

Decoupling infrastructure services from unsustainable resource use: cases from Cape Town

by Blake Robinson

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Supervisor: Professor Mark Swilling
Faculty of Economic and Management Sciences
School of Public Leadership

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Declaration

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Blake Robinson
March 2011

Abstract

Human development is constrained by natural limits, and there is daily evidence that we are exceeding them. If mankind is to survive and prosper, new modes of development are required to advance human interests whilst working within nature's carrying capacity. As concentrated nodes of consumption and waste production, cities will need to change the way they operate. Infrastructure networks connect urban lifestyles to natural resources, and offer opportunities for resource conservation that save money and lighten man's burden on the planet.

Decoupling allows for development with reduced environmental impact. Whereas relative decoupling only reduces resource impacts relative to improvements in wellbeing, absolute decoupling allows for decreases in total resource impact. Relative decoupling alone is no longer a sufficient strategy for sustainability, so we need to move beyond efficiencies to embrace substitutions. Efficiencies can be categorised as dematerialisations or rematerialisations, and are limited to minimising damage. Substitutions in the form of freematerialisation and immaterialisation are necessary for absolute decoupling. The transition toward these new approaches will require considered implementation, supportive environments and quantitative performance targets based on natural resource limits in order to succeed.

The literature on Cape Town demonstrates a growing interest in sustainability issues, but there are few links between the notions of infrastructural services for human development and resource conservation for ecological sustainability. Swilling calls for more sustainable investments in infrastructure in Cape Town, but implies that change is not occurring. This research indicates otherwise, including case studies of sustainable infrastructure approaches currently used within the city, namely solar water heating, small-scale wind power, rainwater harvesting, grey water sanitation, recycling and vermiculture.

Unlike the top-down approach of many Northern cities, the Cape Town cases show that individuals and companies are combining the latest international knowledge with local experience to change the state of play from the bottom upwards. While government struggles with social priorities, those who can afford it are spreading alternative technologies and information to other interested parties. In some cases they are working in collaboration with government programmes, but in others they are making progress despite the slow pace of government change.

The City of Cape Town is working on many levels to improve the resource impact of infrastructural services. Along with national government, it is delivering on a number of promises, and is undertaking noteworthy initiatives in the fields of energy, water and waste to promote resource conservation. While efforts have thus far been focused on efficiencies, there are signs that the City intends to follow this with substitution approaches once the financial benefits of efficiencies have been realised.

The pace of progress is being inhibited by institutional inertia and vested interests linked to outdated approaches. At the same time, entrenched values and service expectations make it

difficult to shift roles and responsibilities in line with more sustainable, decentralised approaches. The strategic use of proactive price increases for services like water provide a relatively simple mechanism for encouraging further innovation and behavioural change, but the City is yet to take advantage of this.

Keywords: Cape Town, decoupling, efficiency, infrastructure, local government, natural limits, resource use, South Africa, sustainable city, sustainable development

Opsomming

Menslike ontwikkeling word ingeperk deur natuurlike grense, en daar is daagliks bewyse dat ons dit oorskry. Vir die mensdom om te oorleef en welvarend te wees is nuwe modelle van ontwikkeling nodig wat mensebelange binne die grense van die natuur bevorder. As gekonsentreerde nodes van verbruik en rommelproduksie moet stede die manier waarop hulle funksioneer verander. Netwerke van infrastruktuur verbind stedelike leefstyle aan natuurlike hulpbronne en verskaf dus geleentheid vir hulpbronbewaring wat geld bespaar en die mensdom se druk op die omgewing verminder.

Ontkoppeling maak ontwikkeling met verminderde impak op die omgewing moontlik. Relatiewe ontkoppeling verminder slegs die impak op die omgewing relatief tot die bevordering van menslike welvaart, terwyl algehele ontkoppeling die totale impak op die omgewing verminder. Relatiewe ontkoppeling is nie meer 'n gepaste strategie vir volhoubaarheid nie en daarom moet ons verby doeltreffendheid beweeg na plaasvervangers. Doeltreffendheid kan gesien word as vermateriëring of hermateriëring wat slegs skade verminder. Plaasvervangers in die vorm van vrymateriëring of ontmateriëring is nodig vir algehele ontkoppeling. Die oorgang na hierdie nuwe uitgangspunte benodig wel deurdenkte uitvoering, ondersteunende omgewings en kwantitatiewe doelwitte wat op natuurlike hulbrongrense gebaseer is.

Literatuur oor Kaapstad toon aan dat daar 'n groeiende belangstelling in volhoubaarheidskwessies is, maar daar word min korrelasies gevorm tussen infrastruktuurdienste vir menslike ontwikkeling en hulpbronbewaring vir ekologiese volhoubaarheid. Swilling wys op die behoefte aan meer volhoubare infrastruktuur in Kaapstad, maar beweer dat verandering nie op die oomblik plaasvind nie. Hierdie tesis bewys die aanspraak met gevallestudies in Kaapstad wat vanuit volhoubare infrastruktuur uitgangspunte funksioneer, insluitende waterverwarming met sonkrag, kleinskaalse windkrag, die versameling van reënwater, gryswater sanitasie, rommelherwinning en erdwurmbouery.

Anders as baie van die stede in die Noordelike halfrond, waar besluite deur regerings geneem word, bewys gevallestudies in Kaapstad dat mense en besighede in die stad eie inisiatief neem. Die mees onlangse internasionale tendense word met plaaslike ondervinding gekombineer om verandering op voetsoolvlak teweeg te bring. Terwyl die regering met sosiale prioriteite stoei, is dit die mense en besighede wat dit finansieel kan bekostig wat alternatiewe tegnologieë en inligting na ander belangstellende partye versprei. In sommige gevalle werk die mense saam met regeringsprogramme, maar in ander maak die mense vordering ten spyte van die stadige pas waarmee die regering veranderings aanbring.

Stad Kaapstad werk op verskillende vlakke om die impak van infrastruktuurdienste op die omgewing te verminder. Saam met die regering is hulle besig om verskeie beloftes na te kom. Noemenswaardige hulpbronbewarings inisiatiewe word aangepak in die velde van krag, water en rommel. Alhoewel hierdie projekte steeds op doeltreffendheid gefokus is, wil dit blyk asof die

Stad beoog om plaasvervanger uitgangspunte in te neem sodra die finansiele voordele van doeltreffendheid uitgangspunte gerealiseer het.

Die pas van vooruitgang word deur vertragings in instansies en agendas wat aan verouderde benaderings gekoppel is gerem. Terselfertyd maak verskafde waardes en diensverwagtinge dit moeilik om rolle en verantwoordelikhede in lyn te bring met meer volhoubare en gedesentraliseerde benaderings. Die strategiese gebruik van pro-aktiewe prysverhogings vir dienste soos water verskaf 'n relatief eenvoudige meganisme om verdere innovasie en gedragsverandering aan te moedig, maar Stad Kaapstad het nog nie hiervan gebruik gemaak nie.

Sleutelwoorde: *Kaapstad, ontkoppeling, doeltreffendheid, infrastruktuur, plaaslike regering, natuurlike beperkinge, hulpbronverbruik, Suid Afrika, volhoubare stad, volhoubare ontwikkeling*

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List of acronyms and abbreviations

AC	Alternating current
ASGI-SA	Accelerated and Shared Growth Initiative for South Africa
CO ₂	Carbon dioxide
CCT	City of Cape Town
DC	Direct current
DEAT	Department of Environmental Affairs and Tourism
DSM	Demand side management
DTI	Department of Trade and Industry
DWAF	Department of Water Affairs
GDP	Gross Domestic Product
IPP	Independent Power Producer
NERSA	National Energy Regulator of South Africa
NIPF	National Industrial Policy Framework
PPA	Power purchase agreement
PV	Photovoltaic
REFIT	Renewable Energy Feed-in Tariff
SABS	South African Bureau of Standards
SESSA	Sustainable Energy Society of South Africa
SWH	Solar water heater
SWM	Solid waste management
UCT	University of Cape Town
UNEP	United Nations Environment Programme
WC	Water conservation
WCS	World Conservation Strategy
WDM	Water demand management

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1. Introduction

1.1 Background

Since the birth of South Africa's democracy in 1994, ecological sustainability has been recognised as an important factor in the country's development. The term 'sustainable development' was formally acknowledged in the *National Environmental Management Act (NEMA)* of 1998 as "...the integration of social, economic and environmental factors into planning, implementation and decision-making so as to ensure that development serves present and future generations" (DEAT 2007:20). Section 24(b) of the South African Constitution places an obligation on the state to secure "...ecologically sustainable development and use of natural resources...", and this has subsequently been translated into various statements of intent across a range of sectors (Fischer-Kowalski & Swilling 2010:57).

South Africa is a resource-rich country, and its economy has been built on the extraction and exportation of primary resources. Global signs that resources are not infinite in supply and that the continued use of fossil fuels will cause irreparable climate change have necessitated a major shift in mindset, and the issue of resource use has become an important consideration in efforts to move toward a sustainable growth path. Like the rest of the world, South Africa faces a number of key natural resource challenges that threaten the prospects of a sustainable future for its citizens:

- Like many of its neighbours on the sub-continent, South Africa is classified as a water-stressed country. Average rainfall is low, there is a shortage of groundwater reserves, and re-engineered spatial flows have exacerbated uneven distribution across the country. Consumption in the urban and domestic sectors is expected to be triple 1996 levels by 2030, but 98% of available water has already been allocated (Fischer-Kowalski & Swilling 2010:95). Declining quality is also a concern as pollution from overburdened and poorly managed sanitation infrastructure and human waste streams is destroying ecosystems and increasing water toxicity. At least 55% of the country's water treatment works require "drastic" improvements to their management practices and abilities (DWA 2009:4). If nothing is done to change current technologies and management practices, it has been predicted that growing demand for water in South Africa will exceed supply by 2025, and the cost of water will increase beyond affordability levels for poor households (DEAT 2007:39). Others have predicted severe water shortages as early as 2013, resulting in stunted growth, water resource wars and growing inequality (Fischer-Kowalski & Swilling 2010:95).
- South Africa's abundant coal reserves have shaped an energy-intensive economy that is one of the world's highest per capita contributors to greenhouse gases (6.91 tons of CO₂ per capita vs. a global average of 3.89) (DEAT 2007:33). Coal provides just over 70% of the country's energy needs, with another 16-20% coming from imported oil. As a result 90% of the country's CO₂ emissions come from the energy sector. Unless the country's

addiction to coal and oil can be broken, the population will be directly disadvantaged by the effects of rising resource prices and climate change. Local impacts will include dramatic changes to rainfall patterns which will worsen the water situation, and temperature increases that could see reductions in agricultural yields and fish populations, and increases in the spread of diseases like malaria (DEAT 2007:32).

- Rising affluence levels have heralded the rapid growth of a 'dispose-and-forget' culture that is placing the country's waste management strategies under severe pressure. In a number of South Africa's cities, growth in municipal solid waste is outpacing that of local economies, with volumes 3-4 times those of most European cities (DEAT 2007:40). Poorly run waste management facilities and landfill sites deposit toxic substances into the soil and water, and the release of methane makes a sizeable contribution to greenhouse gas emissions. As cities have expanded, the options for future landfill sites have diminished and planning for new capacity is falling behind. The problem threatens to spiral out of control unless something can be done to reverse the mounting waste trend.

While sustainable development has become a popular buzzword, it is only in recent years that these principles have started to be incorporated into policy. Whereas neither the *ASGI-SA* of 2006 nor *NIPF* of 2007 recognised natural resource constraints as a limiting factor in the country's growth plans, the *National Framework for Sustainable Development* (NFSD) adopted in June 2008 brought the issue to the fore, elucidating our dependence on natural resources (Fischer-Kowalski & Swilling 2010:100). Sector-specific policies like the *Water Act* of 1998, the *White Paper on Renewable Energy* of 2003 and the *Waste Act* of 2009 reflect similar trends, indicating growing support for sustainable resource management.

Policy change has unfolded concurrently with large-scale public and private sector investments in the upgrade and expansion of infrastructure. These projects play a key role in the South African government's plans to grow the economy, provide jobs and extend services to the country's poor. The government has allocated R846 billion to infrastructural investments over the next 3 years, a third of which will be used for expanding electricity generation capacity. Other areas of focus include upgrading transport infrastructure and improving water supply capacity (Gordhan 2010).

While the media is easily distracted by poor service delivery and corruption, the matter of how the expansion of technical infrastructure systems will influence resource flows into the future is largely overlooked. The country's current bulk infrastructural systems follow Northern suburban ideals based on the implicit assumption of endless resources like fresh water, coal and land. In striving for universal access to these systems in a context of high poverty, making consumption and waste disposal easier for the masses releases suppressed demand, and goes beyond meeting basic needs to create what Girardet refers to as the 'amplified man' (2004:108).

The technologies and systems of infrastructural service provision employed in South Africa have changed little over the years, but the need to take action against climate change and resource depletion requires a questioning of this approach. Instead of improving access to first world

infrastructures designed for the past, greater cognisance needs to be paid to delivering their beneficial services by means better suited to a resource scarce future. Instead of viewing adaptations for sustainability as an additional burden on stretched human and financial resources, they can be linked to development challenges to ensure that new approaches are implemented that better meet the needs of the present and the future (Ziervogel, Shale & Du 2010). There is evidence that government has acknowledged this in its identification of infrastructure investments as “...the most significant opportunity...” for introducing sustainable resource use principles whilst providing services and saving money (DEAT 2007:51-52), but one is hard-pressed to find recognition of this being followed through with action in local academic literature.

Emerging discussions in Cape Town bring the resource flow logics embedded in current infrastructure systems to the fore and make the case for more considered approaches to infrastructure and service delivery in light of sustainability challenges (Swilling 2006; Crane & Swilling 2008; Swilling 2009). If infrastructural change is going to happen in South Africa, the City of Cape Town’s openness to these suggestions and ambitious stance on sustainability-related issues indicates that it is likely to play a leading role (Crane & Swilling 2008). Cape Town thus provides a relatively unique context for South African discussions around resource-appropriate infrastructure, and its efforts to move toward true sustainability could provide much needed inspiration for other cities in a similar predicament.

1.2 Motivation

In the developing countries of Africa, the provision of infrastructural services is closely linked to social aspects of sustainability due to the role they play in improving quality of life for the poor. As a result, the roll-out of infrastructure to improve intra-generational equity is often seen as a sustainability goal in itself. However, the environmental and financial burdens associated with resource-intensive inherited systems are seldom considered. This dooms the recipients of these services to ever-escalating costs as resource supplies inevitably start to decline, having the most serious consequences on the poor (Swilling 2006).

I was primarily drawn to the topic of resource management through urban infrastructure as a result of its potential for addressing social, ecological and economic dimensions of sustainability simultaneously. While the ecological argument can be difficult to sell to those unable to comprehend their role in furthering ecological sustainability, the economic benefits of resource savings are easier to grasp and provide a compelling rationale for the consideration of alternative infrastructural approaches. The *Natural Edge Project* identifies three main economic benefits arising from investments in resource productivity (Von Weizsäcker, Hargroves, Smith, Desha & Stasinopoulos 2009:16):

- They have a higher economic multiplier than conventional expenditure as once the costs of the initial investment have been recouped, savings start to accumulate which can be reinvested in the economy.

- They have a higher economic welfare impact as the reduced requirement for resources means that investments in new infrastructure can be delayed, and the funds can be assigned to areas where they are needed more.
- Jobs are created locally to support these initiatives, contributing to the local economy and attracting skilled workers from elsewhere.

The ‘less resources, less cost’ logic of eco-efficiency can be applied to the provision of infrastructural services that allow for improved quality of life with significantly reduced economic and environmental burdens. When applying this private sector theory to public sector expenditure, there is potential for the public at large to benefit from the savings. Instead of dooming the populous to ever-increasing prices and regular investments in capacity expansion to meet increasing demand, infrastructural decisions present opportunities to create virtuous cycles of savings that can be diverted to more ambitious social development issues. This type of thinking allows for truly sustainable development, and should be encouraged in all areas of public decision making.

While ambitious government infrastructure projects will no doubt contribute to improving lives in the short term, rigid adherence to resource-intensive methods of providing infrastructural services will only serve to impede their long term viability as resources start to run out. With so much growth taking place, South Africa is ideally positioned to channel the funds set aside for infrastructure into projects that avoid many of the mistakes made by developed countries in the past. This has already been observed in the telecommunications industry where many South Africans adopted cellular telephones without ever having had landlines. This so-called ‘leapfrogging’ is possible in the case of infrastructural roll-out too as “...there is space for innovation that does not exist in countries where existing infrastructures are a sunk cost and difficult to change...” (Fischer-Kowalski & Swilling 2010:67). Research into how infrastructure might be differently conceived is thus highly relevant to the sustainable development of Africa’s cities.

1.3 Refining the research topic

The inspiration for this research came from a paper by Professor Mark Swilling entitled “*Sustainability and infrastructure planning in South Africa: a Cape Town case study*” (2006). He makes a strong argument for the consideration of infrastructural systems as a means of addressing looming environmental threats through better management of scarce natural resources in the city. I was interested in the novelty of the concept and the fact that it appeared relatively new to local debates. With a great deal of attention focused on green building materials and designs by the likes of the *Green Building Council*, I felt the less glamorous supporting infrastructure was worthy of further investigation as a topic in its own right. This formed the basis for my first research proposal.

Initially I planned to develop a model for sustainable neighbourhood infrastructure based on the systems used at the Lynedoch Eco-Village in Stellenbosch. On further reading, I became aware of

the importance of context and scale in selecting appropriate technologies (as highlighted by the likes of Engel-Yan, Kennedy, Saiz & Pressnail 2005). I realised that it would be irresponsible to assume that the approaches adopted at Lynedoch could be successfully applied elsewhere, and that the usefulness of my model would be limited. On reading Jensen's views about sustainable infrastructure technologies in context (in Guy, Marvin & Moss 2001), I learned that while green field sites on the urban periphery are well suited to experimentation with alternative infrastructural services, the real challenge lies in integrating them into the existing frameworks of the city to prove their validity and inspire broader adoption. Armed with these insights, I decided against a prescriptive model-building approach and shifted my focus to consider the use of innovative technologies closer to Cape Town city.

As I explored the literature further, I learned more about the issues surrounding decoupling, technology and the urban context. In the process I revised my research proposal a number of times, and in its fourth iteration I arrived at an angle on sustainable infrastructure that I felt sufficiently excited about to warrant further investigation: using urban infrastructure as a means of achieving absolute rather than relative decoupling. Whilst reading up on sustainable infrastructure technologies and systems, it became apparent that they could be broadly categorised into two different yet complementary approaches: 'efficiencies' and 'substitutions'. This gave me a structure around which to base my literature review and served as a useful guideline for distinguishing between relative and absolute decoupling technologies.

Soon after starting my research, I realised that I had to exercise discipline in refining the scope of what to include and exclude so as to best manage the research process. There is a great deal written on how different types of infrastructure can be made more sustainable, but I realised that a sharp focus on those systems with the most direct influence over urban resource flows would be best suited to conveying my message. I therefore decided to focus on physical grey infrastructures rather than 'soft', 'social', 'red', 'blue' or 'green' infrastructures (see Benedict & McMahon 2002; Choguill 1996; Yeang 2008). Within these confines, I chose to restrict my cases to energy, water, waste and sanitation as they directly impact every human's ability to survive in the city, regardless of location.

Another distinction I needed to make was the degree to which I would delve into the sustainability of technologies throughout their lifecycles. According to Von Weizsäcker et al. (2009), it is widely recognised that volumes of energy and water used during a product's useful life are significantly greater than those involved in its manufacture, and this is particularly true when considering infrastructural systems as conductors of energy and water and producers of waste. If I had included analyses of construction material sustainability, I would have run the risk of diverting attention from the core relationship between infrastructural technologies and the resource flows that support urban life. I thus chose to maintain a focus on the influence of the technologies on resources once *in use*, excluding the environmental impact of their construction and decommissioning from the discussion (see Du Plessis 2002, Blum & Stutzriemer 2007, and Doyle & Havlick 2009 for more on these topics). The technologies discussed can thus not

necessarily be considered exemplary cases of sustainable design or panaceas for sustainability¹, but they make an important contribution to urban sustainability through their role in decoupling infrastructural services from resource depletion.

My decision to look at the socio-institutional environment surrounding alternative infrastructure technologies was inspired by Guy, Marvin and Moss's book entitled "*Urban Networks, Buildings, Plans - Infrastructure in Transition*" (2001). Their work looks at how social networks are intertwined with technical infrastructural networks, and shows through a series of case studies how each in turn shapes the other. In so doing, they not only demonstrate that action has been taken to make infrastructure more sustainable, but also show the important role of society as a determinant of success. This closely reflects what I wish to achieve in the Cape Town context, and this has influenced my decision to use case studies to identify broader changes that could be made to promote sustainable resource use and encourage further debate.

1.4 Research problem and objectives

The research problem can be identified as a lack of up-to-date information on technical, social and institutional innovation in the infrastructure field in Cape Town that is resulting in a misperception that the city's infrastructure functions solely by outdated, unsustainable means of managing water, energy and solid waste. My research objectives are thus as follows:

- Build the case for sustainable resource management as a priority in infrastructural decisions from existing literature.
- Draw together diverse examples of how resources are being managed more sustainably through infrastructural approaches in Cape Town.
- Through the case studies, identify factors that encourage or inhibit the use of technologies that reduce consumption of potable water, decrease demand for non-sustainable sources of energy and diminish volumes of waste sent to landfills.

In the words of Von Weizsäcker et al., "...our amazing Earth can't wait for many years of trial and error, research and debate, publications and papers, before we take steps to reduce environmental pressures on a meaningful scale. Hence we need to learn from what is being done in all four corners of the world and rapidly bring this knowledge together as a base for significant resource productivity improvements in the coming decades..." (2009:36). In unifying the selected case studies as tools for improving urban sustainability, my intention is to give the principles they embody the recognition and structure they need to accelerate their transition from the fringe toward more mainstream consideration in Cape Town and other South African cities.

¹ Broader debates on the relevance of predominant economic and social systems and fuller analyses of the resource flows embodied in imported commodities are crucial in this regard (see Jackson 2009), but are typically beyond the scope of infrastructure decision makers.

Key concepts

Cape Town

The urban area serviced by the City of Cape Town municipality.

Decentralisation

Planning the delivery of services in a manner that employs more numerous, smaller operations located in close proximity to service beneficiaries (e.g. at a household or neighbourhood level) rather than fewer, larger nodes of activity located far away.

Decoupling

Breaking the connection between a social or economic 'good' and a 'bad' environmental consequence. In this case it is used specifically to describe the disassociation of beneficial infrastructural services from unsustainable resource use.

Dematerialisation

Achieving an objective using a smaller quantity of a certain resource input than was previously the case.

Eco-efficiency

Improving profitability by reducing resource consumption and waste production.

Efficiency

Using fewer inputs to achieve an equal or better outcome.

Freematerialisation

Using freely available goods and services provided by nature to achieve an objective in a manner that does not deplete these resources.

Grey water

Water that has been used by humans but does not require processing by a water treatment facility before it can be used again for applications that do not require potable water (e.g. irrigation and toilet flushing).

Immaterialisation

A switch in consumption behaviour from the use of one input to another that allows for the achievement of an objective via a less material intensive and less environmentally damaging means.

Infrastructural services

The beneficial services offered to humans by infrastructure, for example hydration and cleansing (from piped water), warmth and light (from the electricity grid), and hygiene (from sewage and solid waste management systems).

Infrastructure technology

The manner in which an infrastructural service is delivered. This extends beyond physical artefacts (e.g. pipes or wires) to include social and institutional constructions.

Non-renewable resources

Resources that, when put to use for human benefit, lose some or all of their potential utility and cannot be regenerated as fast as they are being used up (e.g. coal, oil, steel).

Organic kitchen waste

Food-related kitchen waste like fruit and vegetable peels, cores, seeds, and left-over or spoiled food.

Rematerialisation

Re-using resources once categorised as waste products as useful inputs to achieve an objective.

Renewable resources

Resources that cannot be diminished in their utility by human exploitation, or those which can be regenerated or returned to full utility as fast as they are being consumed (e.g. wood, water, topsoil).

Substitution

Providing a human benefit in a fundamentally different manner to the current norm so as to manage resources in a more sustainable manner, possibly even eliminating the need for some inputs.

Sustainable infrastructure

Systems that aim in one way or another to provide infrastructural services to humans in a manner that does not overstep the carrying capacity of supporting ecosystems. This constraint should ideally influence the planning of the construction, operation, maintenance and decommissioning of the system.

Sustainable resource management

Managing the extraction, processing, transportation, usage and disposal of natural resources in a manner that minimises negative impacts or maximises positive impacts on the natural environment so as to allow future generations an equal or better chance for prosperity.

Vermiculture

The deliberate use of earthworms to process organic waste into solid and liquid soil conditioners.

1.5 Significance of the study

The academic literature linking infrastructure to resource depletion in Cape Town is in its infancy. While there is recognition that the city's resource use is unsustainable and that alternative approaches to infrastructure could help to change this, there is a lack of academic credit given to what is already happening in the city. This gives the illusion of inactivity, but closer inspection reveals ongoing innovation and perseverance from several disparate quarters unified by the intention to achieve more sustainable lifestyles in the city. This study will show through the use of living examples that alternative technologies can be successfully employed, and are already contributing to resource decoupling in the city of Cape Town.

The in-depth case studies will provide insight into the issues surrounding the implementation of sustainable technologies in the Cape Town context. My intention is to contribute towards developing an understanding of the many complex and interrelated factors influencing the transition toward alternative technologies, and in the process identify where the most beneficial interventions could be made to change the status quo. My hope is that this will stimulate debate and inspire areas for further research on related topics in the South African context.

Not only will the research contribute to the South African literature, but it will add to the growing body of international theory on the interaction between sustainable technologies and urban environments. Much of this literature comes from developed countries (see Guy et al. 2001; Engel-Yan et al. 2005; Wackernagel, Kitzes, Moran, Goldfinger & Thomas 2006; Doshi, Schulman & Gabaldon 2007; Codoban & Kennedy 2008; Hodson & Marvin 2009; Wuppertal Institute 2009), so this study is unique in contributing a developing country urban perspective. Instead of looking at fixing the wrongs of the past, the relatively clean slate available to those planning the African cities of the future offers tremendous opportunities for wise growth with the help of careful decision making influenced by sustainability principles.

1.6 Research design and methodology

1.6.1 Introduction

Social science research can be broadly categorised according to its objectives. According to Hart, it is either aimed at explaining, exploring or describing, and each agenda has unique implications for the design, presentation and way in which the research should be interpreted (Hart 2006:45). The purpose of this research is two-fold: the literature analysis is aimed at explaining the importance of decoupling infrastructure from resources, and the case studies explore the Cape Town landscape to provide greater understanding and inspire further study. A discussion of the two research approaches follows.

1.6.2 Literature analysis

The literature review is an important point of embarkation for the research journey. My aim was to build a greater understanding of the issues around infrastructure and decoupling that would help to provide a context for the main body of the research and improve my understanding in preparation for conducting the case studies. Hart defines a literature review as constituting two main parts: "...the selection of available documents ... and the effective evaluation of these documents in relation to the research being proposed" (Hart 2006:13). I will now discuss in more detail how I set about these tasks.

a. Search process

Whilst compiling a preliminary literature review for my research proposal, I spent time with the subject librarians at the JS Gericke Library at Stellenbosch University to work out how best to conduct my search for literature. Based on their recommendations, I used a combination of online searches and leads from other literature. Extensive use was made of the university library's online databases, in particular the *EBSCO* database for international literature and *Sabinet* for locally relevant pieces. I also made use of *Google Scholar* to conduct preliminary investigations into new topics, followed up with more specific searches in the library's e-journals.

Much of the search process was organic, evolving as I came across new ideas, insights or inspirations. There was, however, a greater degree of thoroughness required for the review of Cape Town literature on infrastructural systems, and I found that I had to rely on a complicated mix of academic theses, local publications, and references from academics instead of published papers. To ensure that I covered all of the subject matter, I compiled a matrix of search terms which I sequentially inputted into database searches in various combinations. The matrix was as follows:

Table 1.1: Matrix of search terms used to review the literature on Cape Town

Resource	water	Energy	Electricity	Waste	sewage	coal	fossil fuel
Decouple	efficiency	Productivity	Sustainable	Renewable	recycling	infrastructure	
Cape Town	South Africa	City	Urban				

Although arduous, this process gave me confidence that I had thoroughly covered the available literature. It also reconfirmed that my thesis would be adding something new to the field in its collation of diverse technologies under the umbrella of sustainable infrastructure. In the process, I came across interesting literature based on other parts of South Africa, but I was careful to include only that pertaining to Cape Town in line with the scope of the research.

b. Research themes and structure

As I accumulated new literature, I was able to formulate a strategy for how I might structure my argument. Hart explains the importance of organising information around some form of structure to allow for connections between various sources to be made and to ensure that the overall purpose is achieved (Hart 2006:143). To process large volumes of data systematically and progressively, he proposes some form of classification during the analytical process. With this in mind, I discerned that I was dealing with three basic themes around which I clustered my findings:

- Resource management in the context of natural limits
- Infrastructure as a resource management tool for cities
- Infrastructure and sustainability in Cape Town

Although the sub-sections within each of these changed a number of times, the basic themes remained constant in line with my objectives. Due to overlap across a number of themes, classification of literature was at times difficult and the editing process was one of ongoing re-arrangement to improve the flow.

With themes established, I needed a plan for organising them. In line with my belief that academic literature should be as accessible to as many disciplines as possible, I have a preference for writing in a manner accessible to people from all backgrounds rather than limiting my readership to enclaves of academic expertise. On Hart's recommendation that one should think of the needs of the reader when structuring the literature review (Hart 2006:193), I chose to order the themes from broad to specific in order to give a solid background context to my research and justify its relevance to sustainability newcomers. In designing the flow of my argument, I tied planetary-scale issues like resource limits to local-scale issues like infrastructure decisions in a clear and useful manner. I feel that establishing this link through the organisation of themes and diminishing the scope from global to urban to infrastructural is better suited to communicating this story than organisation by date or school of thought would have been.

c. Data analysis

A large portion of the data analysis was conducted whilst reading the literature. As I read, I made note of interesting points in each document and where they might fit into a preliminary outline of my argument. This approach was based on Hart's recommendation that analysis and synthesis be conducted as complementary processes of methodically breaking the literature data down into its constituent parts and re-assembling it in a manner that identifies commonalities (Hart 2006:110).

When it was time to compile my notes, I found that the process had been worthwhile as it allowed me to group the data before having to worry about the final wording. This saved time and avoided some of the risks associated with having to remember which observation came from

which author. I did not anticipate how much the data would need to be re-shuffled in the process of editing, and deciding on which connections were most important to make constituted the bulk of the literature analysis.

1.6.3 Case study research

When I first considered how I might approach the research, I was daunted by the prospect of achieving academic rigour in a field that appeared more conducive to qualitative studies than reductionist dissections. Having come from a background of statistics and economics, I mistakenly perceived the production of quantitative facts and provable theory to be the ultimate objective in writing a thesis and was sceptical of qualitative methodologies.

The turning point came when I encountered Flyvbjerg's argument for case study analysis where he observed that "...predictive theories and universals cannot be found in the study of human affairs... concrete, context-dependent knowledge is, therefore, more valuable than the vain search for predictive theories and universals" (Flyvbjerg 2006:224). He describes case stories as being results in themselves, and "...for the reader willing to enter this reality and explore it inside and out, the payback is meant to be a sensitivity to the issues at hand that cannot be obtained from theory" (Flyvbjerg 2006:238).

In Flyvbjerg's words and those of his contemporaries I found that my new field of study was not as pre-occupied with achieving a neatly-packaged end result as I had anticipated, and the research journey gained credibility as an objective in itself. I began to understand how a case study appraisal could be a valid alternative to statistics and spreadsheets, and this gave me confidence in pursuing case study analyses.

a. Approach

Whilst reading Von Weizsäcker et al's book "*Factor 5*" (Von Weizsäcker et al. 2009), I was inspired by the use of case studies assembled under a common theme to substantiate the existence of an emerging phenomenon (and effectively take the wind from the sails of pessimists claiming that it is not possible). According to Hart's description of the different types of research, my intention can best be described as illuminative evaluation, which intends to "...make key behaviours or attitudes in a given context visible for contemplation. The aim is to enlighten policy makers or practitioners to the dynamics of behaviours in comparable situations in order that those behaviours can be understood and attended to in a more appropriate way" (Hart 2006:46).

My research strategy has been heavily influenced by Eisenhardt's paper entitled "*Building Theories from Case Study Research*" (1989). She describes this approach as "...most appropriate in the early stages of research on a topic..." (Eisenhardt 1989:548), and it is thus compatible with this exploratory study aimed at stimulating debate and further research around resource decoupling and infrastructural services in Cape Town. Lijphart categorises case studies into atheoretical, interpretive, hypothesis-generating, theory-informing, theory-confirming and

deviant cases (in Levy 2008:3). This work tends toward the hypothesis-generating or theory-informing style of case study analysis as it aims to contribute to the formation of new theories rather than linking the findings back to existing ones.

Levy elaborates that "...hypothesis-generating case studies contribute to the *process* of theory construction rather than to theory itself... theory, defined as a logically interconnected set of propositions, requires a more deductive orientation than case studies provide..." (Levy 2008:5). The reasoning employed is more inductive than deductive as it entails "...reasoning that proceeds from specific experiences to general truths, from facts to theory..." (Van der Merwe 1996:279). Van der Merwe explains that, unlike deductive reasoning, this kind of research is "...loosely guided by general hypotheses or conjectures..." but essentially lacks a specific conceptual framework.

b. Research population

According to Eisenhardt, the selection of the research population is an important part of building theory from case studies as it "...controls extraneous variation and helps to define the limits for generalizing the findings..." (Eisenhardt 1989:537). With this in mind, the case study technologies were selected according to the following criteria:

1. Operating in Cape Town for at least a year.
2. Claim to be more sustainable or 'green' than conventional, bulk provided services in terms of their resource use in operation.
3. Able to operate alongside conventional urban infrastructure.
4. Provide the same or better utility than that offered by conventional infrastructure.

I decided to focus on the Cape Town area for logistical reasons, and because I wanted to show that sustainable technologies can work in both urban and peri-urban environments. Due to various interpretations of sustainability, I allowed for a degree of flexibility around whether the initiatives are described as 'green' or 'sustainable' or 'eco-friendly' etc., but the point of connection is that they have the intention of improving on the way services are currently provided in relation to resources used.

c. Selection criteria

Due to the depth with which each case was investigated, the number of cases was limited to six. Levy says that although it may be preferable to have larger sample sizes for hypothesis testing, the same is not necessarily true for hypothesis generation: "...the more cases used to construct a theory, the fewer that remain for testing it..." (Levy 2008:8). With fewer stories, their selection warranted special consideration to improve their contribution to the knowledge accumulated.

While random sampling tends to be associated with statistical analyses and academic rigour, Levy observes a consensus that it can generate serious bias when research is being conducted on a

small population of cases (Levy 2008:8). The case studies were thus selected using theoretical sampling, chosen for its high suitability to case study research and the limited time frames available. This meant that the individual merits of each case were considered to assess their theoretical relevance before they were included, and cognisance was given to how they would complement and contrast each other (Eisenhardt 1989:537).

Eisenhardt explains that, "...the goal of theoretical sampling is to choose cases which are likely to replicate or extend the emergent theory...", and suggests identifying conceptual categories to influence the selection of case studies (Eisenhardt 1989:537). The selection of categories allows for the identification of cross-case patterns, i.e. similarities within each category and differences across them (Eisenhardt 1989:540). With this in mind, I decided to restrict my focus to three areas of infrastructure that impact directly on the everyday wellbeing of all South Africans and are closely linked to the Millennium Development Goals. I selected cases that to cover the following:

1. Energy
2. Water and sanitation
3. Solid waste management

To further facilitate cross-case analysis, I followed Eisenhardt's suggestion and chose pairs of cases within each category to allow for comparison (Eisenhardt 1989:540). I also endeavoured to maximise variety in my choice of cases based on Levy's recommendation (Levy 2008:8), and paired popular technologies with more unusual ones. Starting with a short list of options from my own experience, a snowballing technique was used to gather ideas for other case studies and expert interviewees during the research process. I also decided to exclude one of the interviews I conducted when I realised that the technology was better suited to rural locations.

I chose interviewees based on their specialisation in their field, and their experience of the Cape Town environment. In most cases I was able to speak to multiple experts on each topic to gain a broad perspective on each theme, but in the case of the water conservation technologies I was only able to interview one person within the research period. I allowed 8 weeks in June and July 2010 for this process, and was able to secure interviews with most of the experts I hoped to speak to.

d. Interview preparation

As my understanding of the topic grew during the literature review process, the design of my research started to take shape. In line with Kvale's recommendations that the interviewing process only start once there is a clear conception of the themes, structure and ultimate goals of the research (Kvale 2007), I waited until I had finished my review of the literature and formulated my research methodology before planning and scheduling my interviews.

In preparation for the interviews, I compiled an interview guide inspired by notes I had made during the literature analysis. Reflecting on the list facilitated a richer enquiry than if I had written

the interview guide from memory as it reminded me of some themes I might otherwise have overlooked. Eisenhardt recommends identifying constructs to allow one to recognise themes more easily when they arise and facilitate cross-case comparison during data analysis (Eisenhardt 1989:536). Taking this into account, I compiled an outline of topics with suggested questions (See Appendix A) to allow for semi-structured interviews (Kvale 2007:57). I decided against a strict list of timed questions as I wanted to allow space for narratives and interesting insights to emerge.

e. Data collection

The interviews consisted of semi-structured face-to-face interactions, varying in duration from 1.5 to 3 hours. To record the proceedings, I made written notes of important points and an audio recording of the whole interview for later reference where background noise allowed. I decided not to transcribe the interviews verbatim as the audio recordings retained more of the original content than the written word would have been able to and my time was better spent on analysis. Kvale writes that “...transcripts are impoverished decontextualised renderings of interview conversations...” and explains that their weakness lies in an absence of intonation and breathing that can influence meaning (Kvale 2007:93).

To ensure a quality interview, Kvale recommends that the interviewer should not only ensure that he understands what the interviewee is saying, but should attempt to interpret and verify his interpretations during the interview (Kvale 2007:80). Instead of delaying interpretation until after the interview with only the transcripts at hand, I thus aimed to process the interviews as much as possible while they were in progress to allow me to verify observations on the spot and open up possibilities for further elaboration.

f. Data analysis

The processes of data collection and analysis were conducted simultaneously so as to allow for flexibility in data collection (Eisenhardt 1989). To ensure that insights were captured as accurately as possible and were not tainted by other interviews, I tried to analyse each case within 2 days of the interview before moving on to the next one.

I employed a bricolage approach to analysis, which Kvale describes as “...where the interpreter moves freely between different analytic techniques...” (Kvale 2007:115). Although partly inspired by the narrative approach, my intention was not so much to tell each story from start to finish as it was to extract useful information from the stories. A less systematic approach using ad hoc tactics was thus more appropriate. These included, amongst others, noting themes, clustering concepts, and comparing differences between cases.

Throughout my approach, I endeavoured to follow Eisenhardt’s recommendations for achieving academic rigour wherever possible. The one area in which I was not able to do this was following her suggestion that multiple investigators be used to facilitate cross-comparison. According to her, this would have helped to introduce different perspectives to my own and enhance the

confidence in my findings (Eisenhardt 1989:538). While I endeavoured to remain objective and challenge my views wherever possible, an element of subjectivity is likely in any research so I will end this section with a short discussion of how I may have influenced my results.

1.6.4 Limitations

The role of the researcher is simultaneously integral to the process and fraught with imperfections beyond one's control. Constraints imposed on the interview process have lent this research a character deemed undesirable in more scientific research. According to Kvale, "...through his questions, nods, and silences the interviewer is a co-producer of the narrative" (Kvale 2007:74). I thus feel it is important to highlight some of the unique factors I bring to the research that in one way or another have shaped its ultimate manifestation:

- I come from a business background, having studied a Bachelor of Business Science at UCT and worked in marketing and advertising for 4 years. My understanding of politics and the workings of government is limited, and I have a greater appreciation of private sector perspectives. I have, however, attempted to improve my understanding of government in the process of conducting this research in order to represent a more balanced view.
- My thesis funding comes from the *Centre for Renewable and Sustainable Energy Studies*, which requires that I include energy-related sustainability issues in my thesis.
- I believe that the goal of reducing CO₂ emissions can be achieved as a positive side-effect of reductions in excess consumption and waste, and by replacing mechanical systems with natural or passive alternatives. I do not believe that emission reduction efforts should be prized above the social dimensions of sustainability, and they are not a primary focus of this research.

With the degree of personal involvement required in conveying case studies, one might think that other methods would be more appropriate for achieving research objectivity. Campbell explains that, in fact, "...common sense naturalistic observation... is the only route to knowledge – noisy, fallible, and biased though it may be" (in Flyvbjerg 2006:224). Flyvbjerg finds that subjectivism can occur in all research methods, and that qualitative methods or case studies are no more biased than any other approaches (Flyvbjerg 2006:235).

1.7 Thesis outline

The thesis begins with a review of the literature to link the broad themes of planetary limits and urban infrastructure. Starting with the concept of resource limits, I explain how the future of humanity depends on whether or not we are able to live within these limits, and show that we are already exceeding many of them. I introduce decoupling as a solution to breaking the connections between improvements in human wellbeing and unsustainable resource use, emphasising that relative decoupling is not a solution for sustainability in and of itself. I build the argument for

absolute decoupling before going on to explain how urban infrastructure can be used as a means of reducing the amount of resources consumed and wastes produced by the inhabitants of a city.

Elaborating on how absolute decoupling might be achieved through infrastructure investments, I introduce the concepts of efficiency and substitution. I show that it is free materialisation and immaterialisation that are most needed to move beyond relative decoupling toward absolute decoupling, and follow this with an overview of how to implement new technologies to maximise their chances of success.

The focus shifts from international literature to Cape Town and the sustainability of its infrastructure systems. I start with an introduction to the literature, and move on to a series of case studies that fill in some of the gaps it leaves. I look at two cases of energy approaches that reduce reliance on the grid, two cases of water conservation technologies, and two cases of waste management practices that reduce waste sent to landfill. The case studies are grouped under the themes of energy, water and sanitation, and waste, and each has its own introduction and conclusion due to the unique characteristics of each sector.

I conclude with a narrative overview of the themes running through the literature review and case studies, and identify prominent characteristics of Cape Town's transition toward resource-appropriate infrastructural services.

2. Literature analysis

2.1 Introduction

Since images of the earth from afar were first captured in early space expeditions, man has had incontrovertible proof that the planet is a finite ball. This newfound perspective precipitated a groundswell of sentiment toward protecting the planet and its fragile ecosystems from humankind's polluting ways in the 1960's and 1970's so that it might be protected for future generations to enjoy. In recent years, recognition of our reliance on the earth's resources and the possibility that they will run out in the not-too-distant future as a result of our actions has resulted in a shift in motivation from protecting nature for aesthetic reasons to rescuing it as a basis for the continuation of the human species (Hartshorn, Maher, Crooks, Stahl & Bond 2005: 178; Von Weizsäcker et al. 2009:1).

The issue of sustainable resource use has become intrinsically linked to man's future prospects. As McLaren observes, "...over-use of environmental resources is at the heart of the challenge of sustainable development" (McLaren 2003:20). In the discussion that follows, I give examples of a number of natural limits that we are fast approaching. I show how humanity is exceeding the planet's capacity to support our modern way of life, making the argument for new ways of doing things that break the link between quality of life and resource exploitation. Introducing the concept of decoupling, I discuss how relative decoupling is limited in its ability to help man live within natural limits, and make the case for absolute decoupling that allows for development whilst reducing our overall impact.

With an understanding of the concepts behind resource use and sustainable development, I turn to the study of cities as nodes of intense resource mismanagement. I look at the role infrastructure plays in shaping a city's consumption over time, introducing the concept of urban metabolism as a metaphor. I apply the concept of decoupling to urban infrastructure, explaining that while relative decoupling can be achieved through efficiency measures like dematerialisation and rematerialisation, these concepts are limited in their ability to deal with total resource impacts. Absolute decoupling requires more radical steps toward immaterialisation and what I call 'freematerialisation'. I then provide an overview of how new technologies might best be implemented in the unsustainable context of the city, based on the literature on sustainable infrastructure.

2.2 Limits and sustainability

In 1972, a book entitled *The Limits to Growth* was commissioned by the *Club of Rome* and a group of scientists, statesmen and businessmen from around the world. A team of experts compiled a computer model to forecast the environmental and social outcomes of different development scenarios, and found that resource use and population growth could one day place limits on economic growth (Meadows, Randers & Meadows 2004).

Limits to growth "...include both the material and energy that are extracted from the Earth, and the capacity of the planet to absorb the pollutants that are generated as those materials and energy are used" (Meadows et al. 2004:10). Beyond a certain rate, materials and energy cannot be extracted from these sources without harming people, the economy or the planet's capacity to regulate and regenerate itself.

At the time of the report, these findings were dismissed by many scholars as mankind was still living within the earth's limits and had room to grow. When the study was repeated in 1992, it found that we had overstepped a number of limits and there were visible signs of a shift toward unsustainability. The most recent update in 2002 showed that little has changed to move us off this path following the warnings from the 1970s, and the once-derided predictions have largely proved to be accurate. The authors concluded that we have wasted the opportunity to correct our unsustainable development path and are a lot more pessimistic about our future prospects (Meadows et al. 2004:5). We now find ourselves staring into the headlights of a number of fast-approaching limits:

Water

It is estimated that man can survive for up to 40 days without food, but only 3 days without water. Only 2.5% of earth's water is fresh, and less than 1% of this is able to be used (Du Plessis 2002:27). This rate is declining as pockets of fossil water are extracted from deep underground and global warming erodes reserves of fresh water held in glaciers (Hunt 2004:12). In the mid-90's, serious water shortages were experienced by around 40% of earth's population, and it is predicted that over 5 million people die each year from lack of access to clean water and sanitation. According to UNEP, two thirds of the population will live in water-stressed countries by 2025 (in Du Plessis 2002:28). Global warming, resource depletion, pollution, population growth and increases in per capita consumption are all contributing to the problem.

Topsoil

The topsoil necessary to grow food for humans and animals is also under threat. Approximately 100 billion tons of topsoil is lost due to human activity each year at 5 times the rate at which nature can regenerate it. Over 19.5 million hectares of land are directly affected by urban growth which compacts, poisons and suffocates the soil, rendering it useless. There are around 7,000 gig tons of topsoil left, but current projections warn that this will not last more than 70 years (Du Plessis 2002:29). Per capita grain production reached its peak in 1985, and has been declining ever since (Meadows et al. 2004:11). Our ability to produce food is under severe threat.

Fossil Fuels

In 2000, more than 80% of commercial energy use came from oil, coal and natural gas (Meadows et al. 2004:13). All are non-renewable, and the limited stocks held beneath the earth's surface are declining rapidly as demand continues to escalate. Oil currently supplies 90% of the energy required by the world's transportation industries (Wakeford 2007:1). While our access to oil has typically increased with the discovery of new reserves, the absolute quantity that can be extracted from the earth is limited and we are fast approaching 'oil peak'. Beyond this point, oil will become less and less accessible, making it more difficult to extract and thus more expensive. The world's most credible oil geologists and energy agencies predict that oil extraction will peak in the next decade if it has not already happened (Wakeford 2007:3). Similarly, global coal production is likely to peak around 2025 (EWG 2007), and peak gas production could also occur in the next 50 years (Meadows et al. 2004:13).

Greenhouse gases

Our use of fossil fuels is also limited by the earth's ability to manage the polluting side-effects of combustion. Greenhouse gases like CO₂ are emitted in the process of releasing energy from fossil fuels, and are accumulating in the earth's atmosphere at unprecedented rates. Atmospheric concentrations of CO₂ are higher than they have been in 160,000 years (Meadows et al. 2004:14), and are playing a major role in the changes to temperatures and climates observed around the world. The *Intergovernmental Panel on Climate Change* (IPCC) warn that if average global temperatures rise above 3.5°C (relative to 1980-1999 averages), 40-70% of earth's species will become extinct. The damage can be limited to 20-30% if the range is maintained between 1.5°C and 2.5°C, and a number of greenhouse gas targets have subsequently been proposed to retain temperature increases within this range (IPCC 2007).

In a balanced ecosystem, trees and other plants convert CO₂ in the atmosphere to oxygen, but the limits to which they can cope are fast approaching as the world's forests are decimated to meet man's demand for wood, farmland and other valuable commodities. Only a fifth of the earth's original forest cover remains, and if current rates of deforestation continue, this will not last until the end of the century (Meadows 2004:11).

Land space

As built environments grow and stocks of built up land accumulate, the amount of reproductive and ecologically buffering land available for ecosystems and food production is diminished (Bringezu 2002:198). This threatens nature's ability to maintain ecosystem balance and support human life. In the last 35 years, land limits have begun to be reached, and the world has moved from land abundance to land scarcity (Meadows et al. 2004:11).

Mankind's reaction to this awareness of limits will determine whether or not he has a future on this earth. In 1980, the *World Conservation Strategy* defined sustainability as "...improving the quality of human life while living within the carrying capacity of supporting ecosystems..." (in Birkeland 2008:xv). Unlike some later definitions of sustainability and sustainable development, this definition centres on the facts that that (1) the earth supports human activity, and (2) that its capacity to do so is finite (Birkeland 2008; Swilling & Annecke 2008). It is this basic understanding upon which this research is founded.

The field of sustainable development has been known to lose sight of these relationships. For example, the popular 1987 Brundtland Commission definition states that sustainable development is about meeting the needs of current generations without diminishing future generations' ability to meet theirs (WCED 1987). The only limitations acknowledged in the accompanying report were social organisation and the state of technology, implying that natural resources can be replaced by other forms of capital indefinitely (Norton in Hattingh 2001).

Such equity-focused definitions divert attention from the role of nature in meeting human needs, and have led to the misconceived anthropogenic notion that environmental trade-offs are somehow justifiable in the interest of human advancement. Similarly, Elkington's often used 'triple bottom line' approach to achieving sustainability can result in a "...language of trade-offs..." between the economic, environmental and social agendas (Swilling 2008:5). The understanding is that a minimal degree of overlap between the three supposedly separate spheres equates to sustainable development (Mebratu 1998:513). While all three spheres are considered, the trade-off is in the extent to which each is able to exert influence on the others in moulding the ultimate vision of sustainability.

The remedy to this common misperception lies in a systems approach, described by Mebratu as the *Cosmic Interdependence* model, which sees the three spheres as embedded within one another (Mebratu 1998:514; DEAT 2007:21; Swilling 2008:5). As Mebratu explains, "...the human universe, in general, and the economic and social cosmos, in particular, never have been, and never will be, a separate system independent from the natural universe" (1998:514). While technology has been able to replace natural resources and services in some cases, there are many important instances where this does not hold true as "...natural capital (e.g., the forest) is often a prerequisite for manufactured capital (e.g., the sawmill)..." or substitution is simply not possible (Wackernagel & Rees 1996:36). To think that we are not reliant on nature's limited resources for our survival is nothing short of delusion. The diagram below clarifies the relative importance of the economy and the environment in human wellbeing, and acts as a reminder of where our priorities should lie in our strategies for the future:

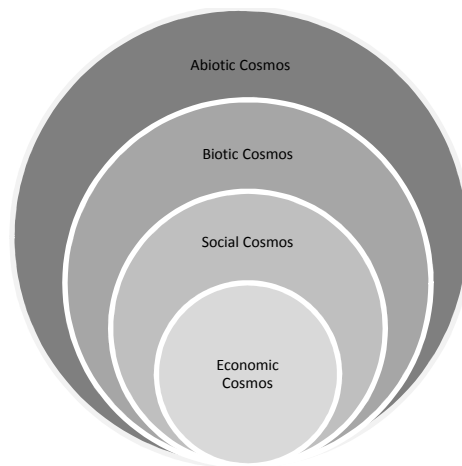


Figure 2.1: The embedded spheres of Mebratu's Cosmic Interdependence Model
(Source: Mebratu 1998:513)

2.2 Resource consumption and overshoot

When considering resource limits, it is important to take into account the different characteristics of the various resource types. Resources can be separated into three broad categories: materials, fresh water and land. The theories discussed here relate mostly to material resources, but many of the principles apply to the conservation of fresh water and land resources too. Material resources are defined by the *International Panel for Sustainable Resource Management* as "...natural assets deliberately extracted from the environment and drawn into economic use. They can be measured both in physical units ... and in monetary terms..." (Fischer-Kowalski & Swilling 2010:12).

A crucial feature of material resources is that they can be 'used up', i.e. the future utility they provide is reduced in the process of being used, and to a certain extent this is true in the case of fresh water and land reserves too. Whereas polluted water can be cleansed and used land can be converted to other uses if required, their ability to provide service to humans can be depleted if not managed properly. For example, withdrawing water at rates exceeding natural renewal rates can be considered unsustainable. These rates vary substantially depending on the water source, ranging from around 18 days for rivers to hundreds of thousands of years for glaciers and fossil water aquifers. According to Hunt "...if water is removed and consumed from these components of the hydrological cycle faster than it is replenished, ...eventually the planet will run out of water" (Hunt 2004:12).

Renewable resources like wood can be regenerated with careful planning to provide utility in the future as they can be re-grown or replenished. Non-renewable resources like oil or coal take millions of years to form and face a very real threat of being used up in the foreseeable future. While it can be argued that many of these resources are not of use to any species on earth other than humans, the processes involved in their extraction and use have environmental impacts that are unsustainable. Society's reliance on some of these resources also presents a real threat in terms of the life-supporting systems that would cease to function if they ran out. Many renewable

resources like wind and geothermal power cannot be used up faster than they are produced, but resources like biomass require more considered usage in order to maintain resilience and longevity, especially when drawn from ecological stocks rather than those under human management (Haberl, Fischer-Kowalski, Krausmann, Weisz & Winiwarter 2004:206).

Globally, the amount of raw materials extracted roughly reflects the amount used in economic activity and was estimated at 47 to 59 billion metric tons (Gt) per annum at the start of this century - approximately 8 times what it was 100 years before (Fischer-Kowalski & Swilling 2010:19). For most of the 20th Century (and those preceding it), consumption of biomass exceeded that of fossil fuels, construction materials, ores or minerals, but in recent years there has been a marked shift in the opposite direction. The contribution of biomass has decreased from three quarters to one third of all material consumption (Fischer-Kowalski & Swilling 2010:19). This shows that in addition to increased consumption, there is a strong and dangerous trend toward consumption of non-renewable resources.

Although GDP is a good indicator of consumption, population and behaviour are more important determinants. Per capita resource consumption or 'metabolic rates' have become a popular means of assessing a country's material standards of living as both food and non-food consumption are integral to the modern way of life (Fischer-Kowalski & Swilling 2010:23). Catton explains that unlike animal species whose consumption is determined by biology and varies little between individuals, the earth's ability to support humanity is determined both by population size and *per capita* consumption (in Wackernagel & Rees 1996:50). On a global average, metabolic rates have doubled from 4,6 tons to around 9 tons since 1900 (Fischer-Kowalski & Swilling 2010:26). The world is not only accommodating more people, but effectively 'larger' people (Wackernagel & Rees 1996:50).

In order for a society to be sustainable, one needs to consider the appropriateness of per capita consumption levels relative to natural limits (Meadows et al. 2004:22). From an anthropogenic perspective, the issue of limits is synonymous with Catton's definition of 'carrying capacity' as "...the maximum "load" that can safely and persistently be imposed on the ecosphere by people..." (in Wackernagel & Rees 1996:50). Estimates of this carrying capacity provide useful benchmarks for sustainability endeavours, with goals varying between living at carrying capacity or significantly within it depending on ethical perspectives on the rights of other species and the need for quality of life over mere survival (see Hattingh 2001).

In an attempt to understand how per capita consumption could be adapted to suit ecological limits, the environmental group *Friends of the Earth* have combined the logic of limits with an equity-based stance on environmental justice to develop 'environmental space' measures. This entails calculating a maximum rate of consumption of natural resources per person by approximating total quantities available in relation to population estimates: a theoretical 'fair share'. In comparing this with a minimum level of consumption required for human dignity, a range of consumption levels between maximum and minimum can be targeted to help achieve

intra-generational equity whilst leaving the planet in a fit state to continue providing resources for our descendents (McLaren 2003).

Wackernagel and his colleagues at *The Global Footprint Network* have taken the notion of consumption one step further in developing the methodology for measuring the 'ecological footprint' of an individual or group. They define this as "...the area of ecologically productive land (and water) ... that would be required on a continuous basis ... to provide all the energy / material resources consumed, and ...to absorb all the wastes discharged..." (Wackernagel & Rees 1996:51-52). Footprinting tools can be used to translate multiple variables into the common language of global hectares, thereby facilitating comparison between consumption patterns and limits in a concise and meaningful way. They are also scalable, allowing for comparisons between individuals, cities or countries.

In 2002, it was estimated that there were 11.3 billion ha of biologically productive space on earth - roughly equivalent to a quarter of the earth's surface. Divided equally amongst humans, this would allow approximately 1.8 ha per person (Wackernagel et al. 2006:104)². For strong sustainability, average ecological footprints would need to be less than this, but studies show that the global average is closer to 2.2 ha. In a developed country like the USA, the average nears 9.7 ha.

This indicates that humanity's ecological footprint exceeds available bio-capacity by over 20%. The implication is that it takes more than 14 months to regenerate the resources consumed in 12 months (Wackernagel et al. 2006:105). The world is in a state of 'overshoot', which means that "...we are drawing on the world's resources faster than they can be restored, and we are releasing wastes and pollutants faster than the Earth can absorb them or render them harmless..." (Meadows et al. 2004:3). The graph below shows that this has been happening since the mid-80's, and that the situation is worsening with each passing year:

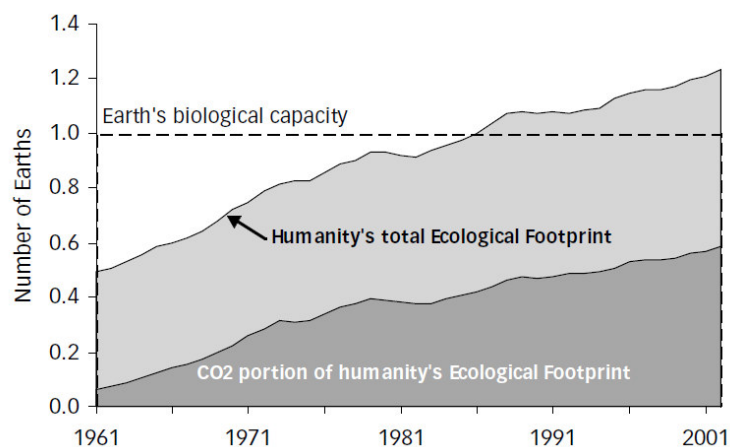


Figure 2.2: Ecological overshoot 1961-2002 (Source: Wackernagel et al. 2006:106)

² These calculations are purely anthropogenic in focus, so the amount calculated to be available can be considered overly generous if one's interpretation of sustainability includes maintenance of biodiversity (Wackernagel et al. 2006:105).

The reason we have been able to survive beyond this point of overshoot is that resources like fish and trees can continue to be harvested faster than they grow *up to a point*, but ultimately there won't be sufficient new stocks to replace them. The 2005 Millennium Ecosystem Assessment showed that 60% of the ecosystems required to support human life are degraded, in most cases beyond repair (in Swilling 2008:15). As Wackernagel et al. put it, "...now we are not only consuming nature's interest but also invading its capital..." (Wackernagel et al. 2006:107).

If business continues as usual for developed countries whilst developing countries are allowed to catch up, global annual resource extraction is projected to be three times that of the year 2000 by 2050. This 'freeze and catch up' scenario is likely to see us overstep all measures of environmental limits, meaning that the planet will simply not be able to accommodate an estimated 9 billion inhabitants (Fischer-Kowalski & Swilling 2010:32). Meadows et al. predict that rising death rates will see the earth's population peak in 2030. As natural resources near depletion, their model anticipates that more will be spent on resource extraction leaving less for investment in industrial output. The resulting industrial decline will drag service and agriculture sectors down with it, and many lives will be lost as food and health systems collapse (Meadows et al. 2004:14).

To all intents and purposes we are careening towards what UNEP described as an "environmental precipice" at an unprecedented rate (in McLaren 2003). If swift action is taken to address these problems, we may at best be able to soften the impact of the shocks to come (Meadows et al. 2004:3).

2.3 Introducing decoupling

Considering that per capita consumption exceeds nature's limits, the question arises as to how many people the earth can support. According to Du Plessis, this is highly dependent on quality of life (Du Plessis 2002:30). She says that "...we can probably squeeze 200 billion people onto the planet if we want no nature left, if everyone lived in high-rise buildings and if everyone was prepared to subsist on their own waste products" (Du Plessis 2002:30). The following table by McCluney supports this view, giving a rough estimation of the planet's carrying capacity if living standards were to be equal:

Table 2.1: Living standards relative to global population (Source: McCluney in Du Plessis 2002:30)

Standard of living	Billions of people
Current USA	2 billion
As above with some environmental restrictions	4 billion
Only US and Europe at current, the rest at Mexico's level	6 billion
Everyone at Mexican level	20 billion
Everyone at African level	40 billion

In light of predictions of a population of 8.9 billion by 2050 (UN 2004), it appears that most of the world's population would need to adjust their standard of living to that of the average Mexican in

order to achieve intra-generational equity and attempt to realise sustainability. The two major flaws in this outlook are that it assumes that reduced consumption will decrease enjoyment of life, and that the relationship between quality of life and levels of consumption is fixed. While life enjoyment may improve with additional resource consumption up to a point, above this level the relationship becomes highly tenuous (McLaren 2003:28; Jackson 2009:53). This indicates the futility of excessive consumption and indicates that, if positioned securely above the minimum level, reducing consumption to allow more for everyone else will not necessarily worsen one's enjoyment of life. The assumed fixed relationship between utility derived and resource consumption also warrants closer scrutiny, and this will constitute the focus of this section.

The concept of 'decoupling' rose to prominence in the early 2000's as a means of breaking the causal links between 'economic goods' and 'environmental bads' (Fischer-Kowalski & Swilling 2010). While economic success in the form of GDP growth is usually used as a measure of this good, it is important to note that there are multiple types of decoupling (Haberl et al. 2004:208). In line with the WCS definition of sustainability introduced earlier and the systems understanding of sustainability demonstrated in Figure 2.1, my use of the term decoupling will consider broader human benefits rather than only economic goods, with an understanding that decoupling can be used to improve wellbeing with less environmental impact. This 'impact' broadly describes the depletion of finite resources, unsustainable management of renewable resources and damages to natural environments caused by the disposal of excessive concentrations or volumes of waste.

Decoupling addresses existing inequalities through a two-level approach deemed by some to be appropriate for different development scenarios: absolute and relative decoupling. Absolute decoupling traditionally entails increasing indicators of economic success whilst decreasing environmental impacts (e.g. resource consumption or waste production). Relative decoupling is a scenario whereby growth in environmental impacts is not as fast as growth in an economic wellbeing, but is still growing nonetheless (Fischer-Kowalski & Swilling 2010). Absolute decoupling is likely to require significant financial investments in developing and implementing new systems, the likes of which are more realistically achievable by industrialised nations. Relative decoupling is more accessible, and is often viewed as a way in which developing countries could meet their need for swift growth in a manner that acknowledges that they cannot follow the outmoded growth paths of developed countries (Fischer-Kowalski & Swilling 2010).

Relative decoupling is not a new idea, and there are many signs that reductions in the material and waste intensity are already taking place despite an absence of proactive legislation. Global material intensities have declined significantly in the last 30 years, energy intensity is 33% less than it was in 1970, and CO₂ intensity has dropped by almost 25% since 1980 (Jackson 2009:48-49). Krausmann has estimated that relative decoupling is occurring at a rate of 1-2% per annum, with the main contributions coming from industrialised countries (in Fischer-Kowalski & Swilling 2010:21).

The weakness of relative decoupling is that it allows for overall environmental burdens to continue to grow alongside GDP. Jackson provides evidence to indicate that the consumption of

certain resources is even increasing at a rate *faster* than GDP. Demand for structural metals like copper, nickel, iron ore and bauxite are good examples, and growth in cement production currently exceeds GDP growth by 70%. While developed countries may be able to level off or decrease their per capita consumption, the construction of infrastructures in emerging economies scrambling to catch up has resulted in increasing resource intensities for many non-fuel minerals, accelerating depletion rates and stressing remaining resources (Jackson 2009:52).

To improve our chances of survival as a species, we need to reduce our overall impact on the planet. In the sustainability scenarios envisaged by Meadows et al., the only option that allowed for long term sustainability was one that reduced humanity's overall ecological footprint (Meadows et al. 2004:19). Absolute decoupling is thus essential (Jackson 2009:48; Fischer-Kowalski & Swilling 2010:37). This means that instead of allowing some to get away with the lesser goal of relative decoupling, everyone needs to aim for absolute decoupling. Certainly, in terms of what is deemed necessary by the IPCC to constrain global warming to within 2 degrees, relative decoupling is insufficient and absolute decoupling is required from developed and developing countries alike (Fischer-Kowalski & Swilling 2010:37). According to the UNEP report on decoupling, "...absolute decoupling, of course, will be much more difficult but is, ultimately, what is really needed most" (Fischer-Kowalski & Swilling 2010:61).

2.4 Urban metabolism and sustainable resource management

The built environment has negative impacts on the planet both directly and indirectly during construction, once in use, and after use. According to Du Plessis, "...buildings impact on their environment directly or indirectly throughout their entire lifecycle, as well as through the lifecycle of the materials and components used to construct them via a series of interconnected human activities and natural processes" (Du Plessis 2002:25). It is estimated that construction of built environments accounts for approximately 50% of the resources extracted from the earth's crust by weight. At the same time, it consumes 16% of fresh water resources and 30-40% of energy whilst producing up to 50% of landfill waste and 30% of greenhouse gas emissions (Du Plessis 2002:25).

Du Plessis says that "...the cities and buildings we are living in belong to the past... it has become necessary to completely rethink our built environments – from the patterns of our cities to the materials we use to build them and the energy sources we use to drive them" (Du Plessis 2002:32). According to Wackernagel et al, "...the global effort for sustainability will be won, or lost, in the world's cities, where urban design may influence over 70 per cent of people's Ecological Footprint" (Wackernagel et al. 2006:112). The rapid decline of the earth's natural resource stocks can be largely attributed to cities in their function as nodes of material and energy consumption, but their centralised nature also offers significant opportunities for redirecting these vast flows in a more appropriate manner (Rees & Wackernagel 1996; Ravetz 2000; Birkeland 2002; Du Plessis 2002; Girardet 2004; Costa, Marchettini & Facchini 2004; Wackernagel et al. 2006; Newman 2006; Hodson & Marvin 2009; Wuppertal Institute 2009; Fischer-Kowalski &

Swilling 2010). With this in mind, the focus now shifts to decoupling flows through urban spaces from ecological degradation.

Applying an ecosystem perspective to the study of cities allows for new insights into how to improve their ecological performance (Costa et al. 2004:32). Construction ecologists and industrial ecologists refer to the city as an ‘anthroposphere’: a metabolic system that takes resources from and deposits wastes on the ‘biogeosphere’. A state of sustainability can be maintained as long as the metabolism of the anthroposphere does not disrupt the biogeosphere’s ability to support life (Bringezu 2002:196). Similarly, Girardet likens the city to a ‘superorganism’ with roads, railways and watercourses for veins, food markets for stomachs and waste dumps for digestion systems (Girardet 2004).

The term ‘metabolism’ is typically used to describe the material exchanges within entities and those between them and the environment (Heynen, Kaika & Swyngedouw 2006:23). Ravetz defines the metabolism of a city region as “...a system of activity which maintains itself with continuous flows of inputs and outputs – as does a living organism...” (Ravetz 2000:9). Costa et al. explain that, as in biology, urban metabolism can be characterised by two ongoing, simultaneous processes: anabolism and catabolism. Anabolism would refer to extracting and importing matter and energy into the city from elsewhere, and catabolism to the destructive processes of producing and disposing of waste (Costa et al. 2004:33). In the case of cities, both incur damage to natural resources.

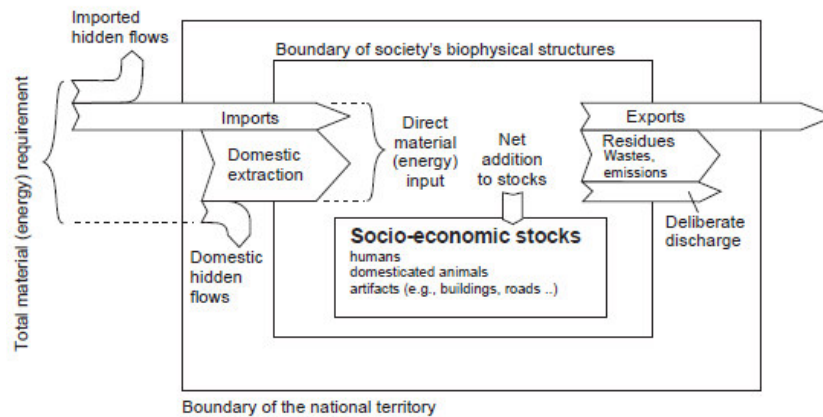


Figure 2.3: Society's material and energy flows (Source: Haberl et al. 2004:205)

Integral to studies of urban metabolism is an analysis of stocks and flows, illustrated in the figure above. Stocks include the urban fabric and resources available within the city, whereas flows involve resource inputs from outside the city and outputs from the city to beyond its borders (Ravetz 2000:10). Haberl et al. refer to the build-up of what they call ‘socio-economic stocks’ within the city, consisting of material stocks (e.g. buildings and infrastructural systems) and the resources that go into maintaining and using these stocks (e.g. energy and water). Studying the patterns of matter and energy moving through cities is critical in finding solutions to optimise them in the pursuit of sustainable resource management (Costa et al. 2004:32). While a complete study of metabolism should include cultural, social, political and ethical issues (Ravetz 2000:19),

the primary focus here is on flows of matter and energy as they have a more direct link to the exploitation of natural resources in the day-to-day functioning of the city.

The role of metabolism in urban environments has evolved as city priorities have changed. Swyngedouw describes how the medical metaphors of circulation and metabolism became synonymous with the process of modernisation in the 1600's. He explains how society came to be imagined as a "system of conduits", and how greater and faster flows through a city's systems were associated with wealth and status. As the focus shifted beyond city boundaries, circulation became "...less and less associated with closed circular movement, and more with change, growth, and accumulation." In the late 1800's, the terminology came to be associated with the need to keep cities hygienic, using flows to flush out undesirable blockages (Heynen et al. 2006:29-32).

The metabolism of typical modern cities can be described as 'linear' in that they extract resources from beyond their boundaries, make use of them within the city and deposit the resulting wastes back onto the external environment (Costa et al. 2004; Girardet 2004; Ravetz 2000). Girardet observes that a city's metabolism is in this way fundamentally different to that of a natural ecosystem (Girardet 2004). Its major shortcoming is that it falsely assumes an endless supply of resources and nature's unlimited capacity to absorb concentrated wastes.

Current thinking indicates that a return to more circular, location-specific urban metabolisms is necessary if cities are to survive (Ravetz 2000; Girardet 2004; Costa et al. 2004; Van Timmeren, Kristinsson & Röling 2004; Hodson & Marvin 2009). Ravetz explains that "...a city or region which contains its own eco-cycles would tend to be less vulnerable and damaging, or more 'sustainable'..." (Ravetz 2000:10). Where growing cities have traditionally expanded the boundaries of the hinterlands on which they depend for survival as a means of accommodating growth, there are signs of a trend toward re-localisation and attempts to create autonomous circular metabolisms in some of the world's leading cities (Hodson & Marvin 2009). Where national security concerns once took precedence, the issue of environmental security is taking centre stage with the use of local resources and re-use of waste products gaining popularity as strategies to reduce reliance on the outside world.

Hodson and Marvin's *Secure Urbanism and Resilient Infrastructure* (SURI) philosophy is based on approaches to infrastructure provision that aim to secure "...ecological and material reproduction..." through re-internalising and re-localising resource flows in manners resembling circular metabolisms (2009:194). They provide evidence of this happening in the examples of New York's energy independence plan, Melbourne's desalinisation of sea water using renewable energy, and plans for Dongtan eco-city in China that will be powered entirely by renewable energy and will re-use waste for biofuels, energy generation and soil enrichment.

2.5 Infrastructure and urban metabolism

Infrastructural networks have a critical role to play in urban sustainability through their impact on natural resources (Guy et al. 2001; Haberl et al. 2004; Wackernagel et al. 2006; Swilling 2006; Wuppertal Institute 2009). Moss says that "...given their strategic importance in shaping the quantity and quality of urban environmental flows, technical networks offer enormous potential for minimising the resource use and environmental impact of cities..." (in Guy et al. 2001:4). They commit cities to the future flows required to maintain and operate them, and can limit the options available for reducing resource consumption in the future (Haberl et al. 2004:206). Wackernagel et al. go as far as to say that infrastructure decisions can "...make or break a city's future..." as the systems influence a city's resource needs for many decades (Wackernagel et al. 2006:112). It is with this in mind that the focus narrows to infrastructure as a key determinant of city metabolisms and their potential for decoupling.

Yeang distinguishes between four types of infrastructure: grey, green, blue and red. Grey infrastructure can be used to refer to "...the usual urban engineering infrastructure such as roads, drains, sewerage, water reticulation, telecommunications, and energy and electric power distribution systems..." (Yeang 2008). Green or 'ecoinfrastructure' refers to interconnected networks of open spaces and natural areas that retain or introduce an element of nature in the city, supporting the functions of natural ecosystems. Blue infrastructure is that involved with surface water management, including drainage, retention ponds, pervious paving, swales etc. Red infrastructure is human infrastructure, including communities, buildings, hardscapes and social systems like policies and regulations. All four influence material and energy flows through the city space, but I will be looking primarily at grey infrastructures as the main tributaries for metabolised natural resources.

Alternative approaches to the provision of infrastructure services can help cities to reduce their virgin resource consumption and net waste production whilst maintaining a quality of life synonymous with modern city living (Guy et al. 2001; Engel-Yan et al. 2005; Swilling 2006; Wackernagel et al. 2006; Codoban & Kennedy 2008; Hodson & Marvin 2009; Fischer-Kowalski & Swilling 2010). Guy and Marvin observe that there are currently two visions regarding how infrastructure can be used to deal with unsustainable resource use in cities: technical solutions to improve efficiencies and social interventions to reduce demand by changing behaviour. Instead of viewing these as autonomous challenges, they believe that the two are interlinked and that infrastructural systems should be viewed as "socio-technical networks" (Guy et al. 2001:23). They warn against adopting a purely "physicalist" understanding of flows which limits solutions to technical interventions and dismisses as noise any unanticipated contextual anomalies that rational models cannot predict. While the focus of this literature review is primarily on technical networks, the importance of a supportive environment cannot be over-emphasised, and will be elaborated on in Section 2.7.

Infrastructural systems have become an intrinsic part of what it means to live in the city. Barton observes that "...utilities such as water supply, waste treatment and energy supply are taken for

granted, the functional backcloth to the drama of human existence” (Barton 2000:99). Guy and Marvin explain how this unquestioned access to infrastructure has become interwoven with understandings of modernism and the public’s expectations. The services made possible by water and electricity have encouraged and reinforced what they refer to as “social constructions of the home, the factory and the office” (Guy et al. 2001:29). Graham and Thrift elaborate on how infrastructure systems have become “...veiled beneath the surface of urban life...”, and say that they tend to be ‘black boxed’ until interruptions in the infrastructural services they provide render them visible (2007). As a result, infrastructural systems are seldom questioned until failures like power black outs or water contamination attract further scrutiny.

The manipulation of natural resources by infrastructure networks has to a large extent disguised the link between urban lifestyles and the natural resources on which they depend. Swyngedouw refers to this phenomenon as ‘urbanised nature’, which “...propels the diverse physical, chemical, and biological “natural” flows and characteristics of nature into the realm of commodity and money circulation with its abstract qualities and concrete social power relations” (in Heynen et al. 2006:36). As natural resources are disguised on entry into the city, it is understandable how urbanites might forget their reliance on nature for survival and be lulled into a false sense of invincibility.

As technical infrastructure networks have shaped modern lifestyles, they have in turn been shaped by the social contexts in which they operate (Guy et al. 2001; Swyngedouw & Kaika 2002; Heynen et al. 2006). Political ecologists see flows of natural resources through the city as intricately interconnected with social processes, and consider factors like power, history and political economics in shaping the flows of “...socially and physically metabolised ‘nature’...” that weave through urban spaces (Swyngedouw & Kaika 2002:577). Swyngedouw explains that “...nature and society are ... combined to form an urban political ecology, a hybrid, an urban cyborg that combines the powers of nature with those of class, gender and ethnic relations” (in Heynen et al. 2006:37). Costa et al. say that any environmental analysis of the city is incomplete without a study of socioeconomic variables due to the influence of humans (Costa et al. 2004:32).

Infrastructure is intrinsically linked to the modern lifestyles enjoyed by city dwellers, and for the most part its services are passively consumed without question as to the effect of these actions on limited natural resources. Infrastructure networks are crucial connection points and shapers of the relationship between resources and society. This brings a burden of responsibility to ensure that this relationship is responsible, and in light of the discussions above it is evident that decoupling has an important role to play in achieving this.

2.6 Achieving decoupling in cities

In the preceding sections, the importance of absolute decoupling and the role of city infrastructures in shaping mankind’s impact on the planet have been discussed. The question now arises as to how technology might be employed to achieve the type of decoupling required. An appreciation for the magnitude of the task at hand can be acquired using the Ehrlich Equation.

The equation states that man's impact (I) is the product of population size (P), affluence (A) and technology (T). Relative decoupling can be achieved with reductions in 'T' through technological improvements, but absolute decoupling requires a reduction in 'I' which can only happen if this is fast enough to counteract increases in 'P' and 'A' (Jackson 2009:53).

Jackson applies the Ehrlich Equation to the case of greenhouse gases to illustrate what the IPCC's recommended goal of 450ppm of CO₂ by 2050 implies for technological change. He calculates that overall emissions will need to decrease at an average rate of 4.9% per year until 2050 to meet this target. Given population growth projections of 0.7% and a modest income growth of 1.4% per annum, technological efficiency would need to improve almost *ten times* as fast as it is currently (Jackson 2009:53).

In the face of such challenges, it is worthwhile to focus efforts on the type of technologies with the greatest likelihood of success in achieving absolute decoupling. The discussion that follows will consider two main strategies influencing the effectiveness of sustainable technology alternatives: efficiency and substitution.

2.6.1 Efficiency

The low-hanging fruit in the quest for more sustainable resource management is to improve the efficiency of existing systems by reducing the quantity of resources consumed and wastes produced. Improved efficiency or productivity is commonly advocated as a solution for achieving sustainability, and in many cases it is recommended as a 'first step' towards achieving sustainability (Hawken, Lovins & Lovins 1999; Brezet et al. in Van Timmeren et al. 2004; Codoban & Kennedy 2008; Von Weizsäcker et al. 2009; TNEP 2010; WBCSD 2000). The *Natural Edge Project* explains the logic behind the prioritisation of efficiency as follows:

“Since achieving sustainability involves a transition, it is wise to find the most cost effective way to achieve such a transition. Efficiency – doing more with less for longer – has one of the best rates of return of any sustainability investment. This is because it is cheaper not to use as much energy, water and materials...” (TNEP 2010)

To understand what such efficiency would entail, a useful starting point is Bringezu's observation that there are two main strategies for improving the efficiency and productivity of resource use: 'dematerialisation' and 'rematerialisation' (Bringezu 2002:200). Robèrt et al. also observe this distinction, referring to these two strategies less elegantly as 'resource productivity' and 'less waste' (2002). This provides two themes around which efficiency initiatives can be clustered.

a. Dematerialisation

The interpretation of dematerialisation used here can be equated to what Hawken et al. (1999) describe as an engineer's definition of efficiency – i.e. reducing material flows by doing more with

less. Dematerialisation can also be used interchangeably with ‘resource productivity’, or the amount of useful output acquired per unit of natural resource input (Robèrt et al. 2002; TNEP 2010). Bringezu’s conception of dematerialization is that it “...aims at the absolute reduction of material flows within the anthroposphere” (Bringezu 2002:200), but I wish to clarify that in this argument it is used to describe a focus on incremental improvements that minimise the quantities of prescribed inputs necessary to achieve a certain output, but there is not necessarily any attention paid to the total impact on resource flows and whether this is in line with limits.

Examples of dematerialisation include installing low-flow showerheads, drip irrigation and variable flush toilets to reduce water consumption, or diverting car users to public buses or motorcycles to reduce fossil fuel use per person³. It would also involve efforts to reduce electricity use as a means of cutting down on non-renewable resources like coal and uranium used to power urban lifestyles. This would encompass the use of energy efficient appliances, the installation of building insulation to regulate internal temperatures, or the use of low energy light bulbs and presence-activated lighting to avoid wasted energy.

The term ‘eco-efficiency’ has come to be strongly associated with commercial efforts to achieve dematerialisation. The concept was derived by the *World Business Council for Sustainable Development* in the early 90’s as the business community’s solution to sustainability, and focuses on identifying and capitalising on opportunities that improve profitability (i.e. economics) by reducing resource consumption and waste production (i.e. ecology) (WBCSD 2000:4).

Ernst Von Weizsäcker, Amory Lovins and Hunter Lovins have coined the ‘Factor X’ terminology to describe levels of resource productivity. ‘Factor 4’ was initially introduced to describe a level of resource productivity that would allow for a doubling of income whilst dividing resource use in half (Von Weizsäcker et al. 2009:24). As the climate change crisis has raised awareness of the urgency with which action needs to be taken, they have raised the bar to ‘Factor 5’ - an 80% reduction in the environmental impacts of economic activity. Given the escalating pace of technological innovation and compound effects of efficiencies, in the near future it will be possible to move beyond Factor 5. This is reflected in the goal of ‘Factor 4-10’ resource efficiency has been proposed for industrialised countries in the next 30-50 years (Bringezu 2002:199).

Dematerialisation can be described as a relative decoupling strategy as it involves using fewer resources to achieve the same goals or using the same amounts to achieve loftier goals. It does not fundamentally eliminate dependence on resources, so as a stand-alone strategy to manage non-renewable resources it can only help to prolong the status quo until limits are reached.

b. Rematerialisation

The addition of rematerialisation to the understanding of efficiency allows for the prospect of ‘zero waste’ societies, and requires a broader perspective on metabolic impacts more in line with

³ Shifting to a different mode of transport can only be considered an example of dematerialisation when it runs on the same fuel, and requires less of it per passenger.

reducing a city's overall impact. Bringezu's conception of rematerialisation is that it "... aims to close materials cycles by reuse, remanufacturing, and recycling... as a consequence, the requirements for primary resource inputs ... and final disposal would be reduced while the volume of flows within the anthroposphere would not be diminished" (Bringezu 2002:200). Rematerialisation seeks to use renewable biomass and re-use that which would otherwise be considered as wastes, and is a crucial strategy in perpetuating human lifestyles that rely on threatened resources.

The conventional linear metabolisms of cities contribute to resource depletion and mounting waste. Girardet proposes that manmade environments "...can only exist on a continuous basis if they learn to mimic the essentially circular metabolism of living systems" (2004:110). Van Timmeren et al. believe that "...in the long term only closed cycles for processes and use of material could result in a permanent urban environment..." (2004:12). Such 'circular metabolisms' would turn every output of the system into an input that "...renews and sustains the continuity of the whole...", holding the entire system together in a 'chain of mutual benefit' between all elements (Girardet 2004:123).

Instead of contributing to the problem of mounting waste, rematerialisation involves harnessing opportunities to utilise waste products as substitutes for new raw materials. If a fraction of wastes can be converted into a positive cycle for use as inputs, increases in this fraction improve the degree of system closure (Costa et al. 2004:39). Closing loops changes metabolic flows from linear to circular, allowing the same materials to circulate through the system and provide utility multiple times. According to Costa et al, it would also help to slow the "...entropic decay of matter and energy...", allowing resources to last longer (Costa et al. 2004:39). Such activities would include getting a second use from grey water before sending it to the sewer, making constructive use of waste heat from electricity generation to provide heating or cooling, or re-beneficiating recyclable wastes as inputs into new products instead of burying them in landfills.

The scope of rematerialisation is broader than dematerialisation, and views waste, pollution and resource depletion as systemic inefficiencies to be avoided (Hawken et al. 1999:13; Birkeland 2002:14; Porter & van der Linde in Hartshorn et al. 2005; Von Weizsäcker et al. 2009:16). It requires looking beyond technical micro-solutions to the formation of new relationships and collaborations for the greater good. According to the WBCSD, eco-efficiency can include efforts to work with other companies to re-valorise waste and achieve zero waste, as well as looking to new ways of meeting customer needs in ways that aren't energy and material intensive (WBCSD 2000). This indicates that the concept can include both dematerialisation and rematerialisation.

Rematerialisation helps to break a city's dependence on resource inputs and waste sinks to deal with its outputs. It does not, however, help to deal with the resource implications of city growth or improvements in living standards. Rematerialisation can at best constrain a city's impact, but is unlikely to prevent overall resource requirements from increasing in a context of population

growth and rising affluence. It can thus be described as more of a strategy for relative decoupling rather than absolute decoupling⁴.

c. The limitations of efficiency

Efficiency pursued through dematerialisation and rematerialisation is essentially about minimising damage. It implicitly assumes that a certain amount of damage is a permissible consequence of human activity, and does not endeavour to change this underlying dynamic. The problem lies in the accumulation of these negative impacts that perpetuate the link to planetary degradation and render efficiency strategies incapable of achieving absolute decoupling.

In the case of non-renewable resources, efficiency measures also suffer from a problem known as the 'rebound effect' or 'Khazzoom-Brookes Postulate' (Roy 2000; Simmons 2002; Alcott 2008; Von Weizsäcker et al. 2009; Fischer-Kowalski & Swilling 2010). This states that focussing on efficiency alone is not enough as efficiency gains have a tendency to encourage greater consumption of the saved resource which cancels out the net environmental benefit (Von Weizsäcker et al. 2009:277).

Bishop questions the ability of efficiencies to achieve sustainability, arguing that efficiencies do not keep an eye on overall limits and can allow for the extinction of species or depletion of renewable resources (Bishop 1993:72). The WBCSD themselves warn that "...improving eco-efficiency does not ... lead automatically to sustainability. Simply improving in relative terms (value per impact) may still mean an overall increase in an activity's impact and create unacceptable harm or irreversible damage" (WBCSD 2000:10). Roy indicates that the rebound effect can be particularly high in developing country contexts where there is unmet demand (Roy 2000). However, the 'negatives' of an overall increase in resource use in such contexts might be counter-balanced by social development 'positives' that contribute to enhancing overall sustainability in a less resource-intensive manner than might otherwise have been the case.

In light of population growth and aspirations for economic development, efficiency inspired by economic agendas alone is unlikely to reduce man's overall impact on the planet (Birkeland 2008; Jackson 2009). De Bruijn et al. find that "...as organizations commit to accounting for natural and social capital costs of doing business, they typically start by picking the "low hanging fruit" and eventually hit a "green wall" where no marginal value is derived ... moving beyond this point often requires a fundamental change in philosophy and the design of new methods and systems" (in Hartshorn et al. 2005:171). With short term profits as the only motivator, the achievement of sustainability through eco-efficiency is likely to be limited in its ability to achieve absolute decoupling.

The pursuit of efficiency through dematerialisation and rematerialisation alone is not a complete solution to absolute decoupling in a context of growth. In the case of non-renewable resources,

⁴ An interesting exception is the mining of landfills to salvage resources, which has the potential to reduce some of the accumulated negative effects of dumping wastes on the environment.

such approaches can at best temporarily extend the lifespan of the status quo through relative decoupling. In cases where the resources have hazardous effects on the environment during their production, consumption or disposal or are facing extinction, more efficient usage is an ineffective strategy for sustainability (Robèrt et al. 2002:200).

Efficiency avoids the kind of radical changes necessary to forge a new path toward the reduction of our impact on the planet and its finite resources, and as such it is limited in its ability to diminish our ecological footprint. While prosperous countries with stable or declining populations may be able to achieve reductions in their total resource impact by replacing ageing infrastructures with more efficient technologies, the rapidly expanding cities of the third world need to combine efficiency measures with innovative new approaches if their citizens are to prosper in a future of resource scarcity. The introduction of substitution technologies is thus a crucial complement to efficiency improvements.

2.6.2 Substitution

A focus on efficiencies can cause one to suffer from minimisation myopia, to the detriment of conceptualising truly sustainable solutions. In order to achieve absolute decoupling, it is crucial that one think beyond the confines of minimisation to alternatives that do not suffer the same limitations. In considering the options for decoupling infrastructure I would thus like to add two alternatives to efficiency to the discussion: freematerialisation and immaterialisation. According to Robèrt et al's definition, these two factors can be classed as 'substitution'⁵, or the "...exchange of type/quality of flows and/or activities" (2002:200).

a. Freematerialisation

There is a strategy embraced by nature that is not adequately covered under dematerialisation or rematerialisation: the use of freely available unlimited resources. In keeping with the rhyming precedent I shall call this 'freematerialisation'. Instead of focusing on diminishing measures, freematerialisation involves looking beyond an activity or process to the *whole* system, including the supporting ecosystem, and looks to harness goods and services provided by nature so that they can be added to the mix of inputs used to provide service to mankind. Whereas rematerialisation involves adding wastes to the list of potential inputs, freematerialisation adds free and renewable natural resources as substitutes for those that are in dwindling supply or polluting the planet.

⁵ The use of the term substitution is not to be confused with the 'substitutes' that free market thinkers suggest will arise as a reaction to resource scarcities. It is also not to be confused with its use by knowledge economy advocates who suggest that knowledge can be a substitute for physical resources, and overlook the displaced resource impacts of knowledge-based economies.

Freematerialisation technologies can be likened to Birkeland's conception of 'eco-innovations', which describe new solutions that go beyond techno-fixes to 'design for nature' by using natural systems to "...replace 'unnecessary' machines or products...". Birkeland asserts that not only would such innovations be kinder to the environment, but they would cost less to operate because they harness free natural resources (Birkeland 2008:xx). The concept can be broken up into three main areas:

Renewable energy technologies

Harnessing energy directly from the sun, wind, rivers, waves, tides, currents or beneath the earth's crust and converting it to electricity would allow for ongoing, undiminished energy without the legacy of damage that accompanies fossil fuel extraction, processing, transportation and use. Examples include the use of wind turbines, solar photovoltaic panels, hydro-electric schemes, floating wave power generators and undersea turbines to generate electricity.

A worldwide report conducted by the *European Renewable Energy Council* (EREC) in association with *Greenpeace* found that if combined with better use of energy, renewable energy technologies could deliver half of the world's anticipated energy needs by 2050. Their plan is based on the immediate introduction of mature renewable energy technologies with the subsequent addition of those currently in development whilst phasing out coal and nuclear power. According to their calculations, this is a financially and technically feasible scenario that would halve global CO₂ emissions by 2050 and considerably reduce the resource requirements of the energy industry (EREC & Greenpeace 2007).

Renewable resource harvesting

This involves harnessing on-site natural services from the sun, wind, rain and earth for purposes other than generating electricity as substitutes for resource-hungry methods. Examples include the use of solar water heaters instead of electric geysers to heat household water⁶, the use of solar heating for industrial purposes (SHIP), hanging laundry outside to dry instead of using a tumble dryer, using wind pumps instead of electric or diesel alternatives, collecting rainwater instead of extracting it from fossil water reserves and using geothermal heat to warm buildings.

Ecological technologies

Ecological technologies also involve getting nature to do the work, but in this case they employ living organisms to serve a human purpose as a substitute for resource depleting methods. Advances in ecological technologies and the field of ecological engineering offer a glimpse of what these innovations can look like. Todd and Josephson say that "...ecological

⁶ This is in cases where there is no connection to electricity. A system using electricity as a backup in poor sunlight conditions would have properties of both dematerialisation and freematerialisation.

engineering has the potential to transform radically the infrastructures underlying contemporary societies and bring them into greater balance with the natural world” (1996:110). Not only would such systems reduce pollution of the natural environment, but they could also help to rectify other man-made imbalances by, for example, aiding the absorption of CO₂ emissions, purifying the air, regulating urban temperatures or retaining moisture in the soil. This would contribute to investments in green infrastructure (see Benedict & McMahon 2002; Yeang 2008), or what Hawken et al. describe as the ‘natural capital’ required to support cities (1999). Kaufmann and Kinsinger add that the use of complex ecological systems can even allow for efficiencies several orders of magnitude greater than those currently made possible by mechanical and chemical means (in Todd & Josephson 1996).

Todd’s ‘living machines’ and ‘restorers’ for the treatment of waste water are noteworthy examples. His machines typically consist of greenhouse-type structures in which a series of small-scale constructed mesocosms perform different functions in the process of effluent treatment, and the restorers are a floating equivalent used to purify polluted waterways. The design of these systems is highly complex, involving carefully calibrated combinations of purpose-selected minerals, plants, microbes, plankton, insects and fish. Todd claims that they can achieve tertiary treatment of sewage at a lower cost than conventional technologies and without using toxic chemicals, and can even help to fund themselves through the production of fruit, flowers and small fish to be used as bait. Their effectiveness has been proven in a number of successful projects around the U.S. with support from the *Environmental Protection Agency*, and in other parts of the world through the work of *Ocean Arks International* (Feinham 2008).

The approaches listed above overcome some of the limits of an efficiency focus and are not diminished by rebound effects or increases in consumption. They offer a glimpse of the theoretical ‘net positive development’ advocated by Birkeland as a way in which urban development can restore and enhance its surrounding ecology instead of looking only to reduce its impact (Birkeland 2002; Birkeland 2008). This opens up new options to take infrastructural services beyond efficiency, creating opportunities for absolute decoupling.

b. Immaterialisation

Another emerging concept that warrants mention is that of immaterialisation. Whereas dematerialisation is concerned with relative minimisation of resource use, immaterialisation is “...characterised by a 'switch' in consumption behaviour from more material to less material” (Simmons 2002:4). Simmons observes that the satisfaction of non-material needs is often achieved via material consumption, but that immaterialisation allows for equally satisficing approaches that are less material intensive and environmentally damaging.

Due to the degree of overlap between dematerialisation and immaterialisation, the two concepts warrant further distinction. While Bringezu's interpretation of dematerialisation might include a shift from delivery of products to the provision of services which could constitute immaterialisation (Bringezu 2002:200), it does not explicitly address options for more radical departures to the status quo that might eliminate the necessity for certain resources altogether. Also, the rebound effect associated with dematerialisation is fundamentally one of own-price substitution, where savings encourage greater consumption of the saved resource. The radical discontinuities accompanying immaterialisation can be described as having an income effect which may or may not result in the availability of more money to be spent on other things (Simmons 2002:7).

Simmons discusses immaterialisation led by Information Society Technologies (ISTs) as an important sub-class of these technologies. Where ISTs have thus far played a role in dematerialisation and eco-efficiency, there is a growing realisation of their potential to contribute to the substitution of material consumption with virtual consumption (Simmons 2002:4). Such examples would include the use of e-mail communication to replace letters and faxes, teleconferencing to replace face-to-face meetings, and combinations of video surveillance and telemetry to replace site visits. Although the primary savings are in the fossil fuels consumed in transporting people and information between locations, significant savings in manpower and other resources are also possible. A new paradigm dubbed 'ubiquitous infrastructure' by the Koreans aims to combine urban infrastructures with automation and communication technologies allowing citizens round-the-clock control of infrastructural systems (Lee, Yigitcanlar, Han & Leem 2008). The technologies already exist that would allow the residents of future 'U-cities' universal access to services regardless of time or place, making infrastructure management more responsive, efficient and democratic.

The concept of immaterialisation can also be extended to include low-tech substitutions that reduce resource consumption. Examples include walking or cycling to replace the fossil fuels used for transportation, washing clothes and dishes by hand to replace the electricity used in home appliances, and installing composting toilets to eliminate water requirements from sanitation.

Due to the sometimes radical nature of these alternatives, immaterialisation requires a different approach to mass implementation. Simmons finds immaterialisation decisions to be culturally informed, with the choice of satisfiers being based on values surrounding lifestyle choices (Simmons 2002:4). He describes a shift in focus from "...the single item (nearby) substitution approach ... to a more aggregated approach based on an individual's patterns of consumption behaviour and deriving from their perceptions of values..." (Simmons 2002:4). Instead of focusing on providing alternatives or instituting regulations to enforce their uptake, transitions toward immaterialisation require more of a 'pull' strategy using marketing and carefully packaged lifestyle solutions to inform and attract people to alternatives (Simmons 2002:5).

Immaterialisation has the potential to make meaningful contributions to reducing the impact of human lives on natural resources. The ASSIST project conducted between 2000 and 2002 found

that 25% of present consumption could be avoided by immaterialisation, and that as worldwide living standards increase to allow the focus to shift from basic needs to quality of life, this figure could rise to 50% (Simmons 2002:3). With a range of technological and lifestyle options for achieving immaterialisation, it is a strategy that can help countries of all affluence levels to move beyond relative decoupling to achieve absolute decoupling.

2.6.3 Conclusion

South Africa's *Framework for Sustainable Development* describes efficiency as "...the key to accelerated and shared growth...", explaining that growth will be undermined by resource constraints and ecosystem degradation without it (DEAT 2007:22). Improving resource efficiency is indeed an important starting point for efforts to improve the sustainability of resource use in current infrastructural systems, but such strategies are unlikely to be sufficient in themselves to achieve an overall reduction in the country's ecological footprint and protect resources from depletion.

More substantial changes to the status quo are required. To realise this goal, the substitutions embodied in the concepts of freematerialisation and immaterialisation introduce the type of changes that threaten the familiar, allowing for development whilst making radical transitions toward absolute decoupling. It must be emphasised, however, that the four 'materialisations' are not mutually exclusive, and that both efficiency and substitution technologies have a role to play. Robèrt et al explain that "...a systems approach consistent with basic principles and the requirements of sustainability shows that these tools are complementary and can be used in parallel for strategic sustainable development..." (Robèrt et al. 2002:197).

2.7 Sustainable implementation of decoupling technologies

We have seen how a combination of efficiencies and substitutions can help to realise absolute decoupling, but the issue of implementing these strategies in the real world warrants further discussion. With this in mind, I will conclude by looking at how a transition toward the decoupling of urban infrastructures might take place and what steps can be taken to ensure that new technologies have the best chance of success.

The process of introducing sustainability principles to infrastructural systems does not necessarily require radical change (Hartshorn et al. 2005:179; Crane & Swilling 2008:265; Von Weizsäcker et al. 2009:18). Von Weizsäcker et al. believe that "...the process of redesigning, as radical as it may be in terms of a new philosophy, can be a gradual and smooth one, encouraged by prudently designed and predictably changing framing conditions..." (Von Weizsäcker et al. 2009:18). Crane and Swilling explain that "...systems change incrementally at the micro-level, as new modes of production and consumption get designed, constructed and implemented via the complex interplay of market forces, policy interventions and regulatory provisions" (2008:265). The process of change is not about destroying all that is familiar to make way for something radically new as much as it is about paying attention to channelling new funds in constructive directions that use resources wisely instead of reinforcing destructive and outdated ways of doing things (Von Weizsäcker et al. 2009).

Instead of a once-off radical change from unsustainable to sustainable, the processes of transformation can be seen to constitute a series of steps. Brezet, Cramer and Stevels liken the transition to a sustainable society to climbing a ladder (in Van Timmeren et al. 2004:12). The first step is making minor improvements to existing operations, for example reducing leaks and wastes. The second step involves optimising existing concepts within the constraints of technology, physics, chemistry and nature, and is a little more ambitious. The leap to the next step is more radical, and involves a great deal of research to come up with alternatives to existing systems. In this step, changes to infrastructure are accompanied by significant changes to institutions, policies, taxes and even lifestyles, requiring a commonality of purpose. Only then can the ultimate goal of a sustainable society be achieved. The ladder of Brezet, Cramer and Stevels is represented below:

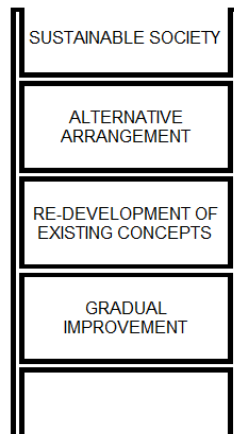


Figure 2.4: Ladder of Brezet, Cramer and Stevels (Source: Van Timmeren et al. 2004:13)

Following this analogy, dematerialisation and rematerialisation of infrastructure systems can be equated to the bottom two steps of the ladder. More radical changes in the form of freematerialisation and immaterialisation are likely to follow as significant alterations to the status quo manifest in broader society to provide the right framing conditions for sustainability. For absolute decoupling technologies to be successful, society cannot stay within the safe confines of the bottom two rungs.

It is important to note that while these steps are distinct in their scope and purpose, there is potential for multiple activities to take place concurrently. Moss finds that the introduction of radically new infrastructural technologies does not necessarily threaten existing systems or those with a vested interest in them (Guy et al. 2001:56). Marvin and Nielsen observe that multiple logics tend to co-exist rather than replace each other, and that the emphasis of change processes should be on integrating new systems with the old rather than replacing them entirely (Guy et al. 2001:81).

In reading through the literature on how decoupling might best be achieved through sustainable infrastructure technologies, I came across a number of themes that indicate that the challenge is far greater than the selection of an appropriate technology. The ensuing discussion collates these observations into 5 main points that act as important considerations in strategies for implementing new technologies aimed at decoupling.

2.7.1 Compatible incentives

Technology can help to reduce an individual's impact on natural resources whilst offering the same quality of life, but without an underlying motive to conserve resources these savings can easily be misdirected into equally damaging or more harmful activities. Rebound effects indicate that reduced consumption in some areas is not enough to constrain total resource consumption. There is wide recognition of the rebound effects from efficiency, but Alcott's theory of a

sufficiency rebound⁷ indicates that it might also apply to cases of immaterialisation and freematerialisation (Alcott 2008). If prices stay constant or trend downwards, there is a tendency for rebound effects to increase (Roy 2000; Fischer-Kowalski & Swilling 2010:54). Real resource prices have historically shown a downward trend as mechanisation has made extraction easier and faster, and as economies of scale have been realised. In light of the need to manage resources better to prevent their depletion, it appears that market mechanisms are inadequate and some kind of intervention is required to change incentive structures.

The pricing of natural resources to reflect their true value is an important requirement for their conservation. The WBCSD explain that pricing plays a pivotal role in whether businesses can financially justify eco-efficiency investments. Without the internalisation of negative externalities into resource prices, the profitability of such endeavours is limited and thus unappealing (WBCSD 2000:12). Artificially raising resource prices through taxation is an example of how this might be achieved, and can make efficiency an economically viable option whilst disincentivising increased consumption (OECD in Haberl et al. 2004:209). It can also be used as a means of accumulating funds for research and development of alternatives that would otherwise be unjustifiable to those motivated by profits (Bishop 1993).

While higher resource prices may help to manage demand, they can offer a perverse incentive for utilities to try to sell more resources rather than support conservation efforts. Incentive structures that connect greater consumption or waste production with higher profits for utility providers thus require revision if decoupling is to be pursued. Regulation has been used to great effect in California, where electricity utility profits have been decoupled from sales and incentives are in place to encourage utilities to assist their customers in improving consumption efficiency (Von Weizsäcker et al. 2009:275). This has allowed for savings on the construction of new generation capacity by delaying expansion or avoiding it altogether.

While financial and regulatory measures are admittedly not the only way to influence incentives, in a market-driven economy they can prove highly effective in manipulating motivations and behaviours in a relatively short period of time. The ultimate goal would be to achieve a society with some kind of moral or ethical obligation toward living for sufficiency rather than excess, but such measures are a useful substitute when faced with the urgency and scale of the transition required.

2.7.2 Contextual relevance

Contextual relevance is fundamental if a system is to be sustainable, and needs to be taken into account in the finer details of designing or adapting systems to work in a particular environment. Van der Ryn and Cowan describe sustainable design as occurring "... in the context of specific places. It grows out of place the way the oak grows from an acorn. It responds to the

⁷ Alcott's sufficiency rebound predicts that the reduced consumption inspired by sufficiency amongst the wealthy results in price drops that encourage others to occupy recently vacated market positions, thus negating the savings in total resource consumption.

particularities of place ... lending it coherence" (Van der Ryn & Cowan 1996:23). Marvin and Nielsen point out that in the case of infrastructure, a flexible approach to design is important "...because there is clearly no single notion of sustainable flow management... the concept of a sustainable infrastructure varies across cities... we cannot define one optimal pathway towards sustainable flow management" (in Guy et al. 2001:81).

Unlike green field developments, the urban context is complicated by a number of human artefacts that need to be taken into account before attempting to design alternative infrastructures. Guy et al. identify technical, economic, organisational and cultural differences as obstacles to the realisation of sustainable living environments in the city (Guy et al. 2001). Barton laments that "...housing, commerce, transport, recreation, energy and water have not only been 'planned' without adequate cross reference, but within each of those spheres there are divided approaches..." (Barton 2000:87). He says that as a result potential synergies between different functions (e.g. water, sewage and waste) are overlooked, perpetuating disconnections in urban spaces that lead to unforeseen health and ecological impacts. Von Weizsäcker et al. demonstrate that significant opportunities for efficiency that exist at the 'energy/water nexus' and 'energy/materials' nexus, and that multiple savings can be achieved simultaneously where infrastructures interact (Von Weizsäcker et al. 2009:50).

Contextuality often requires looking at the sub-city scale to understand how local neighbourhoods function as separate sub-systems and as part of the larger city. Codoban & Kennedy say that revising urban metabolisms needs to start on a neighbourhood level (2008), and Swilling suggests the use of sustainable neighbourhoods as "...building blocks for a sustainable urban future..." (2006). Guy and Marvin propose beginning the design process with a consideration of material and cultural relationships between production, distribution, circulation and consumption of resources for specific areas of the city, before looking at opportunities for environmental innovation within those. They warn that cities are not homogeneous so solutions may differ with demand patterns (in Guy et al. 2001:31). Engel-Yan et al. remind us that "...neighbourhood sustainability is ... highly related to the condition of infrastructure at the regional scale...", and that localised sub-systems need to take intra-urban systems like transport, water and energy into account due to their heavy reliance on them to achieve micro-scale objectives (Engel-Yan et al. 2005:52).

Selecting technologies appropriate for local conditions and adapting them where necessary is an important part of ensuring that they are not rejected by the system. This requires an in-depth knowledge of the details surrounding a specific location, the likes of which are unlikely to be embraced by conventional engineering and design professionals.

2.7.3 Whole-systems thinking

The problem with focusing on local context alone is that one runs the risk of losing sight of the larger issues that sustainable infrastructure ultimately needs to address. This requires that contextual solutions are constantly related back to larger systemic issues like resource depletion

and climate change. Von Weizsäcker et al. propose that the key to efficient design is “...asking the right questions before beginning a design...”, i.e. looking at the human need that must be met and designing from that starting point with the intention of minimising environmental impact throughout the process (Von Weizsäcker et al. 2009:30). Van Timmeren et al. emphasise that it is important to design infrastructure around social goals and needs, rather than adapting society to suit existing infrastructures (2004:12).

Von Weizsäcker et al. recommend ‘whole-systems thinking’ as a design approach, defined as “...a process through which the inter-connections between systems are actively considered, and solutions are sought that address multiple problems at the same time” (Von Weizsäcker et al. 2009:34). *The Natural Edge Project’s* 2008 book entitled “*Whole System Design: An Integrated Approach to Sustainable Engineering*” recommends the following design considerations (Von Weizsäcker 2009:35):

- Ask the right questions to meet the right service need
- Benchmark the optimal system
- Optimise the entire system
- Take all measurable impacts into account
- Design and optimise subsystems sequentially
- Design and optimise subsystems for cumulative resource economies
- Continuously review the system for improvements
- Model the system
- Monitor technological innovations
- Design with flexibility toward future options

Limiting options to narrow conceptions of what is possible based on predominant ways of thinking diminishes the potential for sustainability thinking. Birkeland observes that “...the present configuration of factories, city infrastructure, buildings, machines and tools, energy grids and road networks – and even policies and regulations – all bear the imprint of a particular form of thinking that has co-evolved within the context of an industrial model of development... characterised by the intensive use of fossil fuels and other forms of natural capital. This model is inherently non-sustainable” (Birkeland 2002:13). She says that while presently available technologies can help to reduce the energy and resources consumed by cities, without expanding thinking beyond current paradigms to whole system efficiency such endeavours can only serve to prolong the status quo rather than challenging it.

In the case of design, the challenge of breaking away from old ways of thinking toward whole-system thinking falls on architects, engineers and other designers as innovators (Du Plessis 2002:28; Hartshorn et al. 2005; Fischer-Kowalski & Swilling 2010:61). According to Hartshorn et al. (2005:172) “...the challenge of sustainability will manifest itself in the planning and management of engineering systems most significantly in terms of project scope and scale”. They explain that engineers traditionally have a limited focus and consider only immediate environmental impacts, but that the system-wide imperatives and inter-generational equity considerations that come

with sustainability thinking require that the scope be widened and the timescales lengthened to allow for broader perspectives. They also point out that sustainability innovation is best achieved through intra- and inter- industry collaborations that allow for the contribution of diverse perspectives (Hartshorn et al. 2005:177).

The whole systems approach to resource productivity overcomes some of the limitations of a narrow focus on in-house dematerialisation or eco-efficiencies as it considers human needs and opens up the potential for considering rematerialisation, freematerialisation and even immaterialisation. It allows for significant changes that are more in keeping with the urgency of the climate change crisis than tweaks to the status quo, and can involve making decisions in the interest of the whole that are detrimental to some of its parts. At times this can conflict with businesses' desire for self-preservation, and thus cannot be achieved through eco-efficiency alone.

2.7.4 Quantitative boundaries

An important accompaniment to whole-systems thinking required for absolute decoupling is being able to keep an eye on the target, which in the case of absolute decoupling is decreasing total environmental impact whilst maintaining or improving service delivery. Swilling and Fischer-Kowalski suggest that decoupling should be transformed into "...an operational tool that will help cities to determine their metabolic rates and the potential of different interventions to reduce these rates over time..." (Fischer-Kowalski & Swilling 2010:74). Determining these rates and setting appropriate targets for their reduction is thus an important accompaniment to decoupling technologies.

Although measurement and reductionist thinking is often inadequate in the face of the complexities of sustainability, it has an important role to play when dealing with finite limits. Meadows et al. describe a sustainable society as "...one that has in place informational, social, and institutional mechanisms to keep in check the positive feedback loops that cause exponential population and capital growth" (Meadows et al. 2004:22). Wackernagel et al. deem measurements to be essential for the effective management of natural capital, and liken it to keeping track of financial flows in order to be financially responsible (Wackernagel et al. 2006:103). Jackson cautions that local resource availability should not divert attention from overall global impacts when choosing appropriate measurements, saying that "...what count most in terms of global limits are worldwide statistics" (Jackson 2009:51). Measurement of a city's impact in relation to global resource limits should thus be considered in addition to local limits if the goal of absolute decoupling is to be achieved.

Monitoring progress toward sustainability requires quantification in a language that can be shared by socio-economic and natural systems (Haberl et al. 2004; Wackernagel et al. 2006). Moss recommends that efforts to optimise resource use start with measuring and modelling flows before targets can be set or strategies devised to achieve them (in Guy et al. 2001:10). According to Haberl et al, "...knowing how material and energy flows are related to economic activity or to

social well-being would greatly enhance our understanding of socio-economic driving forces of environmental change as well as our ability to change our behaviour” (2004:200). Material and Energy Flow Accounting (MEFA) is an example of an approach that aims to do just that, using easily quantifiable and readily available variables to track the relationship between socio-economic factors and the biosphere (Haberl et al. 2004:203). Applying such accounting measures to the management of infrastructures would allow for the establishment of design and performance goals relating to total limits rather than vague efforts in a general direction.

Once there is an understanding of flows, targets need to be set to ensure that they are put to best use. Alcott calls for a direct approach to absolute impact reduction, saying that “...since all changes in right-side factors of the $I = P \times A \times T$ equation change other right-side factors, such indirect attacks on impact should be abandoned in favor of supply and emissions quotas” (Alcott 2008). Similarly, Bishop calls for the introduction of policies “...that constrain the day-to-day operations of the economy in ways that enhance the natural-resource endowments of future generations...” (Bishop 1993:72). Setting boundaries would allow for individual interests to pursue efficiency in the management of resources within specified acceptable levels, and he recommends the adoption of ‘safe minimum standards’ for the depletion of natural assets so that they do not become extinct.

The relative merits of various methods for quantifying our impact on resource depletion and waste production can be debated, but the point remains that quantification is one of the best ways of setting goals and monitoring achievement towards them when there are large numbers of role-players. In most cases, natural resource limits and our contribution to depleting them can be accurately estimated, so quantitative analysis of how we are progressing toward the goal of reducing impact is possible. Not only is it possible, but it is necessary to prevent lapsing into relative decoupling by losing sight of overall impact.

2.7.5 Socio-institutional innovation

While there are thousands of technological solutions for sustainability, many of them fail when implemented due to an inability to work with surrounding social and institutional systems. Some might fall into the trap of thinking that new technologies are the solution to decoupling, but there are in fact three types of innovation that are necessary: technological, institutional and relational (Fischer-Kowalski & Swilling 2010:67). The challenge of innovation today lies not so much in the generation of new technologies as it does in a combination of tailoring them to the local socio-cultural context, and adapting the socio-institutional systems in that context to support changes toward sustainability. Investment in human and social capital is a crucial step in creating new, more appropriate framing conditions for the successful implementation of sustainable technologies (Von Blottnitz 2010).

Without changes to the rules and policies that have led to our unsustainable way of life, decoupling technologies are likely to struggle to establish a position for themselves. Meadows et al. point out that markets and technology are merely tools for achieving society’s goals, and doubt

whether they will ever be able to tackle the challenge of overshoot successfully. "If society's implicit goals are to exploit nature, enrich elites and ignore the long term, then society will develop technologies and markets that destroy the environment, widen the gap between rich and poor, and optimize for short-term gain" (Meadows et al. 2004:8). Costa et al. (2004) emphasise the importance of institutions in setting the rules for human behaviour and shaping urban flows. They say that institutions have a valuable role to play in internalising sustainability and decoupling principles within the city's metabolism, and should be considered as a major factor in studies of city metabolism.

Existing infrastructural systems come with a certain momentum supported by institutions, norms, regulations and standards that makes it very difficult for new technologies to succeed. Barton believes that "...the inertia of inherited investments and ... dissected organisational structures..." inhibit the recognition of opportunities that could improve local resource management (Barton 2000:100). Van Timmeren et al. (2004) find that existing infrastructures and the vested interests that surround them often act to restrict the implementation of sustainable alternatives. Montalvo suggests that cities in developing economies might have an advantage over their industrialised counterparts as there is likely to be less existing infrastructure to work around, less significant vested interests in outdated technologies, fewer regulations and relatively unsaturated markets that can be moulded to new kinds of behaviour (in Swilling and Fischer-Kowalski 2010:67).

Hartshorn et al. give the example of how inflexible client policies can limit engineers' ability to come up with truly innovative sustainability solutions. Rigid and compartmentalised procurement policies, prescriptive briefs and cost-minimising mindsets act to inhibit innovative design and the realisation of sustainable alternatives by the profession. They say that when "...project means are prescribed to the engineering trades, either through client cost or material specifications, codes, or regulation, lateral thinking and innovative planning and design are thwarted" (Hartshorn et al. 2005:173).

Where improvements in technological performance were once viewed as the main priority for successful alternative technologies, there is a growing recognition of the importance of management in the success of new infrastructure approaches. Guy et al. find that "...addressing the environmental problems of utility services has much to do with different styles of utility management. The challenge is to develop our understanding of how conducive the social organisation of traditional network management is to resource conservation and pollution prevention" (Guy et al. 2001:198). Moss finds that technologies deemed to be resource efficient in the past can even prove ineffective if managed incorrectly (in Guy et al. 2001:5). This view is shared by Barton, who says that "...the sustainable technologies, if they are to be adopted, imply change not only to the design but management structures as well" (Barton 2000:103). Effective management needs to ensure that changes are made to outdated approaches so that more appropriate technologies have a chance of survival.

Investment in change can be encouraged by the creation of a competitive market environment for utility services. Guy and Marvin find that in Europe, privatised utilities have changed their

business models and are now venturing “beyond the meter” to develop customised service offerings that help their users to reduce their bills and thus their resource consumption. The focus is primarily on big industrial users, but the scope is expanding to include smaller businesses and households. This signals a move away from a supply-led capacity expansion toward “...a major re-fashioning of relationships between users and utilities within which energy-saving activities can flourish...” (Guy et al. 2001:33). This change is not so much a result of changes in technology as the adaptation of the industry as a whole through significant investment in new institutional approaches.

Technology alone cannot solve the problems of an unsustainable city. In order to be effective it needs to operate in collaboration with the society it serves. As Guy and Marvin warn, it is only when the aims of technology and society are congruent and they are recognised as being two dimensions of the same socio-technical network can they work together to achieve sustainability (Guy et al. 2001:23).

2.7.6 Conclusion

The points above are based on lessons learned from some of the more frequent problems encountered in attempts to implement new technologies for sustainability. They emphasise that, although technological change is important, it is unrealistic to expect that technologies can simply be plugged into existing frameworks and expected to work. Successful implementation needs to come from both sides – adaptation of the technology to the context, and revision of the local environment to improve chances of success.

3. Infrastructure and sustainability in Cape Town

Cape Town is becoming known as a centre for sustainability thinking in South Africa, and the city has the most policies on environmental conservation and sustainable resource use in the country (Crane & Swilling 2008:267). Having established local environment conditions as a critical determinant of a new technology's success, I will now turn to the literature on Cape Town's infrastructural context before moving on to the case study analysis of technologies implemented in the city.

3.1 Existing literature

The few examples of South African literature pertaining specifically to urban infrastructural sustainability are based on Cape Town. What follows is a brief introduction to the literature pertaining to the city's metabolism and the relationship between its infrastructure networks and resources. As there are relatively few academic pieces on infrastructure as a general theme, I follow this with an overview of what has been written about sustainability in the energy, water and sanitation, and waste sectors in the city.

3.1.1 Limits and ecological footprints

In 2002, Gasson conducted a detailed investigation into Cape Town's metabolism in order to calculate the city's ecological footprint. He discovered that the city's residents significantly overshoot the 1.9 ha per capita calculated to be available within the earth's limits by the WWF in 1999, requiring an average of 4.28 ha each to support their lifestyles (Gasson 2002). Hansen (2010) points out numerous shortcomings of Gasson's calculation in her efforts to update his estimation, suggesting that the figure may be even higher. While the numbers can be argued, Gasson and Hansen's reports clearly show that Cape Town has significantly overshoot its ecological limits, making the current paradigm unsustainable in the long term.

Crane & Swilling (2008) provide a more comprehensive view of Cape Town's impact on the environment, looking at its energy use, water consumption, waste output, land use patterns, biodiversity loss, transportation issues and contribution to climate change. They find that the city is "...rapidly using up its natural resources in pursuit of growth as it seeks to eradicate poverty...", and that "...thresholds are now being (b)reached, which if ignored will generate dysfunctional economic costs that will undermine investments in growth and poverty eradication..." (Crane & Swilling 2008:280). De Wit et al. pick up on the issue of constraints imposed by natural resource limits on the city of Cape Town, and consider how the city could reduce the impact of external shocks to the system by making relatively simple changes to allow for demand flexibility (De Wit, Swilling & Musango 2008).

3.1.2 Sustainability of infrastructure in Cape Town

Swilling's 2006 paper entitled "*Sustainability and infrastructure planning in South Africa: A Cape Town case study*" stands alone in its consideration of sustainable infrastructure as a means of reducing Cape Town's ecological footprint. He questions the development benefits of infrastructural investments by South Africa's developmental state in terms of their sustainability, and points out that supplying conventional infrastructural services to the poor will not only increase total consumption of resources and production of wastes by releasing suppressed demand, but will place an increasing financial burden on them in the future as resources diminish and costs rise.

Swilling focuses on the impacts of Cape Town's predominant 'consumption city' paradigm on water, waste and energy resources, and shows how investments in eco-efficiencies could help to reduce current estimates of its ecological footprint to within the earth's carrying capacity. To create a more sustainable city, he proposes using sustainable neighbourhoods as building blocks and provides a manifesto for the construction of new neighbourhoods and improvement of others. He concludes by saying that "...sustainable urban infrastructure as the basis for building sustainable neighbourhoods is the only long-term hope for South Africa. It should be the only option worth considering" (Swilling 2006:52).

Crane & Swilling propose that Cape Town is well positioned to be a leader in sustainable innovations and see large-scale infrastructural investments as the ideal opportunity for new approaches to be implemented that allow for measurable reductions in unsustainable resource use. They propose a number of measures to address the resource problems experienced by the city, focusing on developing institutional capacity to support initiatives rather than elaborating on the technical details. They conclude that "...dematerialisation will need to be driven by a multiplicity of innovations inspired by the vision of a more sustainable future, but more importantly incentivised by public and private investments in knowledge networks, experiments, social learning and projects that gradually coalesce into the kind of substantive changes that will really make a difference." (Crane & Swilling 2008:284).

Swilling also looks at the impact that municipal budgeting and financial management has had on Cape Town's struggle for universal service delivery in energy, waste, water and sanitation (2009). He finds that budgets based on estimations of population growth are unfounded, and that service backlogs are continuing despite a significant portion of allocated budgets going unspent each year⁸. While waste production and total energy use have shown high sensitivity to population trends, he finds evidence of decoupling taking place in the city's water and electricity use, with per capita water consumption and growth in electricity use trending downwards from 2001 to 2006. Rather than being a result of new technologies, this decoupling came about as a consequence of external shocks like the 2001 drought and power blackouts, as well as the

⁸ Only 60-70% of capital budgets for EWWS have been spent on average over the last decade (Swilling 2009:9).

awareness campaigns and restrictions that accompanied them. Swilling uses this to show that it is possible to change resource consumption behaviour in the city, and suggests the innovative use of municipal budgets and financial measures inspired by sustainable resource use to realise savings that allow available funds to be most effective.

3.1.3 Literature on Energy, Water and Waste Infrastructure

In 2004, Swilling observed how the South African urban studies literature was barely being influenced by international thinking on sustainable cities (2004:78). He found that the focus of local literature was on the complex social and economic aspects of urban sustainability, but ecological dimensions were "...almost entirely absent..." (Swilling 2004:88). The situation has not changed much in the past 6 years, and it is rare to find over-arching discussions of the relationship between infrastructure and ecological sustainability in Cape Town. There is, however, a growing body of literature on specific infrastructural systems and alternative technologies that indicates that these issues are gaining attention. I will now look more specifically at the literature on energy, water and waste in Cape Town.

Energy

Energy appears to be one of the most talked about of the infrastructure systems in Cape Town. The issue receives high priority in the South African media due to power blackouts and price hikes that have affected the lives and jobs of ordinary South Africans. Cape Town's dependence on oil and a combination of coal and nuclear energy for its electricity is a major sustainability concern (SEA 2007; Jaglin 2009), and with significant changes in the policy landscape in recent years it is not surprising that the topic is now attracting academic attention.

Sustainable Energy Africa compiled a report on the sustainability of Cape Town's energy systems in 2007 as part of the *Integrated Resource Management for Urban Development Project* (SEA 2007). It identified the city's lack of power generating capacity and its heavy reliance on liquid fossil fuels as threats to the city's sustainability. It found that the biggest challenges to renewable energy alternatives were the costs of the technologies and problems relating to energy storage. The focus of the report was primarily on centralised electricity generation, with little attention given to local level energy solutions.

In her paper entitled "*Between electricity crisis and "green hub" marketing: changes in urban energy policies and governance in Cape Town*", Jaglin (2009) provides an in-depth account of Cape Town's energy history and the status quo, looking in more detail at the sustainability challenges faced by the city. She identifies the combination of international climate concerns with the local energy crisis as an ideal opportunity for decentralisation of power provision and improved demand side management which would allow the city to be more self-sufficient and resilient. There is an impressive and growing list of local, provincial and national policies and strategies that support sustainable energy options, but she finds that Cape Town's track record of implemented projects lags far behind.

Jaglin makes mention of a handful of projects, including the City's pilot projects to improve energy efficiency in its buildings, the *Energy Efficiency Initiative* (EEI) to improve awareness of energy saving measures, the Darling Wind Farm, Kuyasa's solar water heating installations in Khayelitsha and the city's proposed solar water heater by-law (Jaglin 2009). She blames the slow progress towards energy diversification on conflicting visions and poor co-ordination between levels of government, indicating the need for institutional reform as a precursor to technological change.

Nissing's 2007 PhD thesis on planning processes for sustainable energy includes Cape Town as an example of a 'southern' city, and goes into detail about the local policy landscape. He includes the Darling Wind Farm, proposed solar water heater by-law, Kuyasa and the Cape Flats Wastewater Works as case studies. Also in the field of policy, Winkler et al. (2006) propose a series of energy policy scenarios that would help to address some of the bigger problems faced by the city, a number of which involve transitions to new technologies.

The literature also includes more specific discussions around renewable energy technologies and their potential to contribute to sustainability in the city, though most of them are proposals or feasibility studies rather than accounts of projects that have been realised. These include the likes of Omar and Mncwango's investigation into the potential to harvest biogas from the Belville South municipal landfill (2005), von Blottnitz et al's investigation into the potential to transform waste into sources of energy (2006), Nissing and von Blottnitz's study of the potential for wood and paper waste to contribute to the city's renewable energy targets (2007), and De Villiers Leach's paper on the potential for energy efficiency in Cape Town's commercial building stock (2009).

Water and Sanitation

Pithey's report on the state of water and sanitation infrastructure in Cape Town gives an overview of the dire state of affairs faced by the city (2007). The main problems relate to its inadequate and failing water-borne sanitation system. The report states that only 3 out of 21 treatment works were operating at acceptable levels of compliance across all variables⁹. The pollution that results is supplemented by the impact of 30,000 impoverished residents without access to basic sanitation, leaking pipes due to inadequate maintenance, and overflows resulting from stormwater infiltration. Insufficient capacity is restraining development in some of the city's fastest growing areas, and is starting to have serious economic repercussions. With the recent completion of the Berg River Scheme, immediate supply of potable water is not considered a major problem. Anticipated city growth and the effects of climate change are, however, seeing recognition of the need for demand reduction measures and alternative technologies, but more pressing priorities have not allowed much room for research and development.

⁹ This figure has subsequently been improved as per the 2009 Green Drop Report (DWAF 2009).

Ziervogel et al. (2010) link the issue of water management to climate change adaptation in the developing world, using Cape Town as a case study. They provide insight into factors that promote and inhibit attempts to reduce the vulnerability of the city's water supply to climate uncertainty, focusing mainly on institutional attitudes, roles and relationships in the water sector. They conclude that adaptation efforts should focus on addressing urgent development needs so that they are not viewed as an additional burden.

The academic literature on sustainable water and sanitation technologies in Cape Town is rare. An example is that of the Lynedoch Eco-Village near Stellenbosch, where a number of innovative infrastructural technologies have been experimented with in the name of sustainability (Swilling & Annecke 2006; Dowling 2007). One of its more ambitious systems is its water and sanitation network, involving a combination of rainwater harvesting, water-efficient fittings, a constructed wetland system to purify water, a dual piping system to supply this water to the toilets, and a Biolytix sewage treatment plant that uses earthworms to break down solids (Swilling & Annecke 2006). Dowling's detailed case study on the eco-san systems employed at Lynedoch documents issues of performance and costs, but mentions nothing about the relationship between the systems and the context (2007).

In contrast to this, Armitage and his colleagues from UCT look at grey water management in two non-sewered areas on the outskirts of the city, and provide a rich insight into the role of context in shaping the success of new approaches (Armitage, Winter, Spiegel & Kruger 2009). Their investigation looked at the construction and use of basic soak-away systems as a means of reducing the negative health and environmental impacts associated with discarding used water onto the ground. While their approach achieved some success, it was designed as a low-cost interim solution to waste water disposal and did little to harness utility from the water in pursuit of resource conservation. Considering the re-use of grey water, Murphy has conducted comprehensive research into the potential for grey water to be used for irrigation in South Africa (2006). While not focused on Cape Town specifically, the report includes useful data from the city and surrounding areas. Murphy's paper is one of many pertaining to water conservation issues conducted by South Africa's Water Research Commission, but most of this is based on rural areas far from Cape Town (e.g. Kahinda et al.'s 2009 research on rainwater harvesting, and Duncker, Matsebe and Austin's 2006 work on urine diverting toilets).

The literature on water and its link to broader sustainability issues in Cape Town is dominated by discussions of the social inequalities exacerbated by the city's approach to distribution. Smith considers the distribution of water from a political ecology perspective, asserting that economic development policies aiming to achieve growth and equity are in fact reinforcing inequalities through the use of market-led distribution mechanisms (2001). Similarly, Smith and Hanson (2003) write of the inefficient management of water as a public good resulting from commercialisation. They show how cost recovery has led to underinvestment and cut-offs in poor areas, perpetuating territorial variations in service delivery established during apartheid. Smith expands on this idea, saying that neoliberal agendas have seen technical solutions prized over political solutions, to the detriment of the city's poor (2004). Jaglin focuses on the failure of

institutional changes surrounding the formation of the Cape Town UniCity to mend deep social-economic inequalities, using the case of water distribution to illustrate her point (2004).

Waste

With the tendency for civilisations to push waste to the fringes of society (see Satterthwaite 2003), it is not surprising that issues relating to Cape Town's solid waste have not attracted as much interest from academics as energy has. Engledow's report on waste in Cape Town is the most comprehensive overview of the city's problems and the measures taken to address them (2007). She explains how the focus has thus far been on end-of-pipe solutions to waste management, but the trend for solid waste to grow faster than the city's population means that this is no longer sufficient. Change is inhibited by institutional issues like outdated legislation, excessive red tape and the lingering effects of municipal restructuring following the creation of the Cape Town UniCity. Hope lies in the City's new focus on waste minimisation and prevention, ambitious plans for household recycling collection, and the development of less formal approaches to waste management that allow for the creation of low-skill jobs.

Engledow's 2005 Masters thesis on the Marina da Gama 'yellow bag' project provides a detailed account of Cape Town's first efforts at kerbside recycling collection (Engledow 2005). By looking at the economic, ecological and social impacts of this early attempt at integrated waste management in the city, she provides a rich insight into the sustainability of the approach along with unique observations of how contextual factors shaped it and subsequent initiatives. More recently, Tyrell has written about the lessons learned during the City's roll-out of kerbside recycling collection projects across a number of suburbs (2008). He finds that in the Cape Town socio-institutional context, success depends on a combination of contractor experience, political support from the solid waste management department, marketing support, strong community cohesion, councillor involvement and the inclusion of informal waste collectors. He warns of the importance of context in applying these lessons to other areas.

As with water and sanitation, the literature linking the broader issue of waste to sustainability in Cape Town raises a number of social rather than ecological issues. Miraftab writes of the negative effects that the neoliberal ideologies entering local government have had on waste collectors in Cape Town (2004). He says that cost recovery has led to the perpetuation of apartheid stratification of the labour force through the casualisation of labour, further exacerbating inequalities. Langenhoven and Dysse's study of the recycling industry in Mitchell's Plain provides a more hopeful vision, finding enormous potential for job creation in the collection, sorting, processing, manufacturing and re-use of waste (2007). Their case study provides a rich insight into the dynamics of this industry and how the Mitchell's Plain context has shaped its formation.

3.1.4 Conclusion

While there is a growing body of literature indicating an interest in sustainable alternatives to conventional infrastructure technologies in Cape Town, there is little that explicitly links the broad themes of infrastructure and resource conservation as a strategy for securing the city's longevity. The literature recognises the need for new approaches that decouple utilities from resource depletion in the city, but in the absence of references to realised projects it is implied that action is yet to be taken. A number of experiments and projects implemented in Cape Town indicate that this is not true, and the case studies that follow will provide evidence to support this.

3.2 Cape Town case studies

In response to the dearth of literature outlining Cape Town's transition toward sustainable infrastructure alternatives, this section provides an insight into what is happening on the ground. In a departure from the theoretical focus of preceding sections, the case studies document the interaction between sustainable infrastructural technologies and the complexities of the local context by capturing the experience of those who have laboured to bring their visions to reality.

The cases have been divided into those dealing with energy, water and sanitation, and waste to identify sectoral themes in three of the most vital areas of infrastructure. Together they tell the story of a city that is struggling in the face of significant challenges on a number of levels, but is slowly but surely embracing sustainability in its own way.

3.2.1 Energy

Introduction

Cape Town's economy is almost entirely reliant on energy from non-renewable fossil fuels. As the chart below shows, liquid fuels and electricity currently dominate the city's energy mix, with very little contribution from infinite sources of energy. While the impact of the transport sector cannot be ignored, the following case studies will focus on the reduction of demand for grid electricity as a means of decoupling modern lifestyles from non-renewable resources. The bulk of Cape Town's electricity comes from coal (50%) and nuclear power (34%), with the remainder made up of pumped storage hydroelectric (11%) and gas turbines for emergencies (5%). The contribution of renewables to Cape Town's energy mix is thus around 3% (Spencer in Jaglin 2009:5).

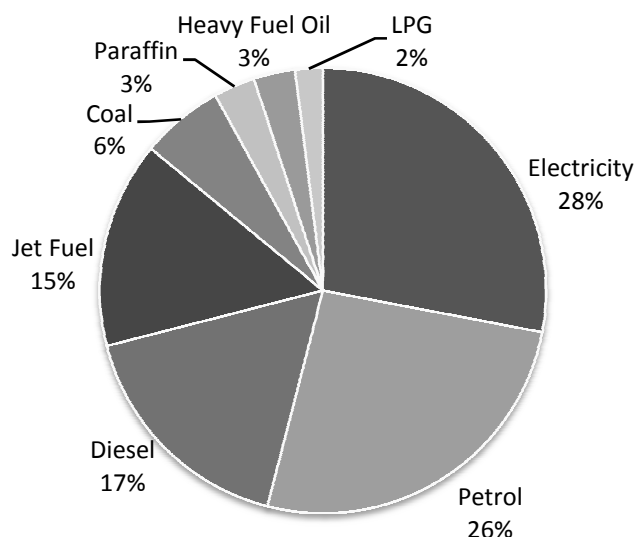


Figure 3.1: Cape Town's energy use by fuel type (Source: PDG 2007:25)

The convenience of electricity is commonly associated with progress and modernity, and since 1994 the South African government has pursued an ambitious electrification agenda to overcome inequalities from the past and improve access to electricity as a clean and safe alternative to the combustion of paraffin and biomass. In 2003, a *Free Basic Electricity Policy* was implemented to ensure that even low-income households would have access to electricity (PDG 2007), and those that use under 400kWh per month currently receive 50kWh free of charge (CCT 2009a).

Since the 1920s, the country's electricity generation and distribution has been for the most part controlled by the national power utility *Eskom*, whose mandate has been to supply abundant energy as cheaply as possible. *Eskom's* unchallenged status as the sole distributor of electricity has seen it become one of the largest single power utilities in the world, and it currently supplies about 98% of Cape Town's electricity (Jaglin 2009:5).

The basic assumption of government's electrification programme was that *Eskom* would increase supply using the lowest cost technology in order to keep pace with predictions of growing demand. *Eskom's* inability to plan for the future and Cape Town's vulnerability to its power management decisions have been dramatically illustrated in a series of power cuts over the last 4 years that have affected the lives and business interests of Capetonians across the board. Those with the resources to do so have sought to secure back-up supply as a precaution against future unreliability, and interest in reducing reliance on the grid has grown.

Eskom was forced to admit that it had failed to keep up with demand for electricity, and hastily announced plans to augment supply with multi-billion Rand investments in coal and nuclear power plants. Coal has traditionally been the most cost-effective source of electricity for South Africa, and as a result it provides almost 90% of the country's primary energy. However, the combustion of coal releases CO₂ gas amongst other pollutants, and cheap electricity has made the country one of the highest per capita greenhouse gas emitters, ranking 14th in the world (SA Info 2008). It has been estimated that the country's energy sector is responsible for 90% of the country's emissions (DEAT 2007:32).

Following international pressure, South Africa has agreed to a reduction in greenhouse gases of between 30% and 40% by 2050 under its *Long Term Mitigation Scenario* (Fischer-Kowalski & Swilling 2010:57). As a response to this, *Eskom* has promised to reduce coal's contribution to South Africa's primary energy mix from 88% to 70% by 2025 (SA Info 2008). Its primary means of achieving this is to match increases in coal generation capacity with expansion in nuclear power generation, which will see additional reactors springing up country-wide (SA Info 2008). While nuclear power may have an advantage over coal in terms of reduced greenhouse gas emissions, methods of nuclear waste disposal have not been tested for safety over the thousands of years that these substances remain hazardous. Contamination threatens the long term sustainability of the environments surrounding mines, nuclear power plants and waste disposal sites, and the short term gains of nuclear power come at an untold future cost. CO₂ emissions aside, it is difficult to make a convincing argument for how nuclear energy might be considered a sustainable energy option.

To finance investments in coal and nuclear, significant increases in the price of electricity will take effect over the next 3 years, forever sullyng South Africa's reputation as a country with cheap electricity. Unless electricity generation is freed from the use of finite resources, prices will continue to escalate as the extraction and transportation of coal and uranium become ever more expensive. With its reliance on *Eskom*, the City of Cape Town is highly vulnerable to energy decisions made at national level.

Growing disillusionment with *Eskom* is manifesting in the swift development of alternatives to reduce demand for grid power or replace it entirely. In the case studies that follow, I introduce two technologies that represent alternatives to the conventional use of grid power for modern conveniences. The solar water heater case looks at energy efficiency, and the small-scale wind turbine example deals with the decentralised generation of renewable energy. In the process, the future sustainability of energy services in Cape Town and the challenges faced by the City are elucidated, providing insights into the potential for decoupling of modern lifestyles from resource depletion, pollution and global warming.

Case Study 1: Solar water heating

Since the Cape's earliest inhabitants first migrated from the north, the sun has played an integral role in daily life in the region. Once used for basic tasks like preserving food, baking clay, drying laundry and separating salt from sea water, this resource has largely been replaced by convenient and cheap electricity supplied by the country's power stations. The ever-increasing use of electricity to enhance convenience has typically been considered a sign of modernity as people seek to replace the sun's energy with appliances that generate their own heat. In recent years, the sun's rays have once again attracted interest as a means of facilitating a new era of modernity in reaction to the environmental damage caused by conventional electricity generation.

The use of the sun to replace fossil fuels in the generation of electricity can be broadly split into the use of its light and heat. Solar PV panels convert sunlight directly into electricity, but are currently an expensive technology with potential for improvement. Solar thermal applications use the sun to heat fluids, and the resulting steam can be used to generate electricity. While conventional approaches to water heating require an electric element, a simpler approach is to replace the use of electricity with the sun's heat, thus significantly reducing or even avoiding the need for electricity. With this in mind, I will discuss the use of solar water heaters (SWH) as a means of reducing Cape Town's dependence on dirty energy sources.

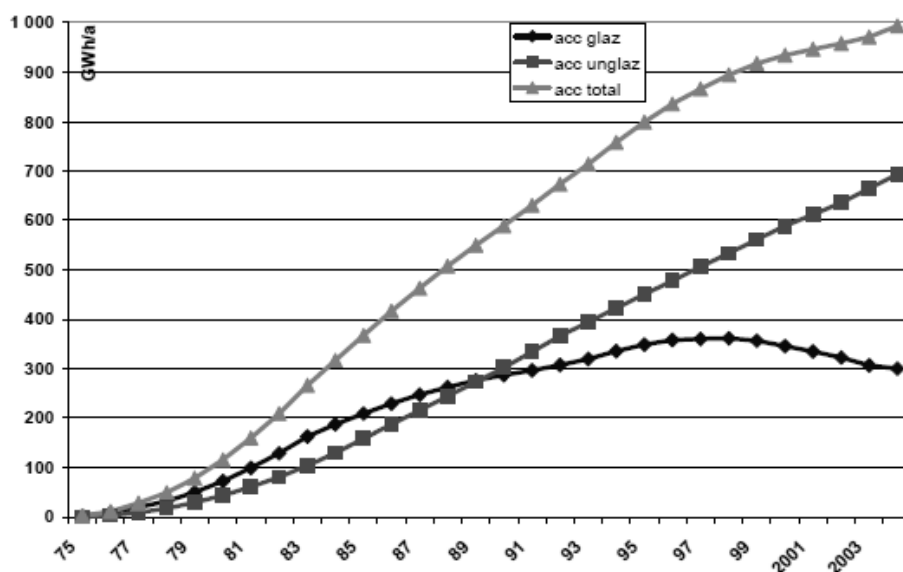


Figure 3.2: Annual energy delivered by active SWHs in South Africa (Source: Holm 2005:30)

Despite the government's relatively recent realisation of solar energy's potential, the use of the sun to heat water is an established technology in South Africa. The graph above indicates that the total amount of energy yielded from the sun in unglazed pool heating systems and glazed household water heating systems has grown since the mid 70's. Toward the late 90's, the total capacity of glazed systems started to drop as older units reached the end of their useful lives, but an up-to-date graph is likely to show this curve rising again in the recent years.

Solardome SA cc is one of South Africa's most established manufacturers of SWH systems, and was founded in 1969 by Gustav Lindenberg of Stellenbosch. He was inspired by the use of solar energy to heat water on a trip to the United States, and realised an opportunity to bring the technology to his home country. His early experiments were adapted and refined over the years as new ideas, coatings and glazing options entered the market, and the company now specialises in the manufacture of flat plate collectors and tanks. With *Solardome's* many years of experience, I decided to interview Lindenberg's son, Tertius, who took over the business in 1997. He says that his father was environmentally conscious but by no means an activist, and the business was more the result of a desire to capitalise on a good idea than a need to address world issues (Lindenberg 2010).

I also spoke to Robin Thomson of *Sunpower*, a supplier, distributor and installer of SWHs in Gauteng and Cape Town. Thomson is also the Treasurer of the *Solar Water Heating Division* of the *Sustainable Energy Society of Southern Africa* (SESSA). This interdisciplinary group of industry representatives, scientists, developers, researchers and members of the public is dedicated to renewable energy and energy efficiency, and plays an active role in supporting the development of the local solar industry in affiliation with the *International Solar Energy Society* (SESSA 2010). His overview of industry issues and engagements with government helped to provide a deeper insight into the industry.

How solar water heaters work

At their most basic, SWHs make use of the sun's energy to heat water instead of an element that requires electricity. Less efficient models using grid works of black pipes are suitable for lower temperature applications like pool heating, but those discussed here are of the glazed variety used to heat household water. There are a number of variables to be considered when designing and installing SWH systems that will affect their performance in different contexts. Of these, the collector type, the heat transfer fluid, and the manner in which it is circulated are the most fundamental (Swanepoel 2007):

1. Collector type: The two main types of collector used in domestic applications are known as flat plate and evacuated tube collectors. A flat plate is essentially a weatherproof box with a transparent glass cover, beneath which is a dark metal plate with metal pipes attached to its surface that circulate the heat transfer fluid. The glass allows heat to enter and traps it in the box, heating the plate and the pipes it is in contact with. An evacuated tube system consists of a series of parallel glass tubes containing narrower glass or metal tubes connected to a header pipe. The sun's heat is captured in the glass tubes and conveyed to a heat exchanger via the narrower tubes. The glass tubes and heat pipes are evacuated to reduce heat loss, and are capable of boiling water in 30°C climates. The evacuated tube systems allow the sun's rays to be harnessed for more hours of the day, and can achieve higher temperatures than flat plate systems.

2. Open-loop or closed loop: In an open-loop system, water circulates through the collector and returns to the storage tank. In applications with low external temperatures, it is not appropriate to circulate water through the collector as it runs the risk of freezing. Where water is hard or acidic, the build up of lime scale or accelerated corrosion can also prove problematic. In such cases a heat transfer fluid like a glycol-water antifreeze mixture can be circulated through the collector, with the accumulated heat transferred to the water via a heat exchanger. This is known as a closed-loop system.
3. Passive or active: Hot water's tendency to rise above cold water allows for a natural circulation of water through SWH systems in cases where tanks are positioned above the collector plates. Such 'thermo-siphon' or 'passive' systems function without pumps, whereas those with cylinders positioned below the collector plates require electricity to pump cold water up into the collector plate to be heated. While a passive system may use less electricity, they may be too heavy for some roofs and externally visible tanks can be unsightly.

Lindenberg estimates that 90% of their clients install passive systems with an electrical back-up for days when the sun is unable to heat the water adequately (2010). Based on a mains-supported system, SWHs can be considered an example of dematerialisation efficiency through a reduction in the amount of electricity required to heat water in the average year. The use of the sun's heat to replace that generated by an electric element could also be considered an example of freematerialisation.



Figure 3.3: Passive solar water heating system with flat plate collector by *Solardome*

The benefits of saving electricity through the use of SWHs instead of electrical geysers can be summarised as follows:

1. Savings on the amount of natural resources depleted to generate electricity.
2. Savings on the amount of pollution and greenhouse gases associated with the mining, transportation and combustion of fuels.
3. Savings on the amount of fresh water used in the cooling of power plants.
4. Reductions in reliance on the power grid.

The use of decentralised SWH systems also allows for savings on transmission losses that result when electricity is transported to the final user over long distances. Depending on the system, positioning the back-up element in the middle instead of at the bottom of the tank further improves electrical efficiency by reducing temperature mixing, and the use of management devices or timers can improve savings by an additional 30% to 50% (Eskom DSM 2010). Although most of the pumps in active systems run off mains electricity, some of *Solardome's* clients have installed solar PV as an alternative which would further reduce grid demand (Lindenberg 2010).

Domestic SWH systems are typically supported by the electrical grid and municipal water supply. Unlike electric geysers, Lindenberg explains that improperly designed SWH installations can represent a threat to users in the event of a power failure (2010). In systems where electricity is needed to circulate water, a power failure can result in a build up of steam in the pipes as the sun continues to heat the water above safe temperatures. This can result in explosions or the scalding of unsuspecting users via taps or shower heads. Systems that produce excessively hot water and do not include precautionary measures to cope with power failures can pose a severe safety threat, so it is crucial that the installer recommend appropriate specifications, assemble the system properly and educate the users about how to use it.

Performance

SWHs rely on sunshine hours to function, and South Africa is known to have some of the best solar energy conditions in the world. Cape Town's *State of Energy Report* found that the city has an average solar resource of around 5kWh/m²/day, but that this is lower than some other parts of the country due to cloud cover experienced in winter. As the map below indicates, there are better areas for the generation of electricity from the sun, but Cape Town's solar resources are considered to be sufficient for water heating (PDG 2007).



Figure 3.4: Annual solar potential in South Africa in average watt hours per square meter per day (Source: PDG 2007:51)

The heating of water for non-cooking purposes places a significant burden on Cape Town’s energy resources. In total, water heating is second only to cooking in terms of residential energy demand, and consumes 27% of the 21,605,308 GJ required by the sector (PDG 2007:32) . In middle to high income households where demand is not suppressed, it constitutes around half of the total energy requirement as per the chart below:

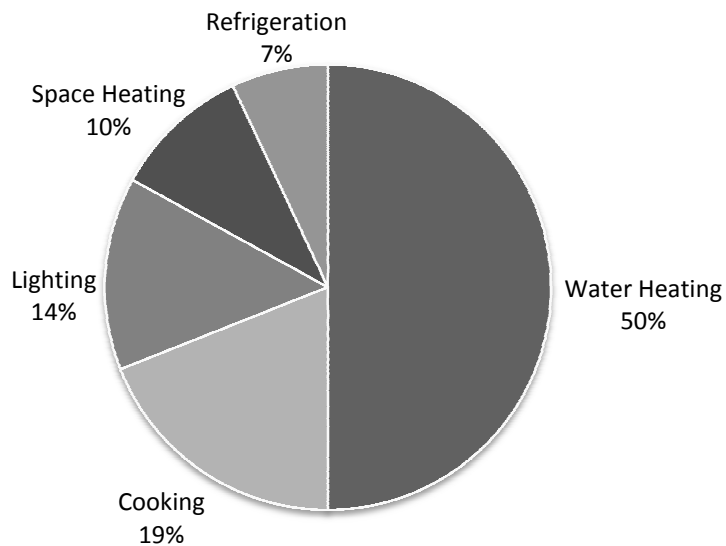


Figure 3.5: Average mid- to high-income residential energy consumption by activity in Cape Town (Source: PDG 2007:32)

Using a SWH instead of an electric water cylinder allows for a substantial portion of the electricity required for water heating to be replaced by heat directly from the sun. It is difficult to make generalisations about SWH performance as factors like their location relative to mountains and taller buildings, collector orientation and weather patterns will have an effect on how much of the

sun's energy can potentially be harnessed. System specifications and water usage patterns will influence how much electrical support is required, so Lindenberg recommends designing systems for each context to optimise their ability to save electricity (2010).

As a rough indication of SWH performance, *Eskom* has calculated that 70% of the electricity used for water heating can be displaced, equating to a 35% saving on a household's bill. The average energy saving on a 200 litre SABS approved system is around 5.67kWh per day at 16MJ of solar input (*Eskom DSM 2010*). According to the City of Cape Town, a SWH system for the average 4 member family would have cost between R7,500 and R12,000 in 2007, and would have been able to pay itself off within 5 years. Subsequent electricity price increases and rebates on SHW systems are likely to have reduced this payback period further (CCT 2007).

On the whole, well manufactured and installed SWH systems should last longer than electrical cylinders and require less maintenance over the years. Most SWH systems are guaranteed for 5 years but are expected to last between 10 and 15 (*Eskom DSM 2010*). Some of *Solardome's* installations have been in situ for over 30 years without problems (Lindenberg 2010). Good design, construction and use of materials enhance durability and make SWH systems easier to maintain, extending their useful lives to improve returns on investment.

Solar water heating in Cape Town

Given Cape Town's strong sun, the choice of an appropriate SWH technology is an important consideration. With over 40 years of experience in solar water heating in Cape Town, *Solardome* has found flat plate collectors to be better suited to the local residential market than evacuated tubes. Lindenberg believes that evacuated tubes are unnecessarily complicated and over-efficient, with undesirable repercussions in terms of safety, maintenance and longevity (2010). He says that these systems were designed to optimise the harnessing of solar energy in cooler ambient environments, and when used in Cape Town's Mediterranean climate, water temperatures can soar to over 200°C¹⁰. These high temperatures make them particularly susceptible to the hazards associated with power failures, and accelerate the degradation of materials and parts resulting in a loss of vacuum and heat transfer over time. For Cape Town installations, Lindenberg also recommends direct systems over more maintenance-intensive indirect systems as the city is not prone to frost.

The implementation of *Eskom's* R2 billion *Solar Water Heating Programme* in 2008 represents the most significant stimulus to the South African SWH industry to date. By providing rebates equating to 15-30% of the total SWH installation costs, the power utility hopes to promote the installation of 925,000 SWH units countrywide by 2013. This would equate to a saving of 578 MW of electricity, releasing some of the burden placed on the country's severely strained power generation infrastructure (Motau 2010). Those using an approved SWH system and registered supplier are eligible to claim their rebate from the programme's auditors in order to improve the financial viability of investments in SWH technology relative to an electric geyser, and the size of the rebate is determined by the potential for electricity savings (*Eskom DSM 2010*).

¹⁰ The commonly recommended temperature for domestic hot water is 50 - 60°C.

Eskom admits that the take up of SWH by the South African market has been slower than expected, due in part to the prevalence of functioning electric geysers not yet in need of replacement and the high cost of SWHs. Following an increase in the rebates in January 2010, *Eskom* observed an 89% increase in claims for the 6 months ending March 2010 against the previous 6 months. The total number of SWHs installed under the programme by the end of March 2010 was 3,445, equating to only 0.37% of the 925,000 unit target, but it is hoped that growing momentum combined with *Eskom's* awareness campaign will accelerate progress toward the target savings (Motau 2010). The rebate programme has increased the number of SWH suppliers in South Africa, and within its first year numbers increased from 10 to 150 (*Eskom DSM* 2010). However, this growth is not reflected in the number of rebate applicants, and it is likely that they represent only a small percentage of the total SWHs installed country-wide.

Lindenberg believes the rebate provides the financial motivation necessary for people to change from electric to solar water heaters, and commends its association with SABS standards for manufacturers and installers that have helped to formalise the industry and build credibility (2010). He also praises the formation of a dedicated *Solar Water Heating Division* within SESSA, which serves as a valuable 'watch dog' for the industry. SESSA membership has grown phenomenally in recent years, and it now plays an active role in supporting the industry through efforts to increase consumer awareness of SWH and develop training programmes for installers (*Eskom DSM* 2010).

While the rebate scheme has its benefits, Lindenberg is sceptical as to whether it is achieving the growth in local manufacturing and job creation originally envisaged (2010). From *Solardome's* experience, the volume of demand has not increased significantly as a result of the rebates. *Eskom* admits that the majority of SWH products used locally are imported, and believes that this is likely to continue to be the case in the short term until local manufacturing capacity has had time to adjust to increased demand. They say there is likely to be an intermediate phase of hybrid local-imported systems (e.g. imported collector with local cylinder) before the local components become more prevalent. They claim to be working on the issue with stakeholders and finance institutions both locally and internationally, and that they have been in negotiations with large role players about increasing local manufacturing capacity (*Eskom DSM* 2010).

Thomson believes that the local industry is fully capable of meeting significant increases in demand, but that a lack of large contracts being awarded to local manufacturers has caused a degree of market uncertainty that is constraining capacity expansion (2010). Lindenberg shares this view, citing examples of large-scale government projects in Nelson Mandela Bay, Khayelitsha and the Gauteng Metropole that were publicised for their use of SWH two years ago, but which have subsequently failed to materialise (2010). He is of the opinion that government's focus on low cost SWH technology is misguided as it largely excludes local manufacturers, and the reduced life spans of cheap products threaten to give the industry a bad name.

Lindenberg reports that the allocation of incentives within the rebate programme has had a noteworthy effect on the nature of demand for *Solardome's* products (2010). Instead of selling a variety of systems to suit each installation's requirements, demand has shifted in favour of their 300 litre unit due to the high rebate associated with it, and it now constitutes about 80% of their sales. Lindenberg explains that the way *Eskom's* incentives have been structured, it works out cheaper overall to install *Solardome's* 300 litre system than to have the 200 litre alternative due to a significantly larger rebate. The rebate is based on the high efficiency of the 300 litre system relative to an electric equivalent, but the value assigned is incentivising 200 litre users to install the cheaper 300 litre systems instead. The resulting use of excessively-sized systems is counter-intuitive if the aim is to save electricity, indicating perverse incentives in the allocation of rebates across the approved systems.

Public response

There is currently no accurate measure of the installed SWH capacity in Cape Town on public record (Thomson 2010). The City has set targets of 10% market penetration by 2010 and 50% by 2020 (Nissing 2007), but in the absence of reliable figures Wouter Roggen of the City's *Energy and Climate Change Sub-Committee* estimates that market penetration is only between 3% and 8% of water heaters at present. A 2006 survey estimated that there are around 478,000 electric geysers in the city, giving an indication of the size of the potential market (Roggen 2010). Thomson is critical of the City's lack of knowledge of the local SWH market and its growth, and believes this should be an area of focus in the promotion of SWH in Cape Town (2010).

While awareness and demand for SWHs have grown in recent years, there remains a degree of market resistance to the technology that inhibits wider roll-out. In addition to cost barriers, Lindenberg perceives a difference between South African homeowners and those in countries where sustainable energy is more prominent (2010). He believes that South African value perceptions are skewed, and that the majority of homeowners are more likely to buy depreciating status symbols like new vehicles than SWHs that pay themselves off and save money long into the future. Over the years, some have rejected solar systems for aesthetic reasons, claiming that they are unattractive, whilst others have felt threatened by the technical aspects of SWHs and have preferred to stick to the relative safety of 'conventional' electric cylinder systems. These observations point to a lack of public understanding of the benefits of SWHs and adherence to values which are not congruent with sustainability.

Lindenberg believes that low electricity prices have lulled South African consumers into a false sense of security regarding the impact of their energy use, and that *Eskom's* price increases planned for the next few years will serve as a catalyst to raising public interest in reducing electricity consumption (2010). Increased electricity costs will also reduce the payoff periods for SWHs, improving the financial viability of what is currently an expensive purchase. Despite the rebate system, the overall cost of a SWH installation remains a barrier to broader public take-up, especially for locally manufactured models. Lindenberg explains how the costs of SABS accreditation, the fixed pricing of metals at international levels, and expenses involved in employing a unionised local workforce combine to make local manufacturing costly. Solar systems

are also significantly more expensive than electrical cylinders as they require additional materials to make the collectors, and the tanks need to comply with higher insulation and corrosion standards.

The future of solar water heating in Cape Town

The need for energy efficiency and renewable energy has long been recognised as a crucial requirement for Cape Town's sustainable development. The *Integrated Metropolitan Environmental Policy* (IMEP) of 2001, the *State of Energy* reports of 2003 and 2007, and the *Energy and Climate Change Strategy* of 2006 all point to the need to reconsider the city's reliance on coal and nuclear electricity in the interests of energy security, but until recently not much has happened to indicate that this is being taken seriously by local government.

In reaction to the slow pace of progress, the City of Cape Town formed an *Energy and Climate Change Sub-Committee* in 2009 to champion the sustainable energy agenda in the city. According to its manager, Sarah Ward, energy security has only recently come to be considered part of a municipality's mandate to its constituents, and the lack of action by local government has been more to do with an unsuitable organisational structure than weak political will. Her sub-committee has been tasked with co-ordinating institutional change across 93 departments and 23,000 employees to make energy and climate change "everybody's business" (Ward 2010). One of their first projects was the formulation of a 161 project *Energy and Climate Change Action Plan* to translate various energy strategies into a task list with measurable objectives. This was approved by the Executive Management Team in March 2010, and some of its primary goals are:

- Objective 1: To reduce electricity consumption on unconstrained growth by 10% between 2010 and 2012
- Objective 2: To meet all growth in demand with renewable energy sources so that 10% of the city's energy will be from renewable or cleaner sources by 2020
- Objective 3: To reduce the energy consumption of council operations by 10% on unconstrained growth between 2010 and 2012.

The initial stages of the plan are biased toward energy efficiency rather than renewable energy as Ward explains that "...the bar is so low it is touching the ground, rotting..." (Ward 2010). While the City has traditionally relied on revenues from electricity sales, Ward points out that it has been possible to separate money-making from resource consumption in the provision of other services, and feels reassured by the fact that the previous head of the budget is now working on the City's energy portfolio.

One of the priority projects under the Action Plan is the *Solar Water Heating Advancement Programme*. It appears that the City has failed to achieve its target of having 10% of Cape Town's households fitted with SWHs by 2010, so a significant increase in installations will be required to meet the goal of 50% by 2020 (Nissing 2007). Ward reports that the City has been working on an energy efficient water heating by-law for the past three years which would focus on the use of SWHs in new buildings. The by-law has been in draft form since March 2007 but has not yet entered the public participation process, and has faced a number of challenges pertaining to

enforcement and legality that have prevented it from coming into effect. Future plans include the mass roll-out of 300,000 SWH systems in mid- to high-income suburbs by 2014, funded by property rates (Ward 2010).

Thomson is critical of the city's approach to promoting solar water heaters, and believes that their efforts have thus far been misguided (2010). While the City has undertaken an arduous process of trying to push through a SWH by-law, the SABS has been working on amending national building regulations to include a host of energy efficiency measures including sustainable water heating under SANS 10400-XA. In May 2010, a draft of the proposed regulations was released for public comment, and included the requirement that "...a minimum of 50% by volume of the annual average hot water heating requirement shall be provided by means other than electric resistance heating or fossil fuels..." (SABS 2010). It listed SWHs as one of the five options for achieving this, and stands to achieve much of what Cape Town's by-law aimed for, rendering it obsolete. It remains to be seen what the revised building standards will ultimately look like as the period for public comment on the first draft ended on 20 July 2010, but if it goes ahead as planned it is likely to further encourage the use of SWH systems in new buildings and renovation projects.

In Thomson's opinion, the City of Cape Town's legal approach to pushing SWH technology is likely to be a waste of money, and he says that they should rather focus on providing positive reinforcement for the industry by filling gaps not currently serviced by other institutions (2010). This could include overseeing the measurement of SWH performance and assessing the size of the Cape Town market in order to get an idea of progress toward renewable energy targets. The City could also play a role in disseminating information on SWHs and promoting success stories in order to change perceptions around the financial viability of investing in energy saving.

At a national level, the incentives behind SWH installation look likely to change with revisions to the Department of Energy's *Energy Efficiency and Demand Side Management* (EEDSM) policy. In June 2010, NERSA released a consultation paper for public comment that proposes the implementation of a 'Standard Offer Programme' that will either add to the incentives from Eskom's rebate programme or replace it. It is described as "...a mechanism to acquire demand-side resources (energy efficiency and electrical load reduction) by offering a predetermined rate for electrical demand savings (kW) and annual energy savings (kWh)" (NERSA 2010:4). Under this programme, organisations that deliver energy saving services can apply for rebates once energy savings have been measured and verified by a NERSA accredited entity. The rebates would apply to a wide range of energy saving devices including SWHs, and would be paid out monthly over 5 years instead of in the form of a once-off upfront payment. It remains to be seen what the outcome of the public participation process will be, and to what extent this new approach will stimulate SWH installations.

Case Study 2: Small-scale wind power

Cape Town's location and topography make it a city of strong winds. Temperature differences in the air above the land and sea cause thermal air currents, which are amplified by the coastal mountain ranges running through the city and its suburbs. Once known as 'The Cape of Storms', the city's residents have typically experienced the winds as a nuisance, but in light of energy and climate change challenges they are attracting interest for their potential to reduce dependence on the grid.

Since May 2008, the city has purchased a small portion of its electricity from South Africa's first independent wind farm in Darling, selling it on to Capetonians at a 25c premium per kWh via the grid. The farm has four 1.3 MW turbines, and the 13,200 MWh of electricity it generates contributes to meeting around 0.18% of Cape Town's electricity demand (Jaglin 2009). *Eskom* has built a demonstration wind farm in Klipheuwel, but this is currently not connected to the grid. According to the City, "...these are still relatively expensive options, and are thus unlikely to proliferate in the short to medium term..." (PDG 2007:51).

An alternative is the use of smaller scale turbines in urban areas to help reduce reliance on grid electricity. For an insight into the dynamics of decentralised wind power in the city, I spoke to Peter Becker, a Southern Suburbs resident who is making a name for himself with his homemade wind turbines. With a background in mathematics and computer science, Becker works as a software developer but has developed a keen interest in demonstrating that the general public can take energy issues into their own hands. Inspired by power blackouts in 2006, he realised that wind power could allow people to generate their own electricity without having to incur the substantial investment costs of off-the-shelf products. He is motivated by the desire to show up *Eskom* for their poor commitment to renewables by demonstrating how simple it is to harness energy from freely available natural resources, and he hopes to inspire people to question the parastatal and push for real reform in the energy industry (Becker 2010).

Becker has developed his wind turbine designs from scratch, and engages in a constant process of revision and improvement (2010). His early models produced minimal power, but with the aid of research and experimentation he has refined variables like the materials, construction methods, magnet sizes and blade shapes to improve energy yield and durability. His designs are constrained by a set of self-imposed parameters that specify the following (Becker 2010):

- Affordability, but with sufficient resilience to Cape Town's strong winds
- Materials and parts easily available at low cost
- Poses minimal risk in the event of failure or damage
- Compact and easy to mount by hand
- Low-tech construction requiring only a drill press and band saw

In maintaining a focus on ease and affordability of construction whilst ensuring safety, Becker offers a more sustainable alternative to expensive imported turbines or solar PV panels that are

currently the preserve of the wealthy. His focus on local materials helps to support domestic industry and small-scale operations, and reduces the transport impact of imported parts. He admits that in the absence of South African suppliers he has had to import rare earth magnets from China, but other than this he has managed to source all parts locally (Becker 2010).

In an effort to share what he has learned, Becker runs courses on constructing wind turbines for interested parties and does free talks at schools and events to broaden awareness of energy issues (2010). What sets him apart from the other interviewees is that he is not motivated by profit or the need to make a commercial success out of wind power. Instead of patenting his designs to recoup research and development costs and secure future revenues, he has made his intellectual property available to the world on his website www.windpower.org.za. He aspires to follow in the footsteps of Hugh Piggot, a Scottish wind turbine maker who has travelled the world teaching people to harness the wind and participated in a number of aid projects to bring power to the developing world.

How homemade wind turbines work

Small-scale wind turbines work similarly to electric motors, except that the cause and effect are reversed. Blades attached to a rotor are turned by the wind, causing rotational energy that is used to generate power. By moving strong permanent magnets in the rotor swiftly past wire coils embedded in the stator (attached to the tower), the rapidly changing magnetic fields generate an electric current in the wires. By varying the configurations of magnets relative to coils, a turbine can produce either double or triple-phase AC electricity, both of which can be rectified into DC power using a diode network (Becker 2010).

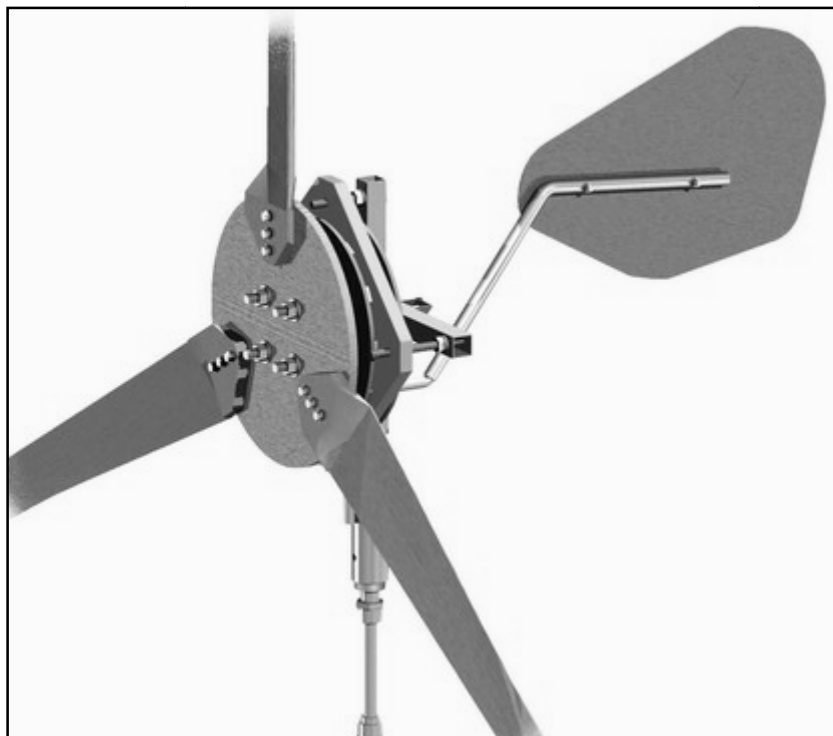


Figure 3.6: Computer image of a basic homemade wind turbine as per Becker's design
(Source: Wind Power 2010)

The ability to produce power from wind varies substantially with magnet strength, the number of magnets, number of coil windings, wire thickness, quantity and arrangement of wire coils, and it is not surprising that the maximisation of wind turbine efficiency has become a science of its own. Becker uses a combination of 24 magnets and 9 coils of enamelled copper wire embedded in epoxy to protect the metal from oxidation (Free as the Wind 2007). Having realised the importance of the alignment of magnets and coils, Becker has his rotor disks precision cut from 5mm mild steel using a stencil he has developed to ensure perfect positioning of the magnets and screw holes. His approach has been to aim for an acceptable yield of electricity between 250W and 500W, and to work towards it using trial and error. While he has endeavoured to improve efficiency where possible, he avoids complicated scientific theories and prefers to keep his technology accessible.

The design and construction of blades is also an important determinant of performance, with the number, diameter, width, length, taper, angle and aerodynamics of blades allowing for wide variations in the performance of a standard generator (Wind Power 2010). Initially carving the blades from balsa wood, Becker now uses a mould to set a sandwich of balsa wood, plywood and fibreglass in epoxy resin to allow for quicker replication and enhanced durability. Wind turbines also require a vane to keep the blades facing into the wind, and the supporting tower needs to be tall and strong enough to catch the wind without swaying or adding to turbulence. Becker advises using a steel pole with stainless steel stays for residential installations.

Rectified DC from the turbine is conveyed via wire to ground level, where it is stored in batteries for direct use in DC compatible devices, or via an inverter for conversion to mains voltage at 220V AC for lighting and small appliances (Wind Power 2010). Becker uses 'high cycle' batteries designed for trucks due to their longevity and relative affordability compared to deep cycle batteries. To prolong their lifespan, a low voltage disconnect circuit is used to protect the batteries from being drained below 12.2V. A dump load controller is used to divert excess power to a heating element or light bulb to protect the battery from overcharge in high winds. He makes use of a 24V system for safety reasons, and does not recommend higher voltages.

The use of decentralised micro-wind power to supplement grid electricity can be considered an example of freematerialisation and dematerialisation, as it uses freely available wind power to reduce but not eliminate household demand for grid electricity. In summary, small-scale wind power has the following benefits:

1. Savings on the amount of natural resources depleted to generate electricity.
2. Savings on the amount of pollution and greenhouse gases associated with the mining, transportation and combustion of fuels.
3. Savings on the amount of fresh water used in the cooling of power plants.
4. Uninterrupted supply of basic electricity during power failures.

Becker has also found that those who generate some of their own electricity are likely to be more conscious of their household energy use and are prone to engaging in complementary efficiency

measures (2010). He believes that the prominence of wind towers acts as an advertisement for renewable energy, and encourages urban dwellers to enquire about alternatives to grid power.

The maintenance requirements of a homemade wind turbine are likely to be more onerous than those of a high-precision factory-made model, and this route is not advised for those without basic workshop skills (Becker 2010). Moving parts introduce problems of wear and tear, and unprotected exposure to wind, rain and sun accelerates material deterioration. While Becker would like to develop a protective housing for his turbines, he has not yet had the wherewithal to build the required moulds. For each repair, the mechanism needs to be retrieved from above the tower and re-installed once fixed, making regular maintenance inconvenient.

Performance

The map below shows that Cape Town has one of the highest wind potentials in the country, experiencing velocities of over 4 metres per second. The combination of coastal location and mountain ranges generates conditions that have been described as ‘excellent’ for harvesting wind energy (PDG 2007). Peak winds can get so strong that they present a threat to poorly designed or constructed turbines, so it is critical that they are sufficiently robust to cope with the likes of the strong South Easterly ‘Cape Doctor’ that plagues the city in the early summer months.

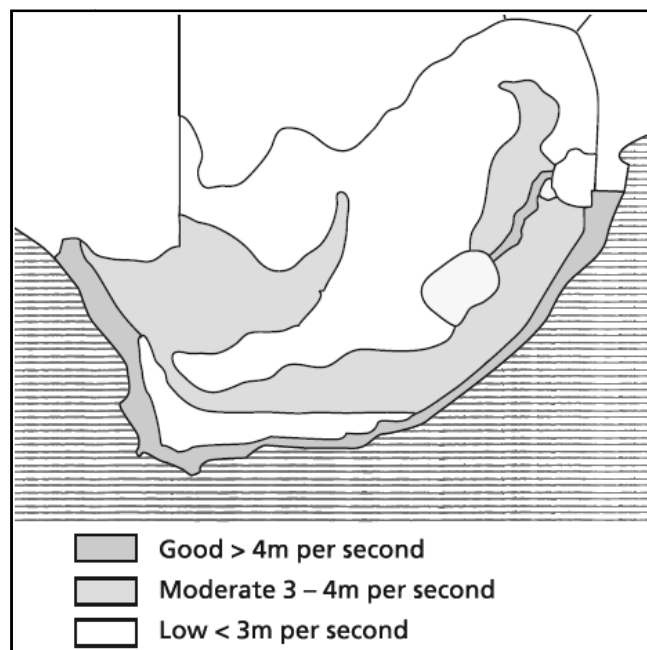


Figure 3.7: Wind generation capacity in South Africa (Source: PDG 2007:51)

The electricity yielded from a wind turbine is heavily dependent on its size, location and the prevailing wind conditions. Cape Town’s strong winds cause high peaks at certain times of year, but as with other renewable energy technologies the turbines are limited in their ability to provide uninterrupted electricity. Becker recommends that urban turbine blades should not exceed 1m in radius as larger sizes are less likely to be accommodated by neighbours (2010). The following graph thus gives a rough indication of the average and maximum yields that could realistically be expected per turbine in the city’s built up areas over the period of a year.

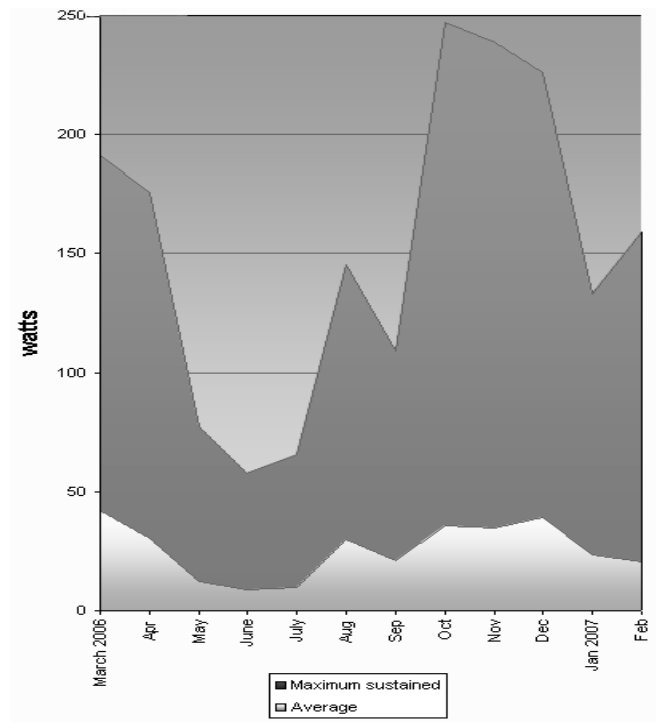


Figure 3.8: Wind power available from 1m diameter rotor in Cape Town between March 2006 and February 2007 (Source: Wind Power 2010)

Becker has not pursued quantitative analyses of wind turbine performance due to the complexities involved in metering (2010). Considering the limitations on rotor and tower size in urban areas and the fact that turbines typically operate at between 20% and 80% efficiency, it is highly improbable that current wind technologies would be able to meet the average suburban home's energy demand without support from other energy sources. Becker estimates that a turbine would be unlikely to supply more than a third of a household's energy requirements, and that this would be heavily dependent on its energy usage patterns. He admits that wind power currently has a long payoff period, and that solar water heating would be a wiser financial investment.

In addition to the cost of a wind turbine, the manner in which it is constructed and installed can add significantly to the total cost. While Becker has managed to keep the cost of his basic generator mechanism to between R3,000 and R5,000, the overall cost needs to include the blades, tower, batteries and other electrical devices depending on the application (2010). The inverters required to change DC to AC for a mains connection are currently prohibitively expensive, so Becker's prototype is based on a more affordable battery connection. Financial performance is highly dependent on the costs of maintenance, which are higher for coastal locations due to corrosion of metal parts.

Small-scale wind power in Cape Town

Becker has found Cape Town to be a receptive environment for wind turbine technology, but the processes involved in getting an installation approved currently present a barrier to those wishing to follow official channels (2010). While most of his students have not sought formal approval for

their handmade turbines, Becker knows of a case where a Cape Town installation was approved by following the correct channels. The home owner reported that the officials he dealt with were willing to help, but that the lack of precedent meant that it took a long time to work out what needed to be done and this resulted in unnecessary administration that would have put off someone less determined. Much of this has to do with the fact that a tower is regarded as a permanent structure that requires more levels of approval than a roof covering like a solar collector or PV panel.

Of the obstacles likely to be faced by those wishing to install wind turbines in the city, neighbours have the potential to pose the biggest challenge (Becker 2010). A wind turbine tower needs to be at least twice as tall as the highest structure nearby to avoid turbulence, and this poses threats to neighbours in the form of flickering shadows, obstruction of views and the risk of broken blades or a collapsing tower causing physical damage. Although Becker's suburban neighbours have been receptive to his turbine installation, others may not be as accommodating considering the prevalence of strong winds and mountain views.

In terms of the legislative environment, Cape Town's recently revised *Electricity Supply By-Law* is accommodating of decentralised renewable electricity generation (CCT 2010a). It specifies that all electricity generation equipment must receive prior consent from the Director, must have a Certificate of Compliance and must be isolated so as to prevent the mains from being re-energised. Anything more ambitious than supplementing one's own energy requires a special agreement with the service provider. With such arrangements, an electricity generating device like a wind turbine may be electrically coupled to and run in parallel with the supply mains, and allowance can theoretically be made for the export of surplus energy.

South Africa's approach to electricity service delivery at a national level presents a number of financial and technical challenges that add significantly to obstacles facing on-site renewable electricity generation in Cape Town (Becker 2010). Electricity prices are currently low by international standards despite recent increases, lengthening payoff periods and discouraging the development of a manufacturing industry for renewable energy technologies. The digital pre-paid meters designed to improve the collection of electricity service fees do not cater for excess electricity being fed back into the grid. While one can technically generate one's own electricity from renewables, current digital meters cannot measure surplus energy being fed back to the grid like they can in some other countries, preventing the possibility of financial incentives for contributions to supply. Besides turbines or PV panels, other accompanying technologies like batteries and inverters present a significant additional cost in South Africa due to the patents on their design. Becker would like to see government investment in the research and development of such devices, and the release of designs into the public domain to reduce the costs of wind and solar PV installations (2010).

Public response

In the years that Becker has been experimenting and teaching about wind power, he has been pleasantly surprised by the level of public interest (2010). Thus far, he has run three workshop

courses in manufacturing turbines, and has had enquiries from diverse groups of people connected by an interest in using their hands to gain some control over their energy supply. The majority are those from lower density areas better suited to wind turbines, but he has also instructed people living in urban areas.

The high cost of wind turbines and the associated paraphernalia makes them an expensive option for reducing demand on the grid. Becker only knows of about 5 installations of homemade turbines in Cape Town itself, and is unable to comment on numbers of those purchased from manufacturers to give an idea of the market (2010). He believes that electricity prices are not yet sufficiently high to act as a significant motivator to pursue small-scale generation, but views the media's focus on *Eskom* and its problems as free advertising for the renewables industry.

The future of small-scale wind power in Cape Town

For the use of small-scale wind power to become more prevalent in Cape Town, Becker believes that a streamlining of approval processes supported by well-considered regulations is necessary (2010). The processes currently involved in gaining approval are costly and time-intensive, and discourage people from following proper channels. Guidelines as to how best to implement wind power in urban environments would help to improve safety standards and formalise the growing industry, as has been the case with SWHs.

Becker believes that the City of Cape Town and the Western Cape provincial government are genuinely interested in advancing renewable energy, but that their hands are to a large extent tied by the *Department of Energy* and *The Treasury* at national level (2010). He commends the efforts undertaken by Sarah Ward and the *Energy and Climate Change Sub-Committee* in trying to work around these constraints and make Cape Town a leader in the field. Small-scale wind power is current being pursued as part of the city's goal to meet 10% of its energy demand with renewables by 2020 (Ward 2010). Technical specifications are being put together for industrial and commercial grid connections, and a research report has been completed on comparative legislation used elsewhere to facilitate the formation of zoning and building regulations for urban micro-turbines.

To improve the feasibility of supporting the grid, Becker believes that power producers need a financial incentive to make it worthwhile to contribute their extra energy (2010). A small-scale feed-in tariff accompanied by an alternative meter design would allow for contributions to the grid to be deducted from one's electricity meter at a rate higher than the cost of grid electricity. South Africa's first *Renewable Energy Feed-in Tariff* (REFIT) for large-scale generation of renewable energy was introduced in March 2009, and NERSA has indicated that future phases might allow for generators of less than 1MW to contribute too (Salgado 2009). For this to be feasible and accessible to small-scale producers, technical issues pertaining to net metering and billing will need to be resolved, and substantial institutional innovation will be required to streamline the bureaucracy involved in securing licences and negotiating PPAs.

At a more fundamental level, Becker believes that the battle between renewable energy technologies and nuclear power will determine the future of renewables in South Africa (2010). He has first-hand experience of the power and financial interests behind the pro-nuclear campaign, and identifies the repeated exclusion of nuclear waste impacts from feasibility studies as the main factor in making it appear more viable than renewables. He claims that the *Department of Energy* does not consider nuclear waste to fall under its jurisdiction, and has heard rumours that the disposal of these hazardous substances is considered an externalised cost in the new plant proposals currently being pushed through at high speed. A modicum of hope lies in the required public participation processes that may delay the placing of orders for new nuclear installations and allow time for more careful consideration, but Becker has found this process to be poor in the past. From his experience, the officials involved often fail to comply with requests for information before the end of the participation process, limiting the public's ability to form objections based on facts.

If nuclear gains the upper hand, it is likely that feed-in tariffs will continue to experience limited success. After over a year of stalling it remains to be seen whether any PPAs will be signed at all, and Becker claims that sources within *Eskom's* legal team have informed him that there is an internal mandate to obstruct the approval of PPAs (2010). He predicts that the longer the process of approval is dragged out, the more investors will start to lose interest in South Africa and look to more hospitable countries to establish renewable energy plants. Decentralised energy efficiency measures may retain some of their appeal for financial reasons as coal and nuclear power become increasingly expensive to generate, but the renewables industry looks likely to suffer in favour of large nuclear installations.

Conclusions

The preceding case studies show that there is a great deal happening both in Cape Town, at provincial level and at national level to change the energy environment in favour of efficiencies and, to a certain extent, substitutions in the form of renewable energy technologies. While the City is largely trapped by its reliance on *Eskom* and the national power grid, the establishment of its special sub-committee headed by sustainable energy champion Sarah Ward is a commendable step in the right direction, and shows a commitment to change. Ideally, climate change and energy security will one day be incorporated into the ethos of the Energy portfolio, but for now a separate entity allows for improved collaboration across departments and is less vulnerable to organisational inertia.

The City's *Energy and Climate Change Action Plan* is also an important signal of commitment to translating policy promises into action. Its main focus is on improving the city's public transport infrastructure, which is easy to justify given the city's current addiction to liquid fossil fuels shown in Figure 3.1. Secondary to that, there is a budgetary bias toward eco-efficiencies that minimise resource and financial losses simultaneously. These include energy efficient retrofits of municipal buildings, libraries, clinics and rental stock, and the replacement of energy-intensive streetlights, traffic lights and pumps to reduce the amount of energy the City requires to function whilst saving money and resources. The plan also favours opportunities for the City to generate energy from municipal operations like the harvesting of biogas from water treatment works and landfill sites, and the use of urban water flows to generate small-scale hydro-electric power. Looking beyond eco-efficiencies, the plan includes initiatives relating to public education, research and development, improving climate change resilience, investigations into the potential for carbon trading, the development of feed-in tariffs for South African cities, and plans for a more sustainable urban layout in line with the world's most forward-thinking cities.

When weighing up the benefits and disadvantages of decentralised renewable electricity generating technologies and SWHs, it is evident that SWHs are the low-hanging fruit. The City's decision to focus on them is justified by their relative affordability, simplicity of construction and installation, and easily proven contribution to energy efficiency. At this stage, there are too many technical, financial, legislative and institutional barriers to small-scale renewable energy generation and feed-in tariffs to make them a worthwhile focus for short term energy strategies, and SWHs present equal if not greater potential for reduced grid dependence. The *Action Plan's* approach to developing zoning regulations and specifications for commercial grid connections of wind turbines makes sense as a middle ground between the small scale of residential units and large wind power plants. Installation costs and the expertise required to maintain and operate small wind turbines puts them out of reach of the general public, but businesses may be better able to justify investment in a serviced system and, depending on the location, could potentially get away with larger, more effective systems.

While there have been a number of teething problems with SWH incentive schemes, the fact that action has been taken nationally to reduce electricity through a demand side measure signals a shift in mindset with the potential to carry through into other areas. A degree of refinement is required, but the learning curve has been worthwhile both for the energy sector and other areas like water where decentralised demand side measures may be necessary in future. The effectiveness of the SWH rebate is questionable, but imminent changes in building codes and the proposed *Standard Offer Programme* could soon see an evolution in the approach to encouraging energy efficiency that is more conducive to stimulating context-appropriate innovation.

The City's legalistic approach to SWH appears to have been premature, and in light of national level interventions it would be wise to channel these efforts into supporting the industry instead. Improving the monitoring and measurement of installed capacity and educating the public about SWHs and how they can be of benefit would help to change attitudes in favour of the technology, and could break down some of the stigmas and outdated values that inhibit it. Due to the significant role of state-level decision making in energy matters, it is crucial that the City keep an eye on developments in the field and act to fill gaps rather than taking on national government roles.

South Africa has significant paperwork proclaiming support for renewable energy and energy efficiency, but there is an underlying resistance on a number of levels that is slowing progress and limits the City of Cape Town's ability to pursue sustainable energy alternatives. A fundamental conflict of interest exists between the financial need to profit from the sale of electricity and the need to reduce demand for electricity through efficiencies. If this is to change, incentive structures for *Eskom* and municipalities must be revised, and this will only be possible with support from the highest levels of government.

At the same time, the legacy of the so-called "mineral-energy complex" inhibits change with significant vested interests in retaining and growing the market for the country's coal. Government has an interest in supporting the mining sector as a key employer of low-skilled workers, so it is understandable that efficiency and renewables will struggle to gain ground when decision makers are focused on returns and the protection of dirty industries. The pressure for a sustainable approach is relatively insignificant when weighed up against the challenges of change, so aside from a few placations on paper such as the thus far ineffectual REFIT, the status quo remains largely unchanged.

Proactive price increases by NERSA could help to stimulate consumer participation in demand reduction whilst allowing more funds for investment in the development of electricity generation that is not tied to dwindling resources. Variable pricing according to the time of day would allow for better management of peak demand, but current pre-paid meters do not allow for such incentives. The *Free Basic Electricity* allowance and inclining block tariff structure is designed to protect the poorest of the poor, so the discomfort of higher prices would encourage big consumers to invest in alternatives without requiring too much involvement from government. Unfortunately, *Eskom's* legacy of poor planning for capacity expansion is seeing price increases

used to finance new coal and nuclear plants, and the commitment to these unsustainable energy sources will have negative environmental, human and financial impacts for decades to come. The opportunity to revamp South Africa's centralised power grid into a combination of efficiency and renewables is being largely missed, and the negative impact of *Eskom's* unsustainable choices look to dilute Cape Town's energy sustainability efforts in the short term.

NERSA's recent approval of electricity price increases signals the start of a larger trend linked to the rising costs of coal and uranium extraction, processing, transportation. As greenhouse gas restrictions become more stringent and international pressure for goods and services produced with clean energy grows, previously externalised costs will also come into play. A silver lining can be found in the market reaction to current and future increases of electricity prices, which are likely to lead to greater improvisation in reducing grid dependence. While a more proactive approach at a national level would be ideal, at least Cape Town appears to be thinking along the right lines and indicates a commitment to decoupling in its approach to energy.

3.2.2 Water and sanitation

Introduction

South Africa's Constitution gives its citizens the right to an adequate supply of fresh water, and the right to an environment that is not harmful to health or wellbeing. The *National Water Act* of 1998 is recognised as being one of the most progressive in the world, and in accordance with this South Africa's water policies and strategies are based on principles of equity, efficiency and sustainability. In an effort to redress inequalities of the past and give all of its citizens access to water and sanitation services, the City of Cape Town achieved 100% access to basic fresh water by 2006 and is aiming for universal access to functioning basic sanitation by 2012 (Pithey 2007). To protect the poor, the City supplies 6,000 litres of water for free and allows for 4,200 litres of waste water to be added to the system by each household every month at no cost (CCT 2009a). While efforts to improve access to basic water and sanitation are noble, the manner in which services are being delivered threatens the city's precious water resources, and there is a dire need for approaches that protect them for future generations.

When Cape Town was first colonised and developed as a refuelling station for ships rounding the Cape of Good Hope, it was known for its fertile lands and fresh waters. Long before the city's construction, the area was known by the indigenous Khoi people as Camissa, meaning 'place of sweet waters' (CTP 2010). For centuries the growing city was able to survive on this water, but as it expanded it required water from elsewhere to quench its thirst. A series of dams were constructed on the city's mountain slopes and in surrounding areas, most notably the Wemmershoek Dam near Franschoek, Theewaterskloof Dam near Villiersdorp, Voëlvlei dam near Gouda and, most recently, the Berg River Dam outside Franschoek. Collectively, dams now supply 98.5% of Cape Town's fresh water (Pithey 2007:46).

The amount of water available in Western Cape dams is highly dependent on winter rainfall patterns, and water levels are carefully monitored throughout the year to calculate how long the water will last. When it looks like there will not be enough water to meet the city's demands before the next anticipated rains, water restrictions can be implemented to reduce non-essential use. Where it has been relatively straightforward to predict rainfall and dam levels in the past, climate change is likely to result in unforeseen variations in weather patterns that will make it more difficult to manage supply. A 2002 study by UCT's *Climate Systems Analysis Group* found that Cape Town is one of the areas in Africa whose water supply will be worst hit by the effects of climate change. A drop in rainfall of between 10% and 20% is predicted by 2070, resulting in the city losing more than half of its perennial water supply (De Wit & Stankiewicz 2006:1919). Following the completion of the Berg River Dam, options for enhancing the city's water supply are limited and in most cases highly expensive.

While Cape Town's fresh water resources are threatened by changes in climate, its groundwater reserves and aquatic ecosystems are being devastated by excessive volumes of untreated waste

water overflowing from treatment plants. The resulting pollution also poses a serious health threat to humans in the form of ecoli and other harmful bacteria. A 2007 report revealed that the city was struggling to keep up with the expansion of demand for water-borne sewage systems, and that a lack of treatment capacity was curtailing the development of new areas (Pithey 2007). The 2009 *Green Drop* report on the country's water treatment facilities revealed that the performance of Cape Town's 23 plants is above average for South Africa, but that only 8 of them achieved Green Drop status in line with best practice (DWAF 2009).

With limited capacity to increase water supply and constraints in our ecosystems' ability to maintain balance in the face of untreated waste water, there is a need to consider more sustainable approaches to managing the demand for and supply of water and sanitation services. In the case studies that follow, I will consider two decentralised water conservation measures with benefits for water and sanitation infrastructures, namely rainwater harvesting and the use of grey water for sanitation. While these approaches are not advocated as the only way in which water resources can be more effectively managed, the investigations provide insight into the likelihood of decoupling life in Cape Town from the deterioration of its fresh water resources.

Case Study 3: Rainwater harvesting

Measures to reduce demand for water ease the burdens placed on supply, and are a means of preparing for future water scarcities. The need to change our wasteful ways has long been recognised by Pinelands-based inventor and water conservationist Jeremy Taylor, and was the inspiration for the formation of his business *Water Rhapsody Conservation Systems*. Originally from a background in Botany and Zoology, Taylor worked as a Councillor for the Cape Town municipality for 4 years in the early 1980's, and developed a keen interest in the City's water issues. He subsequently experimented with a number of approaches to harvesting rain water and re-using water around his home, and decided to turn this into a business in 1994.

Taylor attracted attention from the media in 1997 when he received the WWF's Green Trust Award for innovation in the field of water conservation for his *Garden Rhapsody* grey water irrigation system. Over the years he has designed and produced a wide range of water saving technologies suitable for urban applications. These include the *Grand Opus* rainwater harvesting system, the *Rain Runner* rain filter, the *Poolside Tank* swimming pool backwash filter, the *Second Movement* grey water toilet flushing system, the *Multiflush* water-saving toilet flusher and, most recently, the *Poseidon Advantage* grey water filtration system. Starting from scratch, he has grown the business through a series of franchises located in 17 localities country-wide, and has become an expert in household fresh water minimisation in Cape Town.

Whilst interviewing Taylor, it was clear from his knowledge of water supply issues, rainfall patterns, eutrophication and soil toxicity that he has more than a business interest in conserving water. He laments the effect that the canalisation of water courses has had on the destruction of the city's waterside ecosystems and the consequent rise in pollution of river and sea waters, and believes that harnessing the run-off from hard surfaces for human use would simultaneously reduce the need for additional water supply and canals. With lower volumes and speeds of water through canals, waterside ecosystems could be re-established to purify it free of charge, and more water would be able to permeate the soil to support plant life and replenish aquifers (Taylor 2010).

Taylor hints at an almost religious compulsion to advance the water conservation agenda in South Africa, and his passion is infectious. Rather than looking elsewhere for ideas, he admits that much of his inspiration comes to him in his dreams, and he feels driven to bring his ideas to life through experimentation and constant design improvements (Taylor 2010). He is one of the city's foremost thinkers in terms of demand side management, and where similar companies have come and gone, Taylor has persevered through the hard times and established the *Water Rhapsody* brand as a leader in the field.

How rainwater harvesting works

At its most basic, rainwater harvesting involves collecting rain from a hard surface and channelling it into a container for storage and future use. Most urban homes have a system of gutters and downpipes to collect rainwater from the roof and direct it into stormwater drains to prevent

flooding and erosion during heavy rains. The simplest rainwater harvesting installations typically divert these downpipes into water tanks, and use the water for external purposes like irrigation, topping up swimming pools or cleaning cars.

Over the years, Taylor has experimented with a number of approaches to optimise the utility that can be derived from rainwater, and has arrived at a system he calls the *Grand Opus*. In this design, water from the gutters is filtered via a self-cleaning device in the downpipe called the *Rain Runner* that removes leaves and particles larger than 500 microns (including mosquito larvae) (Taylor 2010). The downpipes run below the ground, and are connected by a ring main that runs around the building and feeds into the storage tanks. The hydraulic effect ensures that the water level is consistent throughout the downpipes and connected tanks, and this allows for tanks to be stored away from the house and out of sight.

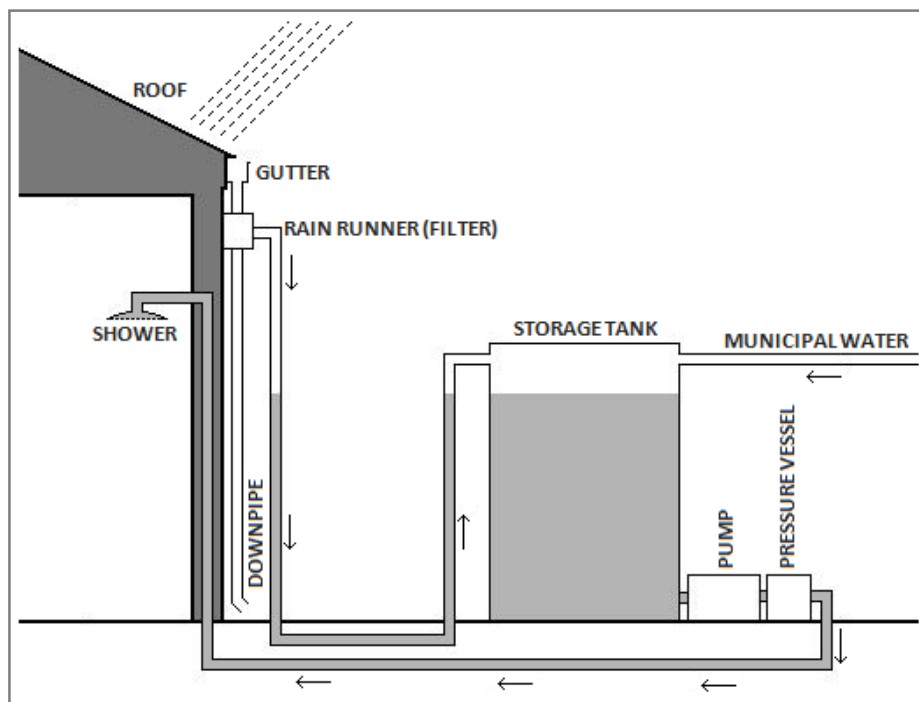


Figure 3.9: Grand Opus rainwater harvesting system (Derived from Water Rhapsody 2010)

To optimise the system and improve returns on investment, Taylor has observed that a middle ground needs to be reached between having the tanks standing too full or too empty, and that it is best to install smaller tanks and use as much of the collected water as possible by extracting it frequently (2010). With this in mind, he has adapted the system so that it can meet the majority of household water requirements and thus derive the most utility from water collected. The *Grand Opus* contains two pressure vessels which meet immediate water demand when a tap is opened, and activate pressure switches connected to an electric pump once their water levels start to drop. The tanks are fitted with an emergency supply which uses municipal water to prevent the water level from dropping below 600mm from the bottom.

Taylor believes that rainwater is a suitable replacement for the majority of household water uses, and his own home is supported almost entirely by a *Grand Opus* system (2010). Rainwater is used to supply all hand basins, baths, showers and appliances in the house with the exception of a single cold water tap in the kitchen to be used for drinking and food preparation. This is typically supplied by municipal potable water as the storage of water for drinking purposes requires stricter control and additional processing at a higher cost.

The *Grand Opus* system is surprisingly maintenance free and is designed to operate with minimal owner intervention (Taylor 2010). The main requirement is that the pressure vessels are re-pressurised every 3 months using a stirrup pump that comes with the system. This process is similar to pumping a bicycle tyre and only takes a few minutes. By law, the tanks require cleaning at least every 5 years (CCT 2006), and the electric pump requires replacement every 6 or 7 years (Taylor 2010). Other than the normal maintenance required to keep gutters clean, there is no need for additional intervention as the *Rain Runner* is designed to wash leaves and large particles off the filter and prevents them from blocking the pipes.

The *Grand Opus* rainwater harvesting system can be seen as an example of freematerialisation and dematerialisation as it makes use of free rain water to replace a portion of that supplied by the municipality. By storing rain water in on-site tanks instead of transporting it over long distances from dams, rainwater harvesting systems can contribute further to dematerialisation in the broader system as losses of water from evaporation and leaking pipes are also reduced. The benefits can be summarised as:

1. Significantly reduced demand for municipal water. Taylor estimates that over the period of a year the average consumer's daily potable water demand can be halved from 240l to 120l with the use of rainwater, resulting in resource savings and financial benefits (2010).
2. Reduced demand for the municipal infrastructure required to capture, store, cleanse and transport water, alleviating pressure for capacity expansion.
3. Reduced volumes of water entering stormwater pipes and canals from urban hard surfaces. This reduces the risk of flooding, and at scale could allow for cement canal linings to be removed in some areas to resurrect waterside ecosystems.

When considering the percentage cost savings associated with reduced water demand, it is important to note that they will always be higher than the percentage of water saved, i.e. a 20% saving in water consumption saves significantly more than 20% of the water bill (Taylor 2010). This is due to the current block-rate tariff system that charges incrementally higher rates per kilolitre for water according to how much is consumed in total. There is no flat rate for water, so savings would come from the most expensive part of the tariff paid. In addition, sewage costs are calculated as a fixed percentage of water consumption, so there is a knock-on saving in sewage rates.

While *Water Rhapsody's* rainwater harvesting system significantly increases independence from the grid, it relies on electricity to circulate water to the household and falls back on municipal water supplies when rains are insufficient (Taylor 2010). In the case of a power failure, connection

to the water mains can be re-established by simply turning a tap. In the event of mains water being cut off, there would be a small reserve of water in the tanks. If the tanks were to become contaminated by dirty municipal water, for example when work is conducted on broken pipes, they could be drained via a tap and cleaned before being refilled.

Performance

Cape Town experiences a Mediterranean climate, characterised by hot summers and winter rains. In his years as a resident of the city, Taylor has observed how rainfall patterns have changed as a consequence of broader climate change (2010). Up until around the 1980's, winters were typified by a few weeks of driving rain, interspersed with a day or two of no rain. Today, the city seldom sees more than 3 days of rain at a time, and it is not uncommon to experience several days of sunshine mid-winter. Soil requires a certain degree of saturation before runoff can occur, and as rainfalls are now shorter in duration, less rain is available for runoff into rivers and dams. During the winter months, the use of rainwater from the roof can allow buildings to run almost entirely independently of municipal water. Cumulatively, this relieves pressure on dams struggling to re-fill themselves in time for summer and reduces the potential for urban flooding that is regularly experienced with the build up of stormwater on hard surfaces.

The amount of water that can be harvested from a roof can be determined by the rainfall, the roof area, and the roof material. Metal roofs have a greater rainwater harvesting potential than tiled roofs as tiles absorb heat and encourage evaporation of water before it reaches the gutters. Taylor says that for every 100m² of metal roof area, 1000l of rainwater can be gathered with 11ml of rain (2010). Tiled roofs would require 16ml of rain to achieve the same yield.

The installation of a full *Grand Opus* system represents a sizeable financial investment of over R27,000, and Taylor has adapted its design over the years to reduce the payoff period to around 4 or 5 years (2010). An important consideration is the size of the tanks, and *Water Rhapsody* franchisees use an Excel spreadsheet to calculate the smallest possible tank to meet a building's requirements based on the roof size, number of users, nature of usage, local rainfall patterns and other water saving measures employed. This helps to reduce costs and ensure that the system is not over-designed.

Rainwater harvesting in Cape Town

Rainwater harvesting has not always been an option for Cape Town residents, and despite its simplicity it is a relatively new phenomenon in the city. According to Taylor, the Cape Town City Council implemented a law in 1927 forbidding the use of what were then called 'water butts' in the city (2010). They claimed that the storage of water was a mosquito hazard, so homeowners were prevented from storing rainwater for use around the home and garden and conditioned to use municipal water only. Taylor believes that the real reason for the ban was the recent completion of a new dam on Table Mountain, and the City's desire to optimise the use of their facility. For 70 years, Capetonians were not allowed to harvest their rainwater, and were it not for the Minister of Water Affairs and Forestry Kader Asmal abolishing the law in 1998, this would still be the case. Figures from 2007 indicate that the number of rainwater harvesting tanks in Cape

Town remains significantly lower than in other cities in South Africa, with an estimate of no more than 30 tanks per quaternary catchment as shown on the map below:

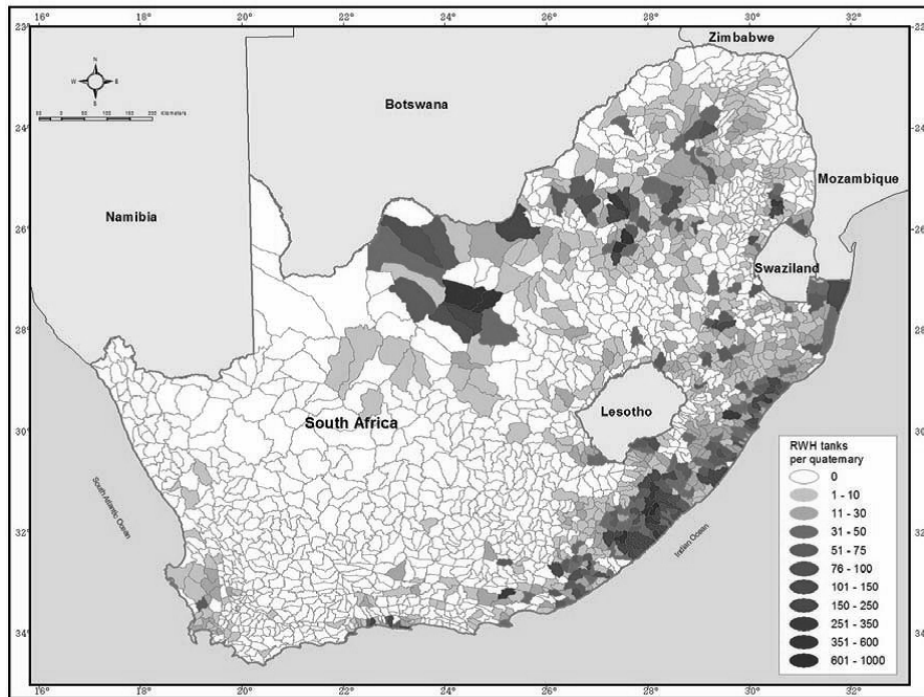


Figure 2.10: Map indicating the number of rainwater harvesting tanks per quaternary catchment area in South Africa as of March 2007 (Source: DWAF in Kahinda et al. 2009:10)

The City of Cape Town’s current Water By-law includes guidelines and restrictions on the use of tanks for water storage to prevent unsafe situations from arising. It requires that owners must “...not less than once in every five years, cause such tanks to be drained, inspected and disinfected, in accordance with SANS 10252...”, and owners can be forced to do so if an inspector finds the tank to be in an unsatisfactory condition (CCT 2006). Tanks need to be positioned to allow for the interior and exterior to be easily inspected, cleaned and maintained, and written consent is required for burying tanks. Other than this, there do not appear to be any significant barriers or incentives to the storage of rainwater for general use, but more stringent specifications apply if it is to be used for drinking purposes. The city’s stormwater by-law is focused solely on preventing damage or additional burdens on existing infrastructure, and neither discourages nor encourages reductions in the stormwater load (CCT 2005b).

The Water By-law lists cases of water wastage which are prohibited, and specifies 16 “good water conservation and demand management practices” that include limits on irrigation, external cleaning and pool top-ups, and specifications for sanitary fittings (CCT 2006). No mention is made of rain or rainwater in the document, and it indicates no intention to promote the use of rainwater harvesting as a means of conserving water. Taylor suspects that a conflict of interest exists between the need for revenues to be earned from the sale of water and the need to conserve it as a natural resource in water-stressed Cape Town (2010). He describes the city’s track

record of demand management as “paying lip service” to the need for water saving, and cites the following example from the late 1990’s to illustrate that this has been the case for many years.

When initial objections were raised to the Berg River Scheme, Kader Asmal put the project on hold until a demand management strategy could be implemented in the city. According to Taylor (2010), an annual budget of R2 million per year was set aside for water demand side management, and Charles Chapman from Rand Water was appointed by the City of Cape Town as Water Demand Management Manager. In the few weeks it took Chapman to relocate from Johannesburg to Cape Town, the budget had been reduced to R200,000. Early into the job, the budget was further cut to R50,000 per year. Besides leaving the DSM campaign with inadequate funds, Chapman’s contract stated that he was not permitted to speak to the press, leaving him voiceless as well. He did not stay in the position long, and construction of the multi-million rand Berg River Dam commenced soon afterwards in 2002.

Subsequently however, the importance of demand side water management appears to have been recognised in the compilation of Cape Town’s *Long-term Water Conservation and Water Demand Management (WC/WDM) Strategy* in 2007 (Conward Consulting 2007). At a total cost of R759 million over 10 years, the strategy was calculated to be able to delay the construction of new water augmentation projects at least until 2026, or even until 2051 (depending on water requirements). The strategy proposed that the city commit the five years from 2007 to 2012 to implementing and monitoring the strategy, and that no decisions be taken regarding new augmentation schemes until the effects of the test can be evaluated (Conward Consulting 2007:11).

Following the strategy, the city’s water saving goals are categorised into three priorities:

- Goal A: To reduce and maintain the non-revenue water to below 15% of total average demand.
- Goal B: To reduce water wastage by consumers to below 2% of the total demand by 2012 and achieve water efficiency targets amongst most consumers by 2016
- Goal E: To reduce projected potable water demand to a growth rate averaging no more than 1% per annum from 2007 to 2017 and protecting the city’s water resources

Judging by the areas of highest budget allocation, the focus is primarily on reducing revenue losses (e.g. by repairing leaks, adjusting water pressure, replacing faulty meters and improving debt management) and improving earning opportunities for the city (e.g. by selling treated effluent) rather than conserving water resources per se. Rainwater harvesting is mentioned as part of Goal E, and has been allocated R520,000 (0.07% of the total budget) over the 10 year period. The writers of the strategy are of the belief that collecting rainwater from roofs “...may not be too useful in Cape Town due to fact that rainfall occurs during winter and the generally high cost of such tanks. There is an opportunity however that rain harvesting could be useful in low-income areas and can be associated with the promotion of food gardens...” (Conward Consulting 2007:134). The budget is thus allocated to pilot projects in low-income areas, the development of affordable tanks and dissemination of information from 2009 to 2011, with subsequent years focusing on promotion of tanks to other areas.

In the absence of national legislation to enforce the use of water efficient practices, Cape Town's WC/WDM strategy also allocates budget to the development of incentive schemes to encourage homeowners or developers to carry out certain water efficiency practices, including the provision of tanks to collect rain water (Conward Consulting 2007). A budget of R2.85 million has been allocated over 10 years to develop incentives for new consumers, and suggested approaches include subsidies on the purchase and installation of water saving measures and the establishment of a water-efficiency recognition scheme for homes and businesses. Incentive schemes for developers could take the form of accelerated building approvals, discounts, or recognition by an environmental scheme, and a budget of R440,000 has been allocated for this.

Demand side management strategies are being pursued alongside investigations into options for increasing bulk water supply. Recent reports indicate that Cape Town is looking to spend R1,7 billion over the next 6 years on bulk water augmentation to increase storage, conveyance and treatment capacity (Smook 2010). According to the most recent *Water Services Development Plan for Cape Town* (CCT 2009b), the city is investigating the feasibility of a number of large-scale projects including raising dam heights, diverting rivers, extracting groundwater, re-using water and desalinating sea water. Many of these options have negative implications for sustainability, for example the effect of river diversion and the concentrated salts from desalination plants on river and ocean ecosystems, and the risks of depleting underground water reserves when there is little understanding of how fast they are being replenished. Options like desalination also require a great deal of electricity to operate, tying the cost of water to rising power prices. In light of these concerns, demand management will be crucial if the city's water strategies are to be sustainable.

In 2008, the City of Cape Town formulated the *Green Goal 2010 Action Plan* to ensure that the construction of inner city infrastructure for hosting the *FIFA World Cup* would embrace sustainability principles (Green Goal 2010). This acted as a unique opportunity to showcase water saving measures at the new stadium in Green Point, and the design includes an ambitious rainwater harvesting scheme to collect water from the stadium's roof, pitch and podium surface and divert it to a detention pond for irrigation of the surrounding 69 hectare Green Point Common. This is complemented by the use of multi-flush toilets and water efficient taps and shower heads in the stadium, further reducing its water footprint.

Public response

While government does not appear to consider the benefits of decentralised rainwater harvesting to be a serious strategy for water resource management, the private sector is coming round to the idea as a reaction to water restrictions and rising water costs. Over the past 16 years, *Water Rhapsody* has installed rainwater harvesting systems for around 3,000 customers in and around Cape Town, including Kader Asmal (Taylor 2010). They rely mainly on word of mouth references from numerous successful installations, and Taylor believes that this is more effective than any formal marketing. Informative franchisee websites have also helped to push the company to the

top of Google's South African rankings, ensuring that the company is the first port of call for interested parties.

Taylor reports that the market is highly responsive to droughts and water restrictions, and recalls how his phone rang off the hook when they were announced in Cape Town in October 2004 (2010). The summer months tend to yield the most enquiries, but 2010 has seen an increase in winter turnover of around 50%. The main demand has come from the Johannesburg area and Southern Cape where poor water quality and availability have spurred consumer action.

The main barrier to market penetration of the *Grand Opus* system is the cost of installation, and the resulting trade-off between high upfront costs or rising water consumption costs (Taylor 2010). As with SWHs, the issue lies with perceptions of value relating to investments in long term resource savings, and point to the need for greater education as to the financial benefits over time. When water crises draw attention to the issue of water conservation, Taylor admits that it would be cheaper to start with smaller interventions like multi-flush toilets and low-flow shower heads, but their contribution is marginal in comparison to rainwater harvesting.

The future of rainwater harvesting in Cape Town

Considering the relatively small role of decentralised rainwater harvesting in the City of Cape Town's water demand management strategies, government interventions to support the industry are unlikely. The current focus appears to be on eco-efficiencies that improve the City's ability to earn revenue, and there appears to be a bias toward large-scale, centralised interventions rather than those at a household or neighbourhood level. Taylor has found from experience that government is simply not interested in rainwater harvesting, and suspects this is due to the challenge it presents to their revenue models (2010).

While a proactive stance on promoting rainwater harvesting appears unlikely in the short term, the City of Cape Town has mechanisms at its disposal to incentivise home owners to take swift action to conserve water should they deem it necessary (leaving the means to the home owners' discretion). The City's *Water By-law* allows for the prohibition or restriction of water consumption in the city or part thereof, and permits the use of "special tariffs in respect of water restrictions" (CCT 2006). In order to do this, the details of planned measures need to be released for public scrutiny, and 14 days must be allowed for comment. When water restrictions were imposed in 2004, Taylor was able to take advantage of this process and effectively re-wrote the water restrictions for Council before they were implemented (2010).

Capetonians have proven themselves to be highly reactive to water crises, swiftly changing their water usage behaviour to reduce consumption. For example, the drought of 2001/2002 resulted in a 19% drop in average water demand (Pithey 2007:51). Combined with the water restrictions that followed in the summers of 2004/2005 and 2005/2006, a decoupling of economic growth from water consumption was observed in the city, and this has had a lingering effect on suppressing water demand in subsequent years (Swilling 2009). Part of the reason may have been the surge in demand for rainwater tanks, grey water systems and boreholes that accompanied

these crises, allowing a greater degree of independence from municipal supplies. The effect can be seen in the graph below:

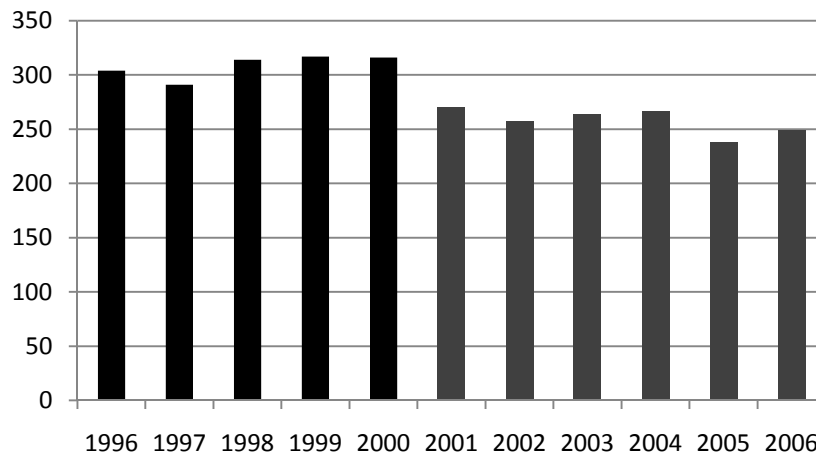


Figure 3.11: Average daily water consumption in litres per capita for Cape Town from 1996-2006
(Source: Swilling 2009:23)

Taylor has observed that Cape Town droughts follow a 6 or 7 year cycle, and predicts that lower than average rainfall will leave Cape Town's dams with insufficient water to serve the city in the next 2 years (2010). Water restrictions are likely to be implemented in the short term as a reaction to this, but are known to be an unpopular option (Conward Consulting 2007). They are unlikely to be considered as a proactive measure to change behaviour in the long run to avoid expenditure on capacity augmentation and preserve freshwater reserves.

When asked what he would most like to see change in the Cape Town context to make water conservation a way of life, Taylor does not hesitate to identify tariff increases as the most important factor (2010). This would allow the city to reduce the amount of water they sell and postpone expenditure on capacity expansion without losing out on profits, and would help to overcome some of the conflicts of interest between revenue earnings and resource conservation. By shifting some of the responsibility for water management to consumers, the City would be able to focus its attention on maintenance and upgrades of existing infrastructure to reduce revenue losses rather than pursuing new capacity that will hasten depletion of the city's limited water resources. Cape Town's water is considered cheap in comparison to other metros, and the adjustment of tariffs to reflect marginal costs of water supply forms part of the WC/WDM strategy (Conward Consulting 2007).

The City raised water tariffs by 10% on 1 July 2010, but Taylor says that this is unlikely to have an effect on changing behaviour (2010). He believes that the per kilolitre cost of water should proactively be set at what it would cost to meet additional demand through augmentation schemes like desalination, and that this should happen in advance of decisions to proceed with such projects in order to allow behaviour to change before giving the go-ahead. A tariff increase of 8% above inflation is estimated to be necessary to fund the city's R1.7bn capacity expansion plan over the coming financial years (Smook 2010), but it appears that commitments to supply

expansion will already have been made by the time this is implemented. This approach will prevent changes in behaviour to reduce demand that might otherwise have rendered the investment unnecessary and allowed for extra revenue for improved service delivery and maintenance.

While rainwater harvesting is not currently mandated in Cape Town, new buildings wishing to receive certification from the *Green Building Council* are able to earn up to 5 points out of a possible 154 by implementing measures to reduce potable water consumption. The number of points is calculated with the use of a potable water calculator, and "...off-setting demand with rainwater or reused water will be necessary to achieve more than two points..." (GBC 2008:195). The *Green Building Council* currently only has guidelines for office and retail buildings, but they plan to develop tools for other building types depending on demand. In the absence of regulations to enforce water conservation measures in new building designs, the Council's guidelines are the closest thing to a specification for sustainable water use in buildings and serve as a useful means of educating those with an interest in greener buildings.

Case Study 4: Grey water sanitation

Saving potable water is soon to become a major issue for Cape Town, but in terms of the Water and Sanitation Department's challenges it is the inadequate capacity of the city's waste water treatment systems that represent the most immediate threat to the city's inhabitants (Pithey 2007). The main culprit is the water-borne sanitation system that has become synonymous with modern lifestyles and is seldom questioned as the most hygienic and user-friendly approach to dealing with human waste in urban environments. As service delivery has extended to informal areas and the poor have been given access to water-borne sewage, the load placed on the city's vast network of pipes and treatment facilities has expanded faster than it can cope with, resulting in pollution that threatens ecosystems and human health.

The re-use of grey water for toilet flushing offers potential to save on fresh water whilst reducing the burden on water treatment infrastructure. Grey water is typically used to describe that which has been used for cleaning in basins, showers, baths or washing machines, and is commonly mixed with black water from toilets, dishwashers and kitchen sinks on the way to the sewer. With enough foresight at the planning stages of a building, it is a relatively simple exercise to separate grey water pipes from black water pipes, and re-use this water for functions around the home that do not require clean water. While its use in gardens around the city has potential to save significant quantities of fresh water in suburban areas, sanitation is a necessity for every urban dweller and it is as a complement to the city's water-borne sanitation system that grey water re-use has the most significant benefits in terms of infrastructure.

With his unique expertise in the field of urban water conservation, Taylor proved to be the most suitable person to interview about grey water re-use. While his initial success was in the use of grey water for irrigation, years of experimentation have led to the development of a grey water toilet flushing system called the *Second Movement*. Taylor took me to see one of his largest installations of 30 toilets at a recently built crèche called the *green s'cool* at Old Mutual Park in Pinelands. Besides the fact that the toilets and hand basins are exceptionally low to cater for their diminutive users, at first sight one is not able to discern any difference between these toilet facilities and conventional ones. On closer inspection, the flushing mechanism is a plastic button on the wall instead of a flush lever, and there is no sound of water filling the cistern after flushing, but other than that the user experience is no different to a conventional toilet.

How grey water sanitation works

There are a number of approaches to the re-use of grey water for toilet flushing, some more viable than others. At their most basic, used water from a bath, shower, basin or washing machine can be collected in a container and poured into the toilet bowl to flush down waste instead of using fresh water from the cistern. There are a number of new toilet designs on the market that replace the cistern with a hand basin, allowing for the water to be used for hand washing before flushing. While these systems are more user friendly, they typically fail to benefit from the significant quantities of grey water generated, and are limited in their capacity to utilise the water to its best advantage.



Figure 3.12: Second Movement toilet installed at the *green s'cool* at *Old Mutual Park*, indicating the flushing mechanism (top left).

The Water Rhapsody *Second Movement* system acts as a replacement for a conventional toilet cistern, using grey water collected from hand basins, baths, showers and washing machines instead of potable water to flush the bowl. Once the fresh water has been used, the resulting grey water runs directly to underground storage tanks via a 2mm mesh filter (Taylor 2010). The filter removes larger items like hair, fibres and stones, and contains a chlorine block that inhibits the growth of bacteria while the water is stored to reduce odours. Each toilet is fitted with a 12V bell push instead of a conventional flusher, activating a pump in the tank to flush the toilet bowl when pushed. A non-return valve ensures that the water is available immediately on pressing the button, and the large storage tank means that one does not have to wait for the cistern to refill after flushing. A simplified illustration of the system is provided below:

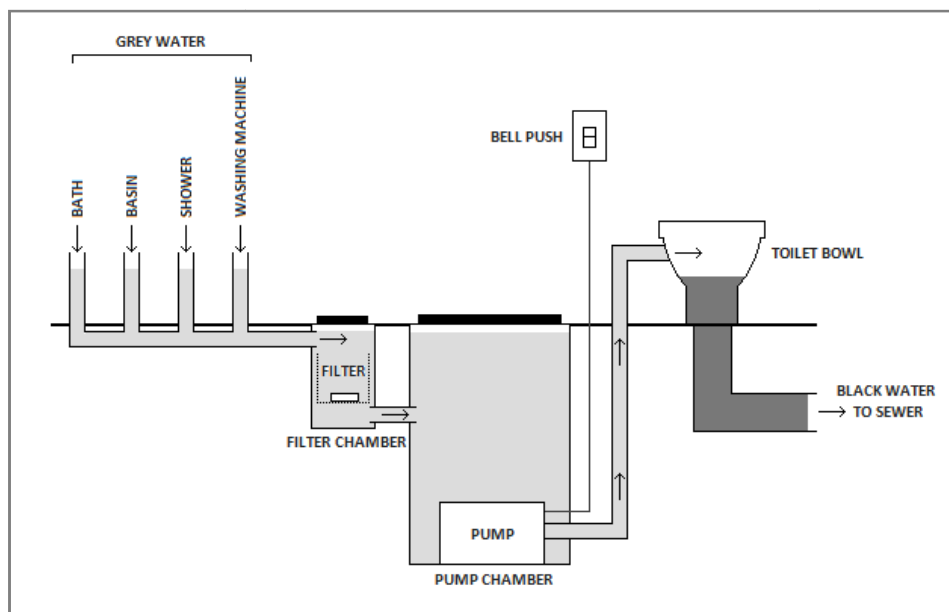


Figure 3.13: Second Movement grey water toilet flush system (Derived from Water Rhapsody 2010)

The benefits of this system are twofold:

1. The demand for potable water for toilet flushing is eliminated. Based on average consumption patterns, there is a greater likelihood of there being excess grey water than a need for supplementation with potable water (See Figure 3.14).
2. Most of the volume of grey water that would otherwise have gone straight to the sewer is being used again, effectively eliminating a burden on centralised water treatment facilities equal to the amount of water saved on toilet flushing.

The system can thus be said to have elements of dematerialisation and rematerialisation. By effectively eliminating the role of fresh water in toilet flushing, it could also be considered a type of immaterialisation. The use of the on-demand flushing mechanism in Taylor's system represents an additional dematerialisation feature as the user is incentivised to save water. Unlike conventional flushing mechanisms that dispense the same volume of water per flush, a more water-intensive flush occupies more time with this system as the user has to hold down the button to use more water.

For the flush system to function, a small amount of electricity is required. Conventional toilet systems do not require electricity, and while the water saving benefits of this system outweigh the small addition to electricity demand, in the absence of a renewable power sources this technology can be considered to add to demand for grid electricity. Taylor acknowledges that reliance on the mains can be a problem when there are power outages, and that future versions of the system could run off renewable energy if clients were willing to pay more for it (2010).

The system also relies on municipal sewage systems as the tanks have an overflow pipe in the event that grey water levels exceed their capacity. Taylor recalls a case where a pipe blockage resulted in sewage from the municipal piping system flowing back into the tanks (2010). Normally this would have pooled outside, so the possibility that some of it might have got into the chlorinated tanks and re-circulated through the toilet bowls did not add a significant additional health risk to the users than would otherwise have been the case. When the system needs to be cleared or re-filled, maintenance operators can simply run the taps or flush the toilets accordingly until the problem is resolved. Other than that, the only maintenance that is required is to clear the filters and insert a new chlorine tablet each week. Taylor estimates that the 30 toilet system at the *green s'cool* takes less than 5 minutes per week to service.

Performance

Due to the nature of the *Second Movement* system, it is difficult to retro-fit it to existing buildings without major changes to pipes embedded in the walls and floors. Taylor has thus only installed the system in new buildings, and has not been able to conduct any 'before and after' analyses of its performance (2010). Instead, he refers to the following widely accepted breakdown of household water consumption as a means of validating its contribution to water saving and sewage reduction:

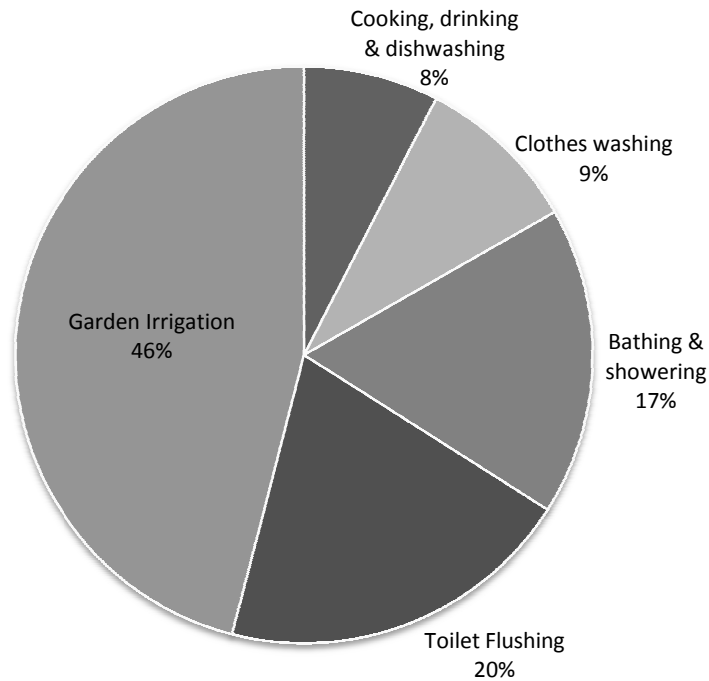


Figure 3.14: Average household water use for mid- to high-income households in Cape Town
(Source: Jacobs et al in CCT 2007:85)

According to the City of Cape Town, a minimum of 20% of the fresh water consumed by a mid- to high-income household is used for toilet flushing (CCT 2007). If the house has no garden, the figure is closer to 37%, and in a low income house it can be as much as 73% of total fresh water consumption. Grey water from the washing machine, baths, showers and hand basins is equivalent to around 26% of the fresh water consumed. The resulting waste water is more than enough to cover the 20% required for toilet flushing. The same cannot be said for low income households due to the enormous contribution of toilet flushing to their water demand, but this indicates the wastefulness of water-borne sewage systems relative to serving basic human needs.

At minimum, a mid- to high-income house can reduce their water demand by 20-37% by using grey water to flush toilets. Taylor estimates that the installation at the *green s'cool* has reduced potable water consumption and the burden on municipal waste water systems by around 50% of what it would otherwise have been (2010). He points out that fresh water savings from the *Second Movement* are enhanced when combined with other water saving and rainwater harvesting systems. As yet, no financial analysis has been conducted on any of the systems to calculate returns on investment, but Taylor estimates that the systems will pay themselves off in around 12 months. He acknowledges that the upfront capital costs can be an obstacle, with a multi-toilet installation costing in the region of R5,000 per toilet. Capital savings over conventional systems result from fewer gullies, water points and cisterns, so the net additional cost per toilet is closer to R3,300.

It is estimated that Cape Town's households generate a total volume of between 66.6 and 111 Mm³ of grey water per year, the bulk of which currently goes directly to waste water treatment

plants (Murphy 2006:27). If all household grey water were to be re-used, Cape Town's available water resources of 369 Mm³ could be enhanced by a further 18% to 30% (Conward Consulting 2007:38), whilst reducing the domestic load placed on the city's overburdened sewer systems by approximately 40% (CCT in Murphy 2006:74).

Grey water re-use in Cape Town

Discussions around grey water in Cape Town are predominantly focused on small volume water users in low income areas. In the absence of plumbed sanitary fittings like basins or baths connected to the sewer system, grey water is commonly discharged onto the ground or into stormwater systems, causing ecosystem and public health risks (see Armitage et al. 2009). Research into the re-use of grey water has focused primarily on its application to agriculture, which is more complicated than its use for toilet flushing due to the potential for negative health and environmental impacts if managed incorrectly (see Murphy 2006).

Cape Town's *Grey Water Guidelines* developed in 2005 are designed to cater for grey water disposal in informal areas, and are not of much use in assisting property owners in more affluent areas who wish to re-use their grey water. In essence, the guidelines specify that "...where sewer is available, this option must be used..." for disposal, and the only acknowledgement of grey water re-use is found in a single sentence mentioning that "...other innovative methods of disposal may also be considered, particularly where beneficial use of the grey water as a resource is possible..." (CCT 2005a). The only specific requirement is that in cases where the grey water does not feed directly into the sewer, a sediment and fat trap is required. The guidelines provide details on the specifications and maintenance thereof.

While countries like Australia have strict laws about the treatment of grey water that make systems significantly more expensive, Taylor has benefited from a certain degree of flexibility within which to develop and perfect his designs. Some have accused his technologies for the re-use of grey water of being against the laws governing Cape Town, but as yet no paperwork has been found to corroborate this (Taylor 2010). Concerned about the effect such legislation might have on his business, he duly investigated the available legislation with the help of Hugh Corder, the Dean of the Law Faculty at UCT to find out what might be considered illegal. Corder distributed the relevant laws to all the professors in his faculty, but the diversity of interpretations resulted in no clear ruling against grey water re-use being ascertained. Until proved otherwise, Taylor's technologies appear to meet the laws and standards specified by the city.

The City's WC/WDM strategy recognised the potential for grey water to be re-used, and allocated a budget of R640,000 (0.08% of the total budget) over 10 years (Conward Consulting 2007:81). The strategy only mentions the use of grey water for landscape irrigation, and according to the time line R150,000 was to be spent on the development of guidelines and regulations for using grey water in the 2008/2009 financial year. An additional R40,000 has been allocated to research into products that can assist with grey water re-use between 2008 and 2012, but Taylor has not received any government interest in his expertise other than the grey water installation he was

recently involved in at the *False Bay Ecology Park* near Zeekoevlei (2010). The City of Cape Town has also adapted the toilets in its Civic Centre headquarters to run off water from the cooling towers of the air-conditioning system, indicating a willingness to re-use grey water for toilet flushing in municipal buildings where possible (CCT 2010d).

While Taylor reports a lack of government interest in his expertise, he was involved in discussions with academics from the Universities of Cape Town, Johannesburg and Natal about the formulation of new legislation for grey water in late 2009. When he volunteered his first-hand experience, he was met with a degree of hostility from those whose views he challenged. For example, he recounts how the academics were focused on concerns surrounding soil salinity in the application of grey water to irrigation, whereas the soil and leaf analyses he had conducted on existing grey water systems showed that phosphates were a much more serious problem. The academics involved were not receptive to his views, and he believes their displays of aggression were due to being shown up for not knowing enough about the realities of the topic. He has subsequently not heard anything from them, and grey water re-use remains largely unrecognised by legislation (Taylor 2010).

While grey water may not appear to be a priority at present, the City has shown that it embraces the concept of water re-use through substantial investments in the treatment of black water as an alternative source of non-potable water. By 2007, eight of the city's wastewater treatment works were providing 21,113 ML of non-potable treated effluent per year for re-use, primarily for irrigation and various construction and industry applications. Potential exists for a total of 31,428 ML of treated effluent to be re-used per year, and work is underway to incorporate the water from an additional eight treatment works into the scheme (BVI 2007).

Public response

Interest in grey water re-use closely follows that in rainwater harvesting and other water saving measures, and is highly dependent on water availability and pricing. Most of the demand for *Second Movement* systems has come from the residential sector, though larger installations have been completed for the *green s'cool* crèche at *Old Mutual Park* and the *Ecology Park* (Taylor 2010).

The usability of the *Second Movement* gives it a distinct advantage over other toilet systems that aim to use less potable water. Familiarity with water-borne sanitation acts as a significant barrier to dry or composting toilets, and their regular maintenance requirement typically makes them an unwelcome addition to urban environments where piped sewage systems are already in place. The only problem that can occasionally arise with the *Second Movement* toilets relates to the discolouration of the toilet water in the bowl. Taylor recounts how some patients using the toilets he installed at a gynaecologist's office were disturbed by the colour of the water, but that the owner has opted to manage his clients' perceptions rather than decommission the system (2010).

The future of grey water re-use in Cape Town

Judging by the WC/WDM Strategy and the focus of investigations by the Water Research Commission (e.g. Murphy 2006), it appears that in the short term the re-use of grey water in Cape

Town is likely to be predominantly focused on irrigation rather than toilet flushing. Though this has potential to help save water, it requires tighter control over the type of detergents used and the storage of the grey water to prevent damage to the natural environment and unpleasant odours. There are few signs of government interest in the use of grey water for toilet flushing beyond its deployment in some municipal buildings, so it is likely to follow rainwater harvesting in relying on demand from the private sector influenced by fluctuations in rainfall and water prices.

Grey water systems are seldom suited to retro-fitting existing buildings due to the need for separation of grey and black water pipes, but there is potential for them to make an impact in new buildings to decouple city expansion from fresh water usage. Like rainwater harvesting, grey water re-use in new buildings allows for between 2 and 5 points to be earned in the *Green Building Council's* commercial building rating system. It also allows up to 4 points for reducing discharge to sewer systems, depending on the percentage saving, making grey water sanitation systems an appealing solution to achieving points in both categories (GBC 2008). It is likely that these water conservation principles will be rolled out to other guidelines as they are developed, and while they will only affect those deliberately pursuing green design, it is hoped that demand for certified buildings will grow as the *Green Building Council* becomes more established.

Conclusions

Cape Town's WC/WDM Strategy is a sign that the City is aware of its water constraints and acknowledges the role of conservation in better managing fresh water resources. While it may not necessarily have advanced the use of rainwater harvesting and grey water re-use to any significant extent thus far, its focus on reducing leaks and improving metering has been worthwhile in improving eco-efficiencies that will help the City to keep a tighter control on its fresh water and reduce lost revenues. As with the *Energy and Climate Change Action Plan*, the focus appears to be on efficiency as a first step toward sustainable resource use, which is fitting considering that it is only in recent years that demand-led supply and long term water security have started to be questioned.

With a number of water supply augmentation options currently under investigation, the next few years will test the City's commitment to demand-side management and sustainability. While many of Cape Town's options for expanding water supply have negative ecological and economic repercussions, the potential for mountain spring water to augment the city's water supply represents a contextually appropriate alternative that has recently attracted the support of local government. The City of Cape Town is part of the *Cape Town Partnership*, a non-profit company representing a partnership between the private and public sector to promote and improve the management of the city. The Green Point Park irrigation project brought to light the untapped potential of the city's mountain springs, and in its wake an ambitious infrastructure initiative called *Reclaim Camissa* has been started by the Partnership as part of their *Sustainable Cape Town* project (CTP 2010).

Reclaim Camissa aims to expose and enhance the long-neglected fresh water channels that once supported Cape Town, and in the process create valuable public spaces, jobs and a stronger connection to the city's history. In the 1970's, there were more people living in the city bowl than there are today, and the fresh water that gushes from Platteklip and the 13 artesian springs on Table Mountain was more than enough to sustain them. These water sources were struck from the City's asset register in the 1990's, but renewed interest in our water resources may see them embraced as a more sustainable alternative to some of the augmentation schemes under consideration. The City wholeheartedly supports this project, and a Public Benefit Organisation has been set up in the form of a Non-profit Trust to collaborate with the City's Mayco Water and Utilities Portfolio to assist its development (CTP 2010). The City's involvement in *Reclaim Camissa* indicates that it is receptive to sustainable water augmentation approaches, but it is not clear as to the role this project will play in plans for water supply augmentation.

As Taylor argues, price increases and penalties on high water usage would help to incentivise water conservation and stimulate innovation that would allow for measures like rainwater and harvesting and grey water re-use to gain prevalence without the hassles of prescriptive legislation (2010). The City is well within its rights to increase water prices to at least equal that of the country's other metropolises. However, the political consequences of such an approach are not for

the faint-hearted, and there are no signs of pricing being used proactively to conserve resources and delay investment in capacity expansion. While a great deal of thought has gone into demand side management of Cape Town's water resources, the extent to which this sustainable approach will be advocated relative to less sustainable capacity augmentation options remains to be seen.

3.2.3 Waste

Introduction

The cases thus far have dealt predominantly with reducing consumption related to natural resources. The focus now shifts to examples of sustainable waste management that are primarily aimed at alleviating the burden placed on nature's ability to safely absorb the by-products of human habitation. As such, these cases look at rematerialisation, freematerialisation and immaterialisation measures, and the approaches represent significant changes to the status quo rather than adjustments to the relationship between material inputs and the utility derived from them.

The proliferation of solid waste by Cape Town's population is out-pacing the city's growth, and represents a severe threat to future liveability. Population is growing at around 2% per year, but the amount of waste its citizens generate is increasing at a rate of around 6% (CCT 2007). This can be attributed to a combination of factors, including urbanisation, rising levels of affluence, release of suppressed demand, improved access to waste disposal services and better record keeping (Engledow 2007). The graph below shows that the average amount of solid waste generated per person is showing an alarming upward trend, indicating that the way of life in the city is becoming increasingly associated with the production of waste.

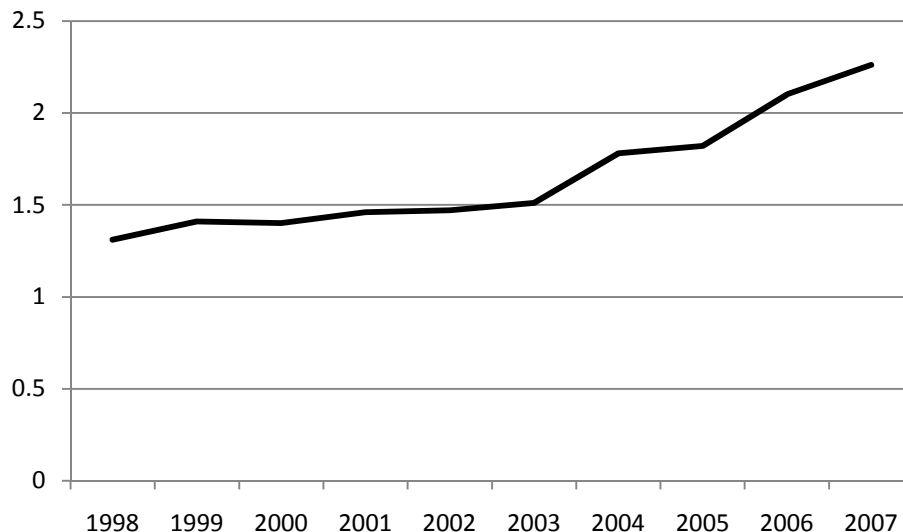


Figure 3.15: Cape Town's waste generation in kilograms per person per day from 1998 to 2007
(Source: Swilling 2009:24)

Growth in waste volumes is placing a heavy burden on the city's landfill sites, and Cape Town is running out of space for new sites. In the last 7 years, the Swartklip, Brackenfell and Faure sites have been filled to capacity, placing increased pressure on the three remaining sites at Belville South, Vissershok and Coastal Park. The Belville South site is not likely to last beyond 2011, and

Vissershok only has capacity to receive waste until 2012, but could be expanded to last another 6-9 years. This leaves Coastal Park near Muizenberg, Phase 2 of which will be full by between 2016 and 2022 (CCT 2010c). There are only two potential sites for additional landfills in Kalbaskraal and Atlantis, but their distance from the city will add to waste disposal costs and the question as to what will happen once they have reached the end of their lifespan remains unanswered.

Once a landfill reaches its capacity, its future usefulness to the city is limited. The decomposition of waste is a slow process, and it can take hundreds if not thousands of years for the contents of a landfill to be re-absorbed into the environment. While the land might be highly valuable due to its proximity to the city, it cannot be built on due to the risks of unstable ground and the release of toxic materials into the soil, air, and water systems. Closed landfill sites can be rehabilitated for use as public open spaces or sports fields by covering them with soil and vegetation, but this comes at a high cost (CCT 2007).

In addition to the land occupied by landfills, their production of methane is attracting attention as a major contributor to climate change. Organic waste is broken down by aerobic bacteria when it is exposed to air, and methane-producing anaerobic bacteria when it is compressed and covered in a landfill. It is estimated that the Belville South site produces between 45,000 and 90,000 m³ of gas per day, of which 40%-58% is methane. This is the equivalent of 244.44kt of CO₂ per year, representing only a fraction of emissions from Cape Town's waste (Omar & Mncwango 2005:135). The chart below shows that landfill sites are the highest producer of greenhouse gases in Cape Town.

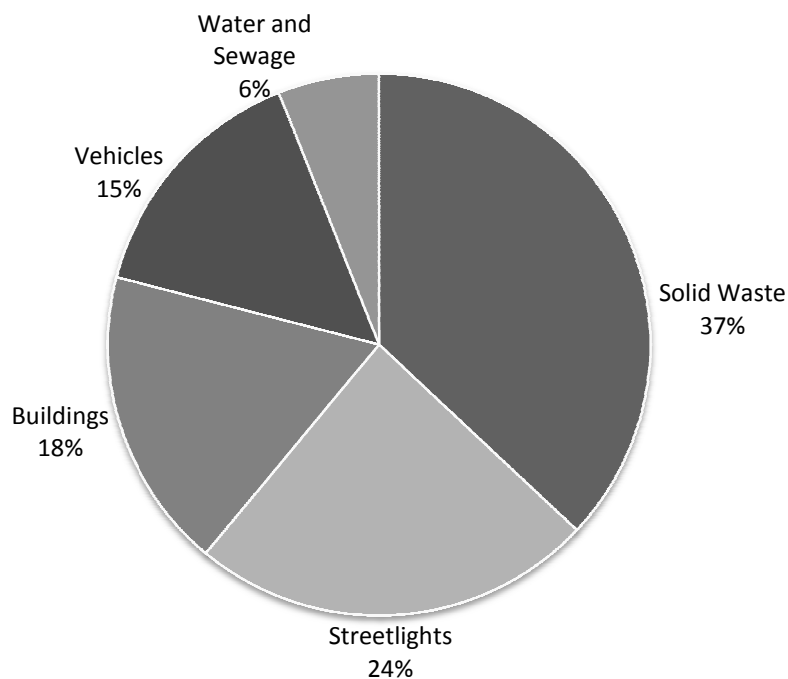


Figure 3.16: Contributors to Cape Town's greenhouse gas emissions (Source: Omar & Mncwango 2005: 134)

Without efforts to reduce the volumes of waste sent to landfill, it is evident that Cape Town will soon run out of land and have to undertake expensive measures to reduce its carbon footprint. Fortunately, action is being taken on a number of levels to decouple the city's growth from the dumping of waste through the promotion of recycling and other waste minimisation measures. The case studies that follow look at the advancement of recycling in Cape Town, and the potential to use vermiculture to deal more effectively with methane-producing organic waste. Together they give an insight into the city's progress toward sustainability through waste management.

Case Study 5: Recycling

Materials recycling plays a key role in reducing the amount of raw materials required to service humanity, and can make a substantial contribution to the creation of circular economies by diverting waste from landfills toward productive use. The hard infrastructure required for successful recycling does not differ greatly from conventional waste disposal systems, so the challenge lies in developing supportive soft infrastructure to ensure that waste is successfully separated and channelled appropriately to allow for it to be re-used.

Recycling has been pursued in one form or another in Cape Town by private interests for the last few decades, but it is only in recent years that it has been recognised by local and national government as a strategy for managing South Africa's escalating waste volumes. In 2006, the *City's Waste Management Sector Plan* shifted the focus from end-of-pipe solutions toward efforts to prevent and minimise pollution and waste at source (CCT 2010b). Three years later, the national *Waste Act* added strategies for waste minimization to the list of waste services such as cleaning, collection and disposal that ought to be provided by each municipality.

The growth of a local recycling industry is seen as a means of increasing the lifespan of South Africa's few remaining landfill sites whilst harnessing the value of recyclable resources and generating much needed jobs for low skilled workers. Recycling is estimated to create 10 times more jobs than conventional waste disposal services (Tyrell 2010), and recent years have seen a number of specialist companies entering the market as collectors or converters of recycled waste, or manufacturers using recycled content in new products.

To gain an insight into the recycling industry in Cape Town, I spoke to Hugh Tyrell of *Green Edge Communications*. His company specialises in environmental consulting and communications, and has been involved in the implementation of a number of recycling projects in the city. Originally from a sociology and copywriting background, he has worked as a consultant in sustainability and environmental communications for more than 15 years. He is the founding editor of two national environmental magazines, one of which is a trade journal for the South African waste management and recycling industry entitled *RéSource*. He has consulted local government and a number of blue chip companies on sustainability issues over the years, and has built up a strong body of expertise in the systems change required for effective materials recycling.

I also spoke to Angus Ryan, Cape Region General Manager at *Re- Ethical Environmental Re-engineering (Pty) Ltd*, an environmental solutions company that specialises in waste issues. *Re-* was started as a waste management company in Kwazulu Natal in 1988, and now offers a range of recycling-related services to corporate, industrial, commercial, retail, and public sector clients in Durban, Johannesburg and Cape Town. They assist organisations who wish to act on their environmental responsibilities whilst maintaining a return on investment, as evidenced by their slogan "return on environment". They have worked in association with *Green Edge* on a number of projects, and together they represent a solid body of expertise in recycling in the city.

How recycling works

Unlike many of the sustainable technologies discussed thus far, the success of recycling hinges on human participation. While the infrastructure required for recycling is relatively simple, there is a heavy reliance on supportive human behaviour to ensure that waste flows are diverted appropriately. With a lingering legacy of ‘hump ‘n dump’ approaches to waste management, this usually requires a significant change from the status quo (Tyrell 2010).

Cape Town’s approach to domestic kerbside recycling collection is relatively simple, based on experience from systems employed overseas. Households are responsible for the division of their waste into non-recyclables and recyclables, otherwise known as wet and dry waste. On the day of waste collection, a bin containing black bags of non-recyclables is wheeled out onto the pavement, and recyclable waste is typically placed on top of it or next to the bin in clear plastic bags provided free of charge. The collection service is operated predominantly by private companies on government contracts who are responsible for ensuring that the collection occurs timeously and that the waste is appropriately handled and distributed. The recyclable waste is typically taken to a depot where it is sorted and sold on to converters like *Sappi*, *Mondi*, *Consol* and *Collect-a-can*.

While domestic recycling might seem fairly straightforward, workplace recycling can be approached in a number of different ways. *Re-* and *Green Edge* have found that attention needs to be paid to the behaviour of the stakeholders as a collective, and that each context demands a tailored approach (Tyrell 2010; Ryan 2010). Clients have varying levels of ambition according to their commitment to environmental responsibility, and their requirements will vary according to factors like their motivation for recycling, the nature of the work they do, the size of their premises, and the number of employees or tenants. Systems can range from two bin ‘wet/dry’ separation at source to having multiple bins for food waste, glass, tin, paper and shredded confidential documents clustered into stations located strategically around the workplace. These bins are typically emptied by in-house cleaning staff, and the waste is taken to large volume bins for collection by recycling companies. Unlike domestic services orchestrated by the municipality, commercial and industrial collections are more often based on direct contracts with the waste service providers.

Even with clearly marked bins, it is inevitable that staff and visitors will fail to some degree in dividing waste accurately. *Re-* has found that it is best to have one of their employees working full time in an on-site rubbish sorting room as an additional quality check to ensure that waste separation is adequate and that ISO14001 environmental standards are maintained (Ryan 2010). This on-site waste manager receives the waste from cleaning staff and ensures that it is properly allocated to larger bins. He is responsible for weighing the waste and keeping records of it in a waste manifest, which is collated into a monthly report to management. He is also tasked with ensuring that the refuse is removed timeously, and scheduling collections either by accredited converters or *Re-*, to be sold on from one of their depots.

Re- has recognised the importance of behavioural change in the success of workplace recycling schemes, and recommends that its clients invest in the management of the transition process by using specialist consultancies like *Green Edge*. Tyrell employs a participative process of design involving all relevant stakeholders to ensure successful implementation of recycling programmes first time round (2010). The facilities manager and cleaning staff typically yield the most valuable insights into what will and will not work within the specific organisation, and achieving their buy-in plays a key role in maintaining quality of separation. He cites an example where he discovered that the cleaners were earning a small additional income by selling paper waste to recyclers and using this to fund their year-end party. A new recycling system threatened to eliminate that incentive, so he was careful to design it in a manner that ensured they would not lose out.

Once an appropriate system has been planned, Tyrell assists with the design of communications to maximise participation and achieve the best results. Combining his knowledge of psychology, sociology and communications, he manages the process of behavioural change in each context according to its unique attributes (Tyrell 2010). His main objective is to enhance participation in recycling, and he believes that once a critical mass of around 60% participation is achieved, social norms start to kick in and recycling can become part of the neighbourhood or office culture.

Tyrell's three primary objectives are to make recycling fun, easy and popular, and he achieves this using a number of approaches learned over the years (2010). For example, he has found that in the case of kerbside collections, the use of clear bags helps to make visible the neighbourhood contribution to recycling, and serves as a means of encouraging non-participants to join in. He has also found that regular feedback on achievements like the quantities of waste recycled help to maintain motivation, and that participation rates can be improved if the recycling scheme is linked to local job creation or environmental projects. In workplaces, he believes that it is important to have a designated recycling co-ordinator to take responsibility for the ongoing functioning of the system, but also to allow space for new champions to emerge.

The separation of recyclables involves a degree of effort in identifying materials, cleaning them and storing them in dedicated containers. On a household scale, the need for separate containers can be a problem where space is constrained. Where there is no kerbside collection service, making regular trips to a recycling depot or organising for a private company to collect the recycling can be an inconvenience that hinders participation. At a larger scale, problems can arise if waste separation is inadequate and food waste is mixed in with the recyclables. This reduces the amount of time the recyclables can be stored on site before collection, and can lead to vermin infestations if the collection is insufficiently frequent. On the whole, recycling does not present a significant threat over and above conventional mixed waste, but requires a greater degree of human involvement for success.

Performance

It is difficult to make generalisations about how successful a recycling scheme will be as there are a number of variables from the nature and volumes of waste to the individual motivations of stakeholders that play a role in success. The success of kerbside recycling schemes can be gauged

by participation rates and the volume of materials recovered. Between November 2007 and April 2010, Cape Town's *Think Twice* campaign achieved participation rates of between 35% and 97%, with figures varying per suburb. This has allowed for the revalidation of 345 tons of plastic, 319 tons of cans, 3,774 tons of glass and 4,969 tons of paper, allowing for significant savings on landfill space (Think Twice 2010).

Ryan was able to share data from one of Re-'s clients that gives an insight into the landfill impact and financial benefits of workplace recycling (2010). Before implementing a recycling system, the client sent an average of 47 tons of waste directly to landfill each month. They would have been paying approximately R6,350 for dumping this waste (R135 per ton), plus another R8,400 for transportation each month (10.5 loads at R800 each).

Using a recycling system, the client was able to extract an average of 35.7 tons of recyclables (76%) from their waste stream per month, cutting the cost of dumping by roughly R4,800 per month and reducing the number of loads sent to landfill by more than three quarters (Ryan 2010). In addition, the client received rebates for the recyclables at an average rate of 50 cents per kilogram across all materials, generating an additional income of over R17,000 per month. By making the effort to separate and recycle their waste, the company is now making a net profit on its waste of around R3,800 per month¹¹ instead of spending R14,750 on waste disposal, equating to a 126% financial saving.

Recycling in Cape Town

Cape Town has adopted a proactive approach to materials recycling and has demonstrated strong support for using it as a means of dealing with the city's waste crisis. Within months of South Africa's *Waste Act* being promulgated in March 2009, the City of Cape Town led the country as the first municipality to implement an *Integrated Waste Management By-law*. The by-law obliges Cape Town's waste producers to minimise their waste, separate it into different waste streams, re-use or recycle it where possible, handle it in an appropriate manner on site, and contract accredited service providers to collect it for disposal at least once per week. Generators of business waste, industrial waste, building waste, event waste, hazardous waste and priority wastes are required to submit integrated waste management plans for approval before commencing with producing waste. Failure to do so can result in a fine of between R500 and R10,000, or a prison sentence of 6 to 24 months (CCT 2009c).

Two years earlier in August 2007, the City added its *Think Twice* kerbside recycling collection service to regular waste collection services in a number of affluent suburbs as a pilot project to assess its feasibility (Tyrell 2010). It now services around 132,000 households in the suburbs of the Helderberg, Atlantic Coast, Pinelands, Camps Bay, Llandudno, Hout Bay and the Deep South region with a free door-to-door collection of mixed recyclables. Households are issued with the clear bags for recycling along with basic information as to how the system works, and recyclables are collected once a week and taken to local materials recovery facilities for separation and

¹¹ Calculated by adding the cost of dumping and removal of 11.3 tons of landfill waste to Re-'s management fee, and subtracting the revenues passed back to the client for the sale of the recyclable materials.

collection by converters. Some of the initial recycling collection projects were considered a failure due to defaulting contractors who were not able to live up to the required service standards, and Tyrell believes this resulted in a degree of scepticism from the public as to council's ability to successfully manage recycling collections. A combination of learning from the mistakes made and overseas best practice resulted in the refinement of the system, and the service has improved substantially.

The City's Solid Waste Management Department has also launched a series of integrated waste minimisation and awareness programmes known collectively as *WasteWise* (CCT 2010d). Their primary target audiences are schools, commerce and industry, and the City's staff. Their schools programme focuses on educators, students and their families, and aims at building a basic understanding of the causes and effects of poor waste management, as well as assisting in the set up of waste minimisation projects. In commerce and industry, the focus is on waste exchange and the formation of waste minimisation clubs, and within the City there is a drive to reduce waste through the separation and recycling of paper and card waste generated at the Civic Centre.

Public response

The enthusiastic involvement of the private sector has been a noteworthy feature of Cape Town's recycling industry for many years. Cape Town's pilot kerbside recycling collections have been well received, and the public has shown their appreciation of the service in the form of high participation rates. Tyrell believes that there is a strong and growing demand for recycling collection in unserved areas, and reports that the City is coming under increasing pressure to find a means of funding what is currently an expensive additional service (2010).

Preceding municipal kerbside collections, members of the public and institutions like schools and churches took it upon themselves to establish recycling drop-off points and private household collection services to capitalise on the growing interest in recycling. While many of these facilities have been rendered redundant with the roll-out of the *Think Twice* campaign to new suburbs, drop-off depots like the *Oasis Association* and collection companies like *Mr Recycle* continue to fill gaps between demand and supply of recycling services.

Motivated groups within the city represent a valuable resource for changing prevalent waste cultures at a neighbourhood level. For example, a small group of environmental activists calling themselves *Zero Waste Hout Bay* formed in 2007 to act as an intermediary between government and the residents of Hout Bay to promote waste minimisation. Their aim was to eliminate the suburb's recyclable waste sent to landfill by June 2010, and although they fell just short of their target, their involvement in a number of projects with local schools, businesses and the residents of the Imizamo Yethu informal settlement has helped to establish a recycling culture in Hout Bay that has made it the suburb with the highest recycling participation rate (97%) in Cape Town (*Zero Waste Hout Bay 2010*).

Ryan reports that there is a growing demand for waste-related reporting from Cape Town companies, particularly those with head offices abroad (2010). Pressure from consumers and investors is forcing large corporates to improve their waste management practices and provide quantitative feedback on their progress. Combined with local by-laws, clients are demanding that their waste be measured so that their recycling can be accurately reported on. *Re-* typically requires that their on-site waste managers weigh the recyclables on entering or leaving the waste sorting area, and are thus able to provide regular reports to their clients.

The future of recycling in Cape Town

If Cape Town's current stance on recycling is anything to go by, the future of the industry looks favourable. In 2007, the City set the goal of reducing landfill airspace savings above 16.5% by 2012, and the figure achieved is already sitting at 15.95% (SWM Department 2010). Key areas of activity in the coming years will be the establishment of partnerships with the private sector to improve access to recycling services, incentives to encourage the formation of waste strategies by private groups, and the further entrenchment of the Waste Act nationally.

Tyrell has high hopes for kerbside dual bag collections spreading to currently unserved areas with the help of public-private partnerships as per Section 78(3) of the Local Government Municipal Systems Act (2010). Cape Town's *Integrated Waste Management Plan* includes a recycling and waste minimisation strategy that aims to "...develop strategic Public-Private Partnerships specifically aimed at developing sustainable materials recovery and recycling industries..." (SWM Department 2010:9), and its short term strategy hinges on a series of investigations, assessments and rounds of public participation relating to Section 78(3). The project has been described as "...the most significant project that will give effect to the long-term vision..." for solid waste management in the city (SWM Department 2010:3).

Tyrell believes that investigations into Section 78(3) could see private companies taking over municipal duties in some areas, allowing them to profit from the salvaged recyclable materials (2010). This would help to address the poor financial viability of the *Think Twice* programme, and could see a shift in the manner in which industries source their raw materials towards using recycled inputs. A number of key industries relating to the production, consumption and processing of packaging materials are located in and around Cape Town, and the Solid Waste Management Department admits that they "...feature prominently in terms of a city-wide recycling and waste reduction strategy..." (SWM Department 2010:5).

An interesting feature of Cape Town's waste by-law is the opportunity for waste minimisation clubs to receive discounts on their waste collection bills. Groups can now get together to formulate integrated waste management plans for submission to the Director, and if approved they are eligible for a special dispensation due to their provision of an "enhanced service associated with waste minimisation" (CCT 2009c). This approach has been successfully employed in other countries, and incentivises those currently not participating in recycling to get together to formulate their own strategies for waste minimisation.

Cape Town's waste tariffs may also increase in the near future, but it is doubtful that this will have an effect on incentivising waste minimisation and participation in recycling. The city has identified "...remodelling of tariffs that will make allowances for future recycling incentives, as well as bring the tariffs closer to actual costs of service..." as a key strategic issue (SWM Department 2010). Tyrell says that this is likely to take the form of a flat tariff increase, with the possibility of a premium rate charged for more expensive homes similar to that on Johannesburg properties valued at over R700,000 (2010). Waste collection is currently offered at a standard rate in Cape Town, but households valued at less than R300,000 can apply for a percentage rebate depending on the property value (CCT 2009a). Other countries have employed 'pay as you throw' tariffs whereby rates are based on the weight of waste collected, but Tyrell reports that there is currently high resistance to this approach from the City and it is not mentioned in the City's waste tariff policy (CCT 2009a).

Looking further up the waste production chain, the Waste Act has also introduced "Extended Producer Responsibility" as a means of encouraging producers to consider the whole lifecycle of what they produce and to take ownership of their impact on waste. The Act allows for certain products or classes of products to be identified as those to which this responsibility applies, and creates room for specific obligations to be assigned to producers in this regard. These could include specifications for product design, materials, production methods, packaging and labelling, and could see lifecycle assessments becoming mandatory on certain products (South Africa 2009:35). This indicates a move toward the type of whole-system thinking that could precipitate meaningful change toward a circular economy, and ultimately a waste free society.

While increased participation in recycling across all sectors may seem like the ultimate goal, Ryan cautions that it can only meaningfully reduce total waste to landfill if there is sufficient demand for the recyclable waste (2010). When there is insufficient capacity to deal with the volumes of recyclable material, bottlenecks can occur that lead to dumping. Converters are limited in the amount of recyclables they can store on site as their waste licences only permit them to hold stock for up to 90 days, and they are sometimes forced to send excess recyclables to landfill. Similarly, fluctuations in commodity prices can severely affect the recycling industry's ability to remain profitable. Ryan points out that plastic recycling is particularly vulnerable to falling oil prices, and that demand for recycled plastic drops when it becomes cheaper to produce new plastic from oil. This makes recycling a risky industry, and may impede the entry of smaller businesses with a limiting effect on capacity expansion.

The growth of a recycling industry in Cape Town will yield benefits for its natural environment, its people and its economy, but it is no substitute for waste minimisation. While the establishment of a recycling culture supported by relevant industries will go a long way toward improving resource efficiencies through rematerialisation, it remains to be seen to what extent the city will be able to reduce total waste levels and achieve immaterialisations that would allow for absolute decoupling.

Case Study 6: Vermiculture

Having considered large-scale, centralised recycling of materials in the previous case study, it is important to remember that reducing waste to landfill can also be approached via smaller-scale, less complicated means. Long before the advent of packaging, natural processes were instrumental in the breakdown of organic wastes generated in the preparation of food. On-site composting has been used for centuries as a means of managing waste whilst yielding useful soil additives to retain moisture and improve agricultural yields, and this approach is gaining new relevance as a strategy for urban waste management, climate change mitigation and topsoil preservation.

Vermiculture or vermicomposting is an approach to composting organic waste that makes use of containerised earthworms to accelerate the process of decomposition. To find out more about this technology, I spoke to Mary Murphy, the founder of Noordhoek-based *Full Cycle*. Her company specialises in the on-site management of organic kitchen waste using natural organisms, and has recently made a name for itself by building awareness and education around vermiculture in South Africa. Their now famous installation at the *Mount Nelson Hotel* in central Cape Town has received a great deal of interest from the media, and has brought them into the international spotlight.

Murphy has been involved with waste issues in Cape Town for many years. Initially from a background in Peace Studies and International Relations, her interest in waste started in the 1990's when she became concerned by the amount of plastic bag waste she saw littering South Africa's roads. Her first involvement in local waste issues was her campaign to build public support for the Minister of Tourism and the Environment Valli Moosa's ban on thin plastic bags. The campaign was instrumental in a ban on the free distribution of thin bags by retailers, and the institution of a fee for thicker, more durable bags at the point of sale to encourage their re-use (Murphy 2010).

As she learned more about waste issues, Murphy became increasingly concerned by the volumes of organic waste from her kitchen that were being sent to landfill via municipal waste disposal systems. She began to experiment with composting at home, and tried a number of approaches before a friend of hers suggested vermiculture and gave her a handful of earthworms. She soon began to see the potential of earthworm-assisted composting, and built her expertise in the field by investigating the topic online whilst trying out different worm farm designs (Murphy 2010).

During her search for information, Murphy came across an Australian company called *RELN Plastics* who produce a range of domestic, industrial and agricultural products from injection-moulded recycled plastic. Their subsidiary company, *Tumbleweed*, specialises in home composting and vermiculture products made from 100% recycled plastic. They were the first in the world to design and manufacture worm farms that could be used in homes or apartments, and have

developed a range of three worm farm products to meet different requirements (Tumbleweed 2009):

- The original *Worm Factory*^(R) for serious vermiculture and multi-unit installations
- The circular *Can-O-Worms*^(R) for encouraging children's participation in vermiculture.
- The stylish *Worm Café*^(R) for smaller spaces and the aesthetically conscious.

Murphy found *Tumbleweed's* designs to be superior to any she had seen or experimented with locally, and decided to import them into South Africa. While she acknowledges that it would be preferable to have them manufactured locally, the small size of the local market does not allow for sufficient economies of scale, and she has not been able to find local suppliers of 100% recycled polypropylene and injection moulding facilities who would be able to make them more affordably. Murphy strongly believes in using 100% recycled plastic rather than 'recyclable' plastics, and has not found another supplier that can match the materials, quality and design of *Tumbleweed* products. *Full Cycle* has secured sole distribution of *Tumbleweed's* products throughout Africa, though the focus thus far has been on Southern Africa.

According to Murphy, the key to encouraging participation in worm farming and other environmentally friendly activities lies in good design (2010). The *Tumbleweed* worm farms work because they are easy and convenient to use, and their appearance makes them suitable for any home - one of her customers even has a worm farm on the marble floor of her expensive Constantia kitchen. Murphy believes that notions of environmental friendliness as being dirty or messy are outdated, and has chosen to import the Australian worm farms because they are aesthetically appealing whilst being environmentally sound.

In addition to selling worm farms and related products, Murphy has been involved in a number of educational campaigns about the importance of recycling organic waste and the benefits of vermiculture. She has led curriculum-based schools programmes, and has presented to a number of garden clubs, women's clubs and other interest groups over the years. In order to manage the number of enquiries that *Full Cycle* receives daily, she conducts a tour of the *Mount Nelson* facility for the public on the last Friday of every month. She openly admits that she is not a business woman, and it is clear that she has developed her company in response to a desire to improve the world around her. She believes in the simplicity of vermiculture and its potential to make a meaningful contribution to solving a number of the country's sustainability problems by allowing consumers to take responsibility for what happens to their waste.

How vermiculture works

Full Cycle's worm farms typically consist of three containers of equal size that sit inside one another to form a stack with a lid on the top. New organic waste is added to the top container, and the middle one houses the earthworms in a layer of older, decomposed compost. Both of these have a series of holes in the bottom to allow the earthworms to retrieve food from the top container, and to allow moisture to collect in the bottom container. This is fitted with a tap to facilitate the collection of the run-off liquid known as 'worm tea'. The design of the circular *Can-O-Worms* is illustrated below:

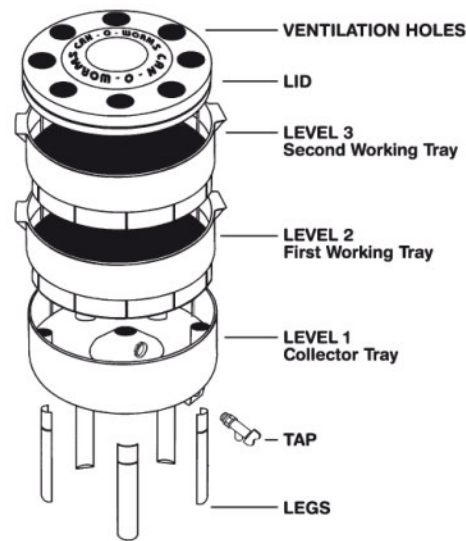


Figure 3.17: Three-layered Can-O-Worms (R) design (Source: Tumbleweed 2009)

The most important component of the system is the earthworm. Murphy explains that there are around 4,700 known different types of earthworms, which can broadly be described as either composting or soil working (2010). The composting earthworms break down organic waste, and the soil working earthworms till the top 4m of soil and aerate it so that water and nutrients can penetrate down to plant roots. The *Full Cycle* worm bins make use of composting worms to break down organic waste into vermicompost and vermitea or ‘worm tea’ which can be diluted and used as a liquid fertiliser. They also naturally attract other micro-organisms and small insects which aid the process and form a small eco-system within the containers.

The earthworms consume anaerobic bacterial slime formed in the early stages of decomposition, and produce thousands of beneficial bacteria in their gut which are released in their faeces or ‘worm castings’ (Murphy 2010). Only 6 species of earthworm are suitable for this purpose, and *Full Cycle* makes use of one called *Eisenia fetida*. Some have accused *Full Cycle* of importing their earthworms from Australia, but Murphy says they are bred locally and can be found anywhere in the world. She says that they like the dark and will die without organic waste to eat, thus making it difficult for them to survive outside their worm bins and rendering them harmless to biodiversity.

Earthworms contribute to improving the balance of beneficial and harmful elements in organic waste. They do not carry pathogens, and Murphy describes them as being “cleaner than your cat or dog” (2010). The earthworms themselves do not require any maintenance, and will control their own population depending on the conditions. They produce negligible noise and the system does not smell as it is aerobic rather than anaerobic. If the earthworms die, their bodies are re-absorbed by the soil within a matter of hours and there is no discernible smell.

The *Full Cycle* worm bins do not rely on energy, water or waste infrastructures, and operate as small-scale on-site recycling systems. They can be considered both an example of

rematerialisation and freematerialisation as they convert what would otherwise be considered a waste product into a useful input using the free labour provided by earthworms. If located at the point of waste generation, they can also serve as a form of immaterialisation as they cut out the need for transportation of waste to landfill. The main benefits to natural resource conservation are threefold:

1. Organic kitchen waste can be diverted from landfills. This extends their lifespan, reduces the amount of virgin land required for additional sites and cuts down on fossil fuels required to transport waste.
2. The aerobic decomposition that takes place inside a worm farm produces substantially less methane gas than if the same waste were to rot anaerobically in a landfill. Murphy estimates that vermiculture produces less methane per ton than the 30kg generated by regular composting, and significantly less than the 365 kg from landfill waste (2010).
3. The volume of organic waste can be reduced 70-80% by allowing earthworms to break it down in an aerobic environment. Organic waste compacted in landfill sites is typically not exposed to air and unable to decompose, resulting in it rotting but not diminishing in volume (Murphy 2010).

If the vermicompost and worm tea is put to productive use as a topsoil conditioner, the following additional benefits can be achieved:

1. The nutrients from the organic matter can be kept separate from the toxins in landfill sites, and returned to the soil in the place of fossil fuel-derived fertilisers.
2. The use of vermicompost improves the soil's ability to retain water, reducing the amount of potable water required to irrigate the gardens it is used on.

For the worm farms to function, new kitchen waste must be added to feed the earthworms (Murphy 2010). This sometimes needs to be chopped up to hasten decomposition before being deposited into the top container. A small amount of damp newspaper should ideally be added to the mix to balance the nitrogen in the kitchen waste with more carbon. This process requires opening the lid to deposit the food, and occasionally turning some of the waste to improve aeration. While the system excels at managing itself, a lack of food, excessive feeding of one food type, the addition of toxic substances or the build-up of worm tea can result in the death of the worms. In these cases, the system will simply cease to work until it is re-started with the addition of new worms and food, and would not generate a smell or danger to humans. A degree of education is involved in using the systems correctly, but this is typically provided on the product packaging and the underside of the worm farm lid.

One of the downsides of vermiculture is the requirement for regular maintenance. The conditions in which earthworms and microorganisms thrive are not aesthetically pleasing, and although the smell is not necessarily unpleasant, maintenance might not appeal to those with phobias relating to dirt, germs, insects or small organisms. Besides feeding the worms, vermicompost should be harvested from the middle container every 3 to 4 weeks. This entails swapping the top two containers and exposing the worm farm to light so that the worms retreat to the new 'middle'

container (Murphy 2010). The new 'top' container contains the vermicompost, which can be used or stored as required once the worms have retreated. The worm tea that collects in the bottom container does not keep for long, and should be harvested regularly via the tap if it is to be used. The *Tumbleweed* worm farms have been designed to minimise the amount of human contact with their inhabitants, but some may find the degree of interaction undesirable.

Performance

Full Cycle keeps regular records of the volumes of waste entering the *Mount Nelson* worm composting installation and the yield of vermitea and vermicompost it produces in order to be able to justify the investment to shareholders (Murphy 2010). An on-site manager updates records via a cell phone-based information system, and the figures have been collated to give a rough quantitative idea of the impact these systems can have on flows. Each worm farm typically takes up to 1.5 years to reach full functionality as the worms need to establish themselves in their new home in order to multiply. Performance can also fluctuate with changes in temperature and maintenance.



Figure 3.18: Rows of stacked worm farms at Full Cycle's *Mount Nelson* installation

The *Mount Nelson* earthworm composting system was designed to handle 1 ton of useful kitchen waste per month, effectively diverting this volume from landfills. *Full Cycle* claims that each of its 60 functioning 'Worm Factories' produce an average of 8 litres of worm tea and 20 litres of vermicompost per month (Full Cycle 2009). This more than meets the requirements of the *Mount Nelson* gardens, and the hotel is considering sending the excess to a food gardens project in Philippi to help the less fortunate in the near future. The value of the compost and vermitea is approximately R25 per kg and R30 per litre respectively, allowing for pay-off in a matter of months if the by-products are used in the place of purchased alternatives (Murphy 2010). Savings in the cost of municipal waste collection (in terms of fewer wheelie bins) and CO₂ emissions can also be estimated, but are less significant.



Figure 3.19: The fertile gardens of the Mount Nelson Hotel, nourished with vermicompost and vermitea

Vermiculture in Cape Town

Although *Tumbleweed's* worm bins were designed for the Australian market, they work just as effectively in South Africa. Murphy explains that earthworms require similar climates to humans to survive, and worm farms can be used indoors or outdoors (2010). *Full Cycle* has not needed to change their technology to suit the local environment in any way. The simplicity of the units, their independence from other infrastructures and their negligible harmful side effects allow them to slip through the legislative net, facilitating the relatively swift uptake of the technology without red tape complications.

While Murphy applauds the political shift in mindset from waste disposal to waste minimisation embodied in South Africa's Waste Act and Cape Town's Integrated Waste Management By-law, she is sceptical of the extent to which talk is being followed through with action. As far as she is concerned, Cape Town's waste minimisation strategies have had "no substance" thus far, and she would like to see the city being more courageous in its efforts to shift outdated perspectives (Murphy 2010). Over the years she has been involved in a number of think tanks and public participation debates, and believes that the powers that be within the city are aware of the need to reduce organic waste to landfill, but suffer from a "knowing-doing gap" that inhibits true progress.

Murphy has observed a bias toward the recycling of inorganic waste at the expense of organic materials, and finds it ridiculous that the city "...consistently ignores organic waste..." (2010). Between 39% and 57% of the average Cape Town household's waste is organic, with higher percentages corresponding to lower income groups (Engledow 2007:37). The city has recognised the importance of separating garden waste from mixed landfill waste, and now diverts significant volumes of it from the city's landfills for chipping and composting, saving an estimated 400,197m³ of landfill space in the 2008/2009 financial year (SWM Department 2010:14). However, current approaches mix kitchen waste with other landfill wastes, overlooking the potential value they can offer as a source of soil nutrients and adding unnecessarily to the burdens placed on landfills.

The Solid Waste Department's website indicates their acknowledgement of composting as a means of minimising waste, and provides instructions on how to make a compost heap and worm bin at home. It also provides a link to *Full Cycle's* website, and that of one of its competitors (CCT 2010b). However, Cape Town's SWM Sector Plan indicates that it has no specific strategy for reducing kitchen waste to landfill, relegating it to the "organic wastes" which form part of the 25% of miscellaneous wastes that would remain after garden, construction and packaging waste have been diverted from landfills. The only mention of organic waste in the most recent review of the plan is recognition of "...a potential partnership opportunity in future..." relating to the re-commissioning or establishment of centralised composting facilities (SWM Department 2010:5), but it is likely that the focus will be on high volume garden waste rather than kitchen waste.

Part of the reason kitchen waste has not received as high a profile as construction waste or packaging waste is that it has not been declared as a 'priority waste' under the national Waste Act. The volumes and composition of organic kitchen waste streams do not appear to be considered a significant threat to "health, well-being and the environment", and thus not a major concern in the country's waste management strategies designed to tackle problems in order of magnitude (South Africa 2009:31). While this might make it difficult to acquire government support for kitchen waste diversion initiatives, worm farmers are free of the boundaries placed on priority wastes by the Waste Act, making it much easier for them to operate within the law.

A major obstacle to waste minimisation lies in perverse incentives to wasteful behaviour resulting from Cape Town's approach to parity of service delivery across all areas. The City's solid waste tariffs are based on principles of fairness which allow for discrimination between different categories of user, but do not allow for waste minimisation to be rewarded with lower rates or rebates (CCT 2009a). Murphy believes that the city's 240 litre wheelie bins are excessively sized for the weekly needs of an average household, and that they encourage additional waste instead of incentivising waste minimisation (2010). Each household pays a flat rate for weekly waste collection regardless of their efforts to reduce waste, with the only concessions being for cheaper properties. Murphy manages to survive without a wheelie bin as she recycles all of her household waste, but she still has to pay a service fee for kerbside collection.

Public response

Murphy believes that the City of Cape Town's unwillingness to reveal the extent of its waste crisis has, until recently, broken the feedback loop between the public and the consequences of their actions (2010). In the last few years, the situation has changed as the city has acknowledged it has a crisis on its hands, and has actively participated in public education through *WasteWise* and other campaigns. This has stimulated public interest in the issue of waste management with a resulting increase in demand for alternatives.

When she introduced vermiculture to the South African domestic market, Murphy recalls a number of adverse public reactions to the concept. She admits that the idea of using worms "freaked people out" to begin with, and even securing the *Mount Nelson* job required a great deal

of convincing over a period of months (Murphy 2010). Misperceptions included confusion between earthworms and more dangerous worms, with some people expressing concern that they might burrow into their skin or that they would eat the garden like caterpillars if they escaped. It is likely that a large portion of the population harbours a degree of dislike toward earthworms, and subjective neuroses about interacting with these creatures and the dirt they call home on a regular basis may outweigh the objective benefits of this method of waste management for many homeowners.

After years of raising awareness and educating people about the advantages of earthworms, acceptance of vermiculture and earthworms has grown. This has been assisted by Murphy's public relations efforts that have been picked up by both local and international media networks. One of the most noteworthy was a report on the South African investigative journalism show *Carte Blanche* that focused on the *Mount Nelson* installation. Although the insert was only a few minutes in duration, it was voted by viewers as that week's 'Viewers' Choice', and was repeated later in the week due to popular demand (Murphy 2010). One of *Carte Blanche's* employees contacted Murphy afterwards to tell her that they had never before received such positive feedback to one of their stories.

As was the case when she initially stumbled across vermiculture, Murphy believes that the simple approach to organic waste management resonates with members of the public interested in living less harmfully (2010). She has experienced firsthand how Capetonians are getting "fed up" or disturbed by the food waste they throw away each day, and has recognised a visible sense of relief and self-empowerment in many of her customers. Like Tyrell, she believes that the bad publicity resulting from the failure of early kerbside recycling projects in the city gave recycling a bad name and introduced an element of scepticism about Council's competence. Worm farming allows them to make a positive contribution in a manner that, unlike centralised recycling, does not rely on government-appointed service providers. It offers them a means to appease their conscience by working around dysfunctional bulk-provided services and taking on some of the responsibility for their waste without significant inconvenience.

Over the years, Murphy has been overwhelmed by the "mind blowing" positive feedback she has received from gardeners who have seen the benefits of using vermicompost and worm tea on their plants, ranging from vegetables and fruit trees to roses and orchids (2010). She believes that there is a feel good factor associated with worm farming that helps to maintain interest and long-term participation. The on-site location of the systems ensures that these messages are reinforced regularly. Whilst materials recycling can also generate a feel good factor, the benefits are more abstract than tangible, and rely more heavily on consumer awareness of the broader benefits of recycling.

The market for worm farms and accessories has grown significantly in recent years, as seen by the entry of a number of worm bin suppliers and manufacturers around the country, and the addition of worm farms to the product ranges of garden supply companies. While there are unfortunately no over-arching statistics about the size of the market, *Full Cycle* reports that they have sold

around 6,500 worm farms in the last 3 years, mainly in Cape Town and surrounding areas (Murphy 2010). The majority of sales have been to domestic homes either directly or via retailers like *Pick 'n Pay*, but they have also worked on larger-scale projects for *Freshmark* vegetable distributors, the *Pick 'n Pay* supermarket in Constantia, *Spier* winery and the *Mount Nelson Hotel*.

A rough calculation based on the performance of the Mount Nelson worm farms¹² indicates that the 6,500 units sold by *Full Cycle* have the potential to divert around 1,300 tons of organic waste from landfills each year. If these figures were to be combined with sales of competitor products and the number of DIY worm farms in homes and gardens around the city, the total contribution of vermiculture to reducing landfill waste is likely to be even greater.

The future of vermicomposting in Cape Town

The reduction of organic waste sent to landfill through the decentralised composting of food waste appears largely absent from City of Cape Town's strategies for waste minimisation. For now, a focus on priority waste issues leaves few resources for kitchen waste reduction, and it is not difficult to see why the City has adopted its current approach. While it acknowledges the benefits of home composting and appears to endorse it, the City is unlikely to be able to provide significant additional support until more pressing consumer demands such as that for the extension of kerbside recycling collection are met.

Even if the City were to incentivise the purchase of worm farms or provide them free of charge, the success of such a scheme would rely heavily on an underlying commitment to vermicomposting and all that it entails from homeowners. Unlike more passive sustainable technologies, vermiculture requires a degree of hands-on involvement with one's waste that many ratepayers are likely to reject. Even if people buy into the idea of assisting the council with waste management as has been witnessed with kerbside recycling collections, deeply-entrenched attitudes surrounding organic waste, dirt, insects and the degree to which it is appropriate to get involved with one's own waste management remain significant obstacles. The required changes to consumer perspectives would be considerably greater than those needed to participate in the rinsing and separation of recyclables, thus presenting a greater challenge.

There is potential for vermiculture to be upscaled and used on a more centralised basis to deal with organic waste from shopping centres, hotels, office precincts and even residential neighbourhoods. Applying Section 78(3) to this issue could potentially see private companies providing collection services for organic waste which they convert into vermicompost and vermitea and sell back to consumers. Similar systems have been employed in the cities of industrialised countries and the developing world where urban agriculture has been promoted as a strategy for food security. Cape Town is catching on to the trend, with companies like *Mr Recycle* adding such services to their door-to-door recycling collections (Mr Recycle 2010).

¹² Based on 60 worm farms processing one ton of kitchen waste per month, i.e. 200kg per unit per year.

There is also an opportunity to use financial measures to incentivise waste minimisation so that households can choose between continuing to receive the City's all-in-one service package, or saving money by getting involved in reducing their waste. The City may not be in a position to consider a weight-based tariff model for waste collection, but an interim approach may be for waste minimising households to apply for a discount on their waste collection rates by submitting a simple waste minimisation plan. Approved waste minimisers could have their wheelie bins swapped for an alternative with a smaller capacity, perhaps in a different colour to attract interest from neighbours. This would reward waste minimisers without threatening the City's efforts to achieve parity of service delivery at significantly lower cost than a pay-as-you-throw system.

For the foreseeable future, it appears that the motivation for household vermicomposting will need to come from consumers themselves. As Murphy observes, much of the appeal of worm farming lies in the ability to empower consumers to take action instead of relying on government to manage their waste (2010). While the majority will be happy to comply with government's service offerings, those with the interest, motivation and finances to pursue this method of dealing with their organic waste will continue to do so. With the proliferation of products, testimonials and information available locally, the number of households using worm farms is likely to increase, and they will no doubt make a contribution to waste minimisation in the city. In the absence of incentives for waste minimisation, however, it appears that this growth will be organic and is likely to remain the preserve of niche interest groups.

Conclusions

While the City of Cape Town has only recently taken concrete action to address issues of energy and water supply sustainability, its dedication to improving waste management practices has been evident for a number of years. Even before the *Waste Act*, the City was actively pursuing waste minimisation strategies and piloting kerbside recycling. Its strategies have focused on priority wastes as a starting point to achieving a 30% reduction in waste to landfill by 2020 (CCT 2007), and significant diversions of waste streams like builder's rubble, garden waste and recyclables have prolonged the lifespan of its landfill sites and allowed for these resources to be re-used for construction, compost or the manufacture of new products (SWM Department 2010).

The city has made commendable efforts to establish kerbside recycling collection in collaboration with private contractors, and is taking advantage of opportunities in national legislation to adapt the model for broader roll-out through its investigations into Section 78(3). The new institutional arrangements between the public and private sector that will potentially result could see significant expansion in Cape Town's participation in materials recycling, and in combination with the new responsibilities placed on manufacturers and other waste producers by the *Waste Act* could see a significant change toward a circular, zero waste economy in the years to come.

The multiple benefits that can be derived from the use of vermiculture to deal with the city's food waste make it an interesting option for the future. It is not difficult to justify the City's short term priorities on reducing more significant waste streams, but as these systems become more established there may well be an interest in composting methods to further reduce landfill waste. Considered objectively, the benefits of decentralised vermiculture outweigh the inconvenience associated with interacting with worms, but irrational fears of dirt and insects perpetuated by the advertising industry are likely to act as a barrier to broader uptake by households. Many of these obstacles could be overcome by employing a more centralised approach to vermiculture, incorporating the collection of organic waste into current kerbside recycling collection services. Innovation in this area is likely to be led by the private sector in the short term as this is not part of the City's current strategies.

For waste minimisation strategies to be truly effective, they need to carry through to behavioural change on the level of individual consumers, affecting the decisions they make at the tills, in their workplaces and at home. A combination of education and the right incentives would help to build a waste minimisation culture, but Cape Town has a long way to go in achieving this. The City's approach to parity of service delivery represents a missed opportunity to incentivise waste minimisation. As long as the production of 240 litres of waste per week is considered an acceptable norm, it is unlikely to see consumers questioning their waste habits or making a conscious effort to choose products with less packaging.

4. Infrastructural change for a more sustainable Cape Town: concluding thoughts

The case studies on energy, water and waste in Cape Town have provided an insight into the city's progress toward more sustainable approaches to infrastructure, and an indication of the direction in which it is headed. Based on the literature analysis and case study research, I will now conclude with a narrative account of the main findings of this thesis to tie the international theory to the real world observations from Cape Town.

The ability of cities to survive and prosper in the face of diminishing natural resources will depend on the manner in which they manage the vast flows of inputs on which they rely, and the waste outputs they produce. Behind the scenes of everyday life, infrastructure acts as a muted manipulator of resources like water and fossil fuels that support modern urban lifestyles. Attempts at behavioural change play an important role in sustainability strategies, but once-off decisions affecting bulk infrastructure have greater potential to reduce the long-term resource impact of both those who are willing to change their actions and those who are not. Looming resource crises are placing an unprecedented additional weight on the shoulders of infrastructural decision makers, but those in the cities of South Africa have been slow to rise to the challenge.

While forward-thinking cities in industrialised nations are struggling against the inertia of inherited infrastructural investments better suited to resource abundant eras, those in developing countries wishing to grow by replicating these archaic approaches without adaptation to locality and future resource scarcity will face similar if not more dire consequences in the not-too-distant future. The opportunity presented by the expansion of infrastructural services in growing cities is seldom recognised as ecological sustainability is traded off against more pressing social and economic concerns, but the long term costs of this myopia will negatively impact all dimensions of sustainability. Unless bold steps are taken to implement systems that deliver modern services in a manner consistent with planetary limits and the need to conserve resources, these cities run the risk of committing their citizens to ever-escalating costs of living and serious disruptions to infrastructural services in the future.

When considering how to approach infrastructural innovation, efficiency improvements to reduce wasteful resource use are a relatively simple and economically viable starting point. The rationale of eco-efficiency has long been recognised by the corporate world as a way to improve profits whilst reducing planetary impact, and can be applied to the provision of infrastructural services as a first step toward sustainability. The 'easy win' financial benefits make eco-efficiency a management ethos well-suited to the public sector, with benefits accruing to all ratepayers rather than just an elite group of shareholders. Dematerialisation and rematerialisation are the primary strategies for improving efficiency, reducing the amount of resources required to deliver a service and capturing value from waste streams to substitute for raw material inputs.

If pursued as the highest objective for new infrastructure investments in growing countries, efficiency can at best achieve relative decoupling by slowing the rise in total resource

consumption as wellbeing improves. However, unless existing systems are replaced with more efficient ones, using efficiency as a growth strategy is unlikely to reduce total resource consumption. Realisation is growing that we have reached a point where total consumption needs to start declining in order for us to secure a future on earth, and relative decoupling alone is no longer a sufficient strategy.

Instead of limiting aspirations to relative decoupling in line with short term financial rationales, more ambitious targets need to be set to achieve absolute decoupling of wellbeing from finite resources. Freematerialisation and immaterialisation are key strategies to achieving greater prosperity with reduced resource impact, and can be applied to the provision of infrastructural services. Freematerialisation technologies like those that harness energy from the elements, use plants to purify water, or turn organic waste into compost with the aid of earthworms allow man to work alongside nature, freeing innovation from an impact-minimising mindset. Immaterialisation allows for inappropriate approaches to be replaced entirely by tried-and-tested simple technologies like bicycles and washing lines, or (where budgets allow) modern technologies like the internet and telecommunications.

For alternative technologies to succeed in context, a supportive environment needs to be fostered. Imported ideas need to be carefully selected and in some cases adapted to the unique characteristics of the local environment. Instead of replacing the old with the new, the process of implementation needs to be gradual and considered to allow the socio-institutional context time to evolve. An important requirement is the transformation of institutions to overcome inertia and embrace change. To move beyond an impact minimisation mindset, whole-systems thinking needs to be encouraged, facilitated by trans-disciplinary knowledge sharing. Quantitative measurement and targets based on real limitations are essential to ensure that the overarching goal of reducing resource impact is achieved. In line with this, incentive structures like pricing need to be amended to encourage resource conservation by both consumers and utilities.

Contrary to what some of the academic literature might suggest, Cape Town is alive with efforts to decouple its liveability from unsustainable resource use. The case studies show that top-down efforts are being matched by the enthusiasm of individuals whose passions have driven them to step in where centralised decision making has been slow to react, and that change is indeed taking place. While their motivations range from making a living to loftier aspirations to change the world, they are unified by the impact their innovations have on the resources used to provide services to the city's residents. No longer passive recipients of a 'black box' of infrastructural services, these well-informed ratepayers are investing their time and money in developing solutions that work in the local context, and are producing valuable knowledge and experience in the field of resource conservation that the City of Cape Town would be hard-pressed to find in the high-tech solutions of developed economies.

Regardless of adaptation from the top, informal networks of informed citizens are introducing alternatives and slowly changing the relationship between modern services and resource use once determined solely by those in power. Dependence on centralised government decisions

regarding infrastructure and the frustrations once typical of those with more worldly perspectives are giving way to a new type of self-empowerment aided by modern technologies. Those who question government's approaches can extract the latest knowledge from sources all over the world, learn how alternative approaches work, adapt overseas learnings to the local context through experimentation and share what they have learned with others. People like Peter Becker and Mary Murphy have done just that, and in the process have captured the imagination of ordinary citizens through their unconventional yet unequivocally logical alternatives to unsustainable service models that work comfortably alongside the existing order. Informal networks of wind turbine makers and worm farmers are spreading organically, and the face of the city is changing as they gain impetus.

Investigations into the areas of energy, water and waste show that the City of Cape Town and other levels of government have been actively involved in planning for change, and have taken some tentative steps toward it. This can be seen in efforts to reduce water wastage by fixing pipe leaks, the recently improved performance of waste water treatment facilities, the roll-out of kerbside recycling in a number of suburbs, and the significant reduction of waste to landfill by diverting garden and building waste. It is encouraging to see that the City is practicing what it preaches in energy saving measures like the replacement of light bulbs with LEDs in street and traffic lights, and the installation of water-saving methods in the Civic Centre, Ecology Park and Green Point Stadium. This lends credibility to its claims of support for sustainability principles, and shows a willingness to play a leading role in change.

The City's stance on the conservation of energy and water and the minimisation of waste appears to be strongly influenced by eco-efficiency principles aimed at cost recovery. Considering the 'ladder' analogy in Figure 2.4, it is not surprising that gradual improvement to existing systems has received priority as a first step toward a sustainable society. The strategies adopted thus far can be broadly described as typical of a relative decoupling mindset, looking at factors like improving efficiencies in water and electricity distribution and the recycling of solid waste rather than making any radical changes to the status quo. While policies and plans allude to more ambitious projects in the future, it is yet to be seen whether these will come to fruition or whether the City will hit a 'green wall' that would prevent it from moving beyond relative decoupling to achieve much needed absolute decoupling.

At a national level, there is noteworthy evidence of a willingness to traverse comfort zones through revolutionary departures from convention in the case of the Department of Energy's promotion of solar water heaters. The decentralised use of the sun's energy represents a significant shift in direction for a country addicted to centralised provision of electricity powered by fossil fuels, and can be viewed as a sign of commitment to inertia-disrupting change. The rebate system is not perfect and the details of current incentives can be criticised, but these approaches are under constant revision and it appears that support for SWHs is here to stay in one form or another. The valuable institutional learnings that have come with the roll-out of this decentralised technology have the potential to be carried over to other areas where such an

approach may be more suitable than conventional large-scale projects, for example the encouragement of rainwater harvesting or home composting.

Civil society and public-private partnerships are playing an important role in promoting sustainability through infrastructure. In the case of SWHs, SESSA has taken on a key responsibility in advancing the SWH agenda and keeping an eye on the growing industry in line with consumers' best interests. The various projects of the *Cape Town Partnership* are using business interest in the city to assist government with sustainability projects like *Reclaim Camissa* that will help to improve the city to the benefit of all stakeholders. The City's kerbside recycling collection system would not have been as successful as it has been without private contractors adapting their business models to make recycling work and ensuring smooth service delivery. It appears that the City is open to mutually beneficial collaborations, and is willing to share the burden of service delivery where it can.

While government is showing an interest in making infrastructure more sustainable, institutional innovation remains a major challenge that is slowing the follow-up of paper promises with action. Decentralisation is a key strategy in many sustainability approaches, and shifting from a centralised service delivery model to one that incentivises the private sector to take on new responsibilities for their resource management involves fundamental changes in mindset, duties, administration, budgeting, reporting, staffing and the scope of accountability in previously heterogeneous government departments. The formation of the *Energy and Climate Change Sub-Committee* indicates that the City of Cape Town is aware of the limitations of traditional government structures, and is willing to innovate to facilitate trans-disciplinary collaboration for sustainability.

There are strong signs of vested interests in existing infrastructures that play a role in inhibiting change toward sustainability in South Africa. This is most evident in the field of energy, where the need to improve energy efficiency is coming up against the need of government and private investors to profit from the sale of electricity. Similarly, the need for renewable sources of energy is battling those with a stake in the existing coal and nuclear industries who are threatened by the introduction of new technologies. While *Eskom's* monopoly gives it an unfair power advantage over South Africa's citizens, the frustration and resentment this has engendered is attracting increasing public interest in energy issues which could well see changes in the industry in the coming years.

Inhibiting factors are also prevalent on the consumer side. The public's expectations of the services they feel they should receive in exchange for rates and tariffs make it difficult to change to a model like waste separation at source where higher participation is involved for equal or higher cost. To build a more sustainability-oriented culture, a greater understanding of why it is important to save resources and recycle waste is required along with improved financial literacy to change value perceptions that prioritise depreciating status symbols over investments in money-saving eco-efficiencies. Collaborations between local government and the education

department could help to shift value systems and awareness of pressing resource issues to support sustainability and facilitate broader societal change.

The broader adoption of innovative systems to replace or improve current means of providing infrastructural services can contribute significantly to reducing Cape Town's resource impact, but the burden of implementing a solution does not need to be placed entirely on the shoulders of government. Pricing can be used as a proactive incentive to change consumption behaviour, presenting a relatively simple and swift means of achieving multiple goals in a manner that incentivises innovation and cooperation from the private sector. Some may argue that prices will naturally increase as scarcities drive down resource supplies, but this approach will have serious negative impacts on future liveability, especially for the poor. Price increases designed to prevent resource scarcities would encourage the public to take action to reduce their consumption whilst improving the possibility of having access to resources in the longer term. The free basic service allowances for the poor would largely protect them from price increases, and would encourage action from the most wasteful upper income groups.

Although Cape Town experienced increases in the price of water and electricity of 10% and 25% respectively in July 2010, they do not appear to have been designed to prevent investment in capacity expansion and are unlikely to have a noticeable effect on total water consumption. The low costs of water, energy and waste services in Cape Town currently act against investments in savings or behavioural change, and while electricity prices may be in the hands of NERSA, the City does not appear to be taking advantage of its power to manipulate the costs of water and waste services as a proactive means of encouraging the wealthy to conserve resources and stimulating innovation in the private sector.

Cape Town has much to achieve on its path to decoupling unsustainable resource use from life in the city, but change is undoubtedly underway. Actions by government, educational institutions, business, industry, civil society and passionate members of the public are advancing the sustainability agenda in disparate areas, and with it the face of the city is changing. Burdened with a legacy of social inequality and lingering poverty, the city and its people are tasked with ameliorating the past whilst looking to the future, and stand to play a leading role in inspiring change on the continent and in the developing world in the years to come.

5. Areas for further research

While researching this thesis, I repeatedly encountered a lack of information about implemented sustainable technologies and their impact on society, resource flows and the economy. As I connected the findings from the case studies to the literature, a number of ideas for future research arose and I needed to exercise a degree of restraint to maintain the focus of this body of work. In the interests of encouraging further exploration into the unfolding dynamics of infrastructural change in Cape Town and the cities of the developing world, I would like to suggest the following areas for future research:

5.1 Performance of sustainable infrastructure technologies

A lack of reliable quantitative information on the performance of the case study technologies represented a challenge to the academic rigour of this thesis. In particular, it was difficult to make accurate claims about the impact of the technologies on resource use as, in most of the cases, no academic research has been conducted. Product manufacturers or agents do not usually have the wherewithal to conduct scientifically rigorous tests on their products, so they rely on 'rules of thumb' to make claims about resource savings. This diminishes the strength of their arguments somewhat, and makes it difficult for government and private investors to calculate the environmental and financial benefits of their technologies. While there is data available for more established alternatives like SWHs, the performance of products like worm farms, rainwater harvesting systems and grey water sanitation systems has not yet been thoroughly assessed in the local context. Research collaborations between educational institutions and the relevant product advocates would help to provide more credible estimates of the role these technologies could play in resource management, and would strengthen the case for their consideration.

5.2 The market for sustainable infrastructure technologies

The extent to which the infrastructure technologies featured in the case studies are influencing Cape Town's resource flows is difficult to estimate without accurate, up-to-date, comparable figures on how many households have adopted them. Accumulating the sales data of various products would go a long way toward building an understanding of demand and market growth, and would be a useful base from which to extrapolate the overall impact of decentralised infrastructure interventions on the city's resource use. With the support of such figures, the trends observed in this research could be given the quantitative support necessary to show the extent to which they are making a difference.

5.3 Further case studies on infrastructure alternatives

The case studies included in this thesis have been limited to six approaches to resource conservation in three main areas. In selecting them, I had to exclude a number of other interesting technologies that also have potential to shift the city's resource flows in the interests of sustainability. Further case study research into sustainable infrastructure alternatives would help to bring the wide range of options to the fore and enhance their familiarity to the academic world. Examples of such technologies include solar photovoltaic electricity, geothermal energy,

biogas, heat pumps, building insulation, grey water for irrigation, eco-san toilet systems, black water treatment, home composting of garden waste, public transport systems, pervious paving and stormwater swales to name but a few.

5.4 The role of social entrepreneurship in sustainable infrastructure service provision

The case studies used in this research have exposed the important role of entrepreneurs in infrastructural change in the Cape Town context. The findings show that individuals and groups from the private sector can play a pivotal role where a government burdened by more pressing social issues is slow to change. While Northern literature tends to focus predominantly on retrofits of outdated infrastructural systems that are either led or supported by government, there is a noteworthy absence of literature pertaining to resource conservation through infrastructure in the developing world. Following on from the findings in Cape Town, research into the role of social entrepreneurs and the private sector in infrastructural change in other developing world cities would help to identify the extent to which this trend is applicable to other cities in developing countries where government decision-making is failing to meet citizens' sustainability concerns.

5.5 Resource custodianship and culture

The focus of this research has been on investments in technologies that, for the most part, allow life to continue unchanged whilst reducing the demands placed on natural resources. While technology can contribute a great deal to a city's sustainability, behavioural change brought about by a greater understanding of sustainability and resource issues would serve a complementary role with the potential to spread and have a greater effect on resource decoupling in the long term. Whereas technologies are only of benefit during their useful lives to those who access their services, a prevailing culture of resource conservation and frugality could encourage both rich and poor to save resources, help the less educated to better manage their finances, inspire innovation, build interest in resource saving and strengthen demand for more appropriate technologies. Learnings from campaigns to encourage recycling, save water or encourage homeowners to invest in solar water heaters could be combined with research into perceptions of infrastructural services, roles and responsibilities, and sustainability issues. This would provide an insight into the challenges and opportunities presented by prevailing value systems and perspectives, and could stimulate further discussions on how to improve participation in sustainability.

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Appendix A: Interview discussion guide

Technology choice

1. Would you describe this approach / technology as sustainable? Why? (e.g. CO₂ reduction, water saving, waste minimisation...)
2. How does it work and what makes it unique? (i.e. product claim or unique selling proposition)
3. Did you consider any other approaches or design features and why did you decide on the current iteration?
4. What other approaches / technologies would you like to try in this market and what is holding you back?

Design

5. What materials are used to manufacture and install this product?
6. In what ways has the approach / technology changed from the original vision or design? (Was it a matter of adapting a design from elsewhere or designed from scratch?)
7. Have you had to make any compromises in bringing your approach / technology to this market, and if so what were they?

Performance

8. How does your approach / technology contribute to reducing resource consumption / waste? (i.e. quantitative analyses)
9. How does your approach / technology perform financially? (i.e. financial analysis of costs vs. savings)
10. Are you aware of any research having been conducted into this approach / technology in South Africa?

Maintenance

11. What inputs are required to operate and maintain this technology?
12. What ongoing management or maintenance is involved once installed and have there been any problems with this?
13. What could potentially go wrong with this approach / technology? (e.g. health threats, system collapse etc.)

Context

14. What obstacles or barriers have you encountered in bringing your approach / technology to the Cape Town market?
15. How would you describe the public reaction to this approach / technology? Do you have any particular examples of noteworthy views?

16. Have there been any factors that have acted in favour of your approach / technology?
(e.g. government incentives, price changes, new laws, NGOs, consumer support, marketing etc)
17. What would you like to see change to facilitate the uptake of this approach / technology?

Cape Town market

18. What have been your most ambitious projects in Cape Town?
19. Who do you consider to be your competitors?
20. How broad an impact is the approach / technology making on overall consumption / waste? (How big is the Cape Town urban market? How many jobs have you done and where is this approach / technology most popular?)
21. Have you attempted to change opinions through education, marketing or stimulating debate around your approach / technology?

Closing question

22. If you were to do it again, what would you do differently?