate Resilience support (with a focus on energy, water and risk prevention) will be integrated as a special area of the CSP. An important objective is to ensure that planning documents (IDPs) include climate resilience related targets and indicators. CPS grants must adhere to climate and energy conditions/ clauses. The CSP is monitored by the Built Environment Performance Plan (BEPP), a framework of indicators.

1 http://mfma.treasury.gov.za/Circulars/Documents/MFMA%20Circular%2086%20-%202018%20MTREF%20-%208%20March%202017/MFMA%20Budget%20Circular%20No%2086%20-%202017_18%20-%2014%20Mar%202017.pdf

2 http://www.cogta.gov.za/mig/toolkit/toolbox/EF.%20MIG%20Operational%20Framework,%20System%20and%20Mecha0nisms/vi%20-%20MIG%20Guideline%20document-%20National%20MIG%20Management%20Unit%20Pr.pdf

Secondary Cities Support Programme

In an effort to extend the financial support beyond metros, CoGTA in collaboration with the World Bank, SECO is designing a Cities Support Programme tailored to the needs of Secondary Cities. During an inception phase the programme will be piloted in Polokwane and Richards Bay. Eight further cities will be supported by diagnostic assessment of opportunities and identification of priority needs with regards to sustainable urban development. Focus will be on sustainable infrastructure, and associated funding needs. The diagnostics will inform the design of the Secondary Cities Support Programme and conditions for project proposals to be submitted by the cities.

Infrastructure Investment Programme for South Africa (IIPSA)

The Government of South Africa and the European Union (EU) jointly developed the Infrastructure Investment Programme for South Africa (IIPSA) for a total amount of €100 million. The main purpose of IIPSA funding is to support the implementation of the government's infrastructure programme. The programme principally funds large projects (R100m to R1b).

The Development Bank of Southern Africa (DBSA) [3]: has been appointed as the Fund Manager and invites project proposals from eligible public entities including municipalities and private entities with a public service mission. The IIPSA Grant funding can take the form of technical assistance or direct investment grants.

Infrastructure Finance Corporation Limited (INCA)

The INCA was established in 1996 as a response to the South African government's call for increased private sector involvement in infrastructure funding. INCA became the primary private sector investor in socio economic infrastructure in South Africa, drawing on local and international marketing funds, raised through a series of INCA bond issues and long term loans from international Development Finance Institutions. Towards 2010 INCA started closing down, only maintaining the INCA Capacity Building Fund. AFD is now working with INCA to revive the product via a different structure focused on secondary cities.

Sub-Saharan Africa: Cities and Climate Change in Africa (CICLIA) Programme

In a partnership with the EU and Agence de Developpement Francais (AFD), SECO (Swiss agency) supports the CICLIA Programme (2017-2020), with a focus on the climate action in Sub-Saharan cities. The programme's objective is to support local authorities in turning urban climate strategies into actual urban projects with climate co-benefits. It helps local governments design and implement low-carbon and climate-resilient urban strategies and facilitate investment[4].

With the support of the CICLIA fund (EUR 300 000) and in collaboration with the Energy & Climate Unit of the City of Cape Town, the AFD, EU and SECO are about to support two studies aimed to assess: (a) the opportunities and needs associated with low-income energy access and (b) to understand the financial and technical consequences of climate change on urban populations. Based on the studies, the city will identify and set up projects to be potentially financed by AFD loans (e.g. through budgetary support, via the INCA lending scheme).

DBSA Infrastructure Finance in South Africa

The Development Bank of South Africa (DBSA)'s Infrastructure Finance mechanism is aimed to support the South African infrastructure development agenda, including financing and non-financing services support for the municipal sector, and financing of large scale infrastructure projects and programmes. Its current focus is on large scale infrastructure projects

3 http://www.dbsa.org/EN/prodserv/IIPSA/Pages/default.aspx for more information

4 State Secretariat for Economic Affairs (SECO), Economic Development Cooperation, Infrastructure Financing, Planned Projects, Update: January 2017

within private and public sectors. Its primary sectors are water, energy, transport and ICT. Municipalities in charge of basic service delivery and infrastructure development are a key market for the Bank. Another focus area of the Bank is support for energy generation capacity, including renewable energy, as well as coal and gas-fired power stations.

Green Fund[5]

The Government of South Africa, through the Department of Environmental Affairs (DEA) has set aside R800 million to establish the Green Fund. The DEA has appointed the Development Bank of Southern Africa (DBSA) as the implementing agent of the Green Fund.

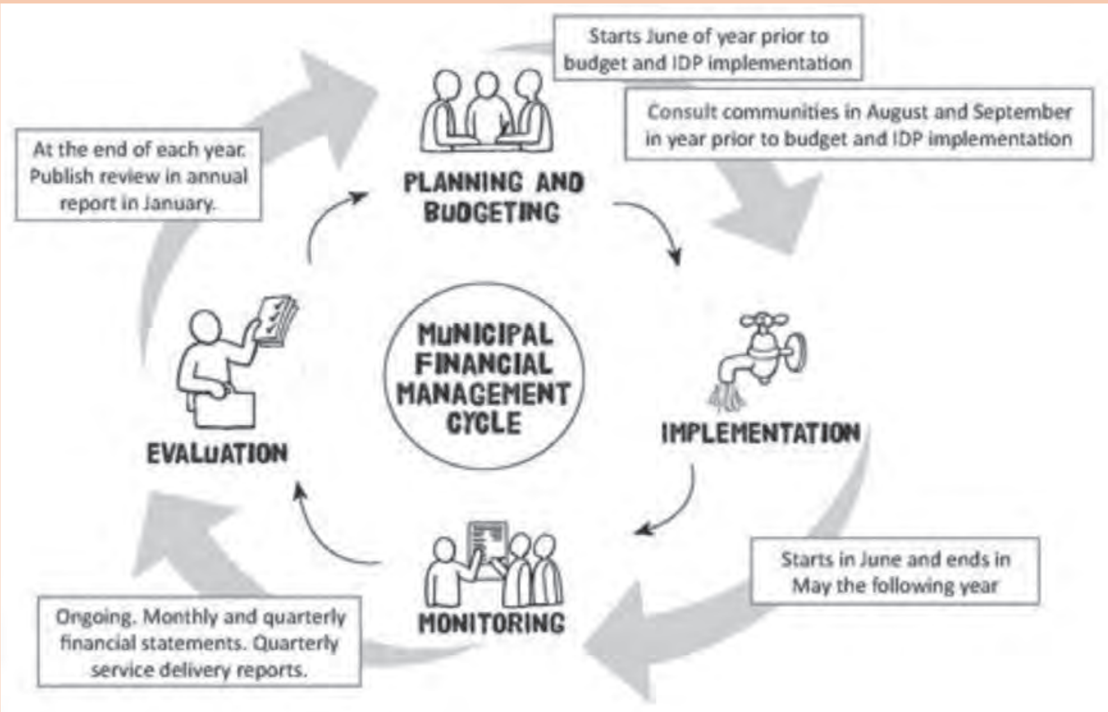
The Green Fund's objective is to lay the ground for the SA economy to transition to a low carbon, resource efficient and climate change resilient economy. It aims to provide catalytic finance to facilitate investment in green initiatives. The Fund only supports initiatives that would not be implemented without its support. It is additional and complementary to existing fiscal allocations. Financial support is provided, based on an application process; it can take the form of grants, loans or equity.

5 http://www.sagreenfund.org.za/wordpress/types-of-funding/

Municipal Budgeting Cycle

Municipal planning and budgeting is governed by the Municipal Systems Act of 2000. All municipal projects must be part of the municipal Integrated Development Plan (IDP) that is drafted every 5 years and annually updated when new projects can be included. During the annual Municipal Financial Management Cycle budgets are allocated to priority projects.

Figure 4: Municipal Financial Management Cycle



Source: GreenCape (2013-14), Understanding Municipal Procurement Processes

The financial management cycle applies to all projects including those funded through national or international grants and loans. The lengthy planning process can make it difficult for municipalities to respond to funding opportunities that have short budget cycles for the disbursement of funds. In order to take advantage of such funding opportunities municipalities should include energy efficiency and renewable energy projects in their IDPs even if no municipal budget can be allocated at the time. When funding opportunities emerge, the Council can approve an adjustment budget for projects. It is noted that details of processes and rules vary in different municipalities.

Once the project budget is approved, the timing until project implementation is determined by the supply chain management process whose duration can sometimes be underestimated even by municipal officials.

Supply Chain Management (SCM) Process

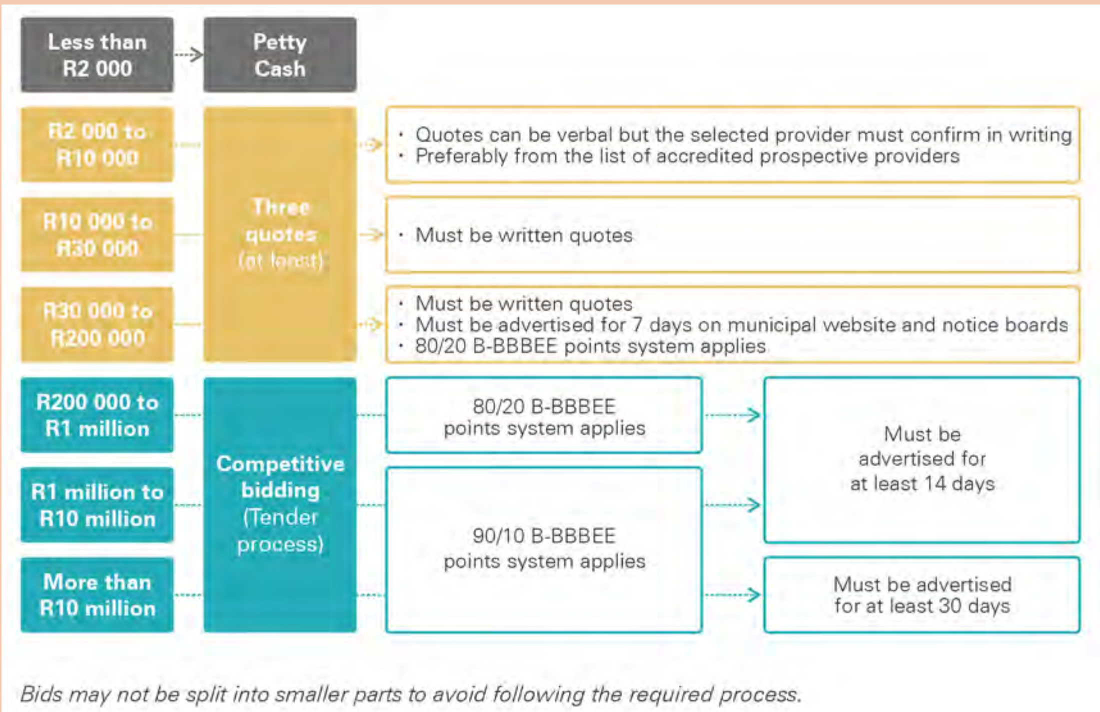
All projects implemented by a municipality must adhere to the legislation and regulations governing the municipal SCM process. These are

- Municipal Finance Management Act (MFMA) of 2003;
- Municipal Supply Chain Management Regulations of 2005;
- Preferential Procurement Policy Framework Act 2000; and
- Preferential Procurement Regulations 2011.

The legal framework is restrictive and the procurement process for larger projects is lengthy. The MFMA and SCM Regulations determine that projects are procured through competitive tenders. The legislation on preferential procurement influences the adjudication of tenders but has principally no influence on the duration of the process.

The details of the SCM processes differ between municipalities who may have their own SCM policies. Supply chain processes differ according to the value of goods or services procured[3]. The figure below indicates the processes that need to be followed for purchases with different values.

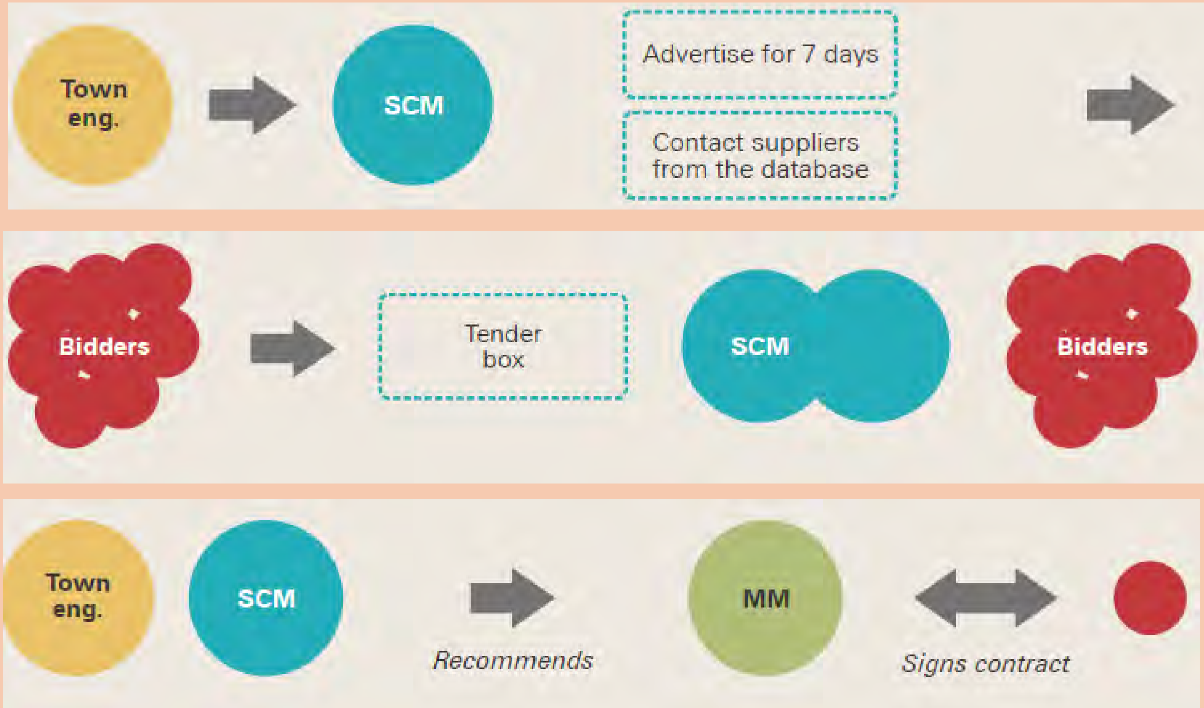
Figure 5: Overview of Supply Chain Management Processes



Source: Ethics Institute of South Africa (2015), Understanding the Municipal Procurement Process, http://greencape.co.za/assets/municipalprocurementguideREPRO.pdf

The SCM Regulations (2005) require that for purchases with a value of more than R2 000 at least three quotations are gathered and evaluated. For purchases with a value higher than R10 000 the quotations must be in writing, and above a value of R30 000 a Request for Quotations (RfQ) must be advertised on the municipal website. In some municipalities these thresholds are lower. Purchases of up to R200 000 can be managed through the relatively simple RfQ process. This process can be completed in four to six weeks and is outlined in the figure below.

Figure 6: Procurement of good and services of value less than R200 000



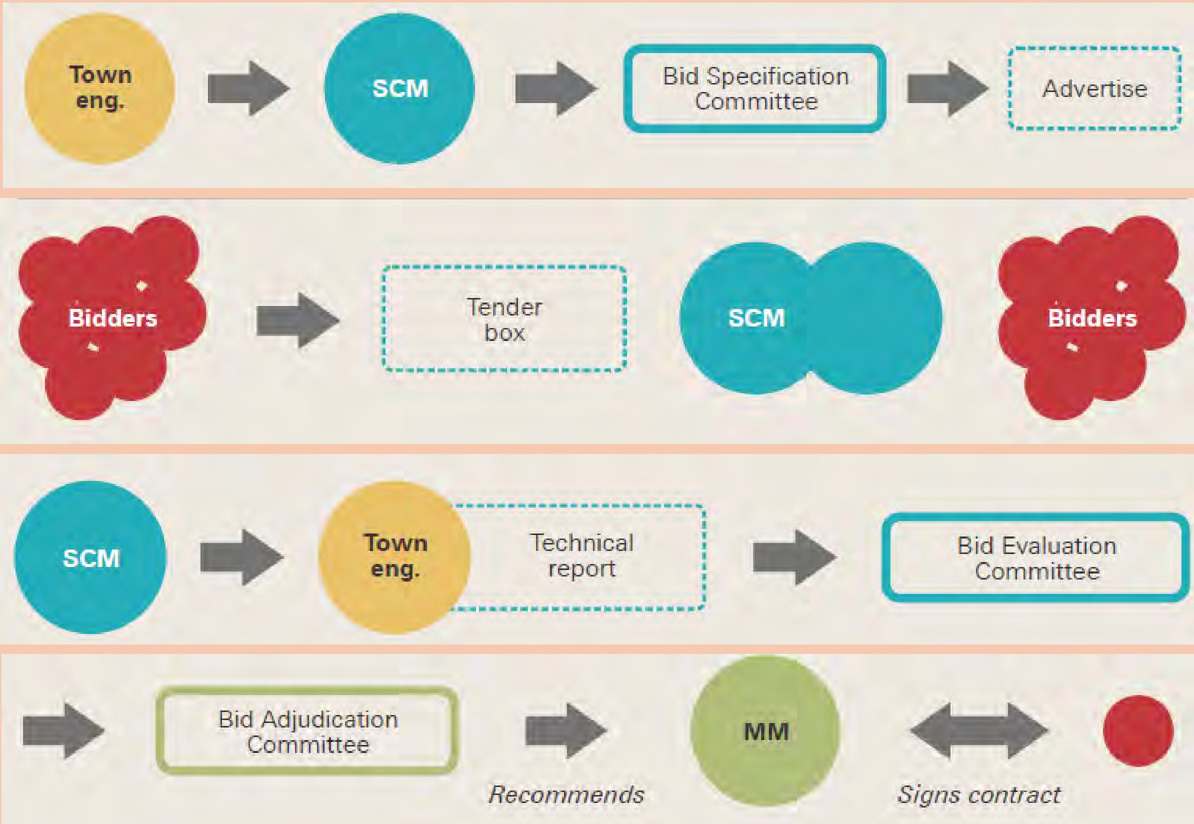
Source: Ethics Institute of South Africa (2015)

The relevant department (indicated as Town Engineer) drafts an RfQ that is advertised by the SCM department. Suitable contractors registered on the municipal database can be notified of the RfQ. Bids are submitted into the tender box and opened publicly shortly after the submission deadline by municipal officials who read out the names of bidders, their preferential procurement status and prices. Officials of the issuing department and SCM evaluate the bids and recommend the preferred bidder in a written report to the municipal manager who finalises the award of the contract.

All goods and services with a value of more than R200 000 must be purchased through a full tender process outlined below. In large cities this process takes about four months to complete. Technically or contractually complex tenders can take longer especially if amendments to the specifications become necessary. Administrative errors or disputes of the award by unsuccessful bidders can also delay the process significantly.

The main difference between the RfQ and the full tender process is that several committees of municipal officials are involved in the full tender process. It is noted that Councillors must never be involved in any SCM process. Before advertising the tender documents are scrutinised by the Bid Specification Committee. This committee checks the technical and legal soundness of the tender documents especially the evaluation criteria. For technically complex tenders a briefing session for bidders is often conducted during the advertising period. The submission and opening of bids procedure is the same procedure as for RfQ.

Figure 7: Procurement of good and services of value more than R200 000



Source: Ethics Institute of South Africa (2015)

Bids are then evaluated by the SCM department for formal compliance and by the technical department for functionality. The functionality evaluation is often done by a small technical team that scores the bids according to their quality. Bids for complex tenders are often voluminous and the evaluators must go through large amounts of documents. A written evaluation report is submitted to the Bid Evaluation Committee that finalises the score including preferential procurement criteria and price. It sends its recommendations to the Bid Adjudication Committee for review. The Bid Adjudication Committee recommends the preferred bidder to the municipal manager who makes the award. In large municipalities the municipal manager can delegate this authority to the Bid Adjudication Committee.

In large municipalities the various committees meet weekly and work through many very diverse tenders. They ensure transparency and compliance with procedure. However the technical department issuing the tender is responsible for the Terms of References and the specifications. Due diligence is critical at all stages of a tender process to prevent the result from being challenged by unsuccessful competitors which can result in long delays.

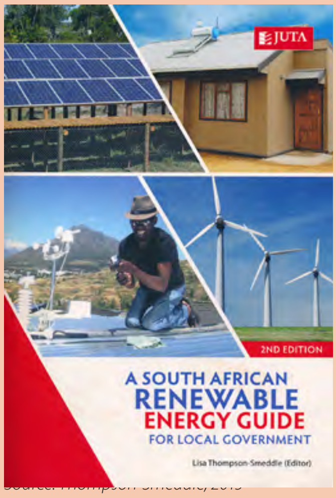
Municipal expertise and capacity

Energy efficiency and renewable energy projects are new to most municipalities, and many do not have sufficient expertise and capacity to conceptualise and specify them, and to oversee their implementation. Often consultants are appointed for these tasks. However, if consultants are appointed capacity building should be an integral part of their terms of references to build in-house expertise (see Case Studies).

Large municipalities have well capacitated technical departments, such as electricity, water and sanitation, architecture, and transport who have staff with relevant skills to familiarise themselves with the specific requirements to energy efficiency and renewable energy projects. The projects should be implemented by the relevant technical departments who will be responsible for operating and maintaining them. The operation and maintenance of projects such as roof-top solar PV or of building management systems are new tasks for these departments and capacity needs to be built.

An outside source of capacity especially for energy efficiency projects are Energy Service Companies (ESCO). ESCOs offer Energy Performance Contracts that use the saved cost of electricity to fund the project. ESCO funding models and contracts are complex and limited experience exists with these contracts in municipalities. Difficulties include the application of the SCM process especially if the pay-back period exceeds three years. The South African Cities Network has set up a website explaining the concept and supporting municipalities in contracting with ESCOs[4].

Numerous topical documents can be found on the website www.cityenergy.org.za. The book: A South African Renewable Energy Guide for Local Government[5] is another source of information. It includes a section on financing solutions.



4 http://www.energycontractsupport.org/

5 Thompson-Smeddle (2nd editon) 2015 A South African Renewable Energy Guide for Local Government, Juta.

Case Study 1: Leeupan Solar PV Project in Ekurhuleni Metro Municipality

The Leeupan solar PV project was developed as a demonstration project by the Ekurhuleni Metropolitan Municipality in 2012. It is located at the OR Tambo Cultural Precinct, a centre for environmental learning and demonstration close to Wattville.

The construction of the PV system was financed through the municipality's capital expenditure budget. The capacity of the plant is 200kWp. The solar PV array is connected to the Eskom low voltage (LV) distribution grid. The electricity generated by the system powers the OR Tambo Cultural Precinct. The power output is lower than the overall power requirements of the precinct. There is no Power Purchase Agreement with Eskom, and it has been agreed between the two parties that any excess power is a contribution to the grid free of charge.

Procurement

The project concept was developed and approved by the council in mid-2011. It departed from the standard tender process through Section 36 of the Municipal Supply Chain Management Policy (emergency procedure) to speed up the procurement process and ensure that the project would be built as a demonstration project in time for COP 17. Three service providers were approached with a request for quotation. The specifications for the technology and mounting structure were developed internally, with the support of DANIDA (Danish agency).

Operations and Maintenance

Operations and Maintenance (O&M) are the responsibility of the Energy Division of the municipality. Although routine maintenance is undemanding, unanticipated operational challenges, notably the theft of panels, have reduced the power production. Where a panel is removed, the affected PV module string is left inactive. The municipality had to resort to a tender process to fix the system, which greatly delayed the replacement and repair work.

Figure 8: Ground-mounted Solar PV installation in Leeupan

Source: http://www.zrwmechanika.co.za/solarpv_projects.php

Lessons Learnt

As this was a ground breaking project, the procurement and contracting process was onerous according to the involved officials. The lack of local suppliers at the time added to the difficulties. Officials are of the view that an operations and maintenance contract should have been entered into after the commissioning of the project because no line department was responsible for this and no standard procurement for spare parts was in place. Due to delayed procurement of stolen parts the plant produced far below anticipated output levels.

The location of the installation proved to be vulnerable to theft. In future the City would consider the location more carefully to minimize this risk.

However, the project contributed to the building of capacity in the Energy Division around solar PV technology, its procurement, installation, management and monitoring.

Case study 2: Solar PV Project in eThekwini Municipality*

The purpose of the project was to install solar PV panels on the roofs of five municipal buildings listed in the table below. The project was completed in 2016.

Table 2: Municipal Buildings with PV installations

Building	**Location**	**PV System Size**
Metro Police Headquarters	29°50′57.05″S, 31° 1′30.66″E	115 kWp
uShaka Marine World office block	29°52′6.07″S, 31° 2′40.43″E	135 kWp
Moses Mabhida Stadium – base of northern arch	29°49′38.58″S, 31° 1′51.74″E	2 kWp
Moses Mabhida Stadium – People's Park restaurant	29°49′55.29″S, 31° 1′43.42″E	110 kWp
eThekwini Water and Sanitation – Customer Services building	29°51′7.74″S, 31° 1′27.72″E	45 kWp

Source: Delta (2015) EOS Project, Electrical concept.

Responsibilities

The overall responsibility for the project was in the Energy Office. It managed the project in close collaboration with other departments with the following responsibilities:

- *Energy Office – responsible for overall project management and funding;*
- *Electrical Building Services in the Architecture Unit – responsible for maintenance of the installations;*
- *Electricity Department – responsible for grid integration; and*
- *Managers of the Buildings where the roof-top PV will be installed – responsible for operation of the installations.*

Procurement and Implementation Process

The project was funded by the eThekwini Municipality. This project was the first of its kind in the municipality and specialised expertise was not available in-house. The project was developed in two stages, each of them requiring a full tender process. Both contracts with service providers had strong capacity building components for municipal officials.

* For more information on the project see: http://www.durban.gov.za/City_Services/energyoffice/projects/Pages/RenewableEnergy.aspx#EOS

Stage one was the design and technical specification of the projects. It was funded through the CSP programme (R750 000). Stage two was the implementation of the project. For this stage R8.5m were set aside in the municipal capital budget. In stage one consulting engineers (electrical and structural) were appointed to design and specify the solar PV installations [6], draft terms of references for the stage two contract, assist with assessment of tender proposals in stage two, supervise the installation, and train two engineers in the municipality.

In stage two a contractor was appointed to deliver and install the systems. The contract also entailed maintaining the installations for a period of 2-years, training municipal officials in operating the systems and taking over the maintenance.

The following tasks of the project were performed by the municipal management team:

- *Technology assessment and choice;*
- *Site assessment and selection;*
- *Consultation with all stakeholders in the municipality;*
- *Terms of reference, tender and appointment of consulting engineers;*
- *Application and approval by Amata (KZN Heritage) for one building older than 60 years; development application and approval for Minor Building Works by eThekwini Municipality;*
- *Tender and appointment of contractor; and*
- *Learning and outreach to the public.*

Figure 9: Roof-top PV on UShaka Marine Offices

Photo: Susanna Godehart

6 The specifications were outcome based and the FIDIC Yellow Book was used for contracting.

The photographs show the PV installation on the roof of the uShaka Marine office block and the inverters and other equipment installed in the basement of the building.

Figure 10: Inverters etc in UShaka Marine

Photo: Susanna Godehart

Lessons Learnt

The project took more than two years to complete mainly because of the two tender processes and a delay due to a minor change of specifications. However it achieved its objectives including learning and capacity building for municipal officials in the Energy Office, the Electricity Department, the Architecture Department and the facilities managers of the various buildings.

Support organisations

USAID South Africa Low Emissions Development Program (SA-LED)
https://www.usaid.gov/sites/default/files/documents/1860/SA-LED-_2016-BUS-V6-Aug.pdf

ADF – Agence Française de Développement
http://www.afd.fr/lang/en/home/pays/afrique/geo-afr/afrique-du-sud/contact-afrique-du-sud

GIZ-SAGEN – South African – German Energy Programme

https://www.giz.de/en/worldwide/17790.html

DBSA
www.dbsa.c.za

Green Public Procurement

Overview

Governments are among the largest consumers in the economy and can use their purchasing power to stimulate markets for 'green' products through the buying of goods and services that have a less negative or even positive impact on the environment and human health when compared with conventional products or services. Considerations of whether a product or service is 'green' should take into account:

- The environmental impact throughout the product's lifecycle; from extraction through to packaging, distribution, re-use and disposal.
- Its lifecycle cost, including capital and operating costs, e.g. an efficient light bulb is more expensive to purchase than a conventional bulb, but it will use less electricity and therefore cost less over its lifecycle.

Motivations for green procurement:

- Resource-efficient options are often cheaper when considering lifecycle costs, but they are almost always cheaper when considering externality costs (e.g. deaths from air pollution).
- Inefficient resource use may be penalised in future, e.g. through a carbon tax.
- Reducing product transport promotes local and smaller suppliers, which in turn supports local job-creation.
- Insisting on green services and products will increase competition and innovation, giving the local economy city a competitive edge.

Implementation

Green procurement policies need to be developed and aligned with the Supply Chain Management (SCM) policy and national legislation.

The following steps can be taken to implement green procurement:

Step 1: Form a green procurement team

Identify and train staff and departmental champions that will drive the process. Temporary external support may be required. High-level backing should be ensured.

Step 2: Decide on an implementation approach

Decide whether to pilot green procurement (recommended) or to introduce it at scale. Successful pilot projects usually include products or services where information on 'greenness' is readily available, local suppliers exist,

This Chapter draws on The Procura+ Manual – A Guide to Cost-Effective Sustainable Public Procurement (undated), published by ICLEI – Local Governments for Sustainability, European Secretariat

Green procurement largely focuses on minimising environmental impacts – only one part of the "triple-bottom-line" considerations of sustainability. The other components of sustainability are social and economic impacts. Addressing social and economic concerns include the buying of locally produced products.

Constitutional mandate

Statements in the Constitution (section 152 (1) of Act 108 of 1996) relevant to green procurement in local government are as follows:

- To ensure the provision of services to communities in a sustainable manner
- To promote social and economic development
- To promote a safe and healthy environment)

Relevant national legislation

- Public Finance Management Act (1999)
- Preferential Procurement Policy Framework Act (2000)
- Preferential Procurement Framework Regulations (2001)
- National Treasury Regulations (2005)
- Municipal Finance Management Act (2003)

prices are similar to conventional products, large quantities are ordered, the conventional products have negative environmental consequences, and the impact of change is highly visible.

Step 3: Review the current situation

Review the current procurement policy and procedures. What are barriers to green procurement and how can they be overcome? If green procurement is already occurring, why did it happen? Do staff have the capacity and expertise to specify green products? Is the institutional structure conducive? Is there a list of pre-screened suppliers? Is re-using and recycling of products considered as criteria of procurement? Has there been a baseline assessment of resource use and chemicals used in production and waste management of products?

Step 4: Market the green procurement project

A project launch will increase awareness, understanding and support. Internal and external communication campaigns will increase buy-in.

Step 5: Market analysis

Various websites are available for evaluating products in terms of their environmental impact.

Step 6: Engage suppliers

Engage existing and new potential suppliers in an interactive communication process to establish realistic standards and discuss future product development. Guiding principles on product and service standards should focus on the elimination or reduction of (1) finite resources, (2) harmful chemicals, (3) degradation and destruction of natural places and processes, and (4) conditions that undermine human basic needs.

Step 7: Decide on a monitoring approach

Monitoring is important to demonstrate project success. It should take into account goals and targets, costs, public and internal response, impacts, the decision-making process, time period, amount of resources and chemicals used and amount of waste produced.

Step 8: Formalise procurement

Ensure the tender/bid specifications reflect the sustainable product or service standards. The legal and SCM departments need to assist in adjusting the procurement policy and standard contracts.

Step 9: Pilot wrap-up

The outcomes of the project should be evaluated by a neutral assessor. Senior management should consider the results.

Table 1: Challenges and solutions in green procurement implementation

Challenge	Solution(s)
Perception that 'green' products are expensive	Challenge the perception with products where this is not the case. Consider full lifecycle costing and the development of a business case.
Lack of political commitment	Secure commitment from all levels, especially in treasury/finance and supply chain management, by making a case based on costing and political and financial mandates, e.g. the Municipal Finance Management Act requires bid assessment on best value for money.
Insufficient knowledge	Include green procurement training in existing training (in particular for the driving team, supply chain management and line managers), have environmental departments provide support on green criteria development, hold awareness-raising sessions, and use a phased approach to allow for the development of expertise/
Limited options on green products and services	Alert and discuss with local suppliers, choose viable pilot projects, and use a phased approach.
No 'green' specifications provided by supplier	Choose a pilot where specifications are available and consider supporting the SABS to establish a body that sets 'green' standards.
Existing purchasing relationships and habits	Work with central procurement, where these relationships are better understood and managed.

Case Studies

National[11]

The Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) is an example of sustainable public procurement; encompassing large-scale renewable energy investment, with concomitant financial and employment benefits. The setting of an ambitious target of 75% local content has resulted in the establishment of local solar and wind industries, as well as investment in sector-specific training.

Western Cape Government (WCG)[12]

Provincial Cabinet mandated the Department of Economic Development and Tourism (DEDAT) to draft a sustainable procurement policy framework that considered both socio-economic and environmental impacts and incorporated national and provincial policy objectives. The WCG Department of Environmental Affairs and Development Planning worked in partnership with Provincial Treasury and DEDAT to develop policy imperatives and strategic initiatives that would fall under such a framework. Actions include supplier development and redesign of the Province's central supplier database. Investment has already taken place towards 'green' procurement at hospitals, service centres and settlement developments.

City of Cape Town[13]

The City has invested R29 million in retrofitting its incandescent traffic lights with efficient LED lights, resulting in savings of 7 459 MWh of electricity, 7 384 tonnes of greenhouse gas emissions, and R11 million per annum. The payback period of this project was three years.

USA

After a Federal ruling in the US compelling public authorities to only purchase Energy Star (energy efficient) compliant computers, the demand for such models was so large that within a few years almost all products available on the market met these standards. Manufacturers realised it didn't make financial sense to run parallel production lines, and phased our less efficient models[14].

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11 Western Cape Government Environmental Affairs and Development Planning (2015) Sustainable Public Procurement Policy Update: An overview to inform implementation in Western Cape Government.

12Western Cape Government Environmental Affairs and Development Planning (2015).

13Western Cape Government Environmental Affairs and Development Planning (2015).

14The Procura+ Manual – A Guide to Cost-Effective Sustainable Public Procurement (undated).

Overview

This chapter applies only to municipalities that are electricity distributers and manage the distribution grid in their area of jurisdiction.

Currently, municipalities buy electricity nearly exclusively from Eskom but many municipalities wish to purchase electricity generated from renewable sources by local or nationally operating Independant Power Producer (IPPs) in order to

- Diversify suppliers and avoid possible supply constraints as experienced in the past;
- Stabilise costs into the future given the uncertainty of Eskom price increases and declining renewable energy costs;
- Reduce greenhouse gas and other emissions related to electricity generated predominantly from coal;
- Support the establishment of or strengthen a local renewable energy industry as part of local economic development; and
- Respond positively to technical change.

Electricity generated from wind and solar PV has become cost competitive with electricity generated from fossil fuels due to falling costs of wind and solar PV compared to the rising costs of Eskom produced power[11]. Municipalities are required to deliver services in a manner that is financially prudent, does not harm the environment and has a developmental impact (Municipal Systems Act 2003 Section 73). Renewable energy is well aligned to these mandates. The price of electricity produced under the REIPPP programme (bid window 4) is competitive with Eskom pricing if partly off-setting peak electricity costs and future Eskom price increases are taken into account. The purchase of renewable energy can be considered financially prudent within the scope of the MFMA requirements.

As discussed above some municipalities have set renewable energy targets in their Energy or Climate Change strategies that they need to meet. A study[12] undertaken by SEA modelled energy/GHG mitigation scenarios in South Africa's largest 27 cities and towns. It indicates that by introducing large-scale renewable energy (wind and solar) and small-scale embedded generation, the cities could achieve an electricity mix that supplies 32% of electricity through renewable means by 2050, rather than the 9% envisaged in the national IRP 2010.

Municipalities can engage in renewable energy through:

a Own generation of renewable energy. This would include projects such as mini hydro within water distribution systems and waste to energy projects that are developed and owned by the municipality.

b Off-taking of renewable energy. Some municipalities already allow for small-scale renewable energy feed-into the grid from small producers. 'Off-taking' refers to municipalities entering into long-term Power Purchase Agreements (PPA) with larger renewable energy developers and selling the power on to their customers.

c Wheeling of power from renewable sources generators and buyer.

The section on Municipal Initiatives of this manual provides details on municipal engagement in renewable power production. This chapter will look at municipal engagement in PPAs and in wheeling of renewable power. Although some municipalities have already entered into PPAs no legal framework for this exists yet. An overview of the current policy environment is provided in the text box.

11 The costs of electricity generated by different technologies can be compared through the levelised cost of electricity (LCOE). The LCOE measures the lifetime cost of generation divided by electricity production.

12 SEA (2015), City-wide Mitigation Potential for South Africa

The National Electricity Plan

The Energy Act of 2008, building on the Energy White Paper of 1998, provides for an Integrated Energy Plan (IEP) to guide the country's energy decisions. The Integrated Resource Plan (IRP) is the national electricity plan – a sub-sector plan of the IEP.

The Energy White Paper of 1998 states government's intention to introduce competition in the electricity sector:

> "To ensure the success of the electricity supply industry as a whole, various developments will have to be considered by government over time, namely:

- giving customers the right to choose their electricity supplier;
- introducing competition into the industry, especially the generation sector;
- permitting open, non-discriminatory access to the transmission system; and
- encouraging private sector participation in the industry."

The IRP approach and methodology for electricity planning was introduced to determine the mix of sources for new generation capacity, incl. renewable sources, and private sector participation in electricity generation.

A 2003 Cabinet decision allocated 70% of new power generation capacity to Eskom and 30% to Independent Power Producers (IPPs). In 2006 the framework for private sector participation in power generation was created with the enactment of the Electricity Regulation Act (ERA), which made provision for market competition.

Although the ERA made provision for market competition in the power generation sector, a 2007 Cabinet decision designated Eskom as the Single buyer of electricity. This signalled a shift in policy based on the motivation that security of supply is a national priority and takes precedence over a competitive market. The Energy Security Master Plan – Electricity 2007-2025 confirmed the Eskom: IPP split of 70:30, but indicated that there was a 'very weak case for full competition on a merchant basis, i.e. it is anticipated that any private participation in the electricity industry will be via the Independent Power Producer (IPP) mechanism with a power purchase agreement with Eskom (single buyer model)' (Reg 3 (1), (2)).

The White Paper on Renewable Energy of 2003 set a national target of 10 000 GWh to be generated from renewable sources by 2013. The IRP details the technology mix for this quantum of renewable energy (in terms of the IRP 2010 this was translated into an installed capacity of 3,275 MW). The Renewable Energy Independent Power Producers Programme (REIPPPP), a joint programme of the Department of Energy and National Treasury, has been designed to achieve the renewable energy target through a competitive bidding process.

The IRP should be updated every few years to accurately reflect changes in demand for electricity, in the costs of supply from various sources and policy changes. Updated IRP documents have been drafted in 2013 and 2016. The IRP 2013 has never been approved. The IRP 2016 is expected to be approved in 2017. The 2016 draft proposes a higher share of renewable energy than the IRP 2010.

Power generation

The IRP guides all decisions regarding the supply mix: new electricity generation capacity must be planned and provided at least cost, while meeting existing ministerial determinations and contractual commitments for any existing new-build, as well as government's policy objectives.

The Electricity Regulation Act 4 of 2006 (ERA) determines that a license is required to generate, trade, import or export electricity.

The following permits are required for power generation (in terms of Schedule 2 of ERA, and the proposed amendments to Schedule 2: Draft licensing Exemption and Registration Notice (1))

- Small-scale generation (up to 1MW), off grid, or generation for 'own use' should be registered with NERSA (via the distributor), but does not require a license to generate;
- Medium scale projects (1 – 10 MW) require a generation license from NERSA; and
- Large-scale generation projects (more than 10MW) require Ministerial Determination (in terms of ERA of 2006 section 34).

Power purchase

The 2007 Cabinet decision determined Eskom as the single buyer within the national IPP process. However, subsequent sets of regulations and on-ground developments have somewhat clouded who is authorised to purchase from private generators. In the IPP procurement framework the 'procurer' is not defined and the Draft Second Electricity Regulation Amendment Bill makes provision for ministerial exemption from the single buyer obligation.

NERSA's Regulatory Rules on Network Charges for Third Party Transportation of Energy (wheeling framework), states that "any load customer shall be free to go into bilateral arrangements with any third-party generator, i.e. non-Municipal and non-Eskom generator" (NERSA, 2012, clause 6.7).

This rule, and the Regulator's licensing of independent power traders to operate in the market, further indicates that bilateral PPAs are allowed. There is nothing stating that municipalities may not engage in such PPAs. However it seems that ministerial exemption/approval would be required for a generator to sell outside of the single buyer model and for the Municipality to enter into a PPA.

Wheeling of power across national and municipal networks

The Electricity Regulation Act of 2006 (Act No. 40 of 2006) requires that the transmission, distribution and trading functions of electricity be separately licensed and that the transmission or distribution functions shall provide non-discriminatory access to all users of the networks.

NERSA's Regulatory Rules on Network Charges for Third Party Transportation of Energy (2012) provide guidance on prices and tariffs relating to the wheeling of power. These include guidelines on: General Use-of System Charges, Network Charges, Reliability Service Charge, Service and Administration Charge, Losses Charge and Connection Charges. It also provides direction around ensuring that the subsidy contributions contained within the system charges are included in the wheeling prices.

Implementation

Power Purchase Agreements

A PPA is a contract between a buyer of power (usually Eskom, a municipality or a licensed power trader) and a commercial electricity generator. The contract partners agree on the delivery of power for a set period of time at a set price. The term PPA does not apply to Small Scale Embedded Generators (SSEG), which are residential and commercial customers who have installed renewable energy systems of up to 1MW – usually solar PV systems – for own consumption and feed excess power into the municipal grid. Small Scale Embedded Generation is explained in the chapter on Solar PV in this manual.

PPAs usually have a contract period of ten to twenty years to give the generators the necessary certainty for the investment. A PPA allows the generator to raise finance to build the power generation infrastructure. In a PPA the power purchaser is an electricity distributor (municipalities or Eskom) who sells the electricity on to its customers. It can also be a private power trader or a business large enough to provide the generator and his financier with confidence to honour a long-term contract. In this instance the distributor (Municipality or Eskom) acts as a wheeler of this power (see below).

For municipalities it is most desirable to enter into PPAs with local power producers that feed directly into the municipal grid because this does not require wheeling and benefits the local economy. Some PPAs are already in place between municipality and local power producers. The eThekwini Municipality has entered into PPAs with sugar and chemical industries that generate electricity from industrial waste (see case study).

Some municipalities are being approached by IPPs who wish to build large-scale power generation capacity for them in other parts of the country. These are often projects at advanced state of planning that were submitted to the REIPPP programme but were not successful. Such projects will be connected to the Eskom transmission network and require a Wheeling Agreement for the electricity to reach the municipal grid.

Barriers and opportunities

As noted, renewable energy purchases offer important opportunities for cities and towns, including local economic development, fiscal savings, greater security of supply through diversification and environmental benefits. However there are barriers and risks that need to be addressed:

- Lack of clear policy around the degree of free market in the sector: The electricity sector is highly regulated and still dominated by Eskom. The current legal framework makes it difficult for municipalities to enter into PPAs with IPPs because of the licensing process that requires Ministerial determination for off-take by anyone other than Eskom. The national government must pursue equity across the country and ensure national power supply, while enabling municipalities to meet local targets and commitments. Close engagement in planning and optimising national and local objectives is required for a workable model to emerge.
- Political will and credit worthiness of municipal off-takers: Renewable energy developments will only achieve 'bankability' if the off-take agreement is considered financially and politically secure by financial institutions. This means that the financial institutions must have confidence that the municipality can honour the PPA for the whole agreement period. Municipalities would need a high credit rating and political stability to provide confidence. The procurement process must be fair and transparent. The financial sector has indicated that the bidding process would need to be adjudicated by the national IPP office.
- Contracting challenges: Municipal supply chain management rules are complex for contracts longer than 3 years. Municipalities must procure goods at the lowest price and principally through a competitive bidding process. For procuring electricity municipalities must comply with the:

- Municipal Systems Act of 2000 (MSA) has equity and value for money requirements as well as process requirements for external services (Section 78) and planning requirements (IDP). Section 73 requires that services provided must be financially viable and environmentally sustainable. Section 78 (1) (a) requires municipalities take into account direct and indirect costs and benefits associated with projects (including health and environment, employment creation) and any developing trends in the sustainable provision of municipal services, when deciding on a service delivery mechanism.
- Municipal Finance Management Act of 2003 (MFMA) states that municipal officials are liable for 'fruitless and wasteful' expenditure (Section 171 (3)). This requires that the municipality has a fair degree of certainty that a PPA will not lock them in if cheaper alternatives become available. If the PPA is going to impose financial obligations on a municipality for a period longer than 3 years, a process set out in Section 33 of the MFMA must be followed, which requires national and provincial government input and public participation;
- Municipalities must principally procure goods and services on the basis of competitive bidding. IPPs approaching municipalities with projects raise the spectre of 'unsolicited bids'. Section 113 of the MFMA makes provision for unsolicited bids but municipalities would need to carefully consider this option versus competetive bidding.

In conclusion, no generally applicable solution is in place for how municipalities can contract with IPPs. However, with rapidly falling costs of renewable energy and the global shift in technology towards distributed generation the financial and environmental case is getting stronger. A few municipalities have entered into PPAs from which experiences can be drawn. Examples are presented in the case studies.

Wheeling agreements

The term wheeling describes the transportation of power through the grid from the seller to the buyer. It deals with the use of electricity networks and related costs. Wheeling charges (or network use charges) reflect the costs of using the network, including connection costs, maintenance, operations, refurbishment, customer services, administration, as well as surcharges, such as electrification and rural subsidy charges.

The National Energy Regulator's (NERSA) Regulatory Rules on Network Charges for Third-Party Transportation of Energy were approved in 2012 and established the broad principle:

> "Wheeling of energy shall be allowed, subject to the generator receiving its approvals from NERSA to sell to a third party and the signing of the network service provider's Connection and Use-of-System Agreement."[11]

Ongoing discussions around the rules relating to this principle are outlined under Policy Framework.

A few municipalities have entered into wheeling agreements. The Nelson Mandela Bay Municipal Metro (NMBMM) has a Framework Wheeling Agreement in place. This is a generic agreement stating conditions under which the municipality will wheel power and the maximum privately generated power that will be accepted by the municipality. According to this agreement, only electricity traders registered with NERSA may wheel power.

Barriers and opportunities

According to NMBMM opportunities in municipal wheeling of renewable power include:

- Local economic development through facilitating energy sector growth. NMBMM have set a target of 10% of their power to come from wheeled renewable energy of which 80% must represent local developers.
- Direct financial benefits from having a portion of power from local, renewable source electricity: demand charge reductions on power purchased from Eskom, no environmental levy and no carbon tax (in the future).
- Improved grid stability.

11 NERSA's Regulatory Rules on Network Charges for Third-Party Transportation of Energy (2012).

Municipalities have expressed concerns in relation to Wheeling Agreements. These include:

- The regulations open up the electricity market, but long-term implications for the municipal distribution business have not been fully explored.
- The current rules expose municipalities to financial risk as they require the municipality to compensate a generator for losses should the network's performance drop below the 98% and 95% availability limits for Transmission and Distribution Systems respectively i.e. they must compensate the generator for energy that could not be exported into the network.
- Wheeling Agreements require that municipalities have a full understanding of the real costs of supply and can adjust tariffs and prices accordingly.
- Wheeling Agreements can be an administrative burden on municipalities, requiring complex accounting arrangements and monitoring.

Establishing Cost of Supply

Before engaging in wheeling agreements, municipalities should undertake a thorough Cost of Supply study to ensure that the tariffs and prices reflect the costs. Unbundling of tariffs on the basis of cost of supply studies facilitates more accurate tariff setting, which will help municipalities not only with wheeling of power, but also with other processes related to efficiency and renewable energy development.

Cost of Supply Study

A Cost of Supply (COS) study is an important tool for power distributors to design electricity tariffs. The objective of a COS study is to understand the real costs of supplying electricity to customers and to apportion them amongst the different groups of customers in a fair and equitable manner.

According to Section 4(ii) of the Electricity Regulation Act 4 of 2003 (ERA), the Energy Regulator (NERSA) must regulate electricity prices and tariffs. Policy position 23 of the Electricity Pricing (GG No. 31741 of 19 December 1998) (EPP) states that:

> "Electricity distributors shall undertake Cost of Supply (COS) studies at least every five years, but at least when significant licensee structure changes occur, such as in customer base, relationships between cost components and sales volumes. This must be done according to the approved National Energy Regulator of South Africa (NERSA or 'the Energy Regulator') standard to reflect changing costs and customer behaviour."

NERSA developed the COS Framework in order to promote sustainability of the electricity supply industry while protecting customers against unduly high tariffs. The framework aims to support all licensed electricity distributors to develop COS studies. It can be found here: http://www.nersa.org.za/Admin/Document/Editor/file/Electricity/Legislation/Methodologies%20and%20Guidelines/Cost%20of%20Supply%20Framework.pdf

Another tool that can support this process is 'The Cost of Supply Study NMB Model Guide' and related excel spreadsheet tool [11]. This study for the NMBMM provides a tool that can be used by other municipalities to undertake COS studies. The Guide and Excel Spreadsheet tool can be downloaded from the www.cityenergy.org.za website: http://www.cityenergy.org.za/uploads/resource_272.pdf.

11 Genesis Analytics (2013) The Cost of Supply Study NMB Model Guide commissioned by GIZ SAGEN.

Case Study 1: Darling Wind Farm, Western Cape

The Darling Wind Farm is located 10 km north of the town of Darling in the Western Cape, in an area that gets strong and consistent winds. The R75-million project was completed in 2008 by a group of private investors including the Darling Independent Power Producer, the Central Energy Fund, the Development Bank of South Africa, and the Government of Denmark. It was South Africa's first commercial wind farm consisting of four 1.3 MW turbines. The project was given substantial government support as an important renewable energy pilot project.

In 2006 the City of Cape Town signed a twenty year PPA with the Darling Wind Farm. Through the PPA the City provided financial security as the buyer of all electricity that was going to be produced. The Council approved of the PPA on the basis that the City would sell the electricity on to customers willing to pay a premium for this 'green' electricity. In 2008 the premium was set at 25c/kWh above the then electricity tariffs. This arrangement was necessary because at that time the cost of wind generated electricity was significantly higher than the costs of electricity purchased from Eskom and the City was anxious about being charged with 'fruitless and wasteful' expenditure in terms of the MFMA.

Initially, some of the wind power was sold on to buyers willing to pay the premium tariff, but the City never managed to sell all power to private buyers. The shortfall was underwritten by the Global Environmental Fund. Currently, the Darling power costs are slightly less than Eskom power. This is an important outcome showing that the cost of electricity from Eskom has caught up even with the relatively high costs of wind power ten years ago.

Figure 34: Darling Windfarm

Photograph: Mark Lewis

The electricity from the Darling wind farm is wheeled to the City through a Wheeling Agreement between the City and Eskom. This was the first wheeling agreement and its development involved substantial time and capacity.

The wind farm produces a tiny fraction of Cape Town's electricity (in 2012 just 7,770 MWh, i.e. 0.07% of demand). Its performance over the years has been fairly erratic, but it has provided an important testing ground for processes and technologies. Over the 20-year PPA period, the Darling Wind Farm is expected to save 142 500 tonnes of coal and 370 million litres of water. A significant reduction in pollutants will also result by:

- *258 100 tonnes of carbon dioxide,*
- *2200 tonnes of sulphur dioxide,*
- *1100 tonnes of nitric oxide,*
- *58 tonnes of particulates, and*
- *42 200 tonnes of ash.*[11]

Case study 2: 3-year PPA in eThekwini Municipality

In 2012 the eThekwini Electricity Department drafted a standard three year PPA for buying electricity from local power producers. The PPA was developed in response to load-shedding and allows the municipality to use additional suppliers to sustain electricity services to customers. A condition for entering into a PPA is that the generated electricity has less greenhouse gas emissions than electricity provided by Eskom.

The power suppliers are industries that generate electricity – e.g. through cogeneration – beyond their own needs and sell the excess to the municipality. The municipality can only enter into PPAs with companies who can invoice the municipality. The municipality cannot accept invoices from private residents. PPAs have been signed with a number of companies.

The contractual conditions reflect the restrictive policy environment of municipalities:

- *The price at which the municipality purchases electricity does not exceed the (Megaflex) tariff at which the municipality buys electricity from Eskom.*
- *The contract period is restricted to three years after which the PPA can be renewed.*
- *The generator is responsible for getting a generation license from NERSA and must comply with all applicable laws, by-laws, regulations and requirements.*
- *The generator must install a bi-directional meter at his cost. The municipality provides half-hourly meter readings that are the basis of accounting for the electricity purchased.*
- *The generator provides the municipality with monthly tax invoices for the electricity fed into the grid.*

The PPA can be found at: http://www.durban.gov.za/City_Services/energyoffice/Pages/Embedded-Generation.aspx

The eThekwini Electricity Department is considering managing energy purchased from local generators through a tariff/off-set process in the future. However a PPA will remain necessary if the value of exported power is higher than the value of power purchased from the grid because municipalities are only allowed to make payments on the basis of a contract.

11 Sources: Cape Town State of Energy (2015) & SEA (2009) How to Implement of energy efficiency and renewable energy options.

Case study 3: Wheeling agreements explored

Currently only one private company, POWERX (previously Amatola Green Power) holds a NERSA-issued licence to trade electricity countrywide. The company buys Wind, Hydro, Solar, Biogas, Biomass, or any other green power from IPPs and sells it to consumers. The company offers the IPPs long term PPAs of up to 20 years.

POWERX negotiates and pays wheeling fees to the owners of the transmission and distribution grids, namely Eskom and municipalities. The wheeling fees compensate them for the cost of the grid/network use and for the administrative expenses of monitoring and undertaking the billing process of the wheeling transaction. Well-structured wheeling fees should ensure that Eskom and the municipalities do not incur losses when a customer selects to purchase green power through its network.

POWERX (still operating as Amatola Green Power) signed a 20 year, non-exclusive wheeling agreement with NMBMM. To date some 5,000 MWh are being wheeled from the Electrawind's Coega wind turbine project alone every year.

POWERX believe that their wheeling agreements can stimulate municipalities as 'green nodes', while ensuring that the process is revenue neutral for municipalities. POWERX provides a Balance Sheet to IPPs to make their projects bankable.[11]

Another wheeling agreement project is the Bronkhorstpruit Biogas Project. This is the first large scale animal and other organic waste-to-energy project in South Africa, based at the Beefcor feedlot in Bronkhorstspruit.

Figure 1: Bio2Watt Biodigester

Source: bio2watts http://www.boschprojects.co.za/bio2watts-bio-energy-comes-to-life-bronkhorstspruit-biogas-plant/

11 GIZ-SALGA Municipal Renewable Energy Case Study Series (2015) Municipal Wheeling Agreement for Green Power Development: NMBMM Renewable Energy Wheeling Agreement for Green Power Trading.

The feedstock of the biogas plant is cattle manure supplemented by chicken abattoir waste, vegetable and fruit market waste, and diary waste. As a by-product the plan produces 20 000t of fertiliser per year.

The project developer, Bio2Watt, obtained a generating licence from NERSA that allows for the export of 4.2 MW of power (with the possibility of increase to 5 MW). Initially the project considered the municipality as off-taker, but this did not materialise given the absence of clear policy and procurement concerns. Instead BMW South Africa signed a PPA as off-taker with the project developer. BMW is based in Rosslyn, Pretoria. Therefore, the power needs to be wheeled through the Eskom and City of Tshwane networks. Wheeling agreements have been signed with both network providers. The plant started producing and wheeling power in October 2015.

The developer notes that obtaining the various licences required for biogas plants and negotiating the agreements with the off-taker and the network providers was a complex and lengthy process due to the lack of a regulatory framework at the national level – both in relation to the power purchase and the wheeling by municipalities[11]*.*

11 SALGA (2015)Supporting Private Renewable Development in a Municipality: Waste Diversion and Wheeling of Power for Biogas to Electricity, City of Tshwane Project: Bronkhorstspruit Biogas.