MAPPING THE TRANSITIONAL PATHWAY TO LOW-CARBON HOMES IN SOUTH AFRICA

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A dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in fulfilment of the requirements for the degree of Master of Architecture

Johannesburg, 2017

DECLARATION

I declare that this dissertation is my own unaided work. It is being submitted for the Degree of Master in Architecture to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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ABSTRACT

Based on a complementary framework guided by the Delphi method for the business-as-usual (BAU) forecast and the backcasting method for envisioning the desired future state, the study finds that by 2050, South Africa will have reached its goal of 80% reduction of CO_2 emissions from the middle-income home sub-sector, through a middle-loading (ML) transition pathway. This pathway was selected from among four alternative pathways because of its ability to mindfully facilitate the required transformational changes in behaviour and lifestyle, especially through support by means of responsive nudging incentives and mandatory policies, responsive technology innovations and market transformations.

The study also applied multiple-level actors (MLA) principles towards the identified four primary pathway-options in CO_2 emissions reduction in the sub-sector, which are front-loading (FL), back-loading (BL), even-loading (EL) and middle-loading (ML). The study further provided substantial motivation for ML as the preferred pathway for South Africa’s transitioning to low-carbon homes by 2050. This reinterpreted transition model of orchestrating transformative change depicted how iterative responses to conflicting accelerator- and inhibitor-factors enabled low-carbon mitigation interventions in the sub-sector, thus facilitating an equitable country-level contribution towards the global goal of stabilising global warming below the scientifically-guided threshold of 2°C by 2050. A co-evolutionary approach will be required on multiple-levels with significant pressures that will overcome systems-inertia in order to achieve the transition to low-carbon middle-income homes in South Africa. The main findings of this study can contribute towards policy tools to guide deeper structural transformations of both society and economy in pursuit of improved/equitable well-being and prosperity while ensuring survival within finite planetary resources. In particular, the process of visioning and pathway-frameworks under backcasting has been adequately substantiated to allow for adaptation to alternative applications in similar studies for South Africa and internationally as well.

Keywords: Low-carbon homes; futures studies; Delphi; backcasting; transitional pathways

DEDICATION

In memory of my mother
Heidi Geszler

ACKNOWLEDGMENTS

I am indebted to the Creator and provider of the energy to pull through and complete the dissertation. This inner fire enabled me to overcome all the obstacles to achieve the end product.

I would especially like to express my gratitude to my supervisor Prof. Daniel Irurah, whose mindfulness, support and understanding provided unprecedented insight and made me take my study one step further all the time.

Among the many people who contributed to this study, the greatest credit goes to my participants. Some participants gave their input on the questionnaires and some participated actively in the charrettes. The people consisted of experts and non-experts who showed a strong interest in, and passion for, sustainability matters.

My family has been encouraging, supportive and shown belief in me and my work. I am sad that my mother, Heidi Geszler, passed away when I was halfway through the dissertation, but I know she would have been proud of me. Last, but not least, I would like to thank my sister Isabella, who supported me in this venture through all the trials and tribulations.

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NOMENCLATURE

Back-loading	BL
Business-as-usual	BAU
Carbon dioxide	CO_2
Combined heat and power	CHP
Compact fluorescent lamp	CFL
Conference of parties	COP
Confidence level	CL
Continual professional development	CPD
Department of Environmental Affairs	DEA
Demand-side management	DSM
Department of Trade and Industry	DTI
Department of Energy	DOE
Diffusion of Innovation Theory	DIT
Energy Information Administration	EIA
Energy Performance Certificate	EPC
Engineering contractor	EC
European Union	EU
Electricity Supply Commission	Eskom
Even-loading	EL
Front-loading	FL
German appliance labelling regulations	EnVKV
Green Building Council of South Africa	GBCSA
Greenhouse gas	GHG
Gross domestic product	GDP
Group of Eight Industrialised Nations	G8
Growth without constraints	GWC
Gigawatt-hours	GWh
Human immunodeficiency virus	HIV
Innovation systems	IS
Intergovernmental Panel on Climate Change	IPCC

Integrated Urban Development Framework	IUDF
International Finance Corporation	IFC
Interquartile range	IQR
Kilowatt	kW
Kilowatt-hours	kWh
Kreditanstalt für Wiederaufbau (German development bank)	KfW
Light-emitting diodes	LEDs
Liquified petroleum gas	LPG
Low and zero carbon	LZC
Low carbon society	LCS
Median	M
Megawatt	MW
Megatonnes of carbon	MtC
Megatonnes of carbon dioxide equivalent	Mt CO_2-eq
Methane	CH_4
Middle-loading	ML
Multiple-level actors	MLA
Multiple-level perspective	MLP
Megajoule	MJ
National Building Regulations	NBR
National Energy Regulator of South Africa	NERSA
National Institute for Environmental Studies	NIES
National Renewable Energy Laboratory (USA)	NREL
National Regulator of Compulsory Specifications	NRCS
Net present value	NPV
Nitrous oxide	N_2O
Non-governmental organisation	NGO
Per annum	p.a.
Petajoule	PJ
Photovoltaic	PV
Public Finance Management Act	PFMA
Quartile	Q

Renewable energy	RE
Renewable energy feed-in tariffs	REFIT
Research and Development Corporation	RAND
Research and development	R & D
Small-scale embedded generation	SSEG
Solar water heater	SWH
South African Bureau of Standards	SABS
Strategic niche management	SNM
Tons of oil equivalent	Toe
Transition management	TM
Terawatt-hours	TWh
UK domestic carbon model	UKDCM
UK Energy Research Centre	UKERC
United Kingdom	UK
United Nations Framework Convention on Climate Change	UNFCCC
United States Dollar	USD
United States of America	USA
Watt	W

CHAPTER 1

INTRODUCTION AND CONTEXT

1.1 Overview

The most fundamental requirement for achieving carbon emission reductions is to change the technologies and human behaviour currently contributing towards climate change. This dissertation envisions living in a low-carbon society (LCS) and the people and their homes within such a society. The study refers to the scientific debate about the potential magnitude of climate change and the likely interactions between human activities and climate systems. The study is aimed at middle-income residents who want to, or should, reduce their carbon emissions in their homes but remain able to live convenient lifestyles and within their means. It has been argued that while this is technically possible, it is not necessarily economically feasible or sociably desirable at present or in the short term (Herring, 2012:1-13). For drivers of low-carbon homes to be actioned, society must be understood as a seamless web in which technological and social aspects are interwoven and mutually reinforcing rather than conflicting. For this to happen, some of the most contentious issues have to be addressed, including– the changes required to be made in homes, complemented by levers of lifestyles, technologies, markets and how strategies can influence these changes to attain deep cuts in greenhouse gases (GHG) emissions by the year 2050. The timeframe of 2050 is the long-term goal required by science (IPCC, 2007) to attain the below 2°C temperatures threshold by reducing greenhouse gas emissions to avoid dangerous climate change.

To achieve reductions in GHG, we need to determine the actions required to address the policy challenges we face with regard to changing our lifestyles. This incorporates the spheres of technologies and markets. It involves reducing demand for energy and thus making changes in our lifestyle choices. We need to produce and use the required energy more efficiently (getting more for less) and supply the reduced amount of energy from non-fossil and sustainable sources. Other behaviour-change drivers have to be devised and diffused to alter the way middle-income homes operate.

While most human needs relate to food, water, transport and their related energy-support systems (homes, workplaces and related connections), needs around the places of living and working must also be addressed. Energy enables people to live better quality lives even in hostile environments. It has become a worldwide phenomenon that the depletion of fossil fuels and its harmful repercussions demands more creative solutions to energy usage. Are South Africans using more energy than required merely to attain or secure a good life? Why, despite all the warning signals of what climate change can cause, is it so difficult for South Africans to make rational choices and voluntary behaviour changes? It was only in the second half of 2007 that South Africa started experiencing the power shock of widespread rolling electricity blackouts. These blackouts were reintroduced in 2014. As energy supply once again fell below demand, the reality of a destabilised power grid called for harsher measures to be taken. However, not much is understood about how the social cues motivate South African homeowners to mitigate climate change. The emphasis in current research on an LCS seems to focus on economics, scenario exercises and especially low-carbon technologies. Research on low-carbon communities is more limited, but it is gradually building up (Herring, 2012:21). Further enquiry is needed regarding the extent to which South Africans are willing to make changes to reduce GHG emissions based on a crisis-free and benign choice approach related to technology and social change. This study is located within this dilemma of crisis-driven versus vision-guided transitions to low-carbon homes for middle-income homes and households of South Africa.

The importance of the study relates to the contributions it can make in spheres such as the environment, developing countries, sustainable development, policy improvements, strategic planning, futures studies and knowledge.

An equitable/fair contribution needs to be made towards the global initiatives to stabilise the atmospheric concentration of carbon dioxide (CO_2) and other GHG at a level that will reduce the dangerous impact of climate change. Low-carbon initiatives can also deliver significant co-benefits that help eradicate poverty and bring about economic growth (Segal and Cloete, 2012:32). Each country has to play a contributing role through relevant sectors that can make changes. There is a vital link between sustainable development and the transition to low-carbon societies; this shift must be achieved in a mutually supportive way, leading to improvements in both these initiatives. Important decisions and changes will be influenced by policymakers and strategists responsible for the planning of South Africa’s future and, in this context, the building industry.

The current gap in knowledge occurs in the demand-side energy efficiency changes. This gap has to be filled by using a combination of theories related to futures studies and the empirical transitioning to low-carbon middle-income homes by 2050. The reason is that currently, no research in South Africa addresses both the social and technical issues necessary to achieving the highly ambitious carbon-emission reductions targets. This is the first study to map a pathway to low-carbon homes by focusing on the trendsetting middle-income group as one of the critical sectors of the economy.

1.2 Background and context

1.2.1 Low-carbon societies

Global emissions of GHG are projected to reach such high levels during the next 100 years that they could have serious and negative effects on the total climate system, natural environment (flora and fauna) and human development endeavours. Deep cuts in global GHG emissions are therefore required to prevent the worst effects of climate change and thus achieve the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) to stabilise GHG concentrations in the atmosphere at levels that avoid dangerous climate change (Kaigisho, 2006:88). Literature highlights the moral responsibility and political feasibility of designing a coordinated global response to climate change (Strachen *et al*., 2008:18; Barry *et al.*, 2013:362).

This study links to an investigation that is complementary to the UNFCCC international policy that responds to climate change. The United Kingdom’s presidency of the Group of Eight (G8) industrialised nations in 2005 set in motion an ambitious research project on climate change, clean energy and sustainable development (Strachen *et al*., 2008:18). This research project was known as the G8 Gleneagles Dialogue. It took as its starting point the need to stabilise GHG concentrations at a level that would avoid dangerous climate change and the concrete steps required to achieve the necessary transitions to low-carbon societies. A key feature of the working definition (there is no existing established definition) is the development and deployment of low-carbon technologies and changes in lifestyles and institutions (Skea and Nishioka, 2008:1). Adaptation to climate change and aggressive mitigation measures are imperative to deal with the multiple stresses that ecological and socio-economic systems face. Studies such as Strachan *et al*. (2008:18–22) endorse the low-carbon goal concept as being feasible and thus more than a utopian ideal.

From another angle, a discourse on the low-carbon economy is rapidly emerging. Flavin (2008:75) stated that building a low-carbon economy is now the central challenge of our era. Meeting that challenge will require restructuring the global energy industry through technological, economic and policy innovations that are as unprecedented as is the climate change they must address.

As a climate economist, Stern (2012) perspective expresses strong views on the role of developing countries in stabilising climate change. The debate about what developed and developing countries must do to reduce emissions and thereby avoid global warming has now changed. If developing countries take no positive action, they will be responsible for two thirds of the emissions by 2030, compared with one third in 1990, (served as the base line for the Kyoto Protocol which came into force in 2005 but is now superseded).

The targets to be pursued as part of the LCS objective are those set by the Intergovernmental Panel on Climate Change (IPCC, 2007:776). To achieve 450 ppm of carbon dioxide equivalent, the IPCC's Fourth Assessment Report refers to Annexure 1 of the report, according to which developed countries are required to achieve a reduction of 80–95% below 1990 levels by 2050, while non-Annexure 1 (developing) countries are required to achieve a substantial deviation aligned with their wider development goals. Other commentators, such as Hourcade and Crassous (2008:608), held the view that decarbonisation according to set IPCC targets of the world economy would not be sufficient, and that we should rather aim at higher carbon reduction targets to keep the world's temperature increase below 2°C within a short time frame. According to Hare *et al*. (2014:5–6), a new analysis on the IPCC AR5 database shows that to limit warming to below 2°C with a greater than 85% probability by 2100 will require a likely reduction of 65–90% below 1990 emission levels by 2050. **Figure 1.1** illustrates the timeline for global emissions to peak and decline towards zero for 2°C and 1.5°C long-term temperature limits.

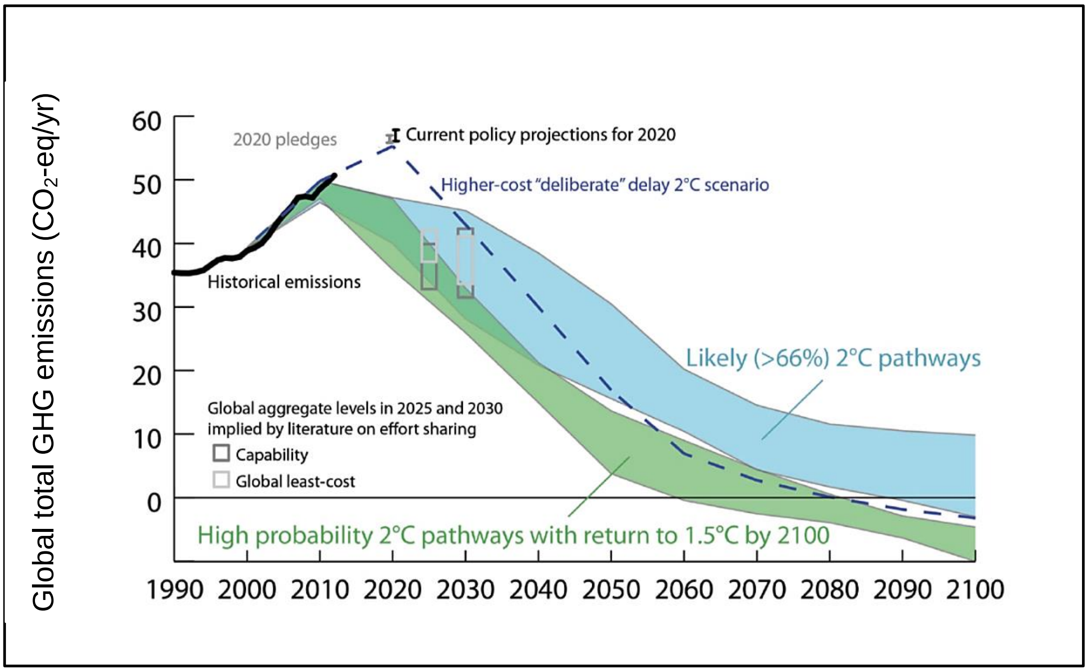


Figure 1.1 Global emissions timeline for below 2 °C temperatures (Hare *et al*., 2014:5)

1.2.2 South Africa's low-carbon context

South Africa is one of the largest emitters of GHG in the world. In terms of energy intensity, South Africa is closer to the developed countries than to the developing countries, when the market exchange rate is used. For each Rand unit of gross domestic product (GDP), 4.18 MJ of energy was required in 2009 (StatsSA, 2012), which is higher than in many European countries and the United States of America (USA). Annual per capita energy consumption in South Africa is 2.51 tonnes of oil equivalent (Toe) compared with the world average of 1.67 (Haw and Hughs, 2007). In 2006, South Africa had the 42nd highest GDP, but was ranked as the world's 21st largest consumer of energy (DME, 2009b:8). The country's dependence on coal has resulted in its having the highest levels of carbon dioxide emissions in Africa (accounting for 40% of the emissions in Africa) and being the 13th largest emitter in the world. According to the latest 2013 estimates of the Energy Information Administration of the USA (EIA, 2015), 72% of South Africa's primary energy consumption came from coal.

Without constraints being in place, the country's primary energy-related emissions, i.e. carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), could almost quadruple by 2050 and contribute significantly to dangerous climate change (ERC, 2007b:7).

The extent of energy-related GHG emissions (which increase in proportion to growth in primary-energy demand) is particularly noticeable in the manufacturing, transport, mining and residential sectors. These sectors use energy sources such as electricity and other fuel types such as coal, petroleum products and gas. In 2006, the final energy usage of these four predominant sectors in South Africa amounted to 2005 petajoules (PJ) out of the overall 2 356 PJ of all sectors. Of this, the residential energy consumption in 2006 was 206 PJ (DME, 2006:1), which can be converted to an equivalent of 45 Mt CO_2-eq emissions (CIDB, 2009:21). This can be compared with the commercial building sector's contribution of 35 Mt CO_2-eq emissions as shown in **Table 1.1**.

Table 1.1 CO_2 emissions per sector (CIDB, 2009:33)

CO_2 emissions per sector (Mt CO_2 per annum; 2006)						
Sector	Electricity	Renewables and waste	Coal	Petroleum products	Gas	Total
Commercial	29	0	4	2	0	35
Residential	40	2	0	3	0	45
Sub-total	**69**	**2**	**4**	**5**	**0**	**80**
Transport	3	0	0	53	0	56
Industry	85	0	46	1	6	138
Mining	32	0	5	2	0	39
Other	27	0	0	6	0	33
Total	**216**	**2**	**55**	**67**	**6**	**346**

The emissions factor for electricity sold for all residential electricity consumption can be confirmed to be approximately 41 Mt CO_2 in 2006. The majority of emissions emanate from middle-income households (26 Mt CO_2), as most electrified households fall within this income bracket (Tait and Winkler, 2012:9–13). Although the residential sector accounts for only approximately 9% of total energy consumption, reducing its contribution to GHG is vital for South Africa to mitigate a looming climate catastrophe. This makes the supply and use of energy a significant factor towards developing an LCS. Therefore, in its future development path, South Africa needs to address energy concerns through the LCS objectives essential to sustainability (Mwakasonda, 2007:6). This arises from South Africa's unique circumstances, such as the depletion and rising cost of non-renewable energy resources that cannot cater for growing demand; the negative effects on health and safety of fuels such as petroleum products and bio-fuels; unfavourable economic developments; low standards of living; and inadequate policy measures (DME, 2009b:1). Attending to energy issues through major carbon reductions in the residential sector could lead the sector towards a sustainable contribution to South Africa's main development objectives. These major objectives revolve around economic growth, job creation and access to key services for the great majority of its citizens.

South Africa has completed a few studies on low-carbon issues in the broader energy sector. The studies include the low-carbon scenarios (Mwakasonda, 2007), long-term mitigation scenarios (ERC, 2007a) and GHG emission reduction potential from buildings (CIDB, 2009). The Energy Research Centre in Cape Town has calculated that the potential CO_2 emission reduction for all homes in South Africa, for all energy sources from all sectors via energy efficiency, is 35% less than the 2003 levels by 2050, amounting to an equivalent of 45.8 PJ. These savings contribute to only 3.5% of the total of all sector savings, in accordance with the earlier IPCC projections on GHG stabilisation (DME, 2009b:20). In view, however, of the IPCC's mandate to regularly reassess the global reduction requirements of Annexure 1 and non-Annexure 1 countries, these figures could change and give new meaning to the “substantial deviation” requirement allocated to developing countries. Winkler (2010:168) provided compelling results of long-term mitigation scenarios on significant emissions reductions within the energy sector, which confirms that even if all the technology- and resource-based actions are carried out together, they will not be sufficient. Hence, the country has to turn to other complementary options such as changing social behaviour. Changes in social behaviour, whether driven by policy, education or awareness, may yet prove to have large-scale and low-cost mitigating effects.

Using modelling tools with statistical input data, Witi (2010:137) argued that the residential sector in South Africa would benefit from supply side measures such as carbon capture and storage as well as the use of cleaner fuels. However, on the demand side, measures such as solar water heaters (SWH), consumer awareness of alternative low-carbon practices, goods and services, as well as energy efficiency are critical. For the two scenarios used in the study, it was concluded that an 86% to 90% emission reduction can be achieved relative to 2000 levels attributed to cooking, water heating, space heating and supply-side measures.

A change in mitigation targets was considered at the Copenhagen Conference in 2009 in Denmark (COP15), whereby South Africa, in a loose commitment, confirmed a higher range by undertaking mitigating actions more closely aligned with those of developed countries. The country committed to a reduction of around 34% by 2020 and around 42% by 2025, below the business-as-usual (BAU) levels (Republic of South Africa, 2010), but conditional upon financial and technological support from Annexure 1 countries (Mundy, 2009:1). This pledge was reiterated at the Conference of the Parties (COP21) in Paris in 2015 with some changes. In 2011, South Africa communicated, as defined in national policy (DEA, 2011: 27), a peak, plateau and decline GHG emissions trajectory range. South Africa’s GHG emissions peak in the period 2020 to 2025, plateau for up to ten years after the peak and from 2036 onwards emissions will decline in absolute terms. Therefore, for the purposes of this study, a target would not be based on the 46% reduction by 2050 on BAU levels according to the national policy for the residential sector, but on reductions required by science due to South Africa’s high per capita CO_2 emissions being closer to those of developed countries. The target for the study was, instead, set at approximately 80% of 1990 levels by 2050.

1.2.3 Low-carbon homes

Research can contribute towards reducing residential emissions of GHG by identifying critical-sector interventions in housing. In 2006, the total residential building stock in South Africa amounted to about 12.5 million units. In 2013, it had grown to 15.1 million units (StatsSA, 2014:124). Of these, about 10.5 million units were formal units, while about 4.6 million units were backyard properties, informal and squatter units, and traditional housing. The most widespread type of dwelling unit was the bricks-and-mortar structure on a separate stand or yard. The market trends were led by the highest energy-consuming category of larger than 80 m^2 sized homes, which makes up 71% of housing plans approved by the metropolitan municipalities (CIDB, 2009:11–17). There has, however, been a trend away from this size in recent years, as homesumers are increasingly turning to flats, townhouses and cluster units, estimated at one million units (CIDB, 2009:15), as recorded in 2006. If one assumes that the population in South Africa will grow from 49.8 million people in 2010 (StatsSA, 2010:6) to possibly 65.5 million people by 2050 (United Nations, 2015:22), provision must be made for 15.7 million additional inhabitants. Housing stock or accommodation for the middle income, taken as the income group falling within quintiles 3 and 4 of StatsSA (2010:12), ranging from R9 877 to R57 099 per month, could grow accordingly, as well as CO_2 emissions, especially following on the planned 100% electrification by 2020, as indicated in **Table 1.2.**

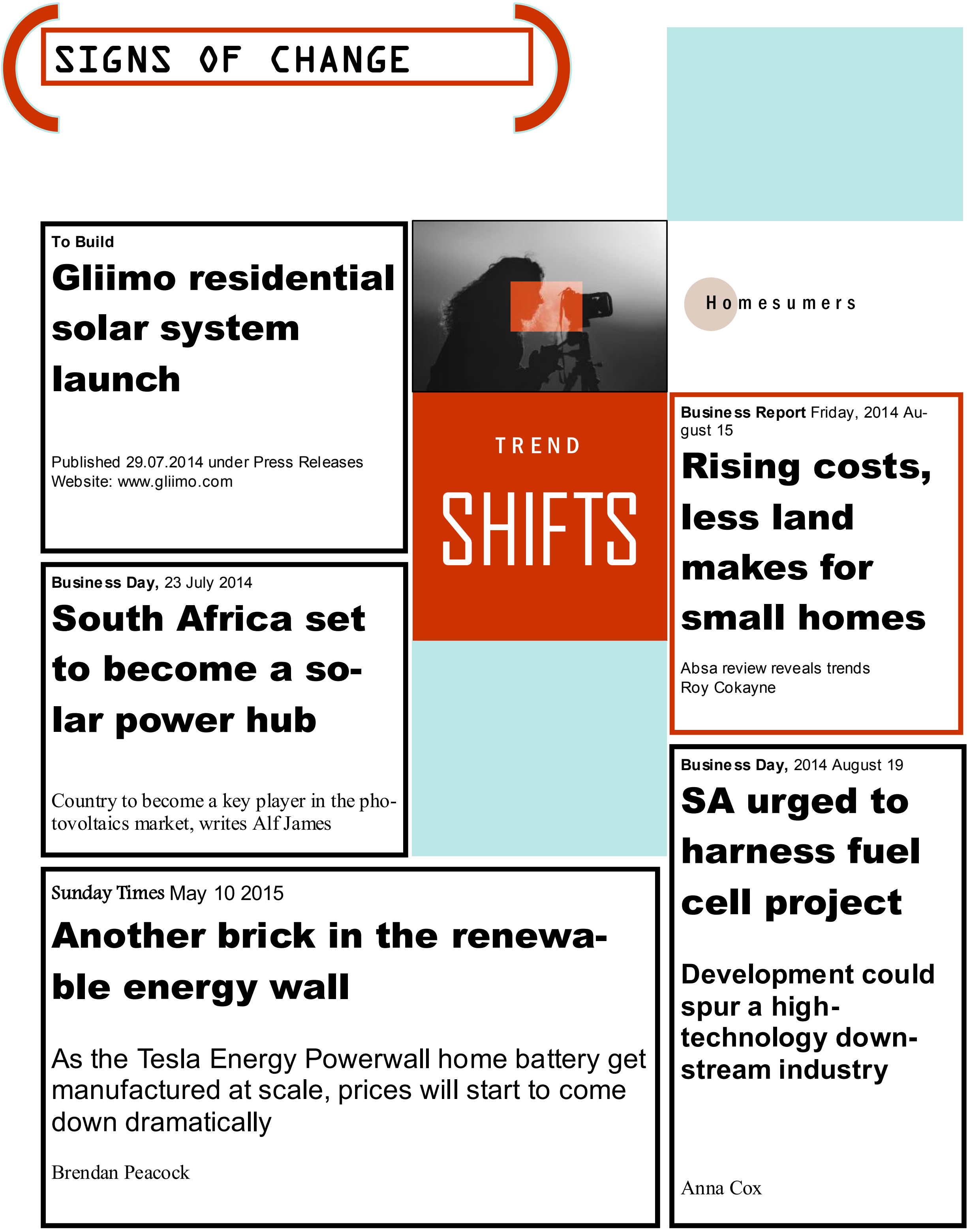
Table 1.2 Total emissions from all households to 2020 (Mt CO_2), assuming 100% electrification in 2020 (Tait and Winker, 2012:14)

Income group	2006	2010	2015	2020	% growth 2006–2020
Low income	1	1.04	1.2	1.4	43%
Middle income	25.4	26.9	30.2	33.9	34%
High income	13.9	14.6	16.2	17.8	29%
All households	40.2	42.6	47.6	53.2	32%

The residential home presents various influencing factors that can shape housing's contribution to mitigating CO_2 emissions. These factors include levers such as technologies, markets, lifestyles and strategies. Even though these levers are unique in their characteristics, in real life they relate to one another, forming a dynamic and critical systems interaction.

The perspective taken on the levers is to focus on those aspects that affect the tempo of change. Those aspects may include factors such as technology lock-in, ineffective pro-environmental behaviour changes and poor communication tactics. All these points reside in a technology niche market, which relies on various actors to make the necessary changes. Herring (2012: Chapter 2) supports this view, and observes that "visions of a low-carbon society are a combination of technical and behavioural factors". The technical measures are already available, but complementary financial and social policies are less developed.

According to Boardman (2007) and Herring (2012), one can reduce CO_2 emissions by 30% by adopting a more modest lifestyle, as explained in Section 1.6 of this chapter. The Electricity Supply Commission, or Eskom (2006:3–17) has provided some guidelines on how consumers can change their behaviour and make good choices to save 10% of electricity without spending any extra money. Consumers can save 30% by changing some minor items (using geyser blankets and insulated pipes, using water-saving shower heads, fixing leaking hot-water taps) and save 50% by installing a solar water heater as well. Currently, there are signs of shifts in trends and preferences developing in homesumers in the South African market. These shifts are helping to reduce energy consumption. **Figure 1.2** shows examples of these signs.



SIGNS OF CHANGE

Homesumers

TREND

SHIFTS

To Build

Gliimo residential solar system launch

Published 29.07.2014 under Press Releases
Website: www.gliimo.com

Business Day, 23 July 2014

South Africa set to become a solar power hub

Country to become a key player in the photovoltaics market, writes Alf James

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Business Report Friday, 2014 August 15

Rising costs, less land makes for small homes

Absa review reveals trends
Roy Cokayne

Business Day, 2014 August 19

SA urged to harness fuel cell project

Development could spur a high-technology downstream industry

Anna Cox

Sunday Times May 10 2015

Another brick in the renewable energy wall

As the Tesla Energy Powerwall home battery get manufactured at scale, prices will start to come down dramatically

Brendan Peacock

Figure 1.2 Newspaper clippings showing current signs of change (Cokayne, 2014:17; Cox, 2014:2; "Gliimo residential solar..", 2014; James, 2014:17; Peacock, 2015:10)

1.3 Research problem

1.3.1 Problem statement

Any delay in acting now on CO_2 emission reductions will increase the impact burden caused by climate change and also escalate the necessary emissions reductions for future generations. There is debate over the precise magnitude of emission reductions required at the global level, in part due to uncertainty regarding climate sensitivity and the nature of the impacts expected. However, it is clear that developed-country emissions need to be reduced by at least half of 2006 levels by 2050 (Kaigisho, 2006:88), which compares well with the 80% carbon reduction relative to 1990 levels. Developing countries especially need to sustain economic growth goals while at the same time radically reducing energy consumption and carbon emissions, i.e. “decoupling” economic growth from energy consumption.

South Africa is a major emitter of GHGs. To play its part in curbing climate change, the country needs to take determined steps to reduce the carbon emissions by middle-income homes according to an agreed-upon target. This requires establishing a pathway whereby SA can transit to a desirable future state. This will have to be driven by factors that affect the rate of CO_2 emissions on multiple-levels, such as levers of technologies, markets and lifestyles for South African middle-income new and retrofitted homes, in order to reduce these homes’ carbon emissions by 80%.

GHG emissions will continue to escalate in the country because of conventional energy usage increases (UNDP, 2009:9). All of this tends to escalate in line with improved income − and South Africa has a rapidly growing middle-income group. Advancing sustainable development goals should be the central focus of efforts to address climate change in all countries (UNDP, 2009:13).

1.3.2 Main problem

The main problem is that it is not known whether it is possible to attain more aggressive changes that affect the rate of carbon mitigation through levers such as technologies, markets, lifestyles and strategies. These changes would be expected to influence South African middle-income new and retrofitted homes to be able to reduce carbon emissions by 80% (from 26 megatonnes of carbon dioxide equivalent (Mt CO_2-eq) in 1990 to 5.2 Mt CO_2-eq by 2050). Opportunities towards this goal need to be determined in order to help map a transitional pathway.

With the vision of 80% reduction by 2050 as the desirable future outcome, the following sub-problem aspects became pertinent in informing the main problem.

- What should change along the pathway and by when − along a timeline to 2050 − to allow for the 80% reduction goal?
- Why do the relevant types of change occur?
- How do South Africa and her citizens make these changes?
- Who are the responsible actors/agents that will make the key relevant changes?

In this endeavour, addressing not only what should change, but also how it could change, and who has to be part of such a change, has the potential to produce richer insights into what South Africa should be doing to achieve an equitable and effective share in global efforts towards the mitigation of climate change.

1.3.3 Main question

In order to address the research problem, the main research question seeks to establish the pathway by which South African middle-income homes could achieve an 80% CO_2 reduction by 2050.

Based on the primary research question, the following sub-questions were derived in order to guide the study:

- What needed to change in the Delphi pathway, and within what time horizon was the 80% carbon reduction in the middle-income homes sector achieved?
- Why could the “what” above have occurred, causing the relevant outcome within the specified period along the pathway?
- How could the mechanisms manifested have achieved the “what”?
- Who would be responsible for making the changes in order for the “what” to occur?

1.3.4 Working hypothesis

To address the main problem, the working hypothesis that guided the study states that through the influences of levers such as technologies, markets, policies and lifestyles, South Africa managed to steer itself through a desirable future pathway that ensured the necessary changes to mitigate climate change and thus achieving an 80% reduction of emissions in its middle-income homes, from 26 Mt CO_2-eq to 5.2 Mt CO_2-eq, by 2050.

1.3.5 Main objective

In order to address the research problem, sub-questions and substantiate on working hypothesis adequately, the research was guided by the main objective, which was to derive the data and findings needed to map the transition to low-carbon middle-income homes by 2050.

1.3.6 Significance of the study

Futures studies is a newly developing multi-disciplinary field, which promises to offer a significant breakthrough in how humanity engages with uncertainties concerning our future well-being. The studies use an iterative process primarily characterised by goal-setting, to outcome, to correction, to goal-resetting as a transitionary mechanism out of an undesirable present (status quo) to a desirable future. This iterative approach is used to sidestep the BAU trap as characterised by inertia and lock-in at individual and collective levels. Reflecting on the role and effectiveness of the backcasting approach constitutes a critical agenda towards mapping a desirable future pathway by which South Africa's middle-income homes can achieve a reduction of 80% of GHG emissions based on 1990 levels. The desirable pathway is contrasted to the BAU pathway to capture the extent of additional interventions (voluntary and mandatory) necessary for attaining this goal.

1.4 Research design and method overview

1.4.1 Philosophical framework

The foundation of the research falls under "futures studies", which calls for a qualitative form of research. Bell (2003:5, 73) stated that futures studies are regarded as a multidiscipline and therefore part of modern humanism – both philosophical and scientific. He added that their distinguishing contribution is in prospective thinking; in particular, "to discover or invent, examine, evaluate and propose possible, probable and preferable futures". Two methods were chosen, stemming from different views on scientific explanation. **Figure 1.3** illustrates the forecasting and backcasting philosophical framework, which was applied in parallel and juxtaposed such that the former represented the context of justification, the latter the context of discovery (Dreborg, 1996:818).

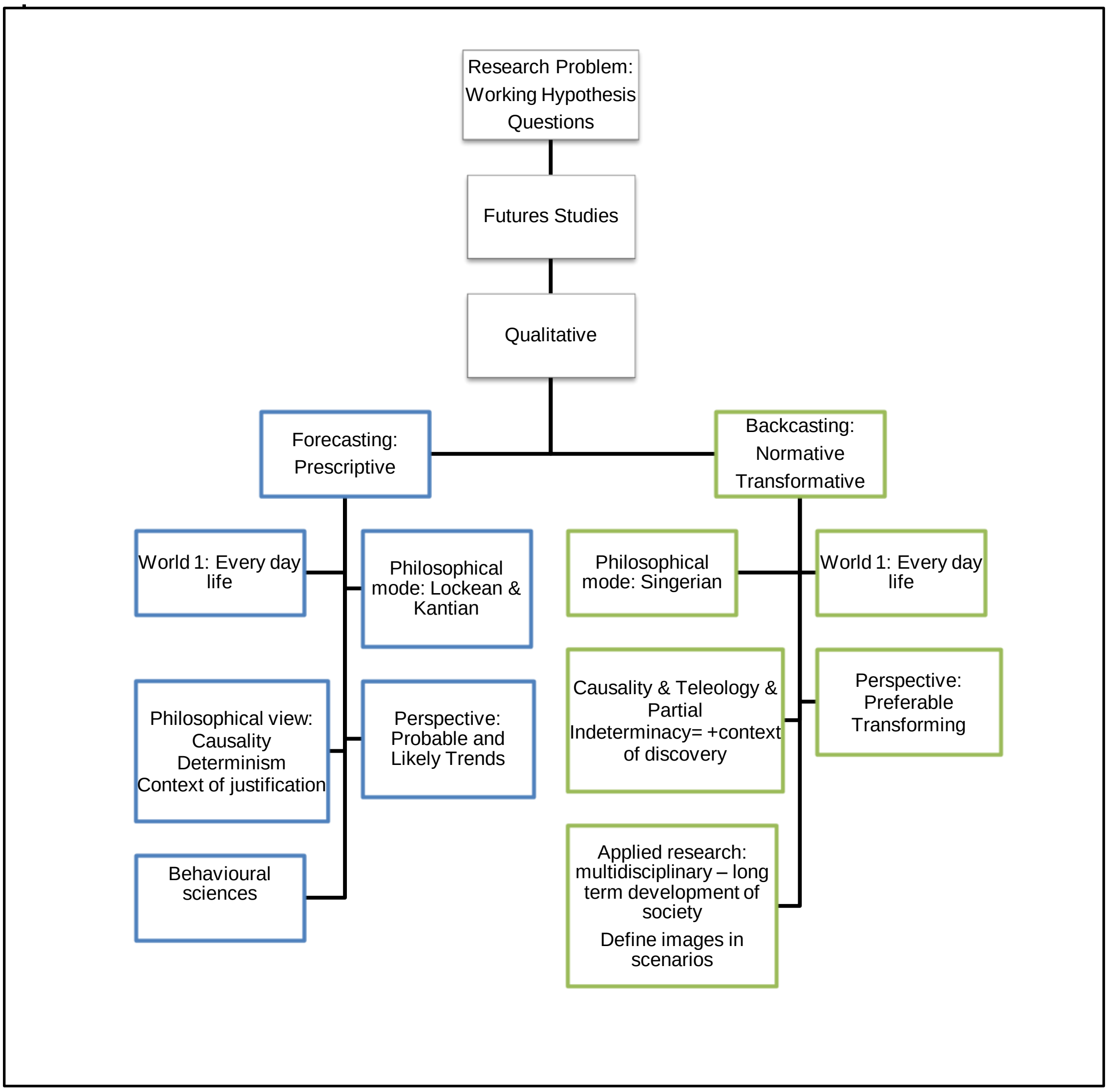


Figure 1.3 Theoretical framework

The forecasting and backcasting philosophical framework was the basis for choosing the Delphi and the backcasting methods, as explained in Section 1.4.2 of this Chapter. Through the Delphi method, quantitative data were collected, presented and analysed. The backcasting method was used to collect and analyse the more normative data qualitatively. Both kinds of data in tandem improved the overall strength of the study more than either numeric or textual data alone could. It is important to emphasise that the backcasting method was applied as the anchoring method and predominant philosophical framework whereby the research findings were derived. The approach was prioritised primarily because it facilitated the transcending of the BAU scenario, as defined in Section 1.6 of this Chapter, and thus allowed for a transformative perspective.

Linstone and Turoff (2002:20–27) presented the foundations of the typologies that form the building blocks of knowledge of futures studies. In the study, the predictive Delphi approach is described as having a broad basis incorporating policy issues and reasons for empirically-quantified data. The truth content of the system is predominantly empirical, reducing complex propositions to simple observations, validated by means of freely-obtained agreement between different human observers. The backcasting approach is explicitly goal orientated (normative) in the sense that the significance of the model is measured with respect to its ability to define certain systems' objectives, propose several alternative means of securing these objectives and finally, specify new goals that remain to be accomplished by some future period or timeline.

Figure 1.4 shows the difference in the underlying principles of forecasting and backcasting as interpreted in Dreborg (1996:815). The study indicated that predicted developments invariably fall short of the sustainability goal, mainly because of the restrictive presuppositions adopted that can inhibit major transformational change to the status quo.

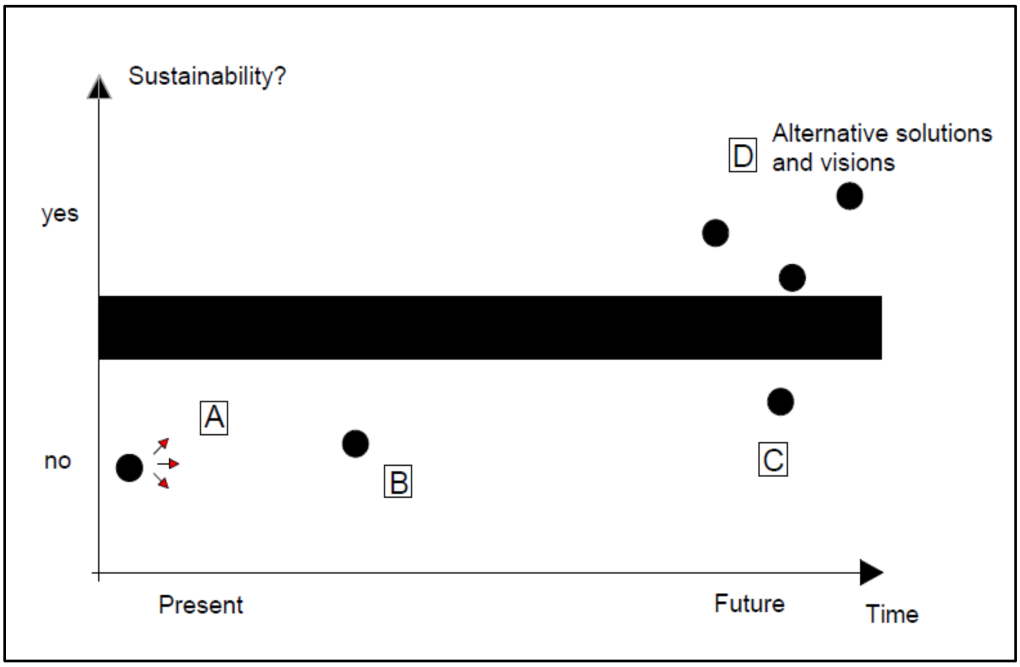


Figure 1.4 Principles of forecasting
A – Directional studies; B – Short-term studies; C – Forecasting studies; D – Backcasting studies (after Dreborg 1996:815)

Dreborg (1996:815) further stated that achieving sustainability would require more than marginal changes ("business-as-usual") at many levels of society. As backcasting is an approach that focuses on the problem to be solved rather than on present conditions and current trends, it is better suited to achieving transformational solutions than a traditional forecasting approach. According to Carlsson-Kanyama *et al*. (2008:36), a participatory backcasting technique involving stakeholders who take an active part in the development of visions emerged only recently. This method was further enhanced in this study through the application of a mini-charrette. A charrette is an intensive workshop in which various stakeholders and experts are brought together to address a uniquely and collectively desirable design outcome, but structured to specific processes (NREL, 2003:7).

The backcasting approach suffers from several limitations. For instance, it offers no direct solution to the problems that the energy sector is facing today. In addition, the results of backcasting are dependent on how the unfolding of future states is defined relative to CO_2 levels in 1990 and BAU scenarios.

As part of the backcasting method an analytic framework consisting of transitions within alternative pathways was developed. The transition theory relevant for the pathway analysis in this study was based on socio-technical transition theories. In the literature, the term is frequently embedded within the framework and context of Frank Geel’s multiple-level perspective (MLP) (Geels, 2005; Geels and Schot, 2007). In this sense, the term *transition* has been defined by Rotmans and Loorbach (2009:184) as: “a structural change in a societal (sub)system that is the result of a co-evolution of economic, cultural, technological, ecological and institutional developments at different scale levels”. A reinterpreted view was applied in the study by combining the MLP and the DIT to develop the multi-level actors (MLA) framework, as described under the definitions of Chapter 1. According to Roger (2003:1–34), Diffusion Innovation Theory (DIT), the rate of accumulative adoption can be diffused over time in a pattern that resembles an s-shaped curve.

1.4.2 Delphi method versus backcasting process and data collection

In the process of the study, three key categories of tasks emerged from both the Delphi method and the backcasting approach to futures studies. First, the study generates ideas and gathers data from diverse sources (primary and secondary). Second, the study includes a stage of analysis and integration. The separate threads (Delphi and backcasting) are woven into a whole in the process of determining findings and making interpretations. Third, the consistency of the scenarios are checked, as guided by Börjeson *et al*. (2006:730).

Delphi method. Following the traditional forecasting method (Delphi), the study generated trends over time to establish the likely/probable future based on the BAU trajectory. The process of the Delphi technique used a series (typically three rounds) of carefully prepared questionnaires and controlled information feedback to build group consensus among individually anonymous experts (Ament, 1970:35). The Delphi process had the following steps (see Chapter 3 for more detail): extrapolations generated; questions validated by reiteration and ranking; options evaluated; and consensus articulated.

Backcasting method. For data collection, the backcasting method was guided by two scenarios: an 80% carbon reduction and a 50% carbon reduction target in middle-income homes. A desirable narrative was built around the targets for the parameters of technologies and policies, markets and lifestyles by 2050. The secondary data for the narratives were derived from literature appraisals as well as by using model examples for the parameters. The cost effectiveness of these parameters was established by using a simple net present value (NPV) (European Commission, 2007:43), including initial costs, operating (electricity) costs and the resale value, excluding the maintenance costs. Lessons on policy-effectiveness were guided by the experiences in the United Kingdom (UK) and Germany. These countries are leading economies in developing “green” technologies and thus they have some of the most ambitious programmes in energy efficiency and renewable energy at present.

1.4.3 Data accuracy and analysis

Delphi method. Structured steps were taken towards formulating the questionnaires, selecting the panel giving inputs and carrying out the dissemination process such that each step contributed to the accuracy and analysis of the data as follows:

- In seeking future trends, existing historical data were extrapolated using one of the following methods: exponential smoothing; linear regression; logarithmic and polynomial methods.
- Weighting forecast points equally was useful when asking experts to forecast change (Armstrong, 2001:57–144).
- The method highlighted by Gordon and Helmer (1964:15–18) was applied towards long-range forecasting when calculating the 50% probability of an item being implemented, using medians and quartiles (Qs).

As uncertainties grow, especially in long-range forecasting, intuitive contingency becomes inevitable, but the reliability of resultant forecasts becomes a challenge. The following measures were applied to improve reliability.

- Domain knowledge was combined with time-series data to improve accuracy. The process was structured and participants remained anonymous throughout the research procedure, so that individual inputs were not influenced by the others.
- Subsequent questionnaires reiterated previous questions for the experts to re-evaluate.
- At both the first round and the re-evaluation stage, a self-rating method was used, such as confidence level (CL). A rating of one to four was requested for validity reasons, which ascertained consistency of answers.

<u>Backcasting method.</u> Some earlier participatory backcasting exercises, found in studies such as Boulding and Boulding (1995), and Vergragt and Quist (2011:750), provided examples of attaining accuracy in the method involving citizens together with experts. The factors they believe would enhance accuracy are the type of participants, structured processes and attaining sufficient congruence, as explained in Chapter 3. However, to enhance the backcasting process even further, one could use charrette

principles. Since sustainable design issues were added to research topics about 15 years ago, charrettes and mini-charrettes have been used in planning and design teams. When dealing with integrated design matters, a collaborative approach was used to create realistic and achievable design ideas (WDBD, 2013). The charrette would therefore provide useful guidelines as part of the backcasting method whereby desirable future visions needed to be attainable.

The preliminary visions and their feasibility were conceptualised and appraised to guide the mapping of a transitional pathway to low-carbon homes as follows:

- A well-planned mini-charrette made a crucial contribution to the outcome goals. Guidelines by NREL (2003) were followed relating to the planning, material development, logistics, conducting of the charrettes and the feedback processes.
- The preparation material consisted of the project goals, descriptions, project status, issues and concerns.
- Creating effective breakout groups allowed for intense discussion and formed a first step to group agreement from which conclusions were summarised. A feedback session then recapped all the conclusions of each group.
- The whole group analysed the summaries of the breakout groups to reiterate options for attaining sufficient congruence. This was achieved through prioritising on the most and least desirable options based on consensus-building process on the final goals to be achieved, i.e. a preferable scenario narrative for South African homes along a timeline to 2050 of which technologies and their influencing markets, lifestyles and policies were important parameters.

When dealing with accuracy in the data collection process, the following methods were used:

- In the face of uncertainty, decisions were not made on the “right” answer, but rather became a question of which choices might work best in the face of different preferable/possible futures (Salter *et al*., 2010:712–714).
- Better decisions were made through more inclusive choices by expanding the range of decision-makers to include stakeholders and citizens in an interactive way.
- Multiple possible futures were envisaged: disseminating two pre-conceptualised vision scenarios and their related assumptions with the invitation to the stakeholders to participate allowed the stakeholders to deliberate and eventually develop one desirable future in each of the two provinces where the charrettes were convened.
- Consistency was achieved through proper preparation of toolkits and facilitation and management of workshops. However, for logistical and costing reasons, the facilitation was carried out by the author and not by an external facilitation expert.
- After following systematic steps at the mini-charrette workshop, the data were pre-analysed. Once the data were transcribed, they were then coded and the resultant data were further analysed and interpreted.

1.4.4 Interpretation and derivation of findings

Following the analysis that took place after the charrette, a narrative was developed from which relationships within the data were identified and interpreted, and a new hybrid pathway narrative was developed. Miles and Huberman (1994:245–6) talk about “generating meaning” and provided a list of strategies one could use to achieve such an objective. In this study, two sets of data were derived from two methods, investigating similar themes. The following strategies were used to interpret and derive findings:

- A theoretical framework of alternative pathways that ascertain less-likely and more-likely scenarios investigating polarities of occurrences was developed. These polarities were the factors that can accelerate or inhibit the rate of CO_2 mitigation for each pathway.
- Amongst the many approaches to analysis, some of the “fairly classic set” of analytical tactics (such as contrasting, comparing and noting relationships between variables using graphs) were used when substantiating the traction-influencing factors.
- Frameworks based on system innovations theories that guided the structuring of data were created. The main function of the theories was to focus on actors/agents/role-players on different levels of a niche technology environment, such as government, services, and individuals and communities along a pathway of innovation, technology uptake and behaviour change, and stabilisation and decline. The pathways were steered by strategies informed and guided by a framework consisting of the socio-technical transition theory, as illustrated in **Figure 1.5**.

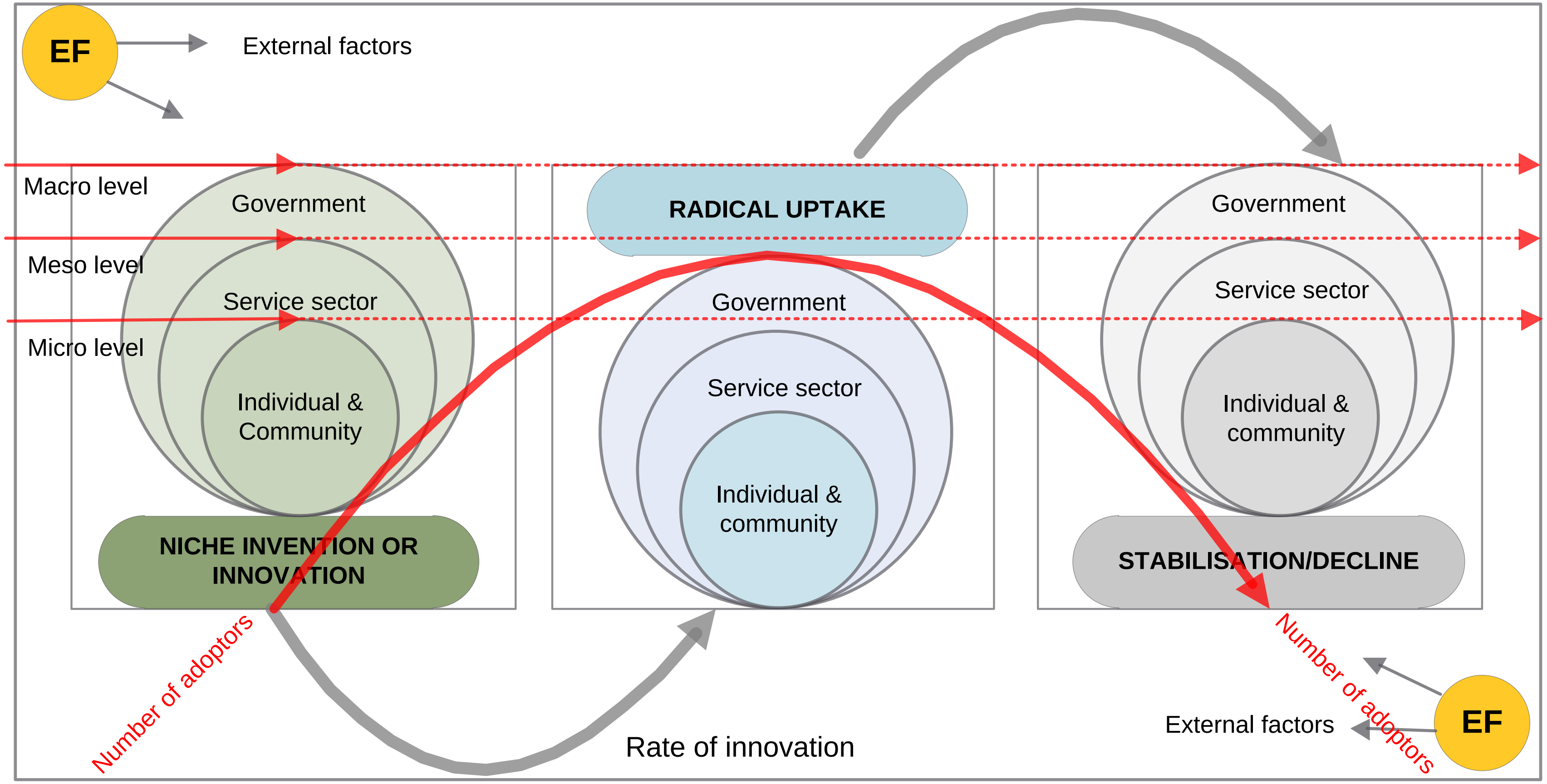


Figure 1.5 Interrelationships of traction influencing cycles (Geszler, 2014)

1.5 Assumptions, limitations and delimitations

Certain *assumptions* were made in the backcasting method to create a pathway narrative against a proposed societal background for the preferable vision to 2050. These assumptions were based on secondary data such as GDP, discount rates, interest rates, population, stock numbers, CO_2 savings, home sizes and income. In the Delphi method, however, it was assumed that direct correlation could be made with costs and carbon-reduction trends of technologies measured overseas, obtained from literature, for which data were not readily available in South Africa, and for imported products. In general, the author used photovoltaic (PV) technology as the renewable energy option when creating examples for scenarios, considering its cost reduction potential over time, and realised that other suitable renewables could be used instead.

Specific *limitations* occurred in the study in both the Delphi and backcasting methods. The sources of secondary numeric data in the Delphi method and its comparability were critical to its plausibility. Consistency of numeric secondary data (costs and CO_2 savings) was a challenge to achieve because of incomplete databases and the inevitable need to combine data from multiple sources (sometimes from different countries) in order to be able to approximate the desired level of detail. In some instances, this limitation arose from the fact that national studies simply did not systematically record or analyse data. In Chapter 1, recent cohesive statistics on energy and carbon for specifically the middle-income sub-sector in South Africa were limited. Statistics were chosen from 2009 – 2012 datasets, which was when the critical statistics of CO_2 emissions for the residential sector were available. This approach allowed for making better comparisons across different units of measurements. Developed countries were examples/sources used as role models for compiling secondary data for improving lifestyle patterns, technology options, strategies and market trends, either tested in the Delphi method or debated during backcasting mini-charrettes in terms of the extent of comparability. Different countries were chosen from which lessons could be learnt with regard to policies and lifestyles because of their relevant strengths in demonstrating pathway experiences South Africa could expect to go through.

Good charretting principles propose assigning different roles to different people on the organiser’s side. In this context, the role of the facilitator and manager of the charrette was carried out by the researcher because of cost constraints and as a way of ensuring first-hand experience of the task. As the anchoring method, the backcasting method did not include a quantitative analysis of lifestyle/behaviour changes that could contribute to the relevant GHG reductions. Instead, it started with goal aspirations based on carbon reductions as guided by science on the imperatives of climate change mitigation to avoid global warming beyond the 2°C threshold.

To represent all market sectors from both a social and technical perspective, the backcasting charrette participants comprised experts and non-experts with context-specific knowledge. To contain costs, homesumers from middle-income communities were not involved, but were represented by multi-disciplinary participants (most of whom were from the middle-income group targeted in the study). This cross-disciplinary nature of the participants was critical for both policy and social development.

In backcasting research, the objectives addressed relevant questions in various combinations of “what”, “why”, “how”, “who” and “when”. The backcasting workshops for this study consisted of one-day workshops in which the “how” question (how the 80% CO_2 was achieved in 2050) was elaborated on. This was followed by circulating the outcome to the participants after the workshops for further inputs, including the strategies and agents to action these in a specific period. Time and resource constraints meant that the basket of scenarios evolved out of the data and results from the Delphi and backcasting sessions. Process outcomes/findings were not disseminated back to the mini-charrette participants for further deliberations with a view to achieving convergence on the preferred scenario beyond the speculated prioritisation. The data results were thus anchored within a framework consisting of “less-likely” versus “more-likely” pathways that then guided the detailed analysis and interpretation of findings in terms of the extent and rate of CO_2 mitigation on a time horizon to 2050. The transitioning framework addressed the research questions “what”, “why”, “how”, “who” and “when” as indicated in the research questions under Section 1.3.3. The study is therefore characterised as an academic research project rather than a government initiative towards influencing public policy. However, if emissions reduction in the residential sector becomes a national priority, the findings have the potential for mainstreaming into government policy.

The *delimitations* of the scope of the study revolve around what constitutes GHGs. South Africa’s residential sector contribution to GHGs was mainly attributed to the consumption of electricity by existing and new middle-income homes on which the study focused. These homes will be setting the trends for other residential sub-sectors. More indirect contributors towards carbon emissions − such as embodied energy of materials (i.e. emissions generated during the manufacture of materials and the construction process) − were not included in this study. Although transport/commuting-related emissions were briefly referred to in the lifestyle context, they were not considered as a core component for the study.

For both the Delphi and the backcasting methods, only key trendsetting technologies were factored in as key interventions towards mitigation of GHGs. The developments and improvements of technology trends were limited to their type and description. Generalisations were made in terms of costs and carbon reduction potential for the South African context based on major prevailing trends. The study used a top-down and bottom-up approach on secondary numeric data to anchor assumptions for determining overall GHG reductions within the pathways analysed.

Finally, classical policy solutions anchored on the rational choice perspective (Section 2.3.2), such as regulations, information and economics, were only ephemerally included where relevant to a developing country context. Further theoretical comparison was made by complementing the rational choice theory with behavioural psychology and neuroscience theories to ascertain the extent of changes to be made for the development of a more-likely pathway to the future.

1.6 Definitions of terms

This section provides the contextualised definitions of key terms and concepts as applied in the study.

Business-As-Usual (BAU): The BAU scenario is when historic energy usage trends follow the same rational pattern along a trajectory whereby no substantial changes occur. In this study, the Delphi method trajectories are also referred to as the BAU scenario as there are no major CO_2 emission-reduction changes that occur over the long-term by 2050.

Nominal and real costs: The market prices for low-carbon technologies were investigated in the Delphi method. These consisted mainly of nominal costs and were provided in terms of the availability of the data. The nominal costs are usually the actual prices that you see in a store every day. These are the actual costs that you pay or the salary you earn on your payslip. Increases in nominal value reflect the effect of inflation, and, where relevant, the exchange rates and import duties.

The real costs take changes into consideration to compare the costs with the base year cost. Usually the real value is less than the nominal value, as the value of the goods compared with the base year has declined. One can buy less with the same budget (real money) in a later period than the earlier period as the purchasing power becomes less. When a currency's purchasing power decreases due to excessive inflation, serious negative economic consequences arise, including rising costs of goods and services contributing to higher cost of living and high interest rates that affect the global market.

Homesumer: This was viewed as a homeowner/user who was responsible for consuming energy in a home as well as decision-maker when purchasing products and making changes as part of his or her lifestyle choices. This person/household was the individual or household who not only made informed decisions on purchasing low-carbon technologies, but also became actively involved in making a contribution to the invention or innovation of a technology. This person needed to change behaviour through deeper changes in values and habits, but also required motivation to do so through being nudged and responding reflexively.

Modest lifestyle: To address the basic human needs for shelter, one can live a decent life without being excessively materialistic. A middle-income person's needs can be met through owning slightly smaller-sized low-carbon homes, averaging 100m², compared with today's average sizes of 148m² (Section 4.2.1 of Chapter 4), and living more modestly in terms of material demands. The houses, though, are customised, of good quality, environmentally friendly, enhance the feeling of space, provide privacy and have a stronger connection with the outdoors. This could also mean collaborating and sharing resources in co-housing setups, but still owning a home and maintaining privacy. Facilities, equipment, chores and maintenance can be shared to reduce the cost of living and enable people to benefit from neighbourly support. In the case of renting flats in more densely populated nodes of South African cities, increasing living standards would require a more home-like feeling, achieved through designs that engender privacy and provide more greening. More green areas should become a priority to be systematically pursued. Preferably, work, food and amenities should be in close proximity to a person's home so that people can afford to spend more time within nurturing social networks such as family and friends.

Multiple-level actors (MLA): Key aspects taken from the Diffusion of Innovation Theory (DIT) and the socio-technical transitions approach were used to develop a framework for the traction-influencing factors that influence the rate of CO_2 mitigation. A reinterpreted view was developed from the strengths identified in Diffusion of Innovation Theory (DIT), and the multiple-level perspective (MLP) in which the transition theory is embedded to create a new framework. From the DIT, pertinent lessons supporting a supply-side adoption perspective (more attention to the individual and less to the social context and the role media takes) were included, such as the phases for technology diffusion, which were adapted to include the innovation/invention stage, technology uptake and behaviour change, and a decline process after saturation. What was taken from the MLP approach and applied in this study was the focus on the actors within different market niche spaces of the macro, meso and micro levels. A co-evolutionary approach to innovation was followed whereby different sub-systems have mutual interactions affecting the development of each system. The macro level in this study was represented by government and other external influences. The meso level was represented by the servicing companies where innovation is generated and disseminated. The micro level was represented by the individual and the community where direct choices and decisions were made. An important focus area was the roleplayers involved in a niche technology within the different spaces of a socio-technical regime. Ultimately, it is people who strategise, implement and reflect on actions within specific spaces. The interplay of change-inducing forces between levels comprised the accelerating and inhibiting factors. This study did not map out a predetermined path of the type of interactions between actors on multiple levels. The purpose was to rather identify key pragmatic forces/pressures at work within a certain timeframe for a relevant country that can induce or deter change at the different market levels. These forces directed the pathway narratives.

Pathway narrative: In order to interpret the analysed data of the Delphi and backcasting methods, a framework of “less-likely” pathways (front-loading (FL) and back-loading (BL)) to “more-likely” pathways (even-loading (EL) and middle-loading(ML)) was conceptualised. The framework consisted of pathways reflecting imagined scenarios that were elaborated on in narrative form. A pathway was represented by a graph that characterised the envisaged rate of CO_2 mitigation over a time horizon to 2050. The qualitative part of a future image typically consisted of a narrative describing the future state with words instead of numbers (Wangel, 2012:46). Each pathway was structured further as guided by the socio-technical transitions theory based on social and technical factors, of which the traction influencing factors capable of changing the CO_2 mitigation rate were of core relevance. The pathways were not discussed in the abstract: homes are the empirical context on which transitioning pathways are mapped. The pathway entails both lifestyle and physical changes (technological interventions) to real homes.

Traction influencing factors: Traction is the force acting upon the CO_2 mitigation change rate to attain the high goal target of 80% reduction by 2050, based on 1990 levels. Of relevance were the traction-accelerating and inhibiting factors, which were pursued within a dynamic systems framework as well as related inertia in order to analyse the momentum of change in relation to the goal. This represented the accelerating and inhibiting factors associated with levers such as technology, markets, lifestyles and strategies along alternative, and more- and less-likely pathways, such as FL, BL, EL and ML.

1.7 Overall structure and chapters of the dissertation

The dissertation has been structured into seven chapters as follows.

Chapter 1 contextualises the study in terms of the inspiration for the study and the environment in which it arises. A real-life problem is investigated with the home in South Africa being the main theme. The chapter presents the nested context of the wider LCS consisting of climate-change initiatives in which low-carbon homes will evolve. The focus on the home implies a closer look at the demand-side energy issues, contrasted with relevant supply-side issues, and how energy consumption can be reduced in terms of the amount and type of energy to maintain good living standards. The methodological framework falls primarily under futures studies and the empirical transitioning to the low-carbon homes sub-sector. A contextually reinterpreted MLA framework is developed in order to structure the traction-influencing factors of alternative pathways that affect the CO_2 emission mitigation rate based on the DIT and MLP theories. A working hypothesis is established, and its related research questions and objectives of the study are motivated. The chapter provides a broad overview of the multi-method approach of the study, which primarily involves the Delphi and the backcasting methods within the context of transitions framework. The chapter then concludes with the assumptions, limitations, delimitations and definitions of the study.

In *Chapter 2*, literature appraisal prioritises two theoretical fields to provide a theoretical context for the study. A paper is appraised to identify key theories that can be related to the study’s primary field of futures studies with the transitioning to low-carbon homes as the empirical field of investigation. Two sub-themes inform the broader context of the study: “low-carbon” and the “home”. For the first sub-theme, the paper is appraised with regard to theories related to modelling techniques and visions. The second theoretical pillar focuses on homes in the residential sector, which in this case emphasises foresight scenarios, and to a lesser degree, the modelling thereof. These key theories are then contrasted with the transitions theory to establish relevant relationships. Each study review in this chapter is structured in the following order: relevance, critical appraisal, and conclusion.

Chapter 3 begins with a brief overview of two additional theoretical fields involving a multi-methods approach under the primary futures studies theories. This approach is based on the Delphi method which is anchored within the backcasting approach, and compared with the transition theory. The literature appraisal also investigates secondary, process-related theories, including data collection, analysis, participants and charrettes. With regard to the Delphi method, the focus was on its characteristics and the method most appropriate for the study. Strengths and weaknesses of backcasting, pathways, scenarios and socio-technical transitions are identified. A central theme is the recognition of the co-evolutionary development of technologies, institutions and social and economic sub-systems. The key arguments of the critical appraisals are compared with differing opinions from other studies and the link between the theories appraised and this study are clarified.

In *Chapter 4*, a descriptive summary of the analysed Delphi data is provided and the coded raw data of the backcasting approach is presented in narrative form. In the case of the data collected in the backcasting charrette held in the Western Cape and Gauteng Provinces, the study keeps as close as possible to the verbatim depiction of the workshops in a narrative form. This reflects the discussion of the participants, whereby the mini-charrette data has been coded and grouped broadly into systematic themes. Thereafter, a consensus view is provided by combining the key outcomes of the Western Cape and Gauteng charrettes, thus incorporating the converging and diverging views on South Africa’s preferred pathway, which represents the anchor narrative.

Chapter 5 presents the conceptualisation of the framework that portrays the “less-likely” pathways (front-loading (FL) and back-loading (BL)) followed to indicate how the 80% carbon reduction transition on a timeline to 2050 was attained. The chapter begins by describing the accelerating and inhibiting conditions under which the pathways occurred. Predominant inhibiting factors and the heavy-handedness required to overcome inertia within a short timeframe precluded the FL pathway from being chosen by South African stakeholders. Some of the inhibitors relate to its fast rate of adoption, government tactics, linear approaches and neglected demand-side interventions. The BL pathway would also not entice the country to follow the path because of government delaying action, not allowing enough time for path-correction and the risk of entrenching bad behaviour/habits right from the starting point.

Chapter 6 provides pathways (even-loading (EL) and middle-loading (ML)) more-likely to be chosen for the South African context, based on the view that they provide the conditions that allow for more humanely achievable technology adoption and behaviour-change. Owing to a more gradual rate of adoption for the EL pathway, a long-sighted approach yielded more positive attributes than a short-sighted approach. Pertinent inhibiting factors identified related to gradual change, moderate funding and increasing the possibility of technology rejection. The chapter then establishes that the pathway most-likely to be chosen by South African stakeholders and policymakers is the ML pathway. The emphasis is mainly on the accelerating factors that provide the orchestration of the required change owing to moderate pressures that would result in attaining equilibrium in a dynamic socio-technical system. Accelerators included transformational leadership for achieving transitions on three levels along an s-shaped path, consisting of government and external forces, the services sector and the individual. The changes focused on localisation, a service-orientated economy, and combining regulatory and non-regulatory interventions.

Chapter 7 focuses on conclusions and recommendations and is structured into various sub-sections. The chapter begins by recollecting the motivation and objective of the study and presents the working hypothesis within a new perspective. The salient arguments and literature underpinning the study are then captured. The theories are underpinned primarily by futures studies and empirical transitioning to the low-carbon homes sub-sector. The main theories include the Delphi method, backcasting, pathways, visions, scenarios and transitions, and their relationships and contribution to the research highlighted. For the sub-findings, the key interpretation of findings and how they answer the “what”, “why”, “how”, “who” and “when” questions are indicated. All the aforementioned parts are synthesised and integrated in order to determine the extent to which the research question is resolved/addressed or remains unresolved. Finally, recommendations for future studies are presented.

CHAPTER 2

LITERATURE APPRAISAL

2.1 Introduction

The nature of the overall approach of the study demands a systematic review of the literature on both the theoretical and methodological frameworks. Given that the literature on the methodological approaches contributed significantly to the conceptualisation and development of method and techniques, studies in this category are appraised systematically in Chapter 3. Chapter 2 therefore covers studies referring to the broader theoretical base of this study.

The research title and research questions anchor the study and form the basis of the theoretical framework. A paper is appraised to identify key theories that can be related to the study's primary field of futures studies with the empirical field of investigation being the transitioning to low-carbon homes. Two sub-themes prioritise the broader context of the study: "low-carbon" and the "home". The first sub-theme's objective focused on carbon mitigation interventions to achieve carbon reduction goals within a low-carbon society. The next theoretical pillar focused on homes in the residential sector nested within a low-carbon economy, with the potential to achieve deep carbon emission cuts on a pathway to 2050.

Each study review was structured in the following order: overview providing the relevance and the primary aspects addressed by the reading; critical appraisal of key arguments relative to futures and transitioning as the core issues of interest; and a conclusion with a clear indication of how the insights/views from the reading informed the current study. Relevant arguments and points were highlighted and compared with other related papers.

2.2 Low-carbon theory

2.2.1 Overview and relevance

The starting point of “Policies and practices of a low carbon society” (an international study reviewed by Skea and Nishioka (2008:5–16)), is the need to stabilise GHG concentrations at a level that would reduce dangerous climate change (IPCC, 2007). The paper goes on to create visions of low-carbon societies and identifies the visions required to achieve the necessary transitions. The study provides the objectives of the reading and identifies the key theories that relates to futures studies in connection with quantitative and qualitative methods used.

The study includes nine countries with a strong developing country focus (Japan, the UK, France, Germany, the European Union, Canada, Russia, China, Mexico, India, Brazil, South Africa and Thailand) to resolve complex problems within the low-carbon society (LCS) context. Japan and the UK commenced their respective LCS project with the aim of informing the Gleneagles Dialogue on Climate Change, Clean Energy and Sustainable Development, which was established during the UK’s 2005 G8 presidency (DEFRA, 2005). The dialogue engaged the G8 and other interested countries on significant energy needs and usage. It focused on:

- the strategic challenge of transforming energy systems to create a more secure and sustainable future;
- monitoring implementation of the commitments made in the associated Gleneagles Plan of Action;
- sharing best practice between participating governments.

Taking as its point of departure the need to stabilise GHG concentrations at a level that would reduce dangerous climate change (IPCC, 2007b), the study went on to envision low-carbon societies, identifying the concrete steps required to achieve the necessary transitions. The two governments worked with three of the top climate and energy research centres in Japan and the United Kingdom (UK), namely the National Institute for Environmental Studies (NIES), the Tyndall Centre on Climate Change, and the UK Energy Research Centre (UKERC). The centres undertook a sequence of three workshops and symposia, involving researchers and stakeholders from a diverse group of some 20 developed and developing countries.

At the first project workshop in June 2006, the steering committee was challenged to set out its views on what, in concrete terms, would constitute an LCS. The following working definition was proposed in the appraised reading:

An LCS should:

- Take actions that are compatible with the principles of sustainable development, ensuring that the development needs of all groups within society are met
- Make an equitable contribution towards the global effort to stabilise the atmospheric concentration of CO_2 and other greenhouse gases at a level that will mitigate dangerous climate change, through deep cuts in global emissions
- Demonstrate a high level of energy efficiency and use low-carbon energy sources and production technologies
- Adopt patterns of consumption and behaviour that are consistent with low levels of greenhouse gas emissions. (Skea and Nishioka, 2008:6)

This definition was not intended to serve as a scientific statement, but rather as a flexible framework intended to allow fruitful discussions and thus lead to practical actions. It was also intended to capture the perspectives and needs of countries at all stages of development. The first workshop concluded that this definition provided a valid basis for research and action (NIES, 2006: ii–iii).

Although the definition was meant to cover all international circumstances, the implications were conceptualised differently for countries at different stages of development. For developed countries, achieving an LCS would involve making deep cuts in CO_2 emissions by the middle of the 21st century. It would involve the development and deployment of low-carbon technologies and changes to lifestyles and institutions. For developing countries, the achievement of an LCS had to go hand in hand with the achievement of wider development goals. This would be with a view to ultimately achieving an advanced state of development, with (CO_2) intensity levels commensurate with those achieved by low-carbon societies in developed countries. Another key feature was that the definition, while not neglecting the role of technology in any way, also emphasised the importance of lifestyle and social change. This, along with the close link between the LCS concept and that of sustainable development, was to become a defining feature of the project as it progressed.

A key discussion focus was the various modelling methodological approaches applied by the modelling team. The key message from two workshop presentations and the subsequent modelling activity was that the achievement of low-carbon societies, in the context of global CO_2 emission reduction of 50% by 2050, is indeed technologically and economically feasible. Energy efficiency, demand-side responses and the choice of technologies for electricity generation were among the most important contributors to emissions reduction.

A key element of turning a country's potential for LCS into reality was to develop visions that would be credible and attractive to the general public. A good example of this was the Japanese Low-Carbon Society project. This envisaged a world in which a global temperature rise was held below 2°C, global CO_2 emissions were cut by 50% by 2050, and Japanese emissions were cut by 70%. The results of this project were presented at Workshop 2 in London (Matsuoka, 2007; National Institute for Environmental Studies *et al*., 2007).

However, a key conclusion was that more than one path of social development was consistent with this outcome. The research team constructed two contrasting visions of a Japanese LCS. Vision A ("Doraemon") was technology-driven, with citizens placing great emphasis on comfort and convenience. They lived urban lifestyles with centralised production systems and GDP growing at about 2% per annum (p.a.). Vision B ("Satsuki and Mei") was of a slower-paced, nature-orientated society. People tended to live in decentralised communities that were self-sufficient in that both production and consumption were locally based. This society emphasised social and cultural values rather than consumerism and individual ambition.

In both cases, a 70% reduction in CO_2 emissions could be achieved by 2050. However, the mix of technologies employed was different. In both cases, energy efficiency improved considerably – both in industry and in the home. The major differences were in transport needs relating to the very different patterns of settlement and in the structure of electricity production. The technology-driven society relied heavily on nuclear power and fossil-fuel coupled with carbon capture and storage. Hydrogen was produced for use in fuel-cell vehicles. The nature-oriented society instead relied heavily on biomass, both for electricity generation and biofuel production for use in hybrid vehicles.

The second workshop addressed the roles that different stakeholder groups could play in developing low-carbon societies. It looked at the roles of the investment community, business and consumers. However, a key message from the associated stakeholder symposium was that government had the primary responsibility to initiate low-carbon development (DEFRA, 2007:34).

South Africa's development objectives focused on growth, job creation and access to key services including energy and housing (Mwakasonda, 2007:1–7). Increasing the percentage of renewable energy in the electricity generation mix was a specific goal. The government strategy aimed to ensure that 5% of power supplied by the national-grid-was generated by renewable technologies, such as micro-hydro, biomass-fuelled turbines, solar thermal, wind turbines and photovoltaic (PV). A national target for renewable energy sources could lead to local environmental benefit, and GHG reductions. Under this target, at least 50% of all new houses built in communities would incorporate climate-conscious solar passive design principles in their construction, thereby eliminating the need for space heating and cooling, resulting in lower CO_2 emissions.

2.2.2 Critical appraisal of key arguments

The intention of this section is to identify the strengths and weaknesses of the study's contribution to futures studies. The appraisal mainly focusses on method (modelling techniques and visions). A core area for discussion is the various methodological approaches used by the modelling teams, but it does not elaborate on modelling methods. The objective of the modelling exercise was to review country-level GHG emissions scenario studies in developed and developing countries and study methodologies for achieving low-carbon societies. The first workshop in the reading included a comprehensive set of presentations and papers describing emissions scenario exercises, both globally and for a range of developed and developing countries. Although modelling activity has demonstrated that low-carbon societies are technically and economically feasible, implementing policies that will secure the necessary technological and behavioural changes presents a major challenge.

Saleh *et al.* (2008: 42) elaborated on these quantitative methods in futures studies and provided their views on the traditional forecasting (statistical modelling) techniques. These techniques assume that information contained in historical data can be extracted, analyzed, and reduced to one or more equations that can be used to replicate/project historical patterns into the future; the techniques use the mathematics of statistics to deepen understanding of causality in complex systems. However, they argue further that this method entails serious shortfalls primarily due to the following key assumptions:

- All the information needed to forecast desired aspects of the future is contained in selective historical data.
- The causal structure of the model reproduces the real-life structure of the system that gave rise to the historical data.
- The ongoing structure of the system that gave rise to the historical data will be unchanging.
- Surprise-free forecasts are useful.

Saleh *et al.* (2008: 42), however, confirm the importance of quantitative methods in that quantitative analysis is an essential part of Futures research. They have to to be used carefully and most of the time should not stand alone when dealing with complex long-term problems.

McDowall and Eames (2006: 1237–1238) also provided arguments on the significant strengths and weaknesses of forecasting approaches. Forecasts can provide quantitative targets for technology development (providing a sense of the performance and cost levels necessary to compete successfully); and a quantitative consistency check and basis for exploring the importance of different assumptions. Unlike many of the other studies reviewed, McDowall and Eames (2006: 1237–1238) tend to view hydrogen in the context of wider energy systems and competing technologies. However, forecasts, particularly over long time horizons, have been widely criticised for an overly deterministic view of the future in terms of technological change (Berkhout and Hertin, 2002 and Geels and Smit, 2000). Such criticisms challenge the assumption that new technologies simply replace old ones, while failing to factor in the disruptive nature of the technological “regime” or “paradigm” in which they work, especially through creating new markets, new institutions, and new user behaviours and patterns of consumption. Forecasts alone may be preventing us from understanding the complex processes by which large technological systems are transformed (McDowall and Eames, 2006: 1237 –1238).

Vision studies often depict more utopian narrative descriptions of a future, in for example, a hydrogen economy. Their intention is to be both plausible and desirable. These studies tend to be abstract rather than analytical. Their role is not to analyse or predict the future but to expand on the possibilities considered, and create a collective picture of what the future could be. Timelines are often excluded, although visions are often set further into the future than more formal futures exercises. They also tend to include more unexpected elements that disrupt the current trends (e.g. technological breakthroughs, shifts in social values) (McDowall and Eames, 2006: 1240). It can be said that these visions portray a future where technological, infrastructural and institutional changes go hand-in-hand with a shift towards greener social values and a more egalitarian society without making any structural changes along a pathway.

Skea and Nishioka (2008) present two vision pathways of social development towards a low-carbon society. More realistically, a variety of development pathways that combine elements of these more contrasting visions would also be compatible with deep reductions in CO_2 emissions, demonstrating the robustness of the low-carbon society goal. They refer to a development path and practical steps that can be taken today by referring to case studies, but do not explain any analysis method that provides a more structured pathway within a relevant time period.

2.2.3 Links to the study

In recent years, a large number of futures-based studies have been developed in the field of low-carbon technologies. For example, McDowall and Eames (2006) identified six distinct though overlapping types of futures studies in the field of hydrogen. These are categorised under descriptive and normative futures. Descriptive studies include forecasts; exploratory scenarios; and technical scenarios and for the normative scenarios the author has listed visions, backcasting/pathways and roadmaps.

The futures studies paradigm utilises multi-disciplinary research into change, trends, mega-trends, driving forces, emerging counter-forces and uncertainties in all major areas of life in order to find the interacting dynamics that can create opportunities for the the desirable future to emerge. The purpose of futures studies is to study potential change and systematically explore, create, and test both possible and desirable futures to improve long-term plans. It includes analysis of how those conditions might change as a result of the implementation of policies and actions, and the consequences of such policies and actions (Saleh *et al*. 2008: 38).

To ascertain a target for a world in which global temperature rise is held below 2°C, global CO_2 emissions are cut by 50% by 2050, and Japanese emissions are cut by 70%, a modelling exercise was used in the initial stage to quantify whether it was technically and economically feasible. However, to turn a possibility into reality, visions had to be developed. The relevance of this study is that quantitative and qualitative studies can complement each other and are both therefore in futures studies. How they get used in a complementary manner is therefore important. The ongoing structure of the system that gave rise to the historical data would have to be changed through an intentional/conscious application of more normative methods for transformation.

A vision developed using a participatory method comprising a wide range of stakeholders will serve as the starting point of this study thus allowing it to disengage from the present in order to develop a desirable future by means of a backcasting approach. Through this approach, no structural changes in society as a result of some external forces are considered. Transitions represent structural changes in society resulting from co-evolutionary pressures and responses. The role of government, trade regimes and consumer choice and individual action inform some of the key conclusions, but excluding organisational change which does not constitute a key component of this study.

The LCS project has shown that low-carbon societies are achievable, but also that it would require a consistently coordinated effort, nationally and internationally, to achieve this vision. Although advancing the technological frontier will be vital, changes must also go to a deeper social level if climate change and development goals are to be reconciled. This confirms that developing countries need to contribute to global climate change within a low-carbon society, a finding which this study corroborates.

2.3 Home theory

2.3.1 Overview and relevance

With the home being the central theme of the study, a related study on an example of how strategies and policies can drastically reduce carbon emissions in homes was identified and appraised. The paper identified is Boardman (2007:5–111) which highlights market transformation policy in the European Union (EU) on energy demand and focusing on improving product efficiency through a series of inter-related actions and policies, such as labels, minimum standards, fiscal incentives, education, right information, financial incentives, and product designs.

The research was built on a previous report; Boardman *et al*. (2005) on a study conducted with the whole Environmental Change Institute's Lower Carbon Futures team. The UK domestic carbon model (UKDCM) was used together with the UK foresight scenarios to validate the paper reviewed here. The thinking, analysis and conclusions relied on the author's knowledge gained over 30 years in this sub-sector. The scientific consensus was that for the UK to play its part in helping the world avoid a rise of more than 2°C, carbon emissions had to be reduced by 80% by 2050 from 1990 levels. Carbon emissions for homes were rising and government was making it neither cheap nor easy for homeowners to cut emissions. The investment and political courage required are substantial.

When the UK's Labour Party assumed power in 1997, carbon emissions from homes were rising by more than 5% annualy till 2007. This occurred despite powerful government rhetoric about reducing emissions, and a surfeit of initiatives including two energy white papers, a climate change programme, an energy review, the Stern Review report on the Economics of Climate Change, and five pieces of legislation. The government's policy objectives were a short-term projection for the residential sector representing an 11–18% carbon reduction by 2020 from the 1990 levels. There was no proposal of how to achieve the 80% carbon reduction by 2050. In comparison, Germany reduced carbon emissions at a faster pace in the same time frame because of the contributing factor of creating a strong legal standard to underpin change and thus creating certainty on the direction of change the country commited itself to (Power and Zulauf, 2011:14).

According to Boardman (2007), the UK's Labour Party had failed to set out effective strategies and policies. This lack of effective policies affected 17 million units of housing stock owing to absence of support by government for the roll-out of low- and zero-carbon (LZC) technologies. This UK government (Labour Party during the time of writing of the paper) also did not consider how the planned construction of two million homes could contribute to a reduction of carbon emissions.

The reading was concerned with future energy use and carbon emissions from the UK residential sector and the methods used to determine this, namely modelling through the UK domestic carbon model (UKDCM) and foresight scenarios. The modelling is combined with four varied future scenarios. The foresight scenario was expected to deliver the highest carbon savings and was therefore identified so that it can be investigated further and developed into a more robust and realistic scenario. Once developed, the UKDCM was calibrated against current energy use. The aim was to develop a scenario that would achieve 60% carbon emission reduction (40% house) and 80% emissions reduction (home truths) by 2050. In order to quantify the details of possible futures in terms of energy use and carbon emissions, it was first necessary to look at some alternative futures in broad terms where the foresight scenarios were used as a basis for this. The foresight scenarios were framed in the context of two basic dimensions of change which are social values and governance systems, which are taken as the axes to define the four scenarios as illustrated in **Figure 2.1**.

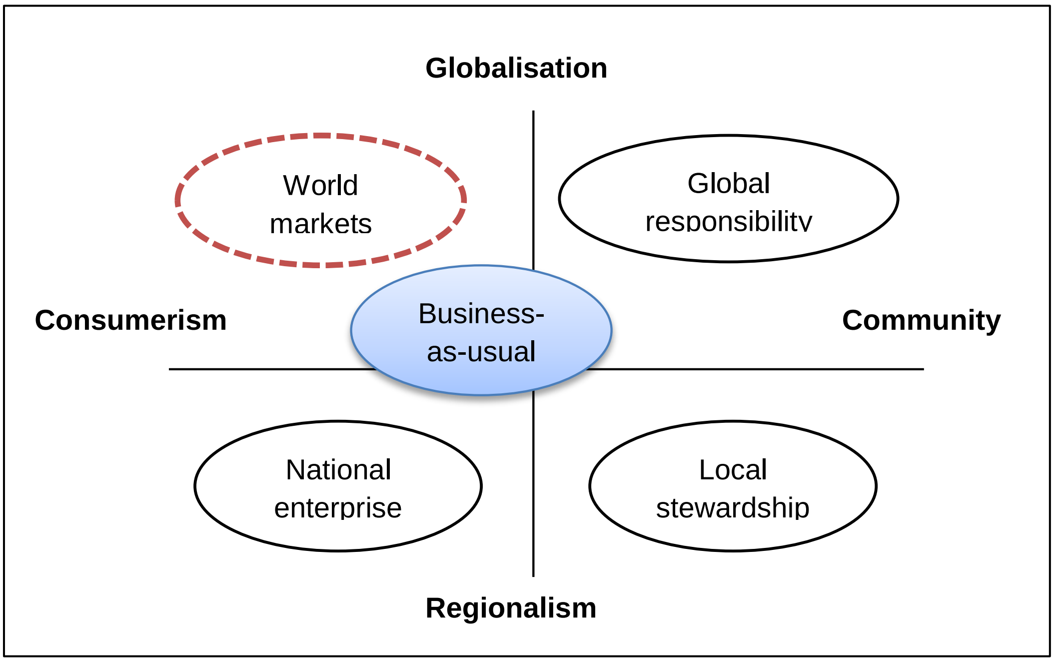


Figure 2.1 Foresight scenarios on a grid of governance and social values (Boardman, 2005:21)

For example, the World Markets scenario has values of consumerism and globalisation, whereas Local Stewardship is the society that develops under strong regionalisation and community values. What was critical was ensuring consistency in terms of world-views underlying the scenarios and compatibility with developments in other sectors, including consumer patterns, investment, regulation, markets and environmental factors. Together with the key aspects of the four foresight scenarios, the energy aspects of the foresight scenarios are given in general terms and show very different fuel mixes, variation in total energy use and strongly divergent aims for energy policy. These overall statements were translated into carbon emissions projections to 2050 for the residential sector, using the UKDCM model.

2.3.2 Critical appraisal of key arguments

Foresight is often considered to be an area of practice based on three more established traditions: technology forecasting, futures studies and technology assessment. Technology forecasting emerged in the aftermath of World War II, when the American military needed a systematic method for making informed judgments of rapid technological developments (Jantsch, 1967). Foresight is also rooted in a European tradition of futures studies that was established in the 1960s and 1970s (Miles, 2010; Bell, 2003). Futures studies are sometimes characterised as an art involving creative and imaginative thinking and acting (Martin, 1995). These terms are used interchangeably and basically only vary in a given user's perspective.

The wide variety of users and contexts in which scenarios have been used has led to a wide variety of approaches and methodologies towards constructing scenarios, as noted by Bradfield *et al.*(2005). For Hughes (2009:10), scenario thinking is the "use of the imagination to consider possible alternative future situations, as they may evolve from the present, with a view to improving immediate and near term decision-making". The central aim of scenario thinking is the highly practical intention to improve the quality of the decisions that we make about the future. If not, "they are nothing more than interesting speculation" (Wack, 1985b).

For Hughs and Strachen (2010: 6057), scenarios involve three key objectives which are improving protective decision-making; improving proactive decision making; and consensus-building. McDowall and Eames (2006) differentiate "exploratory scenarios" from "technical scenarios". Exploratory scenarios seek to inform policy-making by illuminating drivers of change, often drawing on tacit knowledge and expertise in order to construct internally consistent storylines which outline a number of possible futures. These tend to be long term in nature and can include trend-breaking developments. In contrast, technical scenarios are more specific about the way in which systems are envisaged in the future and how particular technologies underpin such system's futures. Frequently they have tended to be "static" studies which often overlook the social and cultural dimensions of technological change.

Saritas and Aylen (2010) provide a useful typology of scenarios:

- Profile scenarios (usually developed around a matrix) with the cross-fertilisation of two key issues or drivers for change.
- Archetypes or alpha, beta, and delta scenarios where alpha represents a "business-as-usual" future; beta, that some things can go wrong; and delta, that changes in direction will occur.
- Success scenario, or one single normative scenario.

In the context of UK Government Foresight techniques, scenarios have been based on a "deductive" process, using techniques developed by SRI (formerly the Stanford Research Institute) in the USA (UK Government Office of Science (2008)). This helps create a "2x2" scenarios matrix (or what Saritas and Aylen (2010) suggest is a "profile" scenario) which captures four possible futures by exploring critical uncertainties. Essentially the scenarios are deduced from an analysis of the drivers for change in order to determine which are important and uncertain, and these are prioritised to identify the two most important uncertainties which create the scenario "axes". This then helps create scenarios through an exploration of the outcomes when uncertainties at each end of the x and y axes are combined. Critics have argued that such a matrix produces at least one scenario which is too "good to be true" and one which is "to be avoided", but a counter argument is that if they are well constructed and exhibit the orthogonal axes (i.e. distinct uncertainties which do not collapse into each other) (UK Government Office of Science (2008)), the scenarios produced represent a range of plausible outcomes for the future.

The deductive approach to scenarios offers a number of benefits which include a structured nature, with a clear relationship between drivers and scenarios, and a relatively simple way to link the scenarios with strategic and policy implications (UK Government Office of Science (2008)).

In contrast, “inductive scenarios” are developed through interpretation of data, trends and other material by a core of expert group. Explorative techniques also encourage multiple scenarios (focused on “what next?” or “what if?” questions), whereas a “normative” approach to scenario-building encourages a “preferred” vision of the future and outlines different “pathways” (see below) from the goal to the present (i.e. they involve “backcasting” sometimes starting with the most desirable future and concerns questions such as “where to?” and “how to?” (Saritas and Aylen, 2010)).

For Hughes (2009) and Hughes *et al.* (2009), such techniques, whilst advancing the cause of energy futures as a long-term planning issue, have failed to address key issues. Critically, Hughes *et al. (*ibid*)* argue that many scenario studies in this field lack strategic applicability for three main reasons:

- Focus on normative, exogenous constraints such as a carbon emissions reduction target.
- Reliance on high-level trends which can lead to overly polarised and homogenised scenarios.
- Co-evolutionary content (recognition that technology interacts with social, cultural and political systems) is often weak, and fails to identify actors and the key networks which underpin socio-technical change.

A complete change of perspective on the part of government is required in terms of energy behaviour of people especially in the context of a home. Ellsworth-Krebs *et al.* (2015:100) confirmed that in order to help progress in domestic energy research, the social aspects of a home become more significant (e.g. comfort, identity, security, privacy). Moreover, new behaviour theories are emerging regularly from research related to sociology, psychology and neuroscience (Janda, 2011:15–22; Wilhite, 2007; Hillman and Fawcett, 2005). These theories are critical in futures studies on empirical transitioning to low-carbon homes, and its importance as emphasised by theories to consider its implications (Sovacool, 2014:529; Victor, (2015:27–29). Although the reading referred to people's behaviour in terms of understanding energy use, rebound effect and personal responsibility, there was a body of sociological and anthropological research (Veitch and Gifford, 1996 and Guy and Shove, 2000) that suggested that people's motivations and actions on household energy were more complex than suggested by the rational model of decision-making based on information, regulations and economics. Papers presented at the European Council for Energy-Efficient Economy summer studies showed that the social context was crucial in understanding consumer energy behaviour (e.g. Bruel and Hoekstra, 2005; Moreau and Wibrin, 2005; Bartiaux and Gram-Hanssen, 2005; Wilhite, 2007).

One of the most successful developments in recent years, for example, has been the introduction of the market transformation policy in the EU, which involved a comprehensive approach to product standards, labelling, marketing and procurement (Boardman, 2004:165–176). The important role that financial incentives can play was also evident in the rapid uptake of micro-generation technologies as a result of the introduction of the feed-in tariff (DECC, 2011). However, because rational choice theory (economic principle that states that individuals make logical decisions guided by the desire to maximise utility) does not adequately define the individual (as a consumer) there was a need to take into account other (social) aspects of being human (Devine-Wright and Devine-Wright, 2005:1343 –1348). Nor was there an investigation into the origins, nature or validity of people's preferences (why they want what they want) or how their needs/wants develop or evolve over time (Jackson, 2011:189 – 212). In addition, little was said about habitual energy-use behaviours. This approach, therefore, was most applicable in situations where a specific, simple response was to be pursued. However, even then it may need to be accompanied by other complementary interventions, as stated by Mayne *et al.* (2012:6 –7).

Two South African studies that discussed behavioural theories and the limitations to people's decisions and choice processes are mentioned in this section. These range from psychological and social situations that influence judgment to the prospect theory, which explains how variability in the way a choice is framed can have a dramatic impact on the decisions people take. This was confirmed by a prospect theory study in South Africa by Gichia (2013:iv), which established that both cost-benefit evaluations and sustainability assessment methods should go beyond the rational-agent paradigm and engage with prospect theory behavioural heuristics and neuro-economic mechanisms that catalyse change to achieve the required transition. Furthermore, Irurah (2013:20) held that prospect theory and neuroscience might emerge as the doorways to our new age of re-enlightenment through explaining and resolving the limitations of the mind as currently understood.

Mayne *et al.*(2012:6–7) refer to two broad influences which are "internal" individual socio-psychological influences and related models, and "external" sociological influences. Community groups are thought to be well placed to influence non-rational behaviour. For example, they are known and trusted by residents, and are more familiar with the factors that shape energy behaviours. Individual influences refer to what goes on inside a person's mind, for example: knowledge and patterns of thinking; values, beliefs, attitudes and intentions; personal agency (a person's belief that he or she can take meaningful action); perceptions of social norms; routines and behaviours. Community/group level influences relate to what goes on within groups, social networks and/or geographic communities. These include group capacity and group norms and standards. These socio-psychological issues that influence and interact with the technologies and markets, as well as policies, are indicated below based on the framework provided by Mayne *et al.* (2012:6–7).

2.3.3 Links to the study

Although the term “foresight” is used in this reading, for this study it is taken that futures studies is the main field of study as it is a more widely used term, as explained by Sardar (2010: 180). Although scenarios as a technique are not the main focus of the study, it does link with “inductive scenarios” concerned with the interpretation of data. More specifically, a “normative” approach to scenario-building is taken, which encourages a “preferred” vision of the future and outlines different “pathways” from the goal to the present in order to guide the pursuit of the goal. It was necessary to investigate this method as it would focus on relevant weaknesses that would in turn foreground the areas that need to be addressed. Essentially, the scenarios are deduced from an analysis of which drivers of change are important and uncertain. These are then prioritised to identify the two most important uncertainties which create the scenario “axes”. The deductive approach to scenarios offers a number of benefits which include a structured nature, with a clear relationship between drivers and scenarios, and a relatively simple way to link the scenarios with strategic and policy implications. However, the study will require more depth through a co-evolutionary interaction between different levels of society that play a role in the social, cultural, political and service sectors. This will include the forces between the levels that will enact changes. One will have to prevent a too high level of homogeneous trends. By focussing on the different levels one will also consider the actors required to make the changes to ensure a more pragmatic approach towards conceptualising and elaborating on the pathways. A “normative” approach to scenario-building is therefore used which encourages a “preferred” vision of the future and outlines different “pathways” (see below) from the goal to the present (i.e. they involve “backcasting” typically starting with the most desirable future and concern questions such as “what changes?”, “why changes?”, “how to?” and “who will?”).

In the previous appraisal of Section 2.2.2, visions were defined and briefly compared with transitions. According to Dixon (2011:24), who compared 21 UK and international low-carbon studies, in many cases terminology can be “fuzzy” and “blurred”. To further provide some clarity on the linkages between scenarios, visions, pathways and transitions, they have been conceptualised in **Figure 2.2**. Futures studies tend to be based around “scenarios” and “roadmaps” whereas transitions literature is frequently characterised by the use of the terms, “transitions” and “pathways” as shown (Dixon, 2011:24).

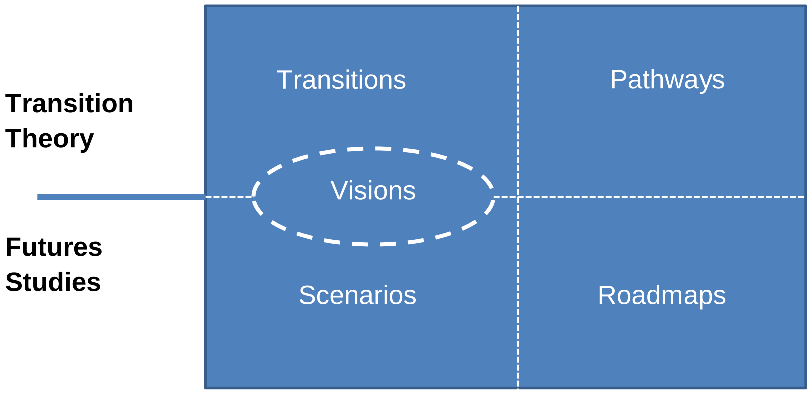


Figure 2.2 Conceptualising techniques in futures/foresight studies and transition theory (Dixon, 2011:24)

This is by no means an absolute rule, and in practice Dixen (ibid) have also seen that there is an overlap and relationship between the four quadrants, particularly with regard to the use of “visions”. The connection with this study is that futures studies is the main field, with visions representing the initial stage of transition pathways.

The modern theory of innovation and transitions has provided a number of concepts and insights that may help foster radical innovation and system transformation involving different actors at different levels. The concepts have created a nuanced and rich picture of the innovation and transition process, with a wide set of implications for those hoping to assist, shape or direct the innovation process and system change. Some of the main ideas include appreciating the importance of actor networks; the role of institutions; the co-evolutionary nature of the technologies, institutions, social practices and business strategies; the role of feedback and path dependency in socio-economic systems; and a greater understanding of the different types of knowledge and learning processes. Frameworks such as technological innovation systems and the MLP provided useful analytical structures for developing innovation and transition policies and strategies (Twomey and Gaziulusoy, 2014:23).

An important link to the literature was that technology by itself, however, will not be sufficient to achieve the required emission cuts and that radical change will be required in people’s mindsets and behaviours. Other social aspects of being human is considered in the study instead of what the rational model of decision-making represents. From a rational choice theory approach (Section 2.3.2), the policies can promote pro-environmental behaviour by providing people with the right information, financial incentives and product designs. However, from a non-rational behaviour change theory approach, the study included behaviour psychology leveraging on preferences of community groups as well as an individual’s cognitive capabilities, emotions and values, social norms and habits.

2.4 Conclusions on theoretical context and perspectives

The two theories related to “homes” and “low-carbon society” have been appraised in order to contextualise this study into its relevant theroretical field. It was imperative to understand the methods used in futures studies and its relationship to transition theory. Futures studies is mainly a multi-disciplinary type of research that links to quantitative and qualitative in a complementary approach such that how they are used together becomes a crucial issue in any related study. Quantitative research such as forecasts can provide a basis for establishing the extent of alternative assumptions by breaking trends using qualitative methods. Forecasts on their own have been severely criticised for their predominantly deterministic view of the future in the long term.

The reading appraisal prioritised modelling method and visions representing both quantitative and qualitative approaches. Visions have been used differently in various studies. As a method, visions studies often depict somewhat idealistic-type future narratives. However, it must be remembered that visions can be anchored in, for example, backcasting pathways to provide concepts of a desirable future state. Visions have even been associated with scenarios, although scenarios can also be interpreted as either method or state. One can argue that this study follows a “normative” approach to scenario-building based on the fact that it follows a preferred/desirable vision of the future and outlines different “pathways” from the goal to the present based on a “backcasting” approach. Although both the scenario and the vision are states, they are anchored in the main backcasting method and connected by pathways. Transition pathways provide a framework for structuring the interrelationships between the macro, meso and micro levels of an innovation system, shifting from one state to another and thus pursuing a renewed state. This study has reinterpreted the DIT and MLP to recreate an MLA theory focusing on actors over three levels that were the main force of change within relevant technology niches. Through this approach, the causality of rational choice theory (Section 2.3.2) was complemented by diverse changes including behavioural psychology factors that did not see people as merely responding to the forces of technological change, but considered changes that result in a more balanced interaction between technology and the human-actor with a sense/awareness of agency.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

The study applied a dual-method approach (Delphi and backcasting) comprising of descriptive and normative data that were comparatively analysed to improve the overall validity/strength of the findings. The two core methods, which ran concurrently, originated from two different theoretical frameworks. The data collected from these two methods were analysed, interpreted, contrasted and compared to eventually develop one strategic narrative pathway. The methods are underpinned by enriched theoretical principles intended to make it possible to generate plausible data for subsequent analysis towards the required findings.

For both the Delphi and backcasting methods, the theoretical background was first appraised to provide the context of the data collection process. The literature appraisals are organised around the field of futures studies and the empirical transitions to a low-carbon middle-income home sub-sector. The appraisals for each method focused on overview and relevance, critical appraisals of key arguments, and links to the study.

After appraising the theoretical background, the chapter documents the design and process followed during the fieldwork. Issues relating to the instruments used for the data collection, sample design, participant-identification and solicitation, data collection process, data capturing and editing, data analysis and limitations are then discussed. The process presented includes the steps required, from tool preparation to conducting the data collection and subsequent analysis

3.2 The Delphi method appraisal

3.2.1 Overview and relevance

There is an array of Delphi approaches and related data types to address specific objectives. The aim was to identify a suitable Delphi method that followed a causal/deterministic path of data collection to provide a basis of comparison with the backcasting. A paper by Hsu and Sandford (2007:1–8) provided some lessons for consensus-building when using a relevant type of Delphi technique. Principles from this reading and other differing views were applied towards developing an appropriate Delphi method. Under the overview and relevance section, the appraised reading is motivated. Thereafter, the critical appraisal key arguments are presented. These include a comparison of the characteristics of the Delphi method with futures studies. Secondary concepts including data collection, analysis and the Delphi method participants were also appraised. Each topic will first refer to the appraised study and then make comparisons with other literature, from which links to the study are finally identified.

Since the 1950s, the use of Delphi has spread from its origins in the USA defence community to applications in the prediction of long-range trends in science and technology applications in policy formation and decision-making. According to Hsu and Stanford (2007:1), who referred to Miller *et al.* (2006:1), the objective of the Delphi applications was to address "what could/should be". On the other hand, Börjeson *et al.* (2006:723–726) developed typologies to make the field of futures studies easier to implement. Under these typologies, forecasts responded to the question: "What will happen, on the condition that the likely development unfolds?". Besides the purpose of establishing the differences in various categorisations under Delphi, it was equally critical to interrogate the effect of different views on the outcome pertaining to the respondents, data type, analysis and how building consensus was achieved.

3.2.2 Critical appraisal of key arguments

McDowall and Eames (2006) categorised futures studies as descriptive or normative. According to Puglisi (2001:449; 452), the Delphi method is the most important of the judgmental futures studies methods, which thus entails a descriptive approach. It aims to substitute quantitative knowledge with qualitative expert knowledge. Of interest in this study is the conventional/classical Delphi method, which has two main purposes, which are the forecasting and estimation of unknown parameters. It is used to build consensus on forecasting dates or developments, especially in the field of technological and scientific long-term changes.

The appraised study refers to the Delphi technique as being generally well-suited as a means and method for consensus-building by using a series of questionnaires to collect data on a selection of subjects (Young & Jamieson, 2001:42–58). In contrast to other data gathering and analysis techniques, the Delphi employs multiple iterations designed to build consensus of opinion concerning a specific topic. Literature describes the Delphi as a method that uses questionnaires conducted in successive rounds to collect ideas and opinions on a particular technology from a group of experts. The ideas and opinions collected at each round are shared with all the experts and the process is repeated until when consensus is reached (Zimmermann *et al*., 2012:1607; Kent and Saffer, 2014:569).

Some advantages of the method as highlighted by Dalkey (1972:21) relate to subject anonymity and controlled feedback. Also, the use of statistical analysis techniques further reduces the potential of group pressure for conformity. Statistical analysis can ensure that opinions generated by each subject of a Delphi study are well covered in the final iteration because “at the end of the exercise there may still be a significant spread in individual opinions”. The tools of statistical analysis allow for objective and impartial data analysis and summarisation (Dalkey, 1972:21).

Hsu and Sanford (2007) do not elaborate on the type of Delphi used but only refer to it generally as a method that focusses on consensus-building. Hasson *et al.* (2000:1008–1015) report that “Modified Delphi”, “Policy Delphi” and “Real-time Delphi” have all been used in the past, but that different categories such as the “Classical Delphi”, “Policy Delphi” and “Decision Delphi” have more broad appeal. In studies on forecasting long-range trends with the aim of acquiring more quantitative data, the Classical Delphi has been employed more frequently (Gordon and Helmer, 1964:15–26), thus revealing the true scientific merits of the method. Delphi can also complement other methods such as backcasting, such that the Delphi findings are made to serve as a baseline that forecasts trends, determines whether targets can be achieved, and then provides guidance on which scenario/s are to be developed towards achieving the targets (Svenfelt, Engström and Svane, 2011; Höjer and Mattsson, 2000:629).

According to Van Zolingen and Klaassen (2003:317–340), a Classical Delphi study is characterised by five key features which are anonymity, iteration, controlled feedback, statistical group response and stability in responses among those with expertise on a specific issue. Participants in this type of Delphi have expertise and give opinions in order to arrive at stability in responses on specific issues. In comparison, the Policy Delphi is a more widely used method with the intention not to reach stability in responses among those with expertise, but to generate policy alternatives and many divergent opinions by using a structured public dialogue. An example of an applied Policy Delphi in South Africa is a study by Barry *et al.* (2008:33–51), which was undertaken to assist decision makers in selecting sustainable energy projects in Africa to ensure successful technological use despite limited human and financial resources.

Researchers investigating other types of Delphi preferred to remain with stronger scientific foundations. For example, Gupta and Clarke (1996:189) noted that “practitioners were often willing, and sometimes even eager, to modify Delphi”. They concluded that while some modifications were useful, others seemed to be random and undermined both the quality and credibility of the technique.

The Forecasting Delphi approach with more quantitative outcomes was also used in demand forecasting, where decisions were required and where managers needed forecasts of, for example, the total size of the relevant market, as well as actions and reactions of key decision makers such as competitors, suppliers, distributors or government officials. When sufficient data were available, such as when the market was well established or when data on analogous markets or products were available, the use of time-series extrapolation methods or causal methods was adequate. The first question confronting a forecaster was whether the data were sufficient to develop a quantitative model. If not, one would need to use judgment procedures. The two were not mutually exclusive as, in many situations, both quantitative and judgment/qualitative methods could be viewed as complementary. Combining forecasts was one of the most powerful procedures in forecasting studies and was therefore applied to a wide range of problems (Green and Armstrong, 2012:5).

The time-series and judgment procedures are more causal models that can represent the more classic stages of, for example, market penetration analysis for a new product based on Roger’s diffusion theory (2003:1–34). The S-curve shape of the path of diffusion reflects the stages of market development that can be transformed into linear models – from a non-linear S-curve to a linear transformation (Daly, 2009:3).

According to Roger’s (2003:1–34) Diffusion Innovation Theory (DIT), the rate of accumulative adoption can be diffused over time in a pattern that resembles an s-shaped curve. Rate of adoption theorises that an innovation goes through a period of slow, gradual growth before experiencing a period of relatively dramatic and rapid growth. The theory also states that following the period of rapid growth, an innovation’s rate of adoption will gradually stabilise and eventually decline. What is critical is the rate of adoption, which is defined by Rogers (2003:210–240) as the relative speed with which an innovation is adopted by members of a social system. The system may be a community, an organisation or some similar social structure.

Contrary to this more linear diffusion model, driven more from the supply side, an important feature of the modern approach to innovation was the interactivity among agents and feedbacks between different stages of the innovation processes (Twomey and Gaziulusoy, 2014:7). This resonated strongly with the field of complexity science, which investigated how relationships between parts gave rise to the collective behaviours of a system, and emphasised non-linear dynamics, heterogeneous agents, networks, evolution and the emergence of system-level properties (Mitchell, 2011 in Twomey and Gaziulusoy, 2014:7).

Witkin and Altschuld (1995:188) also cautioned that “subtle pressure to conform to group ratings” was one of the major drawbacks in the Delphi technique. The outcomes of a Delphi study could be the result of identifying a series of general statements rather than an in-depth exposition of the topic because of unequal levels of expertise in a particular field (Altschuld and Thomas, 1991:178–188).

Hsu and Sandford (2007) provided useful guidance on the more secondary concepts related to data collection, analysis and participants. They referred to the questionnaire design as a process beginning with an open-ended questionnaire as the corner-stone of the process of soliciting information about a content area from the participants. After receiving participants-responses, the investigators convert the collected information into a well-rounded questionnaire. Not much is said about the questionnaire's content and type of questions. It is important to note the distinction between the type of questions asked through the Policy and Classical Delphi, as they stem from different theoretical bases.

In the Policy Delphi, the questions seek to generate policy alternatives and many divergent opinions. Linear numerical scales, such as that described by Likert, and the median score are often used (Jacobs 1996, De Loë *et al*., 2016). A Policy Delphi deals more with statements, arguments, comments, and discussion. To establish some means of evaluating the ideas expressed by the participants, Likert rating scales must be assessed for such items as relative importance, desirability, confidence and feasibility of various policies and issues.

Classical Delphi questions relate mainly to themes with a numeric value occurring in a certain future stage. The major statistics used in Delphi studies are measures of central tendency (means, median, and mode) and level of dispersion (standard deviation and interquartile range) in order to present information concerning the collective judgements of participants (Hasson, Keeney, and McKenna, 2000). Armstrong and Green (2012:11) use trimmed averages or medians for combining forecasts. Hsu and Sanford (2007:2) stated that theoretically, the Delphi process could be iterated continuously until consensus was determined to have been achieved. However, two rounds of forecasts could be obtained independently from a small group of experts (Armstrong, 2006:5). Mullen (2003:37–52) claims that repeated rounds could lead to fatigue in respondents and increased respondent attrition. Nearly all studies agree that the most significant improvement is reported between the first and second estimation rounds (Woudenberg, 1991:140). Using the online platforms for communication and data collection would save time and money (Hung and Law, 2011).

One of the reference studies (Linstone and Turoff, 2002:206) uses graphs showing a trend line, running from 1960–1969, and asking the respondents to extend the line through to 1985. Three questions are associated with each graph: how reliable the graph extension is felt to be; what key developments (i.e. assumptions) were assumed in making the extension; and what other developments (i.e. uncertainties) might result in major revisions to the extension.

Consensus on a topic could be achieved if a certain percentage of the votes falls within a prescribed range (Miller, 2006:1). Some Delphi researchers suggest that agreement among 60% of the panel can be viewed as constituting sufficient group consensus (Hill and Fowles, 1975:176–192). Another strategy to improve the quality of the answers is to use some type of self-rating method. More recent studies (Rowe & Wright, 2011:1489 for example) note that self-rated experts tend to exhibit less drop-out over Delphi rounds than those who rate themselves as having lower expertise. Self-ratings of confidence might be helpful when selecting respondents who might provide more thoughtful responses (Parente and Anderson-Parente, 2011:1710).

Delphi groups are substantially more accurate than individual experts and somewhat more accurate than statistical groups, which are made up of non-interacting individuals whose judgments are aggregated (Armstrong 2001:57– 144). As for accuracy, consensus is almost always maximum after the second estimation round. High consensus is neither a necessary nor a sufficient condition for high accuracy (Woudenberg, 1991:145).

Armstrong (2006:21) states that over the past quarter century, evidence from comparative studies has led to well-supported forecasting methods. Two of these methods can be applied to all types of data: combined forecasts with an estimated 12% error reduction, and Delphi, which shows improved accuracy in 19 of 24 comparisons (79%). Perhaps the most widely used extrapolation method, with the possible exception of using last year’s value, is exponential smoothing. Exponential smoothing is sensible in that recent data are weighted more heavily and, as a type of moving average, the procedure smooths out short-term fluctuations (Armstrong & Green, 2012:10).

Simple extrapolation methods are typically as accurate as complex ones (Armstrong, 2001:215–243). When deciding whether to use experts or non-experts in a Delphi process, investigations indicate a number of perspectives. The best argument does not always win in expert panels as compared with ordinary panels (Piirainen, 2009:3). Aligica and Herritt (2009:256) believe that tacit knowledge, expert or not, is difficult to articulate. A person could provide a reasonably accurate answer by drawing on many small pieces of background knowledge he or she has acquired through the years, much of which could not have been articulated.

Many other studies support diversity among Delphi panels (heterogeneous experts), experts with combined knowledge with expertise, which reflects a better scope of the problem domain. (Schuckmann *et al.*, 2012:1377; Armstrong, 2001:57–144; Yaniv, 2011: 41–49; Green and Armstrong 2011: 69–80; Bolger and Wright, 2011:1502).

In summary, Armstrong (2001: 57–144) suggests that groups in general should probably comprise between 5 and 20 members. The number will depend on the range of expertise available and the cost implications. In the case of more in-depth feedback a smaller panel will be required as there will be fewer experts available. If the sample size of a Delphi study is too small, the subjects might not be considered as having provided a representative pooling of judgments regarding the target issue. If the sample size is too large, the drawbacks inherent within the Delphi technique, such as potentially low response rates and the obligation of large blocks of time by the respondents and the researcher(s), could become a critical risk.

3.2.3 Links to the study

The relevance of the appraised reading to this study has been assessed in terms of theories and concepts that could be identified in relation to futures studies.

The Classical Delphi technique is appropriate as it was an empirical way of thinking to acquire information and combines quantitative questions with qualitative judgmental knowledge because of lack of quantitative data and the complex nature of the study. In futures studies the fruitfulness of the forecasting approach of highly complex long-term sustainability problems may be doubted. Based on business-as-usual/dominant trends, it is unlikely to generate solutions that would presuppose the breaking of trends (Dreborg, 1996: 814). An important purpose of the Delphi is that it can also complement other methods, for example backcasting. Delphi findings are made to serve as a baseline that forecasts trends, determines whether targets can be achieved, and then provides guidance on which scenario/s to develop towards achieving the targets (Svenfelt, Engström and Svane, 2011; Höjer and Mattsson, 2000:629). On its own, the Delphi does not seek to develop co-evolutionery thinking to bring about change, as in the case with transitions theory.

The main reading did not elaborate on the key theories and type of Delphi method used but was useful in identifying some secondary concepts of the classical Delphi relevant to the study, such as processes, analysis and participants. It was mainly guided by use of the common statistical analysis method for quantitative data analysis. However, instead of using a Likert scale method, extrapolated graphs were analysed by obtaining median, inter-quartiles and outliers for each question. The Delphi participants were weighted equally. Simple time-series methods or analogies were used to best fit historic data patterns. The study will rely on first principles extrapolation techiques. The simple trend lines approach, such as linear, exponential smoothing, logarithmic, power and polynomial trend lines were used. A trend line's R-squared values closer to one indicate a better fit and would thus yield more accurate predictions (Walkenbach, 2007:165). This study focuses on first principles extrapolation techniques and judgements instead of using more advanced modelling techniques.

A heterogeneous panel of participants was chosen based on availability and interest in participating while mitigating over-confidence, same-thinking and invalid consensus. The definition of an expert (which was critical in the study) was taken from Armstrong (2001:57–144) to be someone who is knowledgeable and has cross-disciplinary knowledge as a professional or researcher in the field of low-carbon homes. However, it is necessary to highlight that experts with different levels of expertise would improve the study's balance and scope of insight. The study aimed at soliciting 10 to 20 participants in various disciplines comprising of engineers, architects, quantity surveyors, sustainability experts and researchers.

To limit the Delphi reiterations to two rounds would reduce fatigue and prevent drop-outs. Well-prepared and more focused questionnaires can lead to fewer rounds for available data. The study concurs with the point that consensus on a topic is achieved if a certain percentage of the votes of a question fall within a minimum of 60% agreement. Continuous motivation, reminders, and the inclusion of self-ratings lessen the likelihood of respondents dropping out of the investigation.

3.3 The Classical Delphi method as applied in the study

3.3.1 Questionnaire designs

Following the traditional forecasting method of the Delphi, the study generated trends over time to project the likely/probable future, given the current and historical dynamics of the sub-sector. The Delphi process reiteratively employed a series of carefully prepared questionnaires and controlled information feedback towards building group consensus among individually anonymous experts.

The questionnaire was structured into lever categories of lifestyles, technologies, policies and markets and its associated data according to **Figure 3.1**. This generated 38 questions altogether, which were used to determine the likely trends to be contrasted and compared with the backcasting approach.

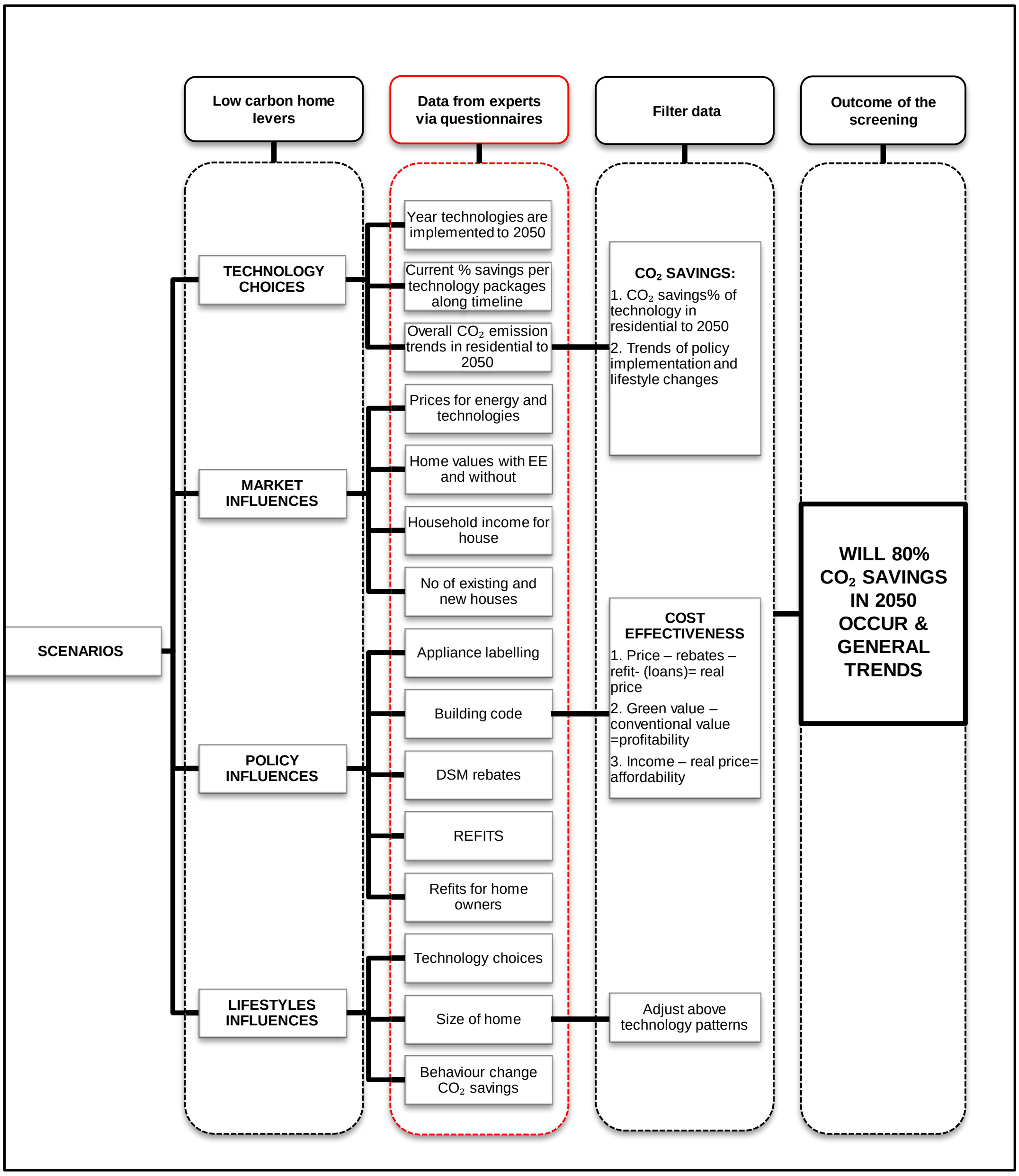


Figure 3.1 Delphi questionnaire content design

Rational choice theory (Section 2.3.2) guided the thinking behind this method so that the choices and cost benefits from secondary data sources obtained from literature and experts could be weighed. Each category comprised time-series graphs based on secondary historic data trends representing the pertinent aspects that would induce CO_2 emissions reductions. To quantify a variable, the questions asked related to the year a prevalent technology will become or remain a trend through lifestyle or policy influences; what the related CO_2 emissions were; what it meant for a product to be affordable and profitable; and what relevant, measurable policies and lifestyle trends could affect the technology trends. Eventually, to obtain final findings in achieving carbon reductions, the data of the categories of technology, markets (cost effectiveness), policy and lifestyle implications were filtered. By filtering the data, the author was able to map out and establish the extent of the CO_2 reductions of the technology trends and their cost effectiveness.

The questionnaire for Round 1 of the Delphi method is attached in Appendix A2 (see page 282). This was disseminated with the precedent case study entitled “A case study on technology innovation diffusion: the cell phone” in order to stimulate thinking on other technologies.

In preparing the questionnaire, the researcher constructed graphs showing a trend line and asked each respondent to extend the line. Three questions were associated with each graph, i.e. how reliable the respondent felt his/her graph extension to be; what key developments (i.e. assumptions) the participant assumed in making the extension; and what other developments (i.e. uncertainties) might result in major revisions to the extension. The questionnaire provided an example trend extension to 2050 for each category, using a simple time-series model (e.g. linear regression) that best fitted the historical pattern that dated back approximately 10 years, depending on the data available.

If the trend seemed to yield intuitively unrealistic results or the uncertainty increased, the trend line was dampened, using another model, in line with the long-term period involved in establishing the results of a question requiring, for example, the year by which an item had a 50% (median) probability of being implemented.

While completing the questionnaire, participants had to stipulate the necessary changes and include external forces (causal forces affecting growth and decay) that were not included in the example extrapolation. Judgment adjustments of the time-series improved the accuracy of the data and provided the primary data. The participants − although knowledgeable only in certain categories − were asked to complete all the questions for all the categories because of the crosscutting nature of the questions.

The questionnaire was completed by verifying whether the example extrapolated trend line given for the relevant question represented the most likely trend data. Supplementary information included the panels' comments and reasons for their inputs. The quality of the respondents' answers was ascertained through their being asked to complete the CL 1–4 for each question.

3.3.2 Selection of participants

A crucial aspect of conducting a successful Delphi study is the selection of the respondents. Consequently, much care was taken in recruiting the panel with the realisation that experts must preferably have knowledge in a relevant domain and have some other crosscutting background, knowledge or experience. The selection of the panel was influenced by participants' interest and availability to complete the questionnaire at a certain point in time within the provided time constraints. The participants were a heterogeous group of experts and professionals with appropriate domain knowledge in fields that influence CO_2 emissions reductions in homes. This encompassed lifestyle, technology, policies and market trends. A number of suitable organisations that employ targeted professionals in the industry were approached,with a view to recruiting participants specialising in or having worked in the field of sustainable buildings as well as academics, of which 18 individuals from different disciplines countrywide initially showed interest. Of the 18 respondents who showed interest, only four withdrew during Round 1 and one withdrew during Round 2 – either because they thought they did not have sufficient knowledge to be able to give inputs or because of time constraints. The 14 participants in the first round and 13 participants in the second round eventually participating in the survey are listed in Appendix A3 (see page 322). The participants' occupations and qualifications are indicated in **Table 3.1**.

Table 3.1 Delphi participants list

No.	Field of employment	No. of respondents	Province	Qualifications
1	Engineering practice	1	Gauteng, Western Cape	BSc (Civ. Engineering); MBA
2	Environmental practice	1	Gauteng	MSc (Technology & Innovation Sciences)
3	Research institution	4	Gauteng, Western Cape	PhD (Architecture); MSc (Energy Studies); DSc (Mech. Engineering); MSc (Architecture)
4	Manufacturing sector	1	Gauteng	BArch (Honours)
5	Architectural practice	3	Gauteng, Limpopo, KwaZulu-Natal	BArch (Prof); BArch; MTech
6	Quantity surveying practice	1	Gauteng, Western Cape	BTech (Quantity Surveying)
7	Public sector	2	Gauteng, Western Cape	MSc (Elec. Engineering); BTech (Mech. Engineering)

The process of soliciting responses (data collection) followed a step-by-step approach as listed below:

- The first step was to identify suitable public and private sector organisation experts in the field of low-carbon/ sustainable/green/energy-efficient buildings in the areas of lifestyles and external influences such as technology, markets and policies.

- The second step was to compile *a* basic introductory letter (see Appendix A1 (see page 281)) that obtained a signed commitment from prospective experts interested in participating in a two-round Delphi comprising 38 questions. The questionnaire was estimated to take not more than 35 to 60 minutes to complete.
- The third step was to contact the heads of the organisations identified in step 1 and, during conversations, provide an introduction and brief background to the research project, upon which,their interest in participating was determined. This step was followed up on a few days before the questionnaire was disseminated.
- The fourth step was to send the interested head of an organisation or the experts referred by them**,** the background of the research and an accompanying letter of commitment for them to sign. It was necessary to follow up with them persistently and personally on progress and interest. If the prospective candidates indicated they were unable to participate, the search would continue to find other suitable organisations or expert candidates.
- The fifth step was to remind all 18 confirmed candidates (see Appendix A3 (see page 322)) in writing of their participation in questionnaire 1, which would be e-mailed in due course, and that they had three days from the date of receipt in which to complete the questionnaire.
- The sixth step was to disseminate all information obtained from questionnaire 1.
- The seventh step for the study was to follow up with those participants who did not fill in the questionnaire within the stipulated three days.
- The eighth step was to use the backup list compiled of other possible participants, when four respondents decided to pull out of the survey.

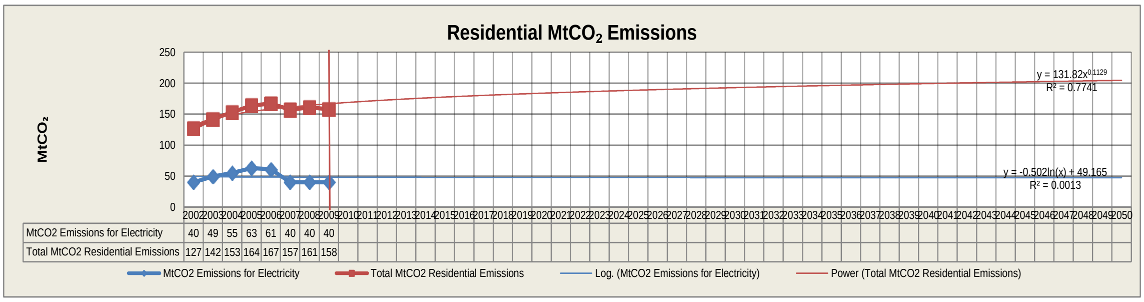
- The ninth step was to analyse responses to the first questionnaire in order to determine the results to be included in the second round. This was then disseminated within five working days of receipt of all the first round responses.
- The tenth step was to contact each participant personally before sending them the second questionnaire and the same process was followed as for iteration 1.
- The eleventh step was to analyse responses to the second round of questionnaire, after which all the participants were sent the final results.

Procedure to collect data. The structure of the processes comprised three main stages: preparation, planning and conducting the method. Within this framework, the step-by-step process and related key dates for the Delphi are indicated in Appendix A4 (see page 323). The preparation process included identifying current trends, identifying sources for historic data and preparing the first questionnaire. Following the preparation phase was the planning phase, which included the designing of the format of the questionnaire, inviting 18 participants, and contacting participants before dissemination. Finally, conducting the Delphi survey consisted of disseminating for iteration 1, evaluating iteration 1, disseminating for iteration 2 and evaluating for iteration 2.

3.3.3 Data capturing and data editing

Participants were requested to commit to the whole process by signing a form confirming their willingness to participate. The intention was to ensure a more complete process of participation by which the degree of convergence could be established. The questionnaires in both iterations were filled in electronically. The respondents indicated their extension figures of the graph, showing historic trends more likely to occur in the boxes provided. However, upon agreement with the proposed graph, they marked the “agree” box with a cross. The new figures had to be completed according to the relevant graphs’ unit measurement, e.g. Rand/unit or Mt CO_2, etc. **Figure 3.2** provides an extract from Questionnaire 1 to illustrate how the responses were captured.

15. Residential CO_2 emissions- electricity



	2002	2003	2004	2005	2006	2007	2008	2009
MtCO2 Emissions for Electricity	40	49	55	63	61	40	40	40
Total MtCO2 Residential Emissions	127	142	153	164	167	157	161	158

(Statssa, 2012. Energy Accounts for South Africa. Pretoria, 30-38)

	Agree	2010	2020	2030	2040	2050	Confidence level 1-4
Total residential $MtCO_2$ emissions	x						2
Residential $MtCO_2$ due to electricity		48	52	54	56	58	2

Statistics of energy use in South Africa are limited and often contradictory. For these purposes the energy accounts from Statssa have been used. However, the General Household Surveys from Statssa indicate that electricity comprised 61% in 2002 and 66% in 2011 of the total energy consumption by source type. Of the total energy used, renewable energy consists of 1%-10%, coal 1%-8% and petroleum products 20%-23%. To convert a unit of energy consumption to a unit of carbon emission the following conversion factors are used: 1GWh = 3,6TJ; 1TJ = 0,278GWh and 1TJ = $278tCO_2$.

(Statssa, 2012. Energy Accounts for South Africa. Pretoria, 30-38, and

CIDB, 2009. South African Report on Greenhouse Gas Emission Reduction Potential from Buildings. Pretoria, 27. http://www.cidb.co.za. Accessed: 2009/10/28)

15. **COMMENTS:**

Key assumptions:
Total residential MtCO2 emissions = total emissions likely to grow with continuing low income property developments, and greater electrification (moving from other fuels)
Residential MtCO2 due to electricity = total emissions likely to grow with continuing low income property developments, and greater electrification (at a similar rate)

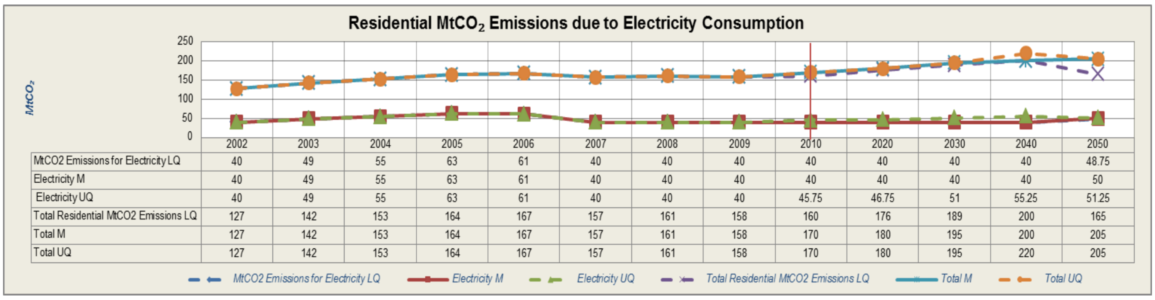
Other key developments (uncertainties): Policies and economic growth of SA

Figure 3.2 Capturing Questionnaire 1 responses (Geszler, 2014)

When the researcher received the responses, the data were documented and/or coded using spreadsheets. Each respondent’s responses were recorded under the following categories: question no.; sub-section; expert name; answers; total no. of responses; confidence level; and comments. All the recorded data were used as input for a box plot analysis tool that determined the minimum, quartile 1, median, quartile 3, maximum, interquartile range (IQR), upper outliers, and lower outliers to determine results for the second iteration. Where historic data were vague when designing the questions, they were repeated in a different way in the same questionnaire to compare answers and ascertain the best plausible result.

A second iteration questionnaire was compiled to provide the respondents with the analysed results of the previous iteration, in order to re-evaluate the data. **Figure 3.3** is an extract of Questionnaire 2 for which participants evaluate the previous iteration.

15. Residential CO_2 emissions- electricity



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2020	2030	2040	2050
MtCO2 Emissions for Electricity LQ	40	49	55	63	61	40	40	40	40	40	40	40	48.75
Electricity M	40	49	55	63	61	40	40	40	40	40	40	40	50
Electricity UQ	40	49	55	63	61	40	40	40	45.75	46.75	51	55.25	51.25
Total Residential MtCO2 Emissions LQ	127	142	153	164	167	157	161	158	160	176	189	200	165
Total M	127	142	153	164	167	157	161	158	170	180	195	200	205
Total UQ	127	142	153	164	167	157	161	158	170	180	195	220	205

(Statssa, 2012. Energy Accounts for South Africa. Pretoria, 30-38)

	2010	2020	2030	2040	2050	CL 1-4	Agree/Disagree
i) Residential $MtCO_2$ Emissions for Electricity	LQ=40 M=40 UQ=45.75	LQ=40 M=40 UQ=46.75	LQ=40 M=40 UQ=51	LQ=40 M=40 UQ=55.25	LQ=48.75 M=50 UQ=51.25	LQ=1 M=2 UQ=2	Agree
ii) Total Residential $MtCO_2$ Emissions	LQ=160 M=170 UQ=170	LQ=176 M= 180 UQ=180	LQ=189 M=195 UQ=195	LQ=200 M=200 UQ=220	LQ=165 M=205 UQ=205	LQ=1 M=2 UQ=2	Agree

The General Household Survey from Statssa indicates that electricity comprised 61% in 2002 and 66% in 2011 of the total energy consumption by source type. Of the total energy used, renewable energy consists of 1%-10%, coal 1%-8% and petroleum products 1%-10%, coal 1%-8% and petroleum products 20%-23%.(1TJ = 278tCO_2)

(Statssa, 2012. Energy Accounts for South Africa. Pretoria, 30-38, and

CIDB, 2009. South African Report on Greenhouse Gas Emission Reduction Potential from Buildings. Pretoria, 27. http://www.cidb.co.za. Accessed: 2009/10/28)

15. **RESULTS OF COMMENTS:**

Key assumptions: Total residential MtCO2 emissions = Total emissions likely to grow with continuing low income property developments, and greater electrification.

Other key developments (uncertainties): Will depend on which technologies become dominant; Policies and economic growth.

ADDITIONAL COMMENTS:

Figure 3.3 Questionnaire 2 reiteration for respondents to evaluate

3.3.4 Data analysis

Accuracy was improved through strategies imposed on the interaction between the respondents and researcher, a systematic process, as well as the mathematical approaches applied to the data sets. A general rationale behind the strategies to ensure accuracy is provided in the following sub-sections.

<ins>How to verify accuracy</ins>. Delphi groups are substantially more accurate than individual experts can be, and somewhat more accurate than statistical groups. Furthermore, heterogeneous experts are preferable to experts focused on a single speciality, as the cross-cutting knowledge improves the interrelationship between parts. Anonymity of the experts preserves positive influences, as group interaction is excluded. When there is a lack of directly relevant data in uncertain situations, judgments are more relevant than when information is available, and consequently, experts are not more accurate than non-experts, because the outcome is strongly influenced by the desirability of the answer. As for accuracy, consensus is almost always maximised after the second iteration. High consensus is neither necessary nor a sufficient condition for high accuracy.

Essentially, two applied mathematical approaches added to the accuracy of the data, i.e. construction of the graphs and analysis of the graphs' data set. Simple extrapolation methods are typically as accurate as complex ones. The former statistical methods and equations were applied to the data set to analyse and interpret the results, explain variations in the data or predict future data. A simple statistical method was used to determine a midpoint between the lowest and highest value of the data set, known as a median. Research on long-range forecasting originally used the 50% probability of an item being implemented, using medians and quartiles. In simple statistical analysis, the lower quartile was such that 25% of the observations were lower than the figure. The upper quartile meant that 75% of observations were lower and 25% were higher than it.

Consensus implied convergence of more outlying data and was achieved where agreement among at least 60% of the respondents had been reached, with the event having a 50% probability of occurring. The recorded data for each question were then used as input data for a spreadsheet that calculated the minimum value, quartile 1, median, quartile 3, maximum value, IQR, upper outliers and lower outliers, as given in **Table 3.2**.

Table 3.2 Delphi analysis criteria

Labels	Results
Minimum	2010
Quartile 1	2020
Median	2020
Quartile 3	2030
Maximum	2030
IQR	10
Upper outliers	0
Lower outliers	0

Table 3.2 indicates an example of statistical results using the median to describe data for the year in which a technology will become a predominant trend along a future time line to 2050 as influenced by either policies and/or lifestyles.

3.3.5 Shortcomings

At first glance, the Delphi seems to be a simple technique that can be applied easily. However, if not carried out thoroughly, it can lead to critical shortfalls. The constraints of the Delphi technique specific to this study have been highlighted. This did not rule out the other common causes that could possibly affect the degree of accuracy, as highlighted in various studies. Some of the key constraints experienced in this study are listed as follows:

- A well-prepared questionnaire was disseminated in Round/iteration 1 to make it easier for respondents to fill in their responses. However, this may have excluded participants’ contribution of other possible perspectives related to the problem.

- Not enough experts were available or interested in participating in the survey to complete the questionnaire, especially if there was no vested interest in the exercise or if they were not financially compensated for inputs given.
- Time constraints in carrying out the data collection placed less importance on the level of expertise involved. While this may have led to respondents dropping out of the survey, it did not necessarily have to be seen in a negative context.
- Linear judgments were made by only a few people and may not have been representative of other judgments.
- Asking the right questions was imperative and required that the questions were written clearly to minimise ambiguity, in order to improve the quality of interpretations and the consistency of answers.
- The author could not ask all the questions for a deeper understanding; if kept to the true intentions of a classical Delphi, this could be limited to answering only the “what” question and its associated assumptions.
- The length of a questionnaire could cause fatigue and result in people dropping out. In this study, one participant dropped out owing to a busy schedule.
- The lack of relevant databases in South Africa limited the compiling of a coherent set of comparable data.
- The cost implications of outsourcing the data collection process meant that the collection entailed a time-consuming process done solely by the researcher, while analysis had to be completed manually by the researcher as well.
- Disregarding the marginal number of questions left empty/ unanswered or questions not completed correctly, such gaps could skew the results.

3.4 The backcasting method appraisal

Backcasting is predominantly a qualitative approach which can be applied towards guiding the process of proactively fulfilling a national target of decreasing energy use in buildings as one example. Most interest focuses on the appropriate strategy towards solving long-term societal problems where transformative change is required. Svenfelt *et al.* (2011:785–796) primarily informed its application in this study. The secondary theories from the literature appraisal concerning the backcasting participants and charrettes are also investigated. Key theories are critically appraised followed by how these theories were applied towards a methodology for this study.

3.4.1 Overview and relevance

Svenfelt *et al.* (2011:785–796) addressed the problem of reducing energy use in residential and commercial buildings in Sweden for reasons of satisfying national targets, where a large proportion of the energy used was not fossil-fuel based. According to the Swedish National Quality Objective, for the total energy use per built area in the residential and commercial building stock, there should be a 50% energy consumption reduction by 2050.

The main question to be addressed was what strategies and measures would be required to achieve the target. The focus here is mainly on changes in attitude and behaviour and the need for radical changes in social structures. In this regard, influential actors capable of directly affecting the measures for the required change to happen have to be identified.

In terms of the question, the objective of the backcasting approach of their study was to attain information on desirable futures within which goals could be accomplished. In backcasting, when one asks the question of how a specific goal can be achieved, one is dealing with normative scenarios.

Such scenarios fulfil the goals for targets that are not reachable conventionally in the long term in the absence of substantial social-cultural transformation. This, in essence, upholds Dreborg's (1996:818) view that backcasting scenarios should represent solutions to a specified societal problem such as the one represented in this study by a potentially unfulfilled carbon reduction target.

The perspective of the appraised paper's on the various themes focused mainly on how the technical potential can be realised, how behavioural changes can be implemented and which actors are crucial for the implementation. The economic aspects of the technologies were considered only to the extent of keeping to cost-effective energy efficiency measures. The themes stemmed from issues related to futures studies that link to sustainability as part of long-term societal goals. Both shared the salient characteristics of a systemic multidimensional concept that encompassed the environment, human well-being, equity, human development and the economy. This time horizon towards attaining desirable future goals allowed for major changes and disruptive technologies, lifestyles, cultural norms and values.

3.4.2 Critical appraisal of key arguments

Of interest are the concepts relating to backcasting visions, backcasting pathways, backcasting versus forecasting, and empirical transition theories. Arguments of the appraised study are compared with other theories from other readings. A sustainable future can be envisioned on many scales, ranging from global to local (Vergragt and Quist, 2011:748).

Various themes are investigated in futures studies, mostly related to technical and social change.

According to Svenfelt *et al.* (2011:785–796), backcasting can be viewed as an analysis and visualisation method (List, 2004:23–43; Patel *et al.*, 2007:546–561; Green and Vergragt, 2002:381–400). They believe that backcasting was framed as the actual analysis of how to attain desirable futures, i.e. the process of “working backwards from a particular future end-point to the present to determine what policy measures would be required to reach that future”. This agrees with Robinson (1982:337). Alternatively, the focus can be shifted to the actual visualisation of futures in which problems are solved or targets fulfilled (McDowall and Eames, 2007:4611–4626). This fulfils the target of mainly finding what can change, but the author did not aim to develop an explicit pathway. Wangel (2011:879) mentions that in the study by Svenfelt *et al.* (2011:785–796), the measures (what) and stakeholders (who) were presented together in a list, but did not incorporate the “agents of change” into any scenario narrative.

Vergragt and Quist (2011:748) argue that a major difference between visions and backcasting is that backcasting is concerned not only with developing a vision, but also developing strategies and pathways to achieve those visions eventually. The development of strategies and pathways to the future has been the subject of future studies for a long time, especially through the development of scenarios. Three classes of scenarios or futures can be distinguished (Börjeson *et al.*, 2006:725–727) by answering the questions: what will happen (forecasting, trend extrapolations; BAU scenarios); what could happen (explorative; foresighting; strategic scenarios) and what should happen (normative scenarios such as those used in backcasting). Normative scenarios are also called desirable futures, visions or future visions. A “normative” approach to scenario-building pursues a “preferred” vision of the future and outlines different pathways from the goal to the present (Saritas and Aylen, 2010) for complex problems requiring significant/deep changes.

McDowall and Eames (2006) also present evidence of the linkage between backcasts and pathways in which a future vision is outlined and storylines worked back from the vision to the present. In a recent study by Truffer *et al.* (2008), vision-based techniques are used within a transitions theory approach (as elaborated here below) in order to explore pathways to a hydrogen-based future in the UK. Based on an extensive analysis of low-carbon studies, Hargreaves and Burgess (2009) argue that good scenarios are transition pathways, and Dixon (2011:21) holds that there are differences in understanding whether pathways are normative and whether they provide robust frameworks for more quantitative modelling. Vergragt and Quist (2011:749) relate normative backcasting scenarios (what should happen) to the more recent development of “transition studies” (Grin *et al*., 2010). Backcasting scenarios recognise the systemic nature of the challenges ahead, and often assume that systemic societal transitions are necessary in order to achieve desirable futures. Thus, it has similarities with transition management (TM) with its underlying multi-level perspective that seeks to develop a methodology, an approach, a toolkit, as well as policies and governance structures for purposeful societal transitions towards sustainability. Hughes (2009) argues that a key deficiency of many low-carbon scenario-based studies is their failure to describe the role of actors within the process of moving to a particular future end point. However, a “co-evolutionary”, “non-linear” conceptualization has been advocated (Hughes, 2009, Rydin *et al.*, 2010) which effectively promotes a more iterative, feedback model where actors hold centre stage.

Within the transitions literature, the concept of a “pathway” is important to recognise. For Hughes (2009), pathways seek to develop well-established technological and economic scenario-building techniques by focusing on the co-evolution of actors and technological infrastructure in transition processes. In short Hargreaves and Burgess (2009: 20) note that "Pathways seek not only to discover if different futures are technically and economically feasible but how such futures might plausibly be brought about by different social actors."

Vergragt and Quist (2008:749) debate the difference between backcasting and transition studies in that backcasting does not assume that the origins of transitions are in socio-technical niches (radical innovation space); it is agnostic about strategic niche management (SNM). It only presupposes that desirable future visions, and pathways potentially leading towards such desirable futures, can be developed. In its essence backcasting is a reflexive and iterative methodology: it does not assume that a group of experts or a group of stakeholders can develop a finalized vision of the future, which then will act as an immovable utopia. Rather, it assumes that both vision development and pathway elaboration encompass processes of higher order learning (Brown and Vergragt, 2008), in which participants learn not only about preferable futures and their contradictions, but also about the present, about each other, about barriers and incentives, about the change agents, and about how to improve the future vision to make it more appealing and resilient. In this sense, backcasting could be viewed as a never-ending iterative process. Of course, in actual practice of time and budget limits, these iterations are often not realized in backcasting studies themselves. Moreover, a vision generated in a backcasting study can become a guiding image for actors and networks, who will subsequently influence, adopt and re-vision the vision itself (Vergragt and Quist, 2011:749).

In this context of substantial changes to be made in the future, associations have been made with transition theories and innovation analysis. More recent frameworks that have been used for analysing system innovation are the innovation systems (IS) approach and the socio-technical transitions approach. Various perspectives for transitions and system innovation are covered in the study as they will be relevant towards conceptualisation of the analytical framework. IS theory is a heuristic framework that operates from the premise that it is not entrepreneurs or firms alone that innovate. Rather, innovation occurs in the context of an entire system. In particular, a core tenet is that technologies, actors and institutions co-determine one another and need to be analysed co-jointly. The socio-technical transition approach is a heuristic framework that emerged from an ongoing research programme pioneered by Dutch researchers (Geels, 2005:75–100; Rotmans *et al.*, 2000:15–31). The socio-technical transition approach is an umbrella term that includes the MLP and multi-phase model, transition management (TM) and SNM. The last two approaches emerged partly from MLP and have a more normative and governance-orientated focus towards supporting radical innovation and system transformation.

Although Innovation systems (IS) and the socio-technical transition theory developed to some extent independently, there has been cross fertilisation of ideas and most of the innovation concepts and insights are shared. Furthermore, there have been recent efforts towards integrating these perspectives (Markard and Truffer 2008; Meelen and Farla 2013).

The MLP research emerged partly from historical studies of system changes and evolutionary economics. The approach is conceived in a societal context that is broader than the IS approach. A central theme is the recognition of the co-evolutionary development of technologies, institutions and social and economic subsystems. The MLP posits three levels to aid in understanding transitions: landscape (macro-level), regimes (meso-level) and niches (the micro-level):

- Landscape level (macro) is the overall socio-technical setting that encompasses the dynamics of deep cultural patterns, macro-economics and macro-political developments that make up the environment or context of socio-technical transition. It is the backdrop to the regime and niche levels, stimulating and exerting pressure on the socio-technical regime and the technological niches and so playing an important role in stimulating socio-technical transitions.

- The regime level (meso) comprises the structures that represent current practices and routines, including the dominant rules and technologies that provide stability and reinforcement to the prevailing socio-technical systems. The regime also presents a barrier to change as well as the expedited uptake of new technological and socio-cultural innovations.
- The niches level (micro) is the level in which space is created for experimentation and radical innovation. The niche level is more loosely structured than the regime and is less subject to market and regulatory influences. There is much less co-ordination among niche actors than among regime actors, but this allows for the emergence of new interactions between actors that may support innovation.

Landscapes are even more structured than regimes and are more difficult to change (Geels 2005). Nevertheless, as **Figure 3.4** suggests, landscapes influence change both at the levels of niches and regimes and in return, niches (may) change the regimes and a new regime changes the landscape in the longer term.

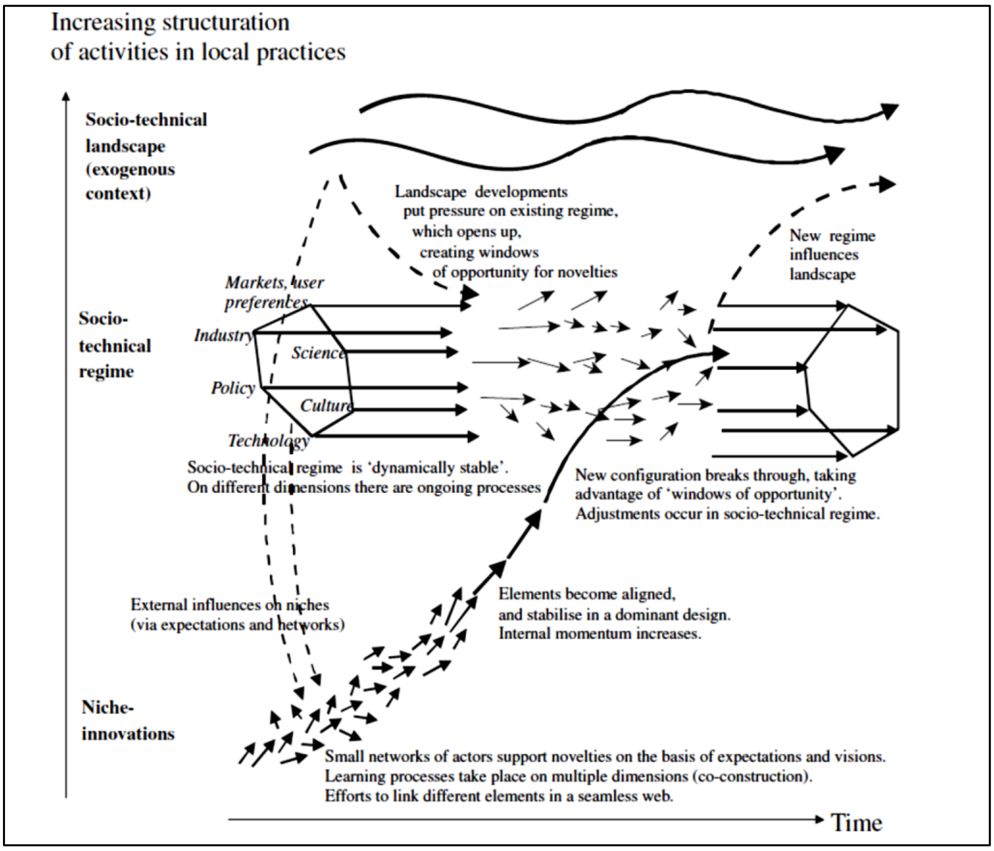


Figure 3.4 Multi-level perspective on transitions (Geels, 2002: 1263)

The socio-technical landscape in this model is relatively static, stands for the external context, represents the physical, technical and material settings which support society at a given point in time, and cannot be changed by actors in the short term (Geels & Schot 2007). Landscapes are constituted by rapid external shocks, long-term changes and factors that do not change or change only very slowly (Van Driel & Schot 2005).

Geels and Schot (2007) suggest there are a range of pathways in transition theory based on the timing of interactions between niches, regimes and landscapes. These comprise:

- Transformation, brought about by external pressures and gradual adjustment. This occurs when actors in the existing regime modify the direction of development paths and innovation activities in

response to moderate landscape pressures and niche innovations not yet sufficiently developed.
- Reconfiguration, characterised by incremental and reconfigured niche developments. Groups of innovations, developed in niches, are initially adopted in the regime to solve local problems, and subsequently trigger further adjustments in the basic architecture of the regime.
- Technological substitution, created by landscape pressures and regime tensions which create windows of opportunity for niche innovations. This occurs when a disruptive change or shock(s) at the landscape level destabilizes the existing regime, and enables previously developed niche innovations to break through and replace the existing regime.
- De-alignment and re-alignment, created by major landscape changes and critical regime problems. This occurs when divergent, large and sudden changes at the landscape level lead to de-alignment and erosion of the existing regime, but niche innovations are not sufficiently developed, and so multiple niche innovation coexist and compete for resources until one of them becomes dominant.

The strength of the MLP approach is that transitions can be explained with reference to the interplay of stabilising mechanisms at the regime level, combined with destabilising pressure from the landscape and radical innovations at the niche level (Markard and Truffer, 2008). In particular, the breakthrough of innovations depends on multiple processes in the wider context of regimes and landscape.

MLP typology is perceived by researchers to have several weaknesses, some of which have been addressed in Geels (2007:401-403). For instance, Berkhout *et al.* (2004:54) argue that “it is unclear how these conceptual levels should be applied empirically.” The second criticism is the relative neglect of agency identified by Smith *et al.* (2005:1492). The third criticism is that the approach places too much emphasis on technological niches as the principal locus for regime change (Berkhout *et al.*, 2004:620).

A major issue is how backcasting studies relate to socio-technical transition studies. In socio-technical transition studies, and especially in the multiple-level perspective (MLP), future visions are also used to orient transition processes. In contrast with backcasting, socio-technical transitions assume in their conceptual model that innovations occur in niches, which then may grow to destabilize the incumbent unsustainable socio-technical regime. It is therefore worthwhile to explore these differences further and determine whether the spin-off of backcasting experiments could be conceptualized as niches. Alternatively, as Vergragt and Quist ask (2011: 359), because backcasting requires systemic changes in society, are such systemic changes too complicated to be pioneered in niches; and do they instead require coordinated action by many different stakeholders?

Secondary theories related to participation and processes were also crucial for the research design. In Svenfelt *et al.* (2011:785–796), backcasting was combined with the use of a focus group consisting of an intentional and interactive participatory stakeholder group.

This qualitative method was based on moderated group interviews where dialogue among invited participants on a given topic or issue was facilitated. There are diverse methodological approaches in the readings on focus groups, primarily based on Kreuger and Casey (2009: 63– 81), who chose to work with five relatively homogeneous groups each which consist of individuals with similar perspectives on buildings. While heterogeneous groups can increase diversity and the range of standpoints is multidisciplinary and transdisciplinary, more homogenous groups can be more compatible and cohesive (Wibeck, 2000). One of the strengths of the focus group methodology is that it enables the researcher to learn from the participants as they communicate with one another. One weakness of the method, compared with individual interviews, is the risk that authority is given to informants with the ability to articulate and express themselves, which is something the moderator has to mitigate (Vergragt and Quist, 2011:754).

Further insight is provided on the participants in the backcasting studies in terms of their status as experts, stakeholders and citizens. Vergragt and Quist (2011:750) recognise that to be able to create visions, participants must be encouraged to distance themselves from present societal constraints, without completely losing their present expertise and their experience. It is a balancing act between complete science fiction versus remaining trapped in present-day constraints and related inertias.

Vergragt and Quist (2011:753) distinguish between groups in terms of context-specific knowledge, stating that no literature describes how the differences should, and could, be bridged. Expert-led backcasting is used more often to reach policy objectives (Vergragt and Quist, 2011:747–755), while participatory backcasting is more often used to achieve stakeholders' and lay people's buy-in (Robson, 2011: Chapter 17; Eames and Egmose, 2011:769–784; Carlsson-Kanyama *et al.*, 2008:34–46).

From an epistemological point of view, the critical concern is not establishing closure or laboratory-like conditions for the sake of accuracy. Instead it would be more about creating better futures (Poulsen, 2005:2). Cognitive science has proven that humans have the mental capability to proactively plan ahead towards a desirable future. Szpunar *et al.* (2007:1363–1377) describe future planning as involving the prediction of the distant future so as to anticipate future needs and the means of satisfying them. This was an extension of the capacity of memory-based predictions described above. Future planning involves “episodic future thought”, the ability to simulate plausible future events or scenarios (e.g. imagining future activities to determine what to pack for an upcoming trip). There is considerable overlap between the neural circuits used to retrieve episodic memories and those involved in simulating future possibilities. This suggests that the two capacities are intrinsically linked. According to Tulving (2002:1–20), it is the combination of autonoetic consciousness and episodic memory that allows an individual to engage in mental time travel. Humans have the ability to “re-experience, through autonoetic awareness, previous experiences as such, and to project similar experiences into the future” (Atance and O’Neil, 2001:533).

Full consensus is often not necessary in backcasting, provided sufficient congruence can be achieved. When participants change opinions, and joint learning and joint opinions are altered to prevail, one can expect consensus to emerge. If not-too-conflicting issues are apparent, and congruence can be achieved, this route is also acceptable (Quist, 2007:44). In backcasting, the steps usually end with the development of the pathways to the envisioned future, while excluding follow-ups and monitoring spin-offs, making networking an interesting addition. The inclusion of network formation could change the dynamics of a backcasting process. Quist (2007:76–77) elaborates on the networking concept, dealing with follow-ups and spin-off activities.

Similarly, Höjer and Mattsson (2000:629) hold that backcasting is dependent on forecasts. Backcasting studies begin with a vision of a desirable future and one or more forecasts. In the subsequent step, the forecasts are compared with the desired vision. If the most reliable forecasts, model calculations and other estimations determine that the vsion will not be reached, the task is to generate images of the future and generate scenarios that fulfil the targets expressed in the desirable future vision. The images are then scrutinised to examine their potential effects.

A few studies integrate forecasting into the backcasting method (see, for example, Quist and Vergragt, 2006:1031; Quist, 2007:28–29), in order to make comparisons and, as in the case of Zimmermann *et al.* (2012:1605–1621), to improve trustworthiness by using two methods with similar objectives but different processes to compensate for each other's weaknesses. This recommendation is shared by Mander *et al.* (2008), who in their study to support the UK towards achieving a 60% reduction in carbon emissions suggested that combining backcasting and forecasting is beneficial for the development of transition pathways towards carbon reduction emissions.

To enhance a participatory process further, a data-collection technique based on the dynamic principles of a charrette was applied. Lennertz and Lutzenhiser (2006:3) state that charrettes are more than just brainstorming or public visioning sessions. They are distinguished from other workshop processes by their intense, collaborative nature and by their holistic approach focused on feasible solutions. Dynamic planning is designed to assure project success through careful charrette preparation and follow-up. The key stages of the process are as follows: phase one includes the research and charrette preparation; phase two consists of the charrette workshops; and phase three involves implementation, which entails several components that work towards ensuring success. This involves all disciplines from the start in an orchestrated series of "feedback loops" that chronicle decisions and opinions made along the way and provide a constant track record. The processes most commonly use a series of two- or three-day workshops to accomplish the three feedback loops required, as shown in **Figure 3.5**. This essentially structures the multiple-day charrette into segments.

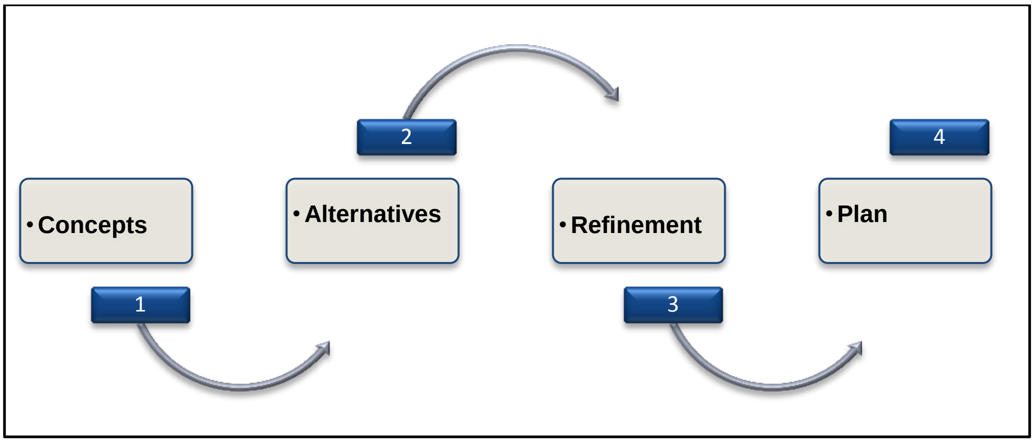


Figure 3.5 Charrette feedback cycles (Lennertz and Lutzenhiser, 2006:11)

The four- to seven-day charrettes have a unique capacity to achieve a feasible solution with broad support more rapidly (Lennertz and Lutzenhiser, 2006:3). Lindsey *et al.* (2009:6–10) further differentiate between a mini-charrette and a full-scale charrette. A mini-charrette is a one- to one-and-a-half-day event that provides the results of the predesign energy analysis, encourages “buy-in” or acceptance of the project, generates enthusiasm, develops promotional material, sets performance goals for energy, emissions and water, among other issues, and then identifies high-performance design strategies and technologies appropriate for the project, often conducted through break-out groups. By comparison, the full-scale charrette of two or more days has more detailed summaries for predesign analysis; strategies and images can be completed. Groups of 25 to 50 people participate in a mini-charrette or a full-scale charrette.

Literature provides various examples of using the charrette according to the principles above in the context of, for example, neighbourhood-, metropolitan- and regional scale building project planning. This method encourages designers to be more creative and allows for an integrated problem solving process (Maryman and Maggio, 2004:64–75; O’ Brien, 2012).

3.4.3 Links to the study

This section draws together the main concepts from the backcasting method literature that are relevant to this study. The backcasting method deals with how desirable futures can be envisioned and analysed through pathways which can then be used to guide the pursuit of the vision towards a desirable future. It is therefore explicitly normative, involving working backwards from a particular desirable future end point to the present in order to map the means by which that future is most likely to emerge from the undesirable status quo.

Scenarios are developed using a normative approach to scenario building. In the study's scenarios, the role of actors within the process becomes critical. The study links with the transitions theory to analyse the pathways through similarities with the socio-technical transition approach, which includes the MLP. The study concurs with the micro, meso and macro levels of market spaces where there is the co-evolutionary development of technologies, institutions and social and economic subsystems. The strength of the MLP approach was that transitions could be explained by the interplay of stabilising mechanisms at the regime level, combined with destabilising pressure at the landscape level and radical innovations at the niche level.

However, the study also acknowledges the weaknesses of the MLP typology. These include the absence of clarity on how these conceptual levels should be applied empirically; a relative neglect of agency; too much emphasis on technological niches as the principal locus for regime change. For this reason, the study suggests three levels (mico, meso and macro) for market spaces driven by actors. These three levels also take into account the different make up of groups in the South African context.

The *macro* level comprises government legislation, institutions and other external forces for a technology market space. This includes government departments that deal with science and technology (research and development). External forces consist of macro-economics and macro-political developments. The *meso* level is represented by the private sector, which includes services to the community. These include technology companies such as manufacturers, suppliers, professionals, research and development and contractors. The *micro* level consists of the general public (individuals, households and communities). The general public are usually the users of a product and the micro level is where deeper behaviour and cultural changes are required. For change to occur along a path of technological uptake and behaviour change, co-evolutionery/non-linear market pressures should be directed by what is pragmatic for a specific country or community. Therefore the differently timed accelerating and inhibiting factors within each level are investigated towards a motivation of the two less-likely and two more-likely pathways conceptualised in this study.

This study incorporates a forecasting component that was used in parallel to the anchoring backcasting as a complementary method. Instead of becoming part of one linear sequence, it was used in parallel to the whole backcasting method as a complementary method. This approach allowed for the most recent relevant comparisons in terms of method and outcomes. The additional mini-charrette tool was brought into the backcasting method to guide the planning process systematically. Visualisation through presentation was initially used in the mini-charrettes in order to inspire the stakeholders out of their likely status-quo inertia.

The backcasting technique used was a participatory one, which involved stakeholder groups with context-specific knowledge. However, the participants were not all experts, but rather represented four societal groups, i.e. companies, research bodies, government, and general public (represented by the other groups) that took an active part in the development of the visions. Literature verified that a homogeneous participatory group lacked integration of diverse content and hence recommended using multi-disciplinary stakeholders so that complex multifaceted problems can reach sufficient congruence and higher-order learning be achieved amongst different disciplines.

3.5 The backcasting approach as applied in the study

3.5.1 Backcasting charrette participation

The main contribution of backcasting participation to a strategy-forming process is that it can include many actors, such as political parties, governmental authorities, municipalities, organisations, private enterprises and an informed general public. In other words, there is not one single, well-defined decision maker. The method uses multi-disciplinary stakeholder interactions in terms of representation and views in order to achieve sufficient congruence and higher-order learning.

The aim was to invite stakeholders from various fields dealing with energy efficiency, green building and sustainability matters associated with the building industry. In order to further enhance the backcasting approach, a mini-charrette was held in the Western Cape and Gauteng with 11 attendees in each. These two provinces were chosen on the basis that most of the frontrunners of the emerging green building industry in South Africa resided in the two provinces, especially since the inception of Green Building Council South Africa certification tools in 2007 (GBCSA, 2013).

Consequently, there was a heterogeneous group of stakeholders with context-specific knowledge of the main themes of the study. These stakeholders represented four major societal groups, including private-sector companies, research bodies, government and public-interest groups. This group also represented the general public/individual/community as most of them fell within the middle-income group who are deemed to be the primary owners and users of the targeted home category. **Tables 3.3** and **3.4** indicate the stakeholders who attended the backcasting mini-charrette and the organisations they represent, but with pseudonyms used instead of actual names in order to ensure anonymity, as per research ethics commitment.

Table 3.3 List of backcasting charrette participants in the Western Cape Province

No.	Societal group	No. of respondents	Name of company/organisation
1	Public sector	1	City of Cape Town – Town Planning
2	Research institution	2	Bureau of Economic Research in Stellenbosch
			Sustainability Institute in Stellenbosch
3	Engineering practice	3	Ecosolution Engineers
			WWS Engineers – Electrical
			WWS Engineers – Mechanical
4	Architectural practice	3	Jackie Giotini Architects
			Jack Harpen Architects
			Bear Architects
5	Quantity surveying practice	1	GN Quantity Surveyors
6	Environmental practice	1	Carbon Strategies Africa

Table 3.4 List of backcasting charrette participants in Gauteng

No.	Societal group	No. of respondents	Name of company/organisation
1	Public sector	3	Eskom
			City of Johannesburg – Energy
			City of Johannesburg – Town Planning
2	Research institution	1	CSIR/Renewables
3	Environmental practice	4	Shades of Green
			Eco-relevance
			Eco-inventions
4	Architectural practice	2	NDH Architects
			Legacy Architects
5	Quantity surveying practice	1	ARDOM Quantity Surveyors

Process of soliciting participation. The following process was used to solicit data for the backcasting charrette.

- The first step was to identify 12 possible organisations in the Western Cape and Gauteng in the public and private sectors that were knowledgeable in the fields of low-carbon/sustainable/ green/energy-efficient building technology, markets, policies and lifestyles. A list of organisations that were active in green building projects, as listed under the Green Building Council South Africa, were approached. Although the issues in this study related only to carbon emissions due to fossil fuels, these companies would have demonstrated interest in and knowledge of the related matters.
- The second step was to compile a basic introductory letter that obtained a commitment from prospective experts who were interested in participating in a three-quarter-day mini-charrette.
- The third step was to contact the heads of the organisations identified in the first step and, in a conversation, provide an introduction, after which the person's interest in participating in the research was solicited.
- The fourth step was to send the interested head of an organisation or the expert referred by them, the introduction and letter to sign to show his or her commitment. The researcher had to be persistent with following up on every individual to determine that he or she remained available. If the relevant experts were not able to participate, then the search continued to find other interested stakeholders. Appendices B3 and B4 include the forms used for soliciting participation.
- The fifth step was to inform the prospective participants that they would be receiving an attendance certificate to qualify for continual professional development (CPD) points, to be provided by the School of Architecture and Planning at University of Witwatersrand.
- The sixth step was to send all the interested participants an invitation, background information and an agenda at least three

weeks prior to the charrette. The draft agenda and background information are attached in Appendix B5 (see page 331). Sending the background information (storyline) to the stakeholders upfront allowed the stakeholders to apply their minds and thus improve on their preparation for providing domain knowledge at the mini-charrettes.

- The seventh step was to contact all the participants four days before the mini-charrette to remind them of the event. A list of attendees is provided in Appendix B2 (see page 328) for which pseudonyms have been used.
- The eighth step was to use the backup list of participants to find one member in both Cape Town and Gauteng, where some participants pulled out before the mini-charrettes commenced and therefore needed to be replaced.
- The ninth step was to make the events interesting and enjoyable (presentations and lunch). This helped the breakout groups be more effective.
- The tenth step was to circulate the outcome and strategies among the participants to confirm that the content was as discussed or to add additional inputs.
- The eleventh step was to compensate the stakeholders that provided feedback in the ninth step with an attendance certificate that also qualified them for relevant CPD points.

3.5.2 Data collection process

The researcher followed a data collection process that included the preparation, planning and conducting of the mini-charrette event where the data were obtained within a predetermined planned budget. The two three-quarter day mini-charrette events were held at the following venues: Spier, in the Western Cape, on 4 July 2013, between 9h45 and 16h30, and River Place Country Estate, in Gauteng, on 11 July 2013, between 9h45 and 16h30.

A specific general framework was developed according to which each mini-charrette process was followed in order to develop narrative pathways that answered the research hypothesis and questions. First, a highly prioritised societal goal was determined. Second, a baseline of current trends and the path of development were established. Third, vision narratives in 2050 reflecting the preferred societal goal for low-carbon homes were created. The latter two trends and preferences served as temporal points between which a journey of change and transitioning could occur.

The backcasting event followed a structured process including an introduction and a presentation addressing the study’s goals, visions and background. The goal of the mini-charrette was to determine the desirable/preferred future as agreed upon by the participants and how this could be achieved for the predetermined themes. There was debate as to whether an imaginary future or realistic preferred future was to be focused on, and the participants settled on a balanced view between the two. These visions, based on narratives, were discussed and debated in two breakout groups (within each mini-charrette). A group representative reported on deliberations at the end of the workshop. A process of reiteration was followed, whereby the groups agreed or disagreed with the feedback provided in order to establish the consensus view.

The processes for the three stages followed for the backcasting mini-charrette data collection and related dates are indicated in Appendix B1 (see page 326). The first stage consisted of the preparation of the data, incorporating the development of the narratives in 2050 and deciding on the steering committee. For the planning stage, 12 interested stakeholders were identified for each charrette, budgets and expenditures were finalised, logistical arrangements were made, charrette material and participant packages were prepared, and invitations e-mailed to those who confirmed an interest in participating. While conducting the backcasting, mini-charrette arrangements for the venues were checked and verified, and the researcher then proceeded with the event according to the programme.

3.5.3 Data capturing and data editing

The approach pursued at the backcasting charrette was to prompt discussion around answering the study's main question and the sub-questions. This led to broad discussions, which provided real-life examples to guide the thinking towards more abstract conceptualising. Owing to the time constraints of the workshop, a vision was ascertained as to how the 80% carbon emission reduction was to be achieved, working backwards from the future to the present as guided by charrette process and principles. The data were coded and circulated to the participants after the workshop for confirmation. A further analysis stage of these data was systematically followed after the workshop to ascertain the most-likely pathway from all the alternative options. The mini-charrette workshop therefore developed a vision and ascertained the general data of a desirable future state. Levers of change were included, of which voluntary and mandatory changes were investigated. Relevant sub-themes emerged after the workshops and especially following from the coding process. **Figure 3.6** indicates the themes and sub-themes that were established.

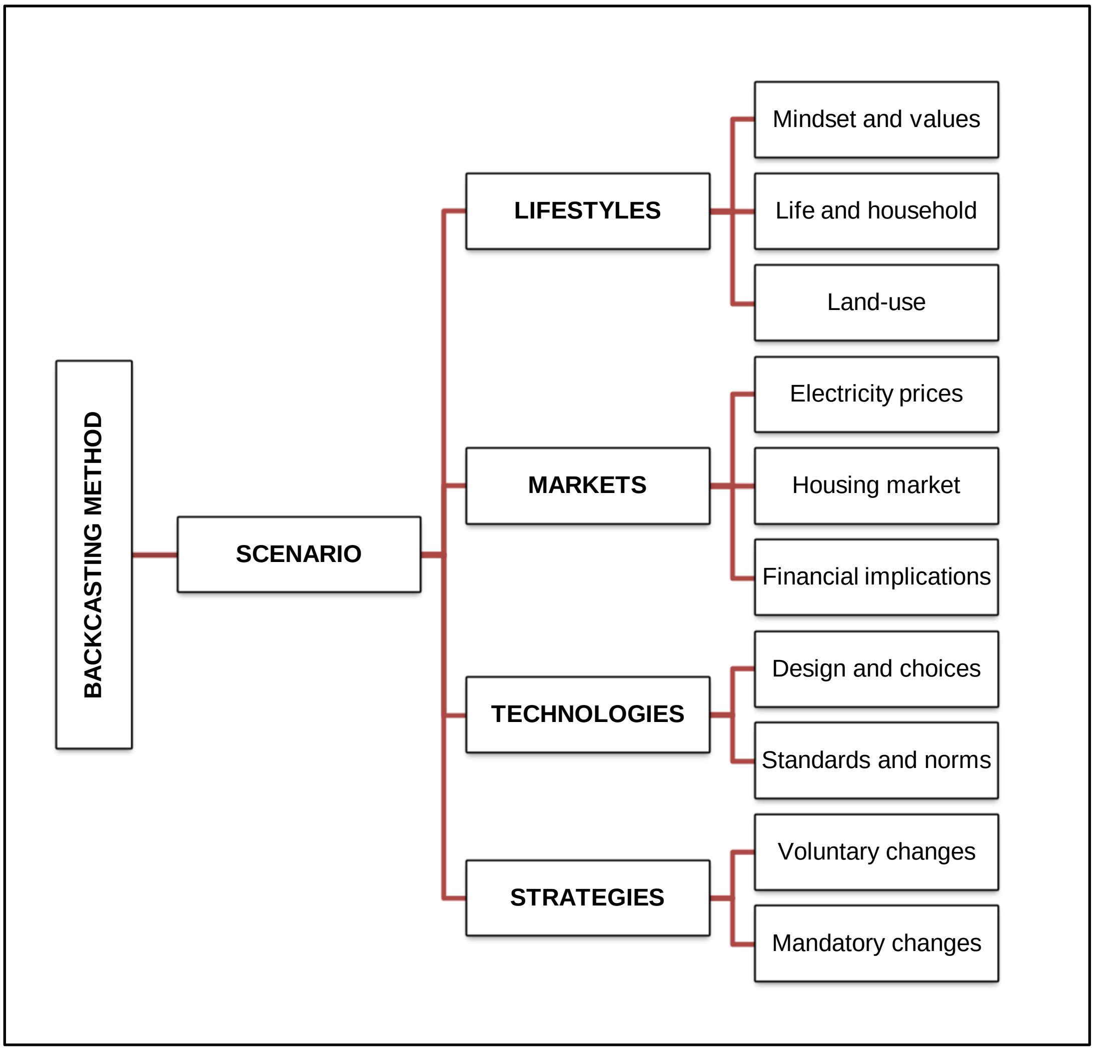
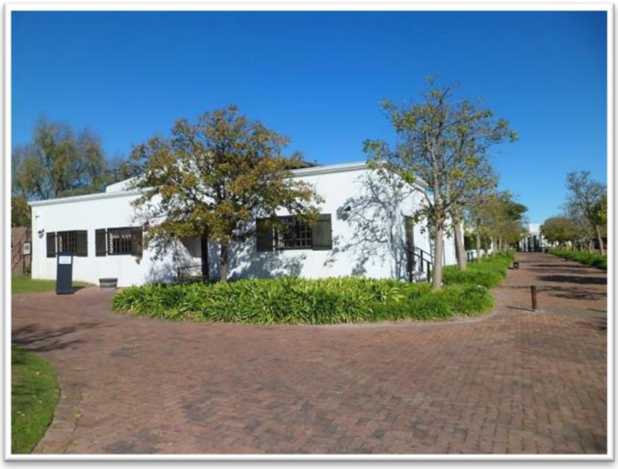


Figure 3.6 Backcasting themes and sub-themes

Innovative tactics were required to get a group of participants to envision alternative futures. These included the preparation of preliminary visions of the future and motivating stakeholders at the workshop with a presentation on behaviour patterns. Methods were sought that could change the opinions of the participants and consequently lead to higher-order learning, which would then facilitate voluntary behaviour changes. At the mini-charrette process, literature on why people make certain decisions was referred to, based on concepts by Thaler and Sustein (2009:1–257) and Ariely (2008:119–167). These concepts included following the herd, collective conservatism, the spotlight effect and priming. This also included a brief background on what motivated environmentally-responsive behaviour, as explained by studies such as Howell (2013:281–290).

The mini-charrette event followed an agenda which encompassed the introductory presentation, goals of the workshop, two multi-disciplinary breakout groups of six people each, group report back, and group consensus. The whole event was voice recorded, photos were taken of the breakout groups, group discussions were presented on flip charts, and sufficient congruence was attained. **Figure 3.7** provides photos of the breakout groups in the mini-charrettes held in Gauteng and the Western Cape. The participants' faces have been blurred to ensure anonymity, according to the research ethics commitment.



Western Cape Spier

Western Cape breakout group 1

Western Cape breakout group 2

Gauteng River Place country estate

Gauteng breakout group 1

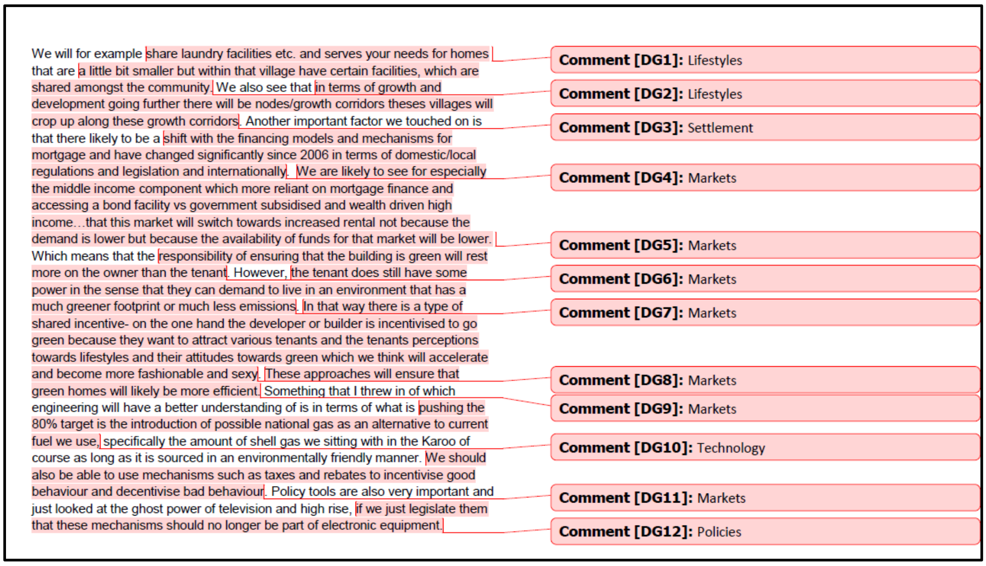
Gauteng breakout group 2

Figure 3.7 Images of the breakout groups in the mini-charrettes – Western Cape (WC) and Gauteng

3.5.4 Data analysis

The 2050 visions and their feasibility served as the goals according to which narrative pathways to low-carbon homes were determined. To achieve environmental objectives, the backcasting method was structured through a sequence of steps. The data were produced through reiteration following the workshop process and were pre-analysed using a coding method to order the data appropriately under the main themes. The parts of the data that were coded were those that were identified and labelled as representing something of potential interest. Codes with the same label were grouped together as a theme or as newly created sub-themes. The following list describes the phases of thematic coding analysis used for the verbatim mini-charrette data:

- Familiarise oneself with the data by transcribing data, reading and rereading the data and noting down initial ideas for sub-themes.
- Give extracts from the data codes in a systematic fashion across the entire data set, with similar extracts being given the same code, using Microsoft Word (use of the textual analysis tools such as TAMS Analyser or NVivo could also be used) as shown in **Figure 3.8.**


We will for example share laundry facilities etc. and serves your needs for homes that are a little bit smaller but within that village have certain facilities, which are shared amongst the community. We also see that in terms of growth and development going further there will be nodes/growth corridors theses villages will crop up along these growth corridors. Another important factor we touched on is that there likely to be a shift with the financing models and mechanisms for mortgage and have changed significantly since 2006 in terms of domestic/local regulations and legislation and internationally. We are likely to see for especially the middle income component which more reliant on mortgage finance and accessing a bond facility vs government subsidised and wealth driven high income…that this market will switch towards increased rental not because the demand is lower but because the availability of funds for that market will be lower. Which means that the responsibility of ensuring that the building is green will rest more on the owner than the tenant. However, the tenant does still have some power in the sense that they can demand to live in an environment that has a much greener footprint or much less emissions. In that way there is a type of shared incentive- on the one hand the developer or builder is incentivised to go green because they want to attract various tenants and the tenants perceptions towards lifestyles and their attitudes towards green which we think will accelerate and become more fashionable and sexy. These approaches will ensure that green homes will likely be more efficient. Something that I threw in of which engineering will have a better understanding of is in terms of what is pushing the 80% target is the introduction of possible national gas as an alternative to current fuel we use, specifically the amount of shell gas we sitting with in the Karoo of course as long as it is sourced in an environmentally friendly manner. We should also be able to use mechanisms such as taxes and rebates to incentivise good behaviour and decentivise bad behaviour. Policy tools are also very important and just looked at the ghost power of television and high rise, if we just legislate them that these mechanisms should no longer be part of electronic equipment.

Comment [DG1]: Lifestyles
Comment [DG2]: Lifestyles
Comment [DG3]: Settlement
Comment [DG4]: Markets
Comment [DG5]: Markets
Comment [DG6]: Markets
Comment [DG7]: Markets
Comment [DG8]: Markets
Comment [DG9]: Markets
Comment [DG10]: Technology
Comment [DG11]: Markets
Comment [DG12]: Policies

Figure 3.8 Extract of coding data to identify themes

- Identify themes and sub-themes and check whether the themes work in relation to the coded extracts and the entire data set. Revise the initial codes and/or themes if necessary.
- Construct thematic networks. Develop a thematic “map” of the pre-analysis.
- Integrate and interpret the data after the pre-analysis.

The themes then served as a basis for further data analysis and interpretation. A framework was developed consisting of alternative pathways that ranged from less-likely (FL and BL) to more-likely pathways (EL and ML). These hypothetical pathways investigated the critical factors affecting carbon mitigation within the South African context in order for the most-likely pathway to be adopted. For each pathway, the following techniques were used for analysis and interpretation:

- Identified the “traction influencing factors” comprising accelerating and inhibiting conditions under which the pathways occurred.
- Applied framework derived from system innovations theory that was reinterpreted to develop the multiple-level actors (MLA) perspective that guided the traction factors of pathways. This perspective consisted of actors on multiple-levels, such as governance, services and individuals, along a route of innovation uptake, technology and behaviour change, stabilisation and decline.
- Substantiated the traction/inhibition factors as guided by the backcasting findings that anchored the study. This was cross-checked with the Delphi along a pathway to 2050. Through substantiating the data, the main research question and sub-questions were addressed.
- A “fairly classic set” of analytical tactics were used for the substantiation, such as making contrasts and comparisons through similarities and differences between and within data sets of the two methods of Delphi and backcasting.

In the face of uncertainty, decisions were not geared towards getting the “right” answer, but rather on trying to make choices that might work best towards the pursuit of the desirable futures. Reduced errors and improved accuracy in the backcasting approach were ensured through the following measures:

- The mini-charrette event was planned well according to good charrette principles and made a crucial contribution to the outcome and goals of the study.
- The project goals, project descriptions, issues and concerns were clear.
- Creating effective breakout groups allowed for intense discussion and formed a first step to group agreement for which conclusions were summarised. A feedback session then recapped all the conclusions of each group.
- Getting the whole group to analyse the summary of breakout groups reiterated options for decisions. The decisions were made by voting on the most and least desirable ideas in order to arrive at a consensus on the final goals to be achieved, i.e. a preferable 2050 scenario for homes in South Africa with technologies and influencing factors, markets, lifestyles and policies as the influencing parameters.
- Better decisions through more inclusive choices were made by expanding the range of decision-makers from stakeholders and citizens in an interactive way. In this study, the stakeholders were from diverse societal groups with corresponding views. The societal representation took preference over numbers and location.
- Although multiple futures were possible, preparing only two narratives, which were disseminated to participants beforehand, allowed for an effective approach with regard to time and depth of deliberations.
- Secondary data were used to make assumptions for the narrative, using basic calculations and using a life-cycle costing tool to

determine viability. The data were shared with the stakeholders who then made their inputs.
- Consistency was achieved through proper preparation of the mini-charrette toolkit, and facilitation and management of the workshops. For cost-minimising reasons, the preparation and facilitation were carried out by the researcher with no outsourced assistance.
- The backcasting charrette process as well as the coding of the verbatim data thereafter became the analysis.
- A new framework for interpretation was developed after the workshops for further interpretation and analysis of the data findings in the form of the alternative pathways analysed, from which the most-likely pathway was identified and motivated.

3.5.5 Shortcomings and key limitations of the process

As natural analysts, humans have deficiencies and biases corresponding to the problems they face as observers. Some of those encountered in the process are listed below:

- Challenges or issues for which information is incomplete tend to be obscured and relatively ignored.
- Stakeholders get locked into ideas too soon.
- There is a tendency to overreact or underreact to new information (revision of hypothesis).
- The facilitator needs to create an environment that allows all participants to provide inputs to get a balanced view and not let some individuals dominate the discussions or input direction.
- To allow freedom of thought in a group can take a lot of time, with the possibility of not being able to address all the issues at the workshop within the limited time available.
- Topic coding seems easy, but trying to determine underlying meanings of why participants say what they say can be more subjective and attributed to various reasons.

- A three-quarter-day mini-charrette is not really enough time to discuss complex issues that need to be thoroughly debated.
- The pathways were based on available South African statistics for the middle-income homes sub-sector between 2009 and 2012, required for the workshops held in 2013. All the statistics were hence chosen from approximately the same years to ensure better cohesion and comparisons. However, more recent statistics from the same dataset would have been preferable.
- Stakeholders do not apply themselves fully if they do not have a vested interest or get paid for their inputs.

3.6 Conclusion on methods

Based on a futures study approach, multiple research methods and theoretical frameworks were applied with the objective of facilitating more plausible results. In particular, the Delphi method was applied in the BAU trends based on quantitative data, and the backcasting approach was applied to substantiate deeper insights into the changes required to achieve carbon mitigation for middle-income households in South Africa. The main research question required an investigation of the extent of CO_2 emissions and other relevant quantified data over the time horizon to 2050. This was established through a consensus-building process based on an iterative Delphi questionnaire as the basis for deriving the baseline trajectory to 2050 (business as usual). The backcasting mini-charrette focused on preferred futures and how a specific goal can be realised in the long term through creative visions for substantial transformation. The sub-questions were answered through an anchoring backasting approach whereby the raw data collected were initially pre-analysed to structure the themes and provide meaning. The data were further analysed through contrasting alternative pathways and interpreted to establish the most-likely pathway chosen by South African stakeholders.

CHAPTER 4

KEY DATA AND PRELIMINARY ANALYSIS

4.1 Introduction and overview

The Delphi findings were based on the analysis of consensus data after the completion of the second-round responses. The recorded data for each question were used as input data for a spreadsheet that calculated the median, quartiles and outliers for trends extrapolated to the year 2050. The results from the spreadsheet are presented under the Delphi narrative based on the extrapolated trends depicted in a table and graph format under the key themes. This was followed by providing the confidence level (CL) results in a graphic format that more clearly presents the quality of the answers and conclusions. In addition to the quantified data, for each graph, the more qualitative/open questions were analysed and the results placed in the text boxes that provide the key assumptions, key developments and other technologies that might be relevant. From the results, only the key data were chosen for comparison with the backcasting findings in the subsequent chapter, in support of further analysis and interpretation.

4.2 Delphi narrative

To address the working hypothesis of the study, the current and likely trends in technologies, markets, policies and lifestyles for the South African middle-income new and retrofitted homes were investigated to establish whether 80% carbon emission reductions (from 24 Mt CO_2-eq to 4.8 Mt CO_2-eq) is probable by 2050. The outcome on the Delphi business-as-usual pathway became a means of comparison to the backcasting pathways.

The key findings of the Delphi questionnaire response for cycle 2 are summarised by including the graph results and by providing relevant key assumptions, key developments and other examples of technologies. The historic data before 2010 were obtained from relevant sources and the data extrapolated to 2050 were obtained from the study's analysed data from the second-round responses. The Delphi narrative is written based on the completed analysed data referred to in past tense, but forecasts data from the present to the future.

4.2.1 Extrapolated trend results of the Delphi process

Technology choices. In a high carbon-reduction scenario, home lifestyles revolve around the active and passive energy-efficiency technologies. The Delphi narrative investigated key active technologies in which energy played a part, such as types of renewables, heating and cooling technologies, appliances and lighting. It also investigated the key passive technologies, utilising mainly natural energy related to the building envelope, heating and cooling technologies and renewables. A table illustrating technology categories on which the selection was based is shown in Appendix A5 (see page 325).

Technology policy and lifestyle timeline. The first set of questions ascertained in which year, on a timeline to 2050, technologies are likely to become predominant trends because of lifestyle choices and/or policy responses. Each question was substantiated with responses on key assumptions, other key developments, and other technologies.

Most of the low-carbon technologies are available on the market already, but not widely used due to their additional costs among other barriers. Only recently, in 2011, did building regulations enforce benchmarks that will require several of these technologies. Most energy in the residential building sector is consumed by producing hot water, at 24% of the total energy consumption, followed by space heating, at 22%, other appliances, at 21%, lighting, at 16%, and cooking, at 11%. The participants forecast the most likely years when active and/or passive technologies will become a predominant trend, as shown in **Tables 4.1** and **4.2**.

Table 4.1 Results of active technology lifestyle and policy timeline trends

Active technologies								
Analysis	**Heating and cooling**		**Renewables**		**Appliances with ratings**		**Lighting**	
	Heat pumps		PV on grid		Fridges		LEDs	
	Policy	Lifestyle	Policy	Lifestyle	Policy	Lifestyle	Policy	Lifestyle
Min.	2010	2010	2020	2010	2020	2010	2020	2020
Q1	2020	2010	2020	2020	2020	2010	2020	2020
Median	2020	2020	2020	2030	2020	2020	2020	2020
Q2	2020	2020	2033	2030	2020	2020	2030	2020
Max.	2020	2020	2033	2030	2020	2020	2030	2020
IQR	0	10	12.5	10	0	10	10	0
Upper outlier	0	0	0	0	0	0	0	0
Lower outlier	3	0	0	0	0	0	0	0
Total respondents	13	13	13	13	13	13	13	13
Agreement %	92%	100%	92%	85%	100%	92%	100%	100%
CL respondents %	100%	100%	100%	100%	100%	100%	100%	100%
CL median	3	3	2	3	3	3	3	3

Table 4.2 Results of passive technology lifestyle and policy timeline trends

Passive technologies								
Analysis	**Envelope**		**Heating and cooling**		**Renewables**		**Fenestration**	
	Mineral wool		SWHs		PV stand-alone		Coated/tinted/insulated	
	Policy	Lifestyle	Policy	Lifestyle	Policy	Lifestyle	Policy	Lifestyle
Min.	2010	2020	2010	2018	2020	2020	2010	2010
Q1	2010	2020	2010	2018	2020	2020	2018	2010
Median	2020	2020	2020	2020	2030	2020	2020	2020
Q2	2020	2023	2020	2023	2038	2030	2020	2020
Max.	2020	2023	2020	2023	2038	2030	2020	2020
IQR	10	2.5	10	5	7.5	10	2.5	10
Upper outlier	0	0	0	0	0	0	0	0
Lower outlier	0	0	0	0	0	0	0	0
Total respondents	13	13	13	13	13	13	13	13
Agreement %	85%	92%	85%	77%	85%	85%	85%	85%
CL respondents %	100%	100%	100%	92%	85%	92%	92%	92%
CL median	3	3	4	4	2	2.5	3	3

With 77–100% agreement, the low-carbon technologies will become the predominant lifestyle or policy trends indicated to occur at the median year 2020, although some were already applied by early adopters and through the National Building Regulations (NBR). This is corroborated by historic data (Barbose *et al.*, 2012:28; Willis 2012, pers. comm., 28 November; IRENA, 2012:9; Dreyer 2013, pers. comm., 25 February; CEC, 2013; Ecogeekliving, 2013; Isover, 2013; Harper 2012, pers. comm., 4 December; Sonlight Power, 2013; National Glass Distribution, 2013). The CLs for most input data were high (3 and 4), with below average confidence for data on renewables. Box 4.1 provides additional data from the open questions.

Box 4.1 Key assumptions, developments and other technologies for renewables

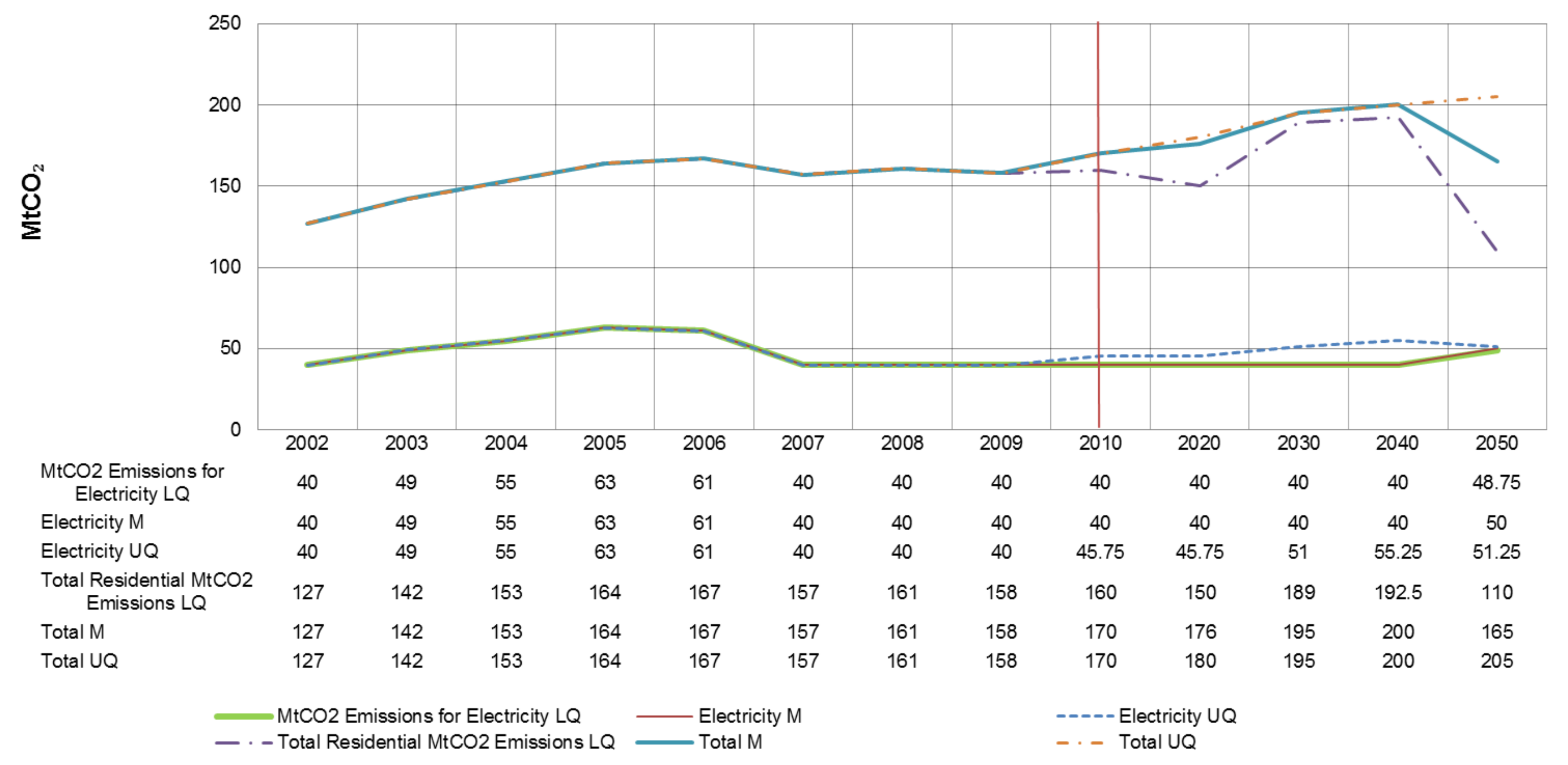
Some key assumptions were made for photovoltaic (PV) on grid for both policy and lifestyle options. Policies need to be extended to include renewable energy feed-in tariffs (REFIT) and a smart grid for domestic application. Electricity rationing leads to lifestyle changes through decentralised PV and wind capacity growth for isolated supply networks/systems.

Other key developments (uncertainties) allude to smart grid technology developments, whereby technological advances in PV may reduce its cost. Other uncertainties are the extent of efficient and reliable storage systems developed in the near future.

Other technologies, instead of the obvious PV on grid, which works well in SA, are the neighbourhood-shared biogas digesters for communal electricity generation as well as geo-thermal energy, which could become a potential solution in some areas. Biomass is very likely to become more freely available, as well as central solar, wind plants and fuel cells.

Additional comments included the view that lifestyle is unlikely to make grid connection of renewable technologies attractive, unless there is some financial incentive. Low-carbon technologies will become a viable option, inducing lifestyle changes, for most people as soon as the cost of electricity makes this a viable option.

Technology energy trends. Based on the second set of questions, CO_2 emission trends were established as well as energy usage patterns. The key relevant CO_2 emissions for electricity consumption are indicated in **Figure 4.1.** This was based on using historic data (StatsSA, 2012:30–38) of which the time-series extrapolation was the most likely to occur with a 50% probability (median).



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2020	2030	2040	2050
MtCO2 Emissions for Electricity LQ	40	49	55	63	61	40	40	40	40	40	40	40	48.75
Electricity M	40	49	55	63	61	40	40	40	40	40	40	40	50
Electricity UQ	40	49	55	63	61	40	40	40	45.75	45.75	51	55.25	51.25
Total Residential MtCO2 Emissions LQ	127	142	153	164	167	157	161	158	160	150	189	192.5	110
Total M	127	142	153	164	167	157	161	158	170	176	195	200	165
Total UQ	127	142	153	164	167	157	161	158	170	180	195	200	205

Figure 4.1 Residential Mt CO_2 emission trends for electricity usage

The median result indicated a slow increase in electricity consumption related emissions from 40 Mt CO_2-eq in 2010 to 50 Mt CO_2-eq in 2050. Instead of any CO_2 reduction occurring, when following the historic patterns, an increase of 10 Mt CO_2 was forecast over the timeline to the year 2050. This was predicted as indicated in **Table 4.3**, with a 92% agreement amongst 13 participants with a median CL of 2. Box 4.2 provides the key assumptions made and developments expected for the open questions for the CO_2 emissions.

Table 4.3 Results of residential sector Mt CO_2 emissions

Technology energy trends					
Analysis	**Mt CO_2 residential emissions**				
	Electricity consumption emissions				
Year	2010	2020	2030	2040	2050
Min.	40	40	40	40	48.75
Q1	40	40	40	40	48.75
Median	40	40	40	40	50
Q2	45.75	45.75	51	55.25	51.25
Max.	45.75	46	51	55.25	52
IQR	5.75	5.75	11	15.25	2.5
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	92%				
CL respondents %	92%				
CL median	2				

Box 4.2 Key assumptions, developments and other technologies for total CO_2 emissions

Some key assumptions made were that total emissions were likely to grow with continuing low-income property developments and increase in electrification. Other comments made were that there will be cleaner technologies, but an increase in consumption.

Other key developments (uncertainties) were that carbon growth rates could increase more drastically if alternative technologies become dominant. A completely new baseline will be developed as monitoring systems are put in place.

Energy-use forecasts were made for the highest energy-consuming activities in a home. Owing to the lack of recorded data over time, only the percentage of total energy usage was investigated for cooking, lighting, space heating, water heating and others such as appliances. This data set was obtained from Haw and Hughs (2007:40) and CIDB (2009:29–30). Likely median energy usage percentages with an average of 86% agreement were analysed as described below.

- Cooking will fall from 11% of total domestic consumption in 2009 to 7% in 2050.
- Lighting will increase in usage from 16% in 2010 to 23% in 2050.
- Space heating will decrease marginally in energy usage from 22% in 2009 to 21% in 2050.
- Water heating usage will fall from 24% in 2009 to 20% in 2050.
- Other usage will comprise 21% of usage in 2009 and 25% in 2050.

Further inputs for the open questions on key assumptions and developments for the energy usage are provided in Box 4.3.

Box 4.3 Key assumptions and developments for energy usage

The key assumptions

- i) *Cooking:* Energy usage reduces as appliances become more energy efficient and move more to liquefied petroleum gas (LPG) (and maybe ultimately to biogas).
- ii) *Lighting:* Energy usage will increase until 2020 before LEDs become more readily available and cheaper, thereafter levelling out or even reducing.
- iii) *Space heating:* Space heating remains unchanged as space heating efficiency and demand increases at an even pace.
- iv) *Water heating:* Eskom electricity price hikes and Eskom rebates encourage increases in solar water heating.
- v) *Other:* For predominantly plug loads and appliances there will be an increased proliferation of devices, therefore increasing percentage of total electricity use.

Other key developments

- i) *Cooking:* This will depend on the availability and price of other renewable energy sources.
- ii) *Lighting:* The uptake in LEDs due to cost is not clear, and if slower than anticipated, reduction in CO_2 due to lighting energy efficiency may be delayed.
- iii) *Space heating:* It will depend on availability and price of gas.
- iv) *Water heating:* Some developments that can influence water heating are: Government rollout is delayed; Eskom subsidy does not deliver numbers of SWHs as expected; SWH cost increase, availability and price of alternatives such as gas.
- v) *Other:* New energy-rated appliances and devices that use less electricity could reduce its percentage usage under this category.

Market trends. The cost of the technology and its compatibility with the users' lifestyles played an important role. Technology cost trends were established for some key technologies (one example under each category), which would be additional interventions such as solar water heaters (SWHs), PVs, insulation, lighting and glazing. Although appliances will become more efficient, they were not considered as an additional item to purchase.

There were both locally produced and imported SWHs. For example, imported products with indirect flat-plate systems of 300 litres had prices inclusive of inflation and exchange rates. Installation charges changed according to the ease or difficulty of installation and hours of labour required. A trend was established from historic data (Harper 2012, pers. comm., 3 December) that indicated SWH costs will steadily increase fourfold by 2050, as shown in **Table 4.4**.

Table 4.4 Results of SWH nominal costs

Market trends					
Analysis	**Solar water heaters (R)**				
	Installed indirect 300 litres flat plate imported				
Year	2010	2020	2030	2040	2050
Min.	18 670	30 000	33 500	40 000	40 000
Q1	18 670	30 000	35 000	40 000	62 500
Median	18 670	40 400	70 000	80 000	80 000
Q2	18 670	40 400	70 000	80 000	110 000
Max.	20 000	60 000	70 600	90 900	120 000
IQR	0	10 400	35 000	40 000	47 500
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	62%				
CL respondents %	77%				
CL median	2				

With an agreement of 62%, prices were likely to increase by 77% between 2014 and 2050 from R18 600 to R80 000. Key assumptions and developments for SWH costs are provided in Box 4.4.

Box 4.4 Key assumptions and developments for SWH costs

The key assumptions made were that prices were likely to increase as per the trend, but in the medium to long term will increase at a slower rate due to SWH system optimisation improvements as the system's basic design matches hot water demands.

Other key developments highlighted were that the redesign of components could reduce cost. *Other technologies* could include boilers with wood chips and gas.

The forecasting trend for PV on grid indicated an overall decline in total installed nominal prices, primarily attributable to a reduction in non-module costs according to trends from Barbose *et al.* (2012:28), as indicated in **Table 4.5**.

Table 4.5 Results of PV on nominal grid prices

Market trends					
Analysis	**PV on grid (US Dollars per watt (USD/W))**				
	Installed prices ≤ 10 kilowatts (kW)				
Year	2010	2020	2030	2040	2050
Min.	5.8	4.87	4.87	4.275	4.075
Q1	5.8	4.87	4.87	4.275	4.075
Median	6.15	5.7	5.7	5.05	4.8
Q2	6.3	6.15	5.9	5.4	4.8
Max.	6.3	6.15	5.9	5.4	4.8
IQR	0.5	1.28	1.03	1.125	0.725
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	77%				
CL respondent %	77%				
CL median	2				
Exchange rate in 2014: $1 = R9.2					

If the installed cost for PV on grid was equivalent to R56.6/W in 2014, the total costs for 3 kW will be R169 000. These installation costs − with an agreement of 77% − will probably come down 22% by the year 2050. Similarly, 85% of participants agreed that installed 3 kW small wind turbine costs will decrease by 42%, from a median value of R71 000 in 2014 to

R41 000 in 2050. Some key assumptions and developments for PV on grid are provided in Box 4.5.

Box 4.5 Key assumptions and developments for PV on grid

Some key assumptions on which the results were based are that new manufacturing techniques for PVs will bring prices down over the long term. Should there be a shortage of raw materials, then there could be periods where costs will start to increase again.

Other key developments were that strategic financial incentives can affect these pricing developments.

Other technologies referred to were fuel cells, central solar and wind plants.

In the case of the more popular roof insulation materials, such as mineral wool fibres, the price trend increases were as a result of the price hikes experienced in electricity and inflation. Production costs of insulation materials using electricity will increase, and the general level of prices for goods and service will rise, with the purchasing power of currency falling. Some key assumptions, developments and other technologies for insulation material are provided in Box 4.6.

Box 4.6 Key assumption, developments and other technologies for insulation material prices

A key assumption made was that costs for insulation materials will continue to increase as the cost to manufacture the product continues to increase.
Other key developments were economies of scale.

Other technologies that could influence the extent of use of insulation materials were whether renewable energy was used, such as solar PVs.

The price trends showed a likely increase of 62% between 2014 and 2050 for the more common mineral wool fibre insulation. The prices ranged from R23.50/m^2 in 2014 to R62/m^2 in 2050 for 100 mm insulation.

Although light-emitting diodes (LEDs) were already available, they were imported but not commonly used in homes yet. Price trends showed a decrease from R276 per 60 W bulb equivalent in 2014 to R37 in 2050, as projected from Cleantech (2011:1–40), resulting in an 87% price reduction, as shown in **Table 4.6**.

Table 4.6 Results of LED nominal prices

Market trends					
Analysis	**LEDs**				
	LED bulb retail prices in USD (60-watt equivalent)				
Year	2010	2020	2030	2040	2050
Min.	23	7.75	6	5	4
Q1	23	7.75	6	5	4
Median	30	8	6	5	4
Q2	30	8.5	7.25	7.75	8.5
Max.	30	30	12	15	18
IQR	7	0.75	1.25	2.75	4.5
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	70%				
CL respondent %	85%				
CL median	3				

Additional inputs are provided on key assumptions and developments for LED prices in Box 4.7.

Box 4.7 Key assumptions and developments for LED costs

Some key assumptions were that the price of light-emitting diodes (LED) lamps was likely to decrease in the short term, with incentives implemented, but they should increase somewhat in the future. Eventually, LEDs will supersede CFLs.

Other key developments were that LED cost reduction could take longer. Also, should the exchange rate weaken, it could result in higher prices for imported LEDs.

The low-emissivity glass example included the energy-efficient frame and 40% (of the total costs) for labour costs on installation. Other additional costs were due to inflation, transport, production, raw materials and importation. There were a variety of energy-efficient glazing solutions. For comparison, normal single glazing had a U-value of 5.8 W/m² °C; low-emissivity glass had a U-value of 3.6 W/m² °C and low-emissivity glass in a sealed insulated glass unit had a U-value of 1.9 W/m² °C (Walton 2013, pers. comm., 19 February). There was almost 40% less energy lost with the low-emissivity product when compared with clear glass.

The extrapolation of costs for energy-efficient glazing, such as low-emissivity glazing, indicated a likely increase from R1 045/m^2 in 2014 to R5 500/m^2 in 2050. Key assumptions, developments and other technologies on glazing and frame costs are provided in Box 4.8.

Box 4.8 Key assumptions, developments and other technologies for glazing and frame costs.

Some key assumptions were that the new SANS 10400 XA deemed-to-satisfy rules and rising energy costs encouraged energy-efficient glazing and frames. One can assume that an increase in production costs will increase selling prices or there will be high demand for large-scale use, which may increase production capacity and therefore lower overall costs on the basis of volumes in production.

Other key developments were the developing trends of automatically adjustable shading devices including the cost-benefit analysis of glazing costs versus heating costs that may result in wider application of energy-efficient glazing. Advancement in technology and materials could reduce costs.

Other technologies will be smart glass with inherently integrated variable properties.

Since 1955, the United States of America’s (USA) Energy Star home certification programme has provided rare data on costs from which lessons can be learnt by the middle-income group of South African homes. The Delphi participants, though, had the opportunity to change these costs to the South Africa context. Extrapolations for the USA, such as King County in Washington (Greenworks Reality, 2013), showed definite trends developing for values of homes that had environmental certification systems in place (Environmentally Certified Homes or Green Certified Homes, Energy Star or LEED Homes) as opposed to homes that were non-certified. For certified homes, the time-series extrapolation for the USA reflected a 73% increase in value between 2014 and 2050, as shown in **Table 4.7**. A different trend was showing that for non-certified US homes in that market value was increasing at a slower rate of 66% increase between 2014 and 2050, as shown in **Table 4.8**.

Table 4.7 Results of nominal costs for certified homes

Market trends					
Analysis	**King County, USA, certified home values**				
	USDs in 1 000s				
Year	2010	2020	2030	2040	2050
Min.	425 000	425 000	400 000	375 000	350 000
Q1	425 000	430 000	680 000	1 090 000	1 600 000
Median	425 000	430 000	680 000	1 090 000	1 600 000
Q2	425 000	430 000	732 500	1 090 000	1 600 000
Max.	425 000	600 000	1 000 000	2 000 000	2 000 000
IQR	0	0	52 500	0	0
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	62%				
CL respondent %	85%				
CL median	3				

Table 4.8 Results of nominal costs for non-certified homes

Market trends					
Analysis	**King County, USA, non-certified homes values**				
	USDs in 1 000s				
Year	2010	2020	2030	2040	2050
Min.	425000	450 000	600 000	800 000	1 000 000
Q1	425 000	450 000	600 000	800 000	1 000 000
Median	425 000	450 000	645 000	905 000	1 250 000
Q2	425 000	450 000	690 000	1 010 000	1 500 000
Max.	425 000	450 000	690 000	1 010 000	1 500 000
IQR	0	0	90 000	210 000	500 000
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	62%				
CL respondent %	85%				
CL median	3				

The difference was a 22% market value variance difference between certified and non-certified homes in 2050 in the USA. Furthermore, by 2020, a definite shift will occur, where certified homes will start showing higher market values up to 2050, diverging from non-certified homes. The average-size homes in these market value trends stretched from 162 m^2 to 218 m^2. In South Africa, a similar trend could occur whereby certification of homes could be a viable option should it provide a higher market value.

Electricity tariff trends indicated a gradual increase in costs to the homeowner over time for the current energy mix, comprising mostly coal/fossil fuels. The electricity price was kept artificially low for many years as part of South Africa’s industrial policy. Electricity Supply Commission (Eskom), therefore, was unable to build up sufficient reserves to cover the costs of maintenance, replacement and new capacity. The National Energy Regulator of South Africa (NERSA) initially ruled that municipalities were allowed to increase their electricity prices by only 15–16% each year and above inflation. The respondents forecast a likely Eskom tariff increase based on trends (Eskom, 2013) from 51.9c/kWh in 2010 to 210c/kWh in 2050, which showed an annual increase of 4%, as depicted in **Table 4.9**. It needs to be noted, though, that the Eskom domestic electricity tariffs were lower than the municipal rates used in Table 4.9. The difference between the tariffs and rates in 2010 were as much as is 60c/kWh as the municipal distributors resell the electricity from Eskom to customers with mark-ups.

Table 4.9 Results of Eskom nominal domestic electricity prices

Market trends					
Analysis	**Electricity prices**				
	Eskom tariffs c/kWh – home power and home flex				
Year	2010	2020	2030	2040	2050
Min.	51.9	90	130	170	210
Q1	51.9	90	130	170	210
Median	51.9	90	130	170	210
Q2	56.4	101	143	183	233
Max.	56.4	180	26	280	400
IQR	4.5	11	13	13	23
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	77%				
CL respondent %	92%				
CL median	3				

Key assumptions, developments and other technologies are provided for domestic Eskom electricity prices in Box 4.9.

Box 4.9 Key assumptions and other technologies for domestic electricity prices

Some key assumptions made were that energy costs will increase owing to higher capital costs for renewables. Operational costs will also increase as the grid evolves into a smarter grid. The costs will vary depending on time of use. Also to be noted is that by 2040, there will be more small-scale production of energy at the customer level. The production costs will need to compete with small-scale systems. This will result in a more competitive energy market.

Other technologies in the energy mix that can influence the domestic electricity tariffs are gas, renewable energies and nuclear energy.

The income for households was derived from StatsSA (2005, 2011), which had divided income groups into quintiles. Income groups that can afford a home between 80 m² and 220 m² fell within quintiles 4 and 5. There was a steady increase in these income groups, which were influenced by the rate of inflation which was at 5.4% in January 2013.

A gradual increase in salary of 4% p.a. was indicated for middle-income households that could afford houses of approximately 140 m^2, which, for median values was R362 000 in 2010, increasing to R1.3 million by 2050, as shown in **Table 4.10**.

Table 4.10 Results of nominal salaries for the middle-income group

Market trends					
Analysis	**Middle-income group for households > 80 m^2**				
	R/annum				
Year	2010	2020	2030	2040	2050
Min.	362 000	562 000	750 000	925 000	1 150 000
Q1	362 000	562 000	750 000	925 000	1 150 000
Median	362 000	600 000	820 000	1 100 000	1 300 000
Q2	366 000	600 000	820 000	1 100 000	1 300 000
Max.	366 000	600 000	820 000	1 100 000	1 300 000
IQR	4 000	38 000	70 000	175 000	1 500 000
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	85%				
CL respondent %	85%				
CL median	2				

Further key assumptions and developments for salaries have been provided in Box 4.10.

Box 4.10 Key assumptions and developments for salaries

Some key assumptions were that salaries at maximum will increase at the inflation rate and that there will be lower than expected economic growth in South Africa.

Other key developments were the world economy and trends in gross domestic product (GDP).

Policy trends. This section deals with policies that will either result to reduction of CO_2 emission or costs to the consumer. Policies for which some historic data were available and which had been shown to be of key influence were identified. Examples include appliance labelling, rebates for low energy consuming technologies and feed-in tariffs. Specific electricity consumption of most of the major household appliances in Germany decreased considerably between 1991 and 2011, thus improving overall energy efficiency. Of all the energy-saving measures, Germany's appliance labelling regulations (ENVKV) had shown the highest CO_2 emission reduction, amounting to 6 million tons of CO_2 between 1998 and 2010. Following historic trends for appliances in Germany for refrigerators, energy savings (Fraunhofer ISI, 2012:19) were evident with the prediction of 250 kWh in 2014 and 125 kWh in 2050, thus resulting to a 50% savings over time.

The incentives for SWHs and heat pumps in South Africa were launched in 2009. In 2010, the SWH rebates increased early in the year, but reduced mid-year and then increased again in 2012 to compensate those who produced more SWHs locally. Eskom withdrew from the programme in 2014. The Department of Energy (DOE) was to resume operating under the programme again in 2015, but would continue only until 23% of the 10 000 gigawatt-hours (GWh) renewable energy target through high-pressure SWHs had been reached (Anel 2012, pers. comm., 1 December). This rebate programme, though, was forecast to run from 2015 till 2020, until the market had been stimulated adequately and energy savings had been achieved. Savings on the electricity bill in this regard can be from 24% to 30%.

All the respondents agreed with 100% consensus that Eskom demand-side management (DSM) rebates for SWHs and heat pumps will be short-lived, and probably last until 2020 only. Only slight rebate increases were predicted for SWHs, ranging from a median result of R3 000 in 2014 to

R4 000 in 2020. Similar rebates were forecast for heat pumps until 2020, from a rebate of R4 000 in 2010 to R4 400 in 2020.

Renewable energy feed-in tariffs (REFIT) represents a policy mechanism designed to accelerate investment in renewable energy technologies. Producers of renewable energy are paid a set rate for the electricity they produce in terms of the size of the installation. The tariffs for roof-mounted renewables, such as solar PV, for homes are approximately 10 Euro cents/kWh higher than the ground mounted types (following Germany's trends, DB (2012)). REFIT often include "tariff digression", a mechanism in which the price comes down over time. South Africa's REFIT initiative started in 2009 with a proposal to eventually achieve the production of 10 TWh per year (NERSA, 2011). This will include cost of generation plus acceptable levels of profit margin. Considering the proposal made, it was forecast that any REFIT-type model will decrease substantially by Barbose *et al.* (2013:28), as shown in **Table 4.11**.

Table 4.11 Results of nominal REFIT digression

Policy trends					
Analysis	**REFITs for small-scale renewables e.g. PV < 30 kW**				
	R/kWh				
Year	2010	2020	2030	2040	2050
Min.	4.7	2.7	1.6	1	0.7
Q1	4.7	2.7	1.6	1	0.7
Median	5.12	2.7	1.6	1	0.7
Q2	5.12	3	2.85	2.15	2.1
Max.	5.12	3	2.85	2.15	2.1
IQR	0.42	0.3	1.25	1.15	1.4
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	92%				
CL respondent %	92%				
CL median	2				

Projects of less than 1 megawatt (MW) needed to be registered with NERSA and had to apply for an electricity generation license. The benefits are that other generation besides that of the municipalities will provide competition and be compensated for feeding surplus power back into the grid. However, NERSA has now redrafted regulatory rules for small-scale embedded generation (SSEG) to introduce standardised tariff schemes but they have not yet been implemented. In the short term, regulations will be made for a modified net-metering scheme (or net-billing scheme) with different tariffs. This will be followed by a second phase of more complex structures to handle fees, subsidies, levies and taxes (NERSA, 2015). Further key assumptions made on REFITs are shown in Box 4.11.

Box 4.11 Key assumptions and developments for REFITs

Key assumptions for policies made were that labelling will be better understood in South Africa once the DOE has finalised the development of the energy labelling policy. Also, funding or rebates will stop by 2030 and will not be sustainable in the long term, and rebates will decrease as the technology becomes more common practice. Small-scale REFIT has not been implemented in South Africa yet, but this will probably occur the following year (2014) with installations soon thereafter and fairly flat tariff reductions into the future.

Other key developments (uncertainties) were referred to, such as the low scale of uptake and that the options remain as yet unknown.

Other related future policies that will be implemented along the timeline to 2050 to reduce CO_2 emissions for the economy as a whole included:

- increased subsidies for renewables and for reduced emissions;
- more stringent energy efficiency regulations;
- more nuclear power;
- net metering will be approved to show payments for homes that supply electricity to the grid from certain renewable technologies (2020);
- carbon tax;

- Green Building Certification in the public sector;
- Energy Performance Certificates (EPCs);
- support for innovative technologies;
- government guaranteed and regulated low-interest loans for certain energy saving installations (2020); and
- requirements to display energy certificates for buildings (energy performance certificates).

Lifestyle trends. The last section deals with lifestyle influences, especially through trends over time, to establish the baseline according to which behaviour change was to be factored. Emphasis was on the size of homes as well as other lifestyle influences on which brief comments had been made by the respondents. The time-series graphs for both South Africa and the USA (used as a guideline for this question) indicated that non-energy-efficient homes were becoming smaller in size. The trends in the USA, however, indicated the opposite for certified homes (Greenworks Reality, 2013). Homes without energy efficiency in South Africa were likely, with a 92% agreement, to become smaller. Extrapolations indicated median sizes of the middle-income group homes were 148 m^2 in 2010 and will be 100 m^2 by 2050 (Loos and Kellerman, 2011). On the other hand, average home sizes with energy efficiency were 200 m^2 in 2010 and are forecast to be 220 m^2 by 2050. Other key assumptions and developments are provided for home sizes in Box 4.12.

Box 4.12 Key assumptions and developments for home sizes

The key assumptions made by the participants on the sizes of homes were:

- more often, homeowners of larger homes could afford certification;
- houses with certification will become more valuable, thus, eventually, also including houses of increasingly smaller size;
- as technology improves and the general public becomes more informed, the tendency will definitely be towards certifying homes, as the cost of living in a non-energy-efficient home will become unaffordable.

Another key development (uncertainty) was that cluster home typologies will become larger.

For the question, “What are the other lifestyle or behaviour changes?”, respondents highlighted how they foresaw behaviour change over time to reduce carbon emissions. These points were summarised from various respondents, but did not reflect converged results. Mention was made that population, urbanisation and densification will increase in the future and that smaller families will emerge. A few thought that middle-income households will be driven to reduce energy use if they become more educated, have access to information, receive improved communication on energy-related issues and benefit from potential cost savings. People will revert to much simpler lifestyles, which could involve communal-type living. Using different transport modes, such as public transport, could become a growing trend.

Regarding the question “Which technologies will be implemented due to behaviour or lifestyle changes, given the above and why, and in which years?”, respondents thought that active and passive heating and cooling technologies will become lifestyle trends. Some examples were given, such as insulation, SWHs, heat pumps and gas stoves, which will become more popular as electricity costs rise in the 2020s. These are likely to be used more as financial opportunities become available, such as low interest low-risk loans. Another expected technology trend in the 2020s is holistic smart technology in middle-income households (smart homes) that automatically switches off appliances, e.g. when the kettle is switched on, the fridge will switch off temporarily. By 2050, the advancement of personal devices such as cell phones will affordably be such that they will be able to monitor smart technologies in homes even remotely.

To establish trends, only formal types of households (only “all households” data was available to determine general trends) were considered. The value of the extrapolated figures from historic secondary data (StatsSA, 2010) was low because of slower population growth and the possible influence of the human immunodeficiency virus (HIV). Housing categories mainly consist of the overall households, detached bricks-and-mortar homes, flats and apartments and cluster homes as defined in the general household survey of StastSA (2010). Apartments, detached bricks-and-mortar, and cluster homes were likely to increase more quickly in number, due to security and shared energy concerns. Growth in bricks-and-mortar homes will increase by approximately 2 million by 2050, apartments by approximately 3.5 million and cluster homes by only 0.2 million, with a total of approximately 5.7 million new households by 2050 from 2014 onwards (as shown in **Tables 4.12** to **4.14**).

Table 4.12 Results for numbers of bricks-and-mortar formal housing units

Market/Lifestyle trends					
Analysis	**Residential growth of formal households**				
	Bricks-and-mortar detached homes – number in millions				
Year	2010	2020	2030	2040	2050
Min.	9.09	9.8	9.6	10	10.8
Q1	9.09	9.8	9.6	10	10.8
Median	9.09	9.8	10	10.3	10.8
Q2	9.09	12	14	15.5	16.5
Max.	9.09	15	16	18	20
IQR	0	2.2	4.4	5.5	5.7
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	70%				
CL respondent %	92%				
CL median	2				

Table 4.13 Results for numbers of flats and apartment units

Market/Lifestyle trends					
Analysis	**Residential growth of formal households**				
	Flats and apartments – number in millions				
Year	2010	2020	2030	2040	2050
Min.	0.65	0.65	0.95	1.6	2
Q1	0.65	0.65	0.95	1.8	4
Median	0.65	0.8	1.8	2.3	4
Q2	0.65	0.8	1.8	2.3	4
Max.	0.65	1	1.8	2.3	4
IQR	0	0.15	0.85	0.5	4
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	77%				
CL respondent %	85%				
CL median	2				

Table 4.14 Results for numbers of cluster home units

Market/Lifestyle trends					
Analysis	**Residential growth of formal households**				
	Cluster homes – number in millions				
Year	2010	2020	2030	2040	2050
Min.	0.46	0.47	0.48	0.48	0.49
Q1	0.46	0.47	0.48	0.48	0.49
Median	0.46	0.47	0.48	0.48	0.49
Q2	0.49	0.49	0.48	0.5	0.6
Max.	0.49	0.6	0.8	1.1	1.5
IQR	0.03	0.02	0	0.02	0.11
Upper outlier	0	0	0	0	0
Lower outlier	0	0	0	0	0
Total respondents	13				
Agreement %	70%				
CL respondent %	77%				
CL median	2				

4.2.2 Confidence levels

Confidence level (CL) ratings in this study reflected to some degree the quality of the answers and which answers would be more likely to occur. The level of confidence for all the questions had to be provided on a scale of 1 to 4, where 1 indicated no confidence, 2 indicated some confidence, 3 indicated reasonable confidence and 4 indicated absolute confidence. The results for the main themes in the questionnaire were categorised as follows:

- Questions 1–14: Technology (**Figure 4.2**)
- Questions 15–32: Markets (**Figure 4.3**)
- Questions 33–37: Policies and lifestyles (**Figure 4.4**).
- Question 36 was left out as it was an open-ended question, which did not require the CL rating.

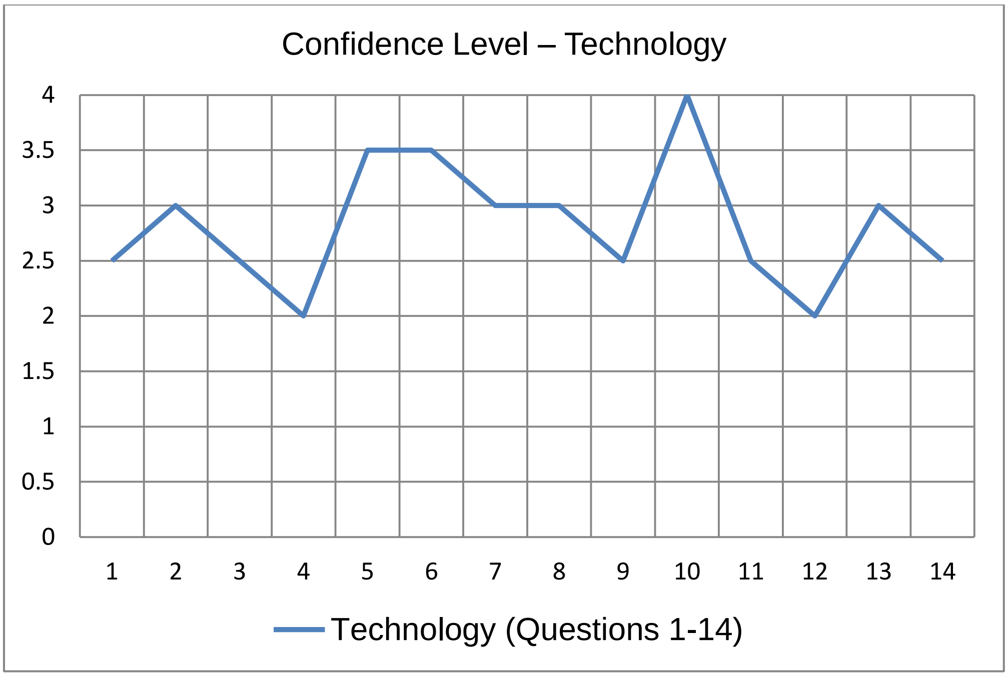


Figure 4.2 CL results for the technology category

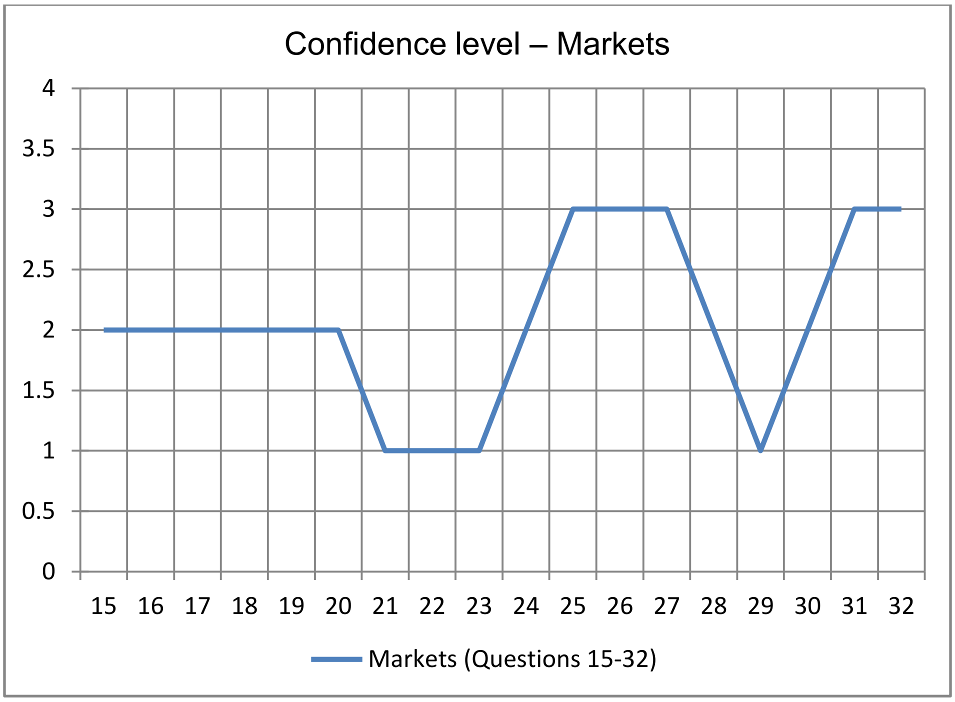


Figure 4.3 CL results for the markets category

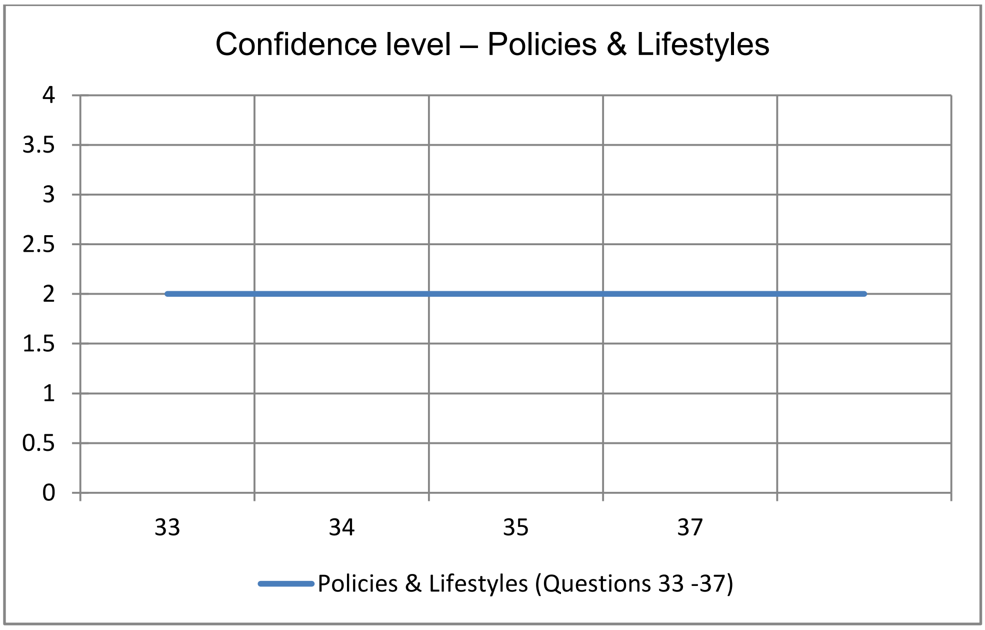


Figure 4.4 CL results for the policies and lifestyles category

For the technology category, enquiring on the timeline for trends in technology types, the results indicated that the respondents reported the lowest CL of 1 for questions 4 and 12, related to wind renewable energy technologies. The highest CL of 4 was given for question 10 on SWHs. For the markets category (related to costs), the lowest CL of 1 was provided for questions 21, 22, 23 and 29 involving wind renewable costs, appliance costs, gas stoves and home values. The highest CL of 4 was provided for questions 25, 26, 27, 31 and 32, associated with LEDs, mineral wool insulation, SWHs, household income and electricity rates. For the policies and lifestyles category, all the CLs were 2 for policies on appliance labelling, DSM rebates, REFIT and others as well as household sizes.

4.2.3 Delphi findings summary

Relevant critical data were chosen for comparison with the backcasting, findings which in this study's context were technology (PV, lifestyle trends and CO_2 emissions reduction trends), markets (costs, income, home values and affordability), lifestyles (home sizes and growth) and policy levers (incentives and standards). The criterion for data selection was assumed to be key issues impacting the rate of technology uptake and behaviour-change.

The guiding trend of the Delphi analysis, on which all other prediction themes were based, was the pathway representing the residential Mt CO_2 emissions to 2050. This was an important pathway as the residential CO_2 emission trends for electricity usage indicated a slow increase in emissions related to electricity consumption, from 40 Mt CO_2-eq in 2010 to 50 Mt CO_2-eq by 2050. This pathway, therefore, did not achieve the 80% carbon reduction, but showed an increase of 25% CO_2 by 2050. This pathway became the BAU pathway for analysis and interpretation. For the technologies, renewables will have a significant impact on the degree of CO_2 emissions reduction. PV was chosen on the basis that it exhibited the most cost reduction potential over time. PV will likely become the lifestyle trend for grid connection only by 2030, and standalone by 2020. Further, Delphi data indicated that PV on grid installation prices would be reduced by 22% by 2050.

An assumption of the Delphi was that energy costs will increase owing to higher capital costs for renewables as well as operational costs as the grid evolves into the smarter grid. The production costs will need to compete with small-scale systems and will result in a more competitive energy market. Data further showed that when comparing electricity rates with feed-in tariffs in c/kWh, the former would be higher and the latter lower by 2050.

The likely trend, according to the Delphi, indicated that household appliance labelling will have a significant effect on CO_2 emissions reduction, with a 50% savings from 2010 levels (250 kWh to 125 kWh).

With very few external disruptions on the current path of development, the median income of R360 000 in 2013 (that can afford a middle-income home of 140 m^2) was forecast to only become only R1.3 m by 2050. Therefore, a 140 m^2 house plus the energy-efficient technologies for 80% savings (3 kW PV, LED, insulation, SWH and low-e glass) in 2013 was equal to R1.1 million (R800 000 house price plus R300 000 energy efficiency technologies), which fell outside the median income bracket of R362 000 and therefore would not be affordable. However, the profitability of adding energy-efficient technologies to 140m^2 homes was calculated by subtracting the increased value of the certified home from the non-certified home, which showed profitability from 2020 onwards.

The pattern of housing growth was forecast, resulting in the likelihood of most growth in apartment units, followed by detached bricks-and-mortar, and then cluster home units. These trends were attributed to security and shared energy concerns. As far as home sizes were concerned, there was 92% agreement that homes without energy efficiency in South Africa will become smaller and extrapolations indicated median sizes of 148 m^2 in 2010, shrinking to 100 m^2 by 2050. On the other hand, average home sizes with energy efficiency became larger, ranging from 200 m^2 in 2010 to

220 m^2 in 2050, but followed the trend reflected set by the USA market for a similar category.

4.3 Narrative of combined consensus on backcasting

The consensus of both the Western Cape and Gauteng backcasting charrettes (as in Appendix B6 (see page 332)) were merged to develop one overall consensus narrative. Overall consensus was portrayed by highlighting the key similarities and differences across the two provinces. A broad overview was provided, followed by two main groups of changes in narrative form, which were categorised under voluntary and mandatory changes. The levers of change under the two main categories were structured to separate the vision outcome and strategies. The backcasting narrative assumes working backwards from the narrative in the future, which has happened, and hence narrated in past tense.

There was overall consensus that the 80% carbon reduction target for homes was achievable by 2050 from both a voluntary as well as an enforced/mandatory perspective. From a technological perspective, carbon mitigation in the building sector of at least 10% by 2020 was deemed practical.

To accomplish deep carbon cuts from a voluntary perspective, the participants’ perceptions for 2050 focused mainly on a service economy and associated models such as collaboration. Participants felt, however, that it could be too idealistic unless other issues such as the massive inequalities and cultural differences were addressed. Collaborative consumption (Section 4.3.1) – if practised in a way that improves access to services and goods for the majority – could help to bridge the cultural divide(s).

So far, there is no collective action or significant cultural drive towards living low-carbon/sustainable lifestyles. Implementing changes quickly will require a fine balance between inducement and enforcement. Voluntary changes can be envisaged, but they can only be made within the choices available, and within the flexibility of policy options. Although the participants thought of desirable ways of living, it was emphasised that our perceptions of comfort will be perceived differently 30 years from now, and by the new generations from 2030 onwards.

4.3.1 Voluntary behaviour changes

Mindsets and values. In order to maintain a good lifestyle while at the same time remaining cognisant of affordability and socio-economic pressures, middle-income household members will have to change mindsets as well as embrace new/alternative other lifestyle models. The participants preferred the forward-thinking concepts of collaboration and collaborative consumption as characterised by cooperation, sharing, generosity, individual choice and flexibility. There could be cross-cultural benefits for collaboration if practiced in a way that will improve access to services and goods and the sharing principles of “Harambee” (an event held to raise funds for a charitable purpose), “Stockfels” (a savings or investment society to which members regularly contribute an agreed amount and from which they receive a lump sum payment) and “Ubuntu” (a quality that includes the essential human virtues, compassion and humanity) that were common practice in a number of cultures in South Africa. This included the re-appreciation of the common, social cohesion and social capital that will strengthen a sustainable society. It was mentioned that one will get collaboration on a neighbourhood scale, meaning neighbourhoods will pull together to achieve a new form of modern social cohesion (communities, villages, cities and high-rise).

Participants referred to collaboration taking different forms, whereby services were provided in dense cities and the countryside, e.g.

institutions that provided services for vegetable-planting schemes. Ideas from a broader perspective alluded to people belonging to multiple overlapping communities as opposed to the insular idea, e.g. a community can be based around education or family. The focus would shift from a nuclear family to more connected community-wide networks, returning to values that encompass sharing in a community sense, e.g. if the grandparents look after the children, the children look after them. These communities would reside in compact convenient homes with a social focus in a community. Some lifestyle changes will include healthier lifestyles, bicycle riding, and preferences for smaller apartments driven by higher costs of construction and energy. Participants expected that in the 40 years to 2050, focus will be on global survival, which will drive the community-focused lifestyle.

Life and household. Participants' visions highlighted the move from a production economy to a service economy, with new models emerging such as the plug-and-play technologies, which can be leased out and eventually becomes part of a smart home. South Africans will be driven by changing fuel shifts and redefinition of modes of ownership. Besides new socio-economic models emerging, participants believed that high reductions in carbon will be attributable mainly to the new technological capabilities.

The big expected mindset change required will be in sharing resources, e.g. cars, power tools and lawnmowers, in order to reduce the number of appliances. Sharing economy business models include renting, bartering, loaning, gifting, swapping and shared ownership. A renewed belief in the importance of community, pressing environmental concerns and cost consciousness was believed to be moving people away from top-heavy centralised and controlled forms of consumerism towards one of sharing, aggregation, openness and cooperation. However, at the base of this was probably also the question of affordability within a poorer society, where high levels of unemployment and job insecurity have continued to escalate.

Participants believed a new form of collaboration on a neighbourhood community level will emerge. Community units in the new form of eco-villages and strong homeowner associations will combine to build smart cities. The form of this smart village – envisaged by 2050 – will be shaped by more compact and convenient smart homes, where resources will be shared and CO_2 emissions reduced. Facilities that serve the need for slightly smaller homes in a community will be shared. They emphasised that the forms of collaboration will not be restricted, thus allowing people to collaborate in any street or in any city, sharing washing or cooking facilities, the crèche, the car pool and gardening services. To make low-carbon homes affordable, society will head towards different economic models. Participants anticipated a pattern shift towards rentals and also dual-income families.

The average home will be only slightly smaller than today's and densification will occur close to city cores. People will still have the option, though, to live further out and in larger homes, but must manage their own electricity supply. Comments were made that people will be prepared to trade off smaller living spaces for the enjoyment of bigger parks. There did not seem to be a preference for high-rise homes as South Africans wanted greenery and space around them. A point made was that if the top income scale set the trend of not living in large homes, then everyone else would also trade downwards.

Participants had similar ideas around private life/free time, and that it will be interpreted differently from today. Some ideas related to people having to work more as technologies surround them more, but with more freedom of choice of when and from where they would be working. Today, people work for luxuries, but in the future, a smaller percentage of the salary will go towards such luxuries. Participants insisted that, with growing densification, there will also have to be more green areas, such as green roofs, green walls and productive spaces that produce food. They envisioned an increase in urban farming through tightly-controlled hydroponics as part of the smart home.

Land use. Participants envisioned nodes, where smart villages will be strategically placed along growth corridors. This type of development will put less pressure on road and transport infrastructure. They noted the virtues of higher density, as density increases choices. Smart village-type thinking will be prevalent throughout the city at all scales, developing into a nested level of smartness. New forms of decentralised infrastructure services are emerging, which could have a major implication for the type and form of development South Africans will have in future.

Medium-density and three-storey walk-up buildings (but making provisions for the frail and handicapped) would be an ideal compromise between higher density and positive lifestyle. High-rise buildings will probably continue to be the central/inner city building typology. Not everyone will be able to move from their current homes to new carbon-efficient developments and therefore all South Africans will have to reduce their current carbon footprints. Workers should try to move nearer to their places of work, make better use of public transport or buy smaller vehicles. Electric cars or green cars are expensive and few are able to afford them. Changing from a large petrol-engine vehicles to a small diesel-engine vehicles already means 52% less CO_2 emission. Biomass fuels could further reduce emissions in future.

The emergence of a new working model in which people will be working more from home and thus requiring fewer office buildings will also influence the building of high-rise office properties.

Technology choices. All participants confirmed that availability of the relevant new technologies will not be an issue as, by 2050, all the technologies that South Africans aspire to will become ubiquitous. Even if renewable energy technologies already existed right now, they will really only be comprehensively implemented around 2050, given the gradual improvements to date. Participants noted that by 2050, technologies would bear no resemblance to what we have now and will be so advanced that they will be able to achieve net zero energy use from the grid. The participants agreed that such technologies will make homes more efficient and smarter.

By 2050, smart homes and smart communities will be more widespread. By 2030, smart homes will be the norm and, by 2050, all houses will feature these technologies. Renewable energy technologies are the key to eliminating the use of fossil fuels. According to the participants, technologies that will be utilised will be highly dense renewable energy sources, such as hydrogen fuel cells, natural gas, solar farms, biogas for combined heat and power (CHP) and cogeneration from waste. For distributed generation, one would rather look at lots of small plants each below 1 MW adding power to the grid. For example, one could comfortably run a house on a 5 kW system based on renewable resource. By 2020, there should be a diverse range in the energy mix, which will include different types of renewables. Other technologies will include integrated IT management systems that work with sensors, e.g. lights that switch off automatically. The value of insulation, particularly in retrofits of existing stock, was questioned, whereas there would probably be a business case for installing insulation in new homes.

Participants decided that prefabrication will lead to the form of a smart house as an object that gets built off-site and is manufactured in a controlled environment. This smart house will be small, compact, simple and affordable, a “sexy object” which becomes desirable on its own merits. As an object and not a building attached to the ground, it will lead towards a trend. Comments were made about the interconnectedness evident in the smart home getting plugged into the smart grid, and the smart grid supporting a matrix of smart villages. The smart car, in the form of an electric vehicle, could be parked in the smart home – mobility will be there for those who can afford it. This car also contributed to the smart grid as the smart car battery-storage served as part of the smart grid.

Modes of house production other than bricks-and-mortar will have to lead the trends. For extended modes of prefabrication, there will be high-rises coming off a standardised framework and pre-manufactured pods (housing units) that are just plugged in. The requisite accuracy or workmanship will call for highly skilled labour. Attributes of materials will include the ability to “breathe”, which implies that the materials must be cooler in summer and warmer in winter. Pre-manufactured materials must be able to perform to such an extent that they can absorb CO_2 as part of their performance. There will be a new generation of structural insulating panels made with ecologically-responsive insulating materials. Cement will not necessarily be used as the main material for structural form, as there could be new technologies that will allow for lighter, less energy-intensive structures.

The advantage of prefabrication was pointed out to be its very high level of “dismantle-ability”, currently a big buzz word. This will facilitate reuse as one can take the structure apart and reuse the components. The best wall formats will prevail and standardisation will become more prevalent. This should help to eliminate monopolies, while local sourcing will offer obvious cost benefits. A high level of local customisation will be required in order to cater for people’s different tastes, preferences and needs. This will come through a factory that deals with mass and has a massive array of ideas from which to choose. There will be consistency of style within the relevant module. Some people will still opt for the traditional approach. Although bricks-and-mortar trends will still remain (but in a greener way), other competing prefabricated technologies could prevail due to an already existing shift to lightweight steel construction, partially attributed to mitigation of escalating costs. Prefabrication will first appeal particularly to the lower-middle to lower income sectors, and later to the other sectors. A key expected trend is towards reusing and recycling, with a focus on dismantling rather than the currently prevailing practice of demolition. Relevant expertise will advise on choices, metering, installations and maintenance services.

Participants anticipated middle-income households resorting to a plug-in for backup systems. PVs covered the home for only eight hours a day and necessitated the ability to store the energy in an economic way. Although participants were aware of most currently available materials, the materials' properties and performances would improve over time with complete service-orientated options in the market.

Market implications. There will be a shift in the financing models and mechanisms for mortgages as a result of the market switching to increased rentals because of reduced affordability of ownership. The responsibility for ensuring the building is green will rest with the owner. Tenants will have some power in that they can demand to live in an environment that has a much greener footprint or lower emissions. This will, therefore, emerge as a market opportunity/drive.

The currently high level of unemployment calls for a return to a global production economy, away from the neo-liberal/unregulated financial economy of the era 1990–2008. As industrialisation matures in the developing world, it will facilitate a shift towards a service economy. Developed service-economies will drive improved resource decoupling, eventually leading to more desirable and sustainable steady-state economies.

By 2050, many South Africans will no longer be able to build their own houses and make them "green" with the new technologies, even if those technologies get a bit cheaper. Therefore, sharing and renting will make it easier to live in a green home that contributes towards the 80% reductions in GHGs emissions. People living in large homes will be taxed more. It will probably be too expensive for many to retain single dwellings and they may have to opt for living in groups and communities.

Owing to the uncertainty of the national budgets available in the future, it was decided that it would be better for more costly (upfront costs) technologies and packages to be implemented for different lifestyle models if they were justified on the basis of payback periods without necessarily becoming incentivised.

4.3.2 Mandatory changes

Government. The big mindset change will be steered by government, which should lead by example. Government coercion will become the main facilitator of change towards achieving deep cuts in CO_2 emissions. There needs to be a heavy-handed top-down approach from government in order to realise CO_2 emissions mitigation efforts, which will lead to a prevalence of people being forced (or nudged) to make changes promptly. At the same time, the heavy-handed approach is likely to be balanced by "nudging" techniques. Government will have to be people-orientated, listen to people, put policies in place and provide incentives. Policies related to "carrots and sticks", especially, towards addressing an existing less enabling environment, will ensure changes and motivate individuals.

Participants highlighted education as an important component in creating change. For example, educating enforcers and bringing the subject of sustainability for planetary survival into schools and universities would be pursued. Today's children learn about climate change, recycling, energy saving and organic vegetable gardens in school subjects such as Life Orientation. Although this lays the foundation for change in mindset in the next generation, more dynamic educational programmes need to be introduced.

Land use and cities. Suggested areas of improvement in urban planning included mixed-use integrated development and shared common and service areas, such as laundries, gyms, swimming pools, gardens and cycling paths. City centres must have high-rise and mixed-use buildings, where people live, work and play in one building. Development will be more prevalent in open land/green fields and exercise more control over urban sprawl. Between 2030 and 2050, there will be continued densification as well as a systematic and comprehensive public transport infrastructure/services put in place. Provision will have to be made for nodal and growth corridors, where smart villages will be strategically incentivised.

Technology policies. Participants confirmed that there will be distributed generation and people will prefer solar panels and wind farms, among other methods, for smart homes. For big commercial buildings, South Africa will pass laws on the implementation of the smart grid system, but private homes will take longer to be regulated as such. It was explained that the full implementation of the smart grid would lag behind owing to a lack of safety measures in place for the grid, which was still financially and politically controlled. Eskom’s focus will shift more to transmission and distribution rather than the current focus on generation thus allowing more private producers to play a generation role. Successful mitigation of CO_2 emission will mean that homeowners will have drastically increased the energy they generated in their homes through means such as PV panels and bio-digesters, among other technologies. By being able to benefit from REFIT, more people will be motivated to install net metering and obtain renewable energy certificates to be able to offset self-generated power against the dirtier grid electricity and related costs. There will be decoupling of own use versus own generation.

There will still be an overall centralised system involving Eskom,and there have also been notions of the national smart grid incorporating nuclear energy. However, participants voiced strong resistance to the proliferation of nuclear plants because of the extreme hazard to people posed by nuclear waste (which, as yet, cannot be safely and affordably processed).

Market enforcement. Certain differences related to the financial drivers elicited further debate. One group preferred not to spend too much time on the type of incentives to use to entice people to make changes, as most of the drivers are in place already. The technologies must be affordable to justify the investment within a normal payback period. Banning high-energy consuming technologies and taxing excessive consumption should be a more realistic approach. Other participants believed that a true democracy would retain options – if one wants to pay more for using more, that option should be there. The participants did not specifically refer to “nudges” as a way of guiding changes but focused more on the “sticks and carrots”.

By 2050, most people will be grid interactive and many smart homes will be able to manage themselves, with lights switching off automatically, among other home-based innovations. Relevant technologies will emerge and saturate their niches through technology innovation diffusion locally and globally.

4.3.3 Strategies and policies

The working hypothesis called for probing the extent of CO_2 emissions reductions through alternative pathways and mitigation interventions. Exploring the significance of low-carbon homes highlighted the multiple benefits, nested level of importance (low-carbon homes fit within larger important CO_2 emissions reduction goals) and social values. Transitions to a low-carbon society relied on relevant technology as well as a significant lifestyle and social change. A perspective was thus taken on how lifestyles and policies affect change in view of technology and markets. What strategies in terms of lifestyles and policies will induce relevant transformation and achieve deep cuts of 80% CO_2 emissions in homes by 2050? Besides these themes, the responsible parties/actors who will ensure that the strategies are enforced were included.

The strategies were distilled from verbatim responses from the Western Cape and Gauteng participants and thereafter circulated for confirmation together with the relevant narratives as indicated in Box 4.13.

Box 4.13 Strategies from the Western Cape and Gauteng mini-charrettes

1. Preferred changes, some voluntary

1.1 Lifestyles

Mindset and values

Making intrinsic changes will be a gradual process to some homesumers, while others will be affected by enforcement. Education and the media will play a critical role in appealing to people’s emotions by using persuasion techniques. Possibly, the manner in which people change their lifestyles will influence values by putting into effect the concept of collaboration and collaborative consumption, which trumps all other approaches regarding values. This can be initiated by redesigning estates with stronger social cohesion principles where possible. Facilities will be shared which serves the need for slightly smaller homes in a community. This can be achieved by research institutions, industry researchers, the Department of Education, professionals in the industry and the Green Building Council.

Life and household

The use of social media will be a mechanism to reach people. It has already become a trend and will be even more so in the future. People influence people on other ways too. People who find intrinsic reasons to want to make lifestyle changes voluntarily and those who will want to make changes will set good examples and thus provoke change trends. This can even mean scaling down or giving up relevant material goods.

With less consumption, more money can be spent on community initiatives, which will become evident by 2030. Lifestyle will be affected by 2030 by being able to manage one’s own working time and free time to evoke a stronger sense of freedom of choice. Starting in the next two years, Architects will have to implement low-carbon designs for communities, which will provide model examples of successful implementation, to stimulate and entice sustainable lifestyle markets and improve quality of life. These designs will induce resource-sharing schemes on a neighbourhood community level, through eco-villages and the modern form of a homeowner’s association.

The private and public sector should focus on community-based social marketing, which fosters sustainable behaviours by: selecting the specific behaviours that need to change; identifying barriers and benefits; developing strategies; piloting; and brand-scale implementation and evaluation. Scaling-down or giving up relevant material consumption will have to become a trend by 2030.

1.2 Technology

Greater efforts need to be made as soon as possible by the private sector and service industry to promote the benefits of prefabrication, amongst other methods, and establish innovation hubs that will demonstrate the durability and benefits of smaller, more affordable, and desirable objects. Innovation must include interrelationships that enhance a nested level of smartness. For example, the smart car becomes part of the smart grid, and the smart car batteries work for the smart grid. The preferences of homesumers need to be considered, such as innovating materials that can breathe, absorb CO_2, be recycled and reused, dismantled, and which are biodegradable. Quality architecture was pertinent for replacing high-energy consuming technologies with high-performance low-carbon options, which included LEDs, heating and cooling, water systems and renewable technologies. This required expertise relating to metering, installation and maintenance services.

1.3 Markets

External macro-economic pressures will encourage the adoption of new purchasing models that will consist of increased rentals, dual-income families and collaborative sharing of assets by 2030. Homesumers will have to look out for financial incentives at banks and insurance companies. Affordability of technologies will be justified if the life cycle costing and/or normal payback period benefits the consumer.

2. Mandatory changes

2.1 General

DOE will set energy reduction and carbon reduction targets of 80% for the housing sector by 2020 at the latest. Rational agents and professionals in research institutions, the Department of Education and the service sector will play a leadership role in educating and motivating government and individual behaviour changes to benefit from the virtues of sustainable development. Relevant government departments will have to introduce an even bigger educational drive in schools, universities and the workplace, starting as soon as possible. Focus will have to be on a number of education techniques related to sustainable lifestyles including forums, workshops and courses. Also, the use of social support, goal setting and commitment procedures will achieve targets.

Government can support collaborative consumption by clarifying the rules, raising awareness, through partnership and funding, legislation and providing infrastructure. To support the latter, it will be vital to enhance governmental policies to ensure interrelationship of product (buildings), service designs, behaviour change as well as policies related to infrastructure, transit systems and town planning collaboration. Sustainable lifestyle models can be implemented more freely if strict safety policies are enforced that will change South Africa into a safe country to live in and address the challenges of job creation.

2.2 Land use

Town planning must plan for nodal and growth corridors more vigorously, where smart villages are strategically placed. This further requires improved cooperative planning that integrates smart villages that will be serviced and assimilates new forms of mass transit. Designers in government will have to apply smart thinking throughout cities at all scales according to a nested level of smartness. Municipalities must control development on urban edges to prevent urban sprawl. Greening of all open spaces and high-rises must become standard to reduce overall use of energy. This requires densification models supported by public spaces and a mix of infrastructure services to increase choices. Town planning will need to focus especially on the balance of built area/density versus green area. There should preferably be housing limited to a maximum of three levels (but making provisions for the frail and handicapped), but in denser city centres allow high-rise strategically. Town planning schemes must include mixed-use housing located close to regional shopping centres, employment and along bikeways. All the above will involve updating town planning schemes to include new zoning, coverage, floor space ratio (FSR), building lines and requirements that will accommodate smart communal living.

2.3 Technologies

To transit to a low-carbon society, South Africa must fundamentally reconsider the design of a comprehensive and integrated energy system, to be achieved by Eskom, NERSA and the DOE, implementing an effective grid that allows for a diverse energy mix. Promoting the distribution generation through many small renewable energy plants of below 1 MW adding to the grid would be a viable solution. To entice homesumers to install renewable energy technologies, municipalities will have to introduce a system to install net metering for homes to benefit from REFIT. Any renewable generation will require a renewable certificate.

Limiting all appliance types to the highest efficiencies can be accomplished by the National Regulator of Compulsory Specifications by 2020 by discontinuing all undesirable technologies and not allowing them to be manufactured or imported, such as incandescent lamps and two-bar heaters. A way of preventing high-energy usage was to disclose the carbon consumption of businesses and homesumers, enforcing the naming and shaming approach as well as coercing carbon taxes for large consumers of home energy, not to mention the effects of the classic methods of regularly upgrading energy efficiency standards in terms of insulation, lighting, renewable energy sources, etc.

Through local manufacture of materials and products, the import of products will be mitigated. By 2030, policies will be implemented, such as those standardising methods on recycling, reusing and dismantling. Increasing regulation of labour within a controlled environment of factories will become crucial by 2020. The accuracy or workmanship will call for highly skilled labour. The Department of Trade and Industry (DTI) must open up competition to stimulate the increase of regulating the quality management systems of factories. By adopting global technical standards by 2030, the country will curtail barriers to trade. One will achieve maturity of pre-manufactured homes through choice and numbers within the limits of a specific module.

2.4 Markets

Low-carbon living should be motivated, although only for a short- to medium term, through government incentive mechanisms such as tax credits, rebates and subsidies as soon as possible with the assistance of Treasury, the Development Bank of South Africa and international donors. Other softer financing schemes can be introduced, such as interest rates linked to building efficiencies and extensions of loan repayments from banks by 2020.

Government and the private sector must ensure that mechanisms are in place to allow technology innovation diffusion and leapfrogging to assist with introducing emerging technologies that will be cost effective as soon as possible. Research institutions and the service sector must promote and market trustworthy technology breakthroughs with improved properties. Through DTI enforcing revised directions for patent and copyright by 2020, the country will be able to open up monopolies for higher competition. The aim will be to accomplish CO_2 emissions reduction in the building sector with either negative costs or marginal costs through mature low-carbon technologies aimed at reducing energy consumption and improving energy efficiency.

4.3.4 Backcasting findings summary

The findings represented the dialogue at the one-day backcasting mini-charrettes, which focused on the “what”, “why” and “who” questions towards achieving the necessary change to be able to transit to a desirable low-carbon future, and addressed whether 80% CO_2 emissions reduction was achievable. The outcomes related to the general levers of change that will require dynamic orchestrated interactions along a generic pathway to 2050. These critical issues of a social and technical nature will require a change in mindset, lifestyle shifts, government commitment, financial incentives, interactions between fields of knowledge, improved research and technology uptake, improved quality of homes, environmentally friendly materials and more greening.

However, the backcasting mini-charrettes did not deliberate in a structured way on the likely options that could influence the rate of change. This necessitated another process of analysing and interpreting the findings in terms of possible alternative pathways. Pathways were identified according to options from less-likely to more-likely occurrence, which then guided the conceptuallisation of a new framework of four prospective pathways characterised by the level of effort required within specific timelines, with the adoption rate guiding the patterns of change that will lead to an 80% CO_2 emission reductions. The conceptualised pathways were front-loading (FL), back-loading (BL), even-loading (EL) and middle-loading (ML). Once conceptualised, the pathways were further characterised in relation to their chance/possibility of becoming the preferred/adopted pathways. This lead to the two categories of “less-likley” and “more-likely” pathways which one further analysed in Chapters 5 and 6 respectively, followed by the prioritisation of the most preferred/likely pathway.

CHAPTER 5

LESS-LIKELY PATHWAYS

5.1 Introduction

Based on the level of effort principle for the required change, two pathways were categorised within the “less likely” pathways. These are the front-loading (FL) and the back-loading (BL). This chapter investigates what these hypothetical pathways would have contributed towards bringing about socio-technical transformation either positively or negatively in relation to the 80% reduction target. An elaboration of the main conditions necessary for the pathways to have occurred, as well as arguments in favour of their rejection by the country, are substantiated in this chapter.

The analysis was guided by the relevant accelerating and inhibiting factors crucial to effecting the rate of change within a complex/dynamic system. This was accomplished by first providing the accelerating conditions for the hypothetical pathway to have occurred. Accelerators are the conditions under which increased CO_2 emissions reduction occurred over the specified period of the relevant pathway. The accelerators are seen in a positive context as the factors that initially enable the FL and BL pathways to have occurred, but later (if so justified) are motivated as inhibitors due to their inability to adequately sustain the approach as the chosen and adopted pathway. They are followed by the inhibiting factors, which slow down mitigation of carbon emissions thus supporting the likely rejection of a relevant pathway by South African actors and stakeholders.

The accelerators or inhibitors are substantiated with selected abstracted backcasting and Delphi data, as reported in Chapter 4 within the boxed text, which serves to provide a “beacon” role when navigating the narrative. This cross-referencing was systematically applied without overwhelming the chapter with numerous citations, as was done in Chapters 1 and 2. The data from the methods include what the stakeholders in South Africa preferred.

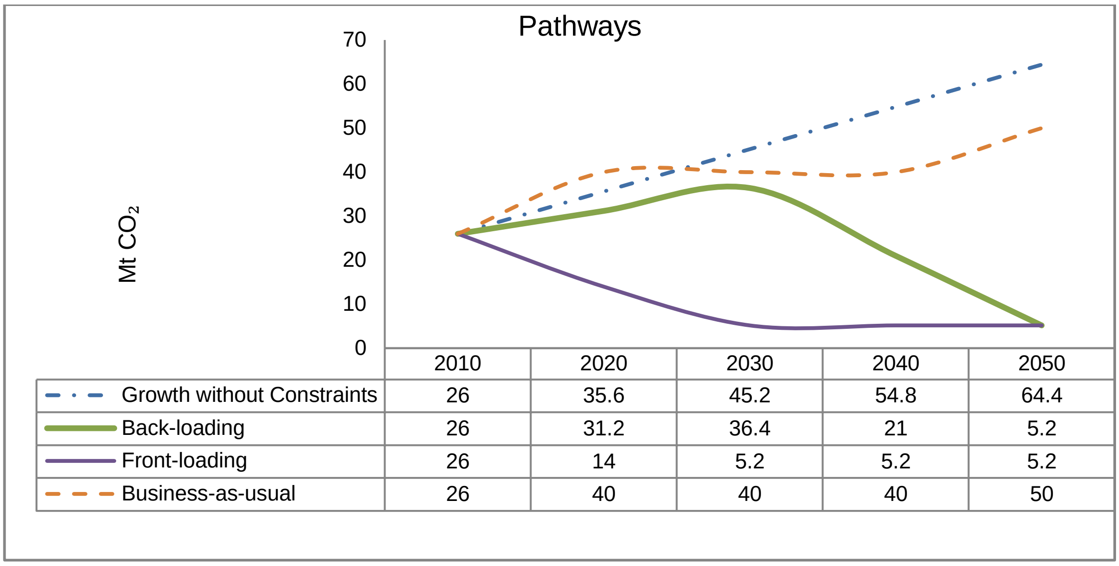
The accelerating and inhibiting conditions are structured under the different multiple-level actors (MLA) levels including:

- the macro level of governance incorporating government, institutions and infrastructure that develop policies and strategies;
- the meso level of supplying services to the individual including manufacturers, suppliers and contractors; and
- the micro level of individuals/households, their lifestyles and behaviour.

5.2 Front-loading (FL) pathway

5.2.1 Early commitment

Accelerating factors. A condition for steep reduction was government committing early to shifting priorities and allocating resources to enable large-scale changes. Something, perhaps some emergency, precipitated the salience of the need for change. This could which could have been due to some sudden crisis, such as the electricity crisis the country experienced in 2008 and again in 2014. This urged government to make decisions to resolve the problem with stringent enforcement of low-carbon technology measures. The authoritarian style of leadership in which management and governance structures interacted in this case reverted to predominantly dictatorial policies. In this scenario, an 80% CO_2 emissions reduction from 26 Mt CO_2 to 5.2 Mt CO_2 was achieved in middle-income homes between 2010 and 2030, after which the reduction stayed on a plateau for two decades until 2050, as shown in **Figure 5.1**.



	2010	2020	2030	2040	2050
Growth without Constraints	26	35.6	45.2	54.8	64.4
Back-loading	26	31.2	36.4	21	5.2
Front-loading	26	14	5.2	5.2	5.2
Business-as-usual	26	40	40	40	50

Figure 5.1 Less-likely pathways – Front-loading (FL) and back-loading (BL)

This allowed for short-term policies that prioritised mostly PVs (used as a renewable energy example owing to its cost reduction potential) to be implemented in middle-income households. Increasing the uptake of renewable energy, which is carbon neutral facilitated for replacement of fossil fuel usage and hence improved the energy efficiency of medium-sized homes. It led to the shortest route towards achieving deep cuts by 2030 by firstly targeting the supply-side issues, such as gradually installing bi-directional meters and ensuring a reasonable supply of photovoltaic (PV) technologies in the market. Government engaged local and mostly international service providers to provide the products and do the installations. A linear thinking approach was pursued involving a few key players, which proved to be the quickest way to make this renewable energy boost initiative work.

Incentives were introduced, with concerted efforts made to partner with international companies and redistribute government funds towards the initiative. Much effort went into ensuring that existing and new homes were retrofitted within the shortest possible term, with the belief that the initial uptake would create a snowball effect, with citizens later taking more of the responsibility of investing in renewables.

Inhibiting factors. Decision-making in a crisis is always going to be problematic in government, especially when having to make certain commitments. We need to be aware of its shortcomings and avoid hasty reactions without thinking through implications and consequences. Decisions can be constrained by the short-term and disjointed nature of the government policy-making framework responsible for the renewable energy boost expected to occur by 2030. Some of the limited decisions stem from a bad collective process. The “leadership team” emphasis on collaboration and fitting in – the trend since the turn of the 21st century – turns out to have a negative side. When a team-collaboration becomes a chorus, and strengthens commitment to the course through working for consensus for its own sake, it can become counterproductive.

After a strict reinforcement period, between 2030 and 2050, despite a period of stabilisation, the uptake of PVs declined. Results of short-term policies and contentment with the status quo brought about a “hard landing”, exacerbated by a lack of deep-level/sustained technological and behaviour change progress in South Africa. Although promising technologies in the country – such as carbon capture, renewables and batteries – could have transformed how energy was produced and stored, providing a boost to real economic activity, the future of technological innovation was inherently uncertain. The levels of R & D in renewable energy were relatively low, in part owing to doubt regarding government’s long-term environmental policies. From a social perspective, not many changes occur and citizens acquired a reactionery approach thus allowing little flexibility for making voluntary changes. In addition, the absence of supporting structures that would sustain the quality and number of PVs led to the decline of installed and functioning renewables. Despite the opportunity for path correction, which this pathway allows, the follow-up in monitoring, evaluation and revision between 2030 and 2050 was minimal or lacking. Consequently, the early commitment in the FL pathway did not have a positive outcome as not all the influencing factors of technology growth and development (maintenance, affordability and behaviour change) required to ensure the sustainability of the PV boost initiative were considered.

5.2.2 Impulsive heavy-handedness

Accelerating factors. The pathway occurred within government essentially as a result of heavy-handed tactics. Severe government coercion achieved the transition to low-carbon homes at the earliest period of all other pathways. Coercion played a major role in regulating the supply and demand-side through the introduction of a renewable energy boost programme. This included mandatory enforcement for each household to install PVs to provide an alternative means of producing energy and simultaneously mitigating fossil fuels. Punitive mechanisms for non-compliance were preferred for immediate results within a rigid regulatory regime. This relied on municipal regulators proactively policing the renewable energy installations, taking legal action and imposing steep fines. These fines for not complying with the policies to install renewable energy were avoided by citizens as there would be exorbitant financial losses over time.

From a government perspective, the thinking behind the approach was that citizens endured government coercion every day in their normal lives, including being forced to pay taxes, traffic signs, recycle waste products, as well as being precluded from harming endangered species or taking another's property against the other person's will. In most cases, government coercion in free society is aimed at prohibiting people from doing something harmful to others or to the environment – concepts central to authoritarian principles**.** Knowing human nature to constitute a mixture of good and evil, the authoritarian person does not put his or her trust in mere altruism. Constitutional restrictions, political checks and balances, adequate enforcement of the laws, the old intricate web of restraints upon will and appetite – these the authoritarians approve as instruments of freedom and order. In essence, the authoritarian government simply found permanence more pleasing than the "chaos" within a progressive framework.

Inhibiting factors. Heavy-handedness**,** oppression and hard paternalism created an atmosphere whereby people had little flexibility in voluntarily furthering environmental goals. What was best was not the general freedom (few policies) one would have liked to exercise, but what freedom some person may need that would be different from what a rigid regime would expect to do things beneficial to a low-carbon society. This type of freedom was especially essential in a culturally diverse society that would justify more options towards attaining low-carbon homes and lifestyles.

Sometimes people made bad choices, making their lives worse (and shorter). In some cases, public officials were in an excellent position to help. But the human desire to help could very easily be overshadowed by the desire to rule – in other words, to move from benevolence towards political authoritarianism. From a more "progressive" perspective, one could distinguish between soft and hard paternalism. It was argued that people preferred measures that got individuals to do what was rational for them to do through devices that shaped how decisions were presented to them (such as rules on how potentially harmful goods were displayed), rather than by aiming at eliminating the possibility that they might consume them entirely.

So one could ask when does “good coercion,” critical to maintaining ordered liberty and the public good, cross the line into “bad coercion” and threaten our freedoms and liberty? A just government maintains a healthy tension between the claims of authority and the claims of liberty. In essence, it suggests that humans respond better to change through “nudging” or “reflexivity” than “coercion”. Non-regulatory or regulatory measures used in isolation are often not likely to be effective; the most effective means of changing behaviour at a population level is usually a range of policy tools based on both regulatory/mandatory and incentivised/voluntary approaches.

5.2.3 Acquiring international services

Accelerating factors. As a developing country, South Africa aimed at focusing on renewable energy technologies that would directly solve the energy crisis in a carbon neutral way in which the service sector level played an important role. In that case, renewables such as PVs intentionally leapfrogged the outdated technology with better quality and more cost-effective storage batteries, particularly for stand-alone systems, which were identified as being more reliable than the grid. What impacted the rate of change was the innovation and diffusion of renewables in the housing sector at an unprecedented rate.

The quickest way was to install PVs (used as an example owing to its cost reduction potential) and promote diffusion through procuring qualified service providers, of which there were few. A lack of skills in the country led to the appointment of many international engineering contractor (EC) companies that sourced local manual labour for projects to meet localisation thresholds. This led to the development of partnerships with relevant international companies for improved low-carbon renewable technology transfer programmes. Predominant trends still existed, requiring a transformational turnaround from energy-efficiency-dependent interventions to renewable energy transition.

By 2030, PVs were saturating the market due to a linear problem-solving approach with the supply side dictating uptake and consequent adoption occurring. With energy-efficiency usage still following BAU trends, PVs were able to reduce CO_2 emissions by 80% thus stabilising the CO_2 emissions. A few local service providers and predominantly international companies provided the services and dominated the renewable energy market in the middle-income housing sector.

Inhibiting factors. As a result of government dictating what innovation should be implemented, people did not easily accept innovation. There was a lack of interacting factors critical to the diffusion process that required local innovation, how information about the innovation was communicated, and the time and the nature of the social system into which the innovation was introduced. The required orchestration of change normally occurs across multiple levels of actors when dealing with complex problems which necessitate major discontinuities. It would have been more realistic to plan for diffusing innovations over time and go through a period of slow, gradual growth before experiencing a period of relatively dramatic and rapid growth, followed by gradual stabilisation and eventual decline. The rate at which PV installations escalated was unjustifiable within the country's complex socio-technical system, which faced the risk of instability to cope with such rapid diffusion as verified in Box 5.1.

Box 5.1 Plausible rate of renewable technology uptake

The data from the backcasting and Delphi indicated that the ambitious targets for renewables in the FL pathway were not likely to have been met. The backcasting alluded to the distributed generation of small plants of below 1 MW adding power to the grid working best between 2030 and 2050. The Delphi findings showed a variety of renewables that could likely have become trends – PVs would become a lifestyle trend for grid connection only by 2030 and stand-alone by 2020.

However, the Delphi assumed that energy costs would increase due to higher capital and operational costs for renewables as the grid evolved into the smarter grid. The production costs would need to compete with small-scale systems and would result in a more competitive energy market.

The effect of learning by research and learning by doing had an effect on technical progress. Between the period of 2010 and 2030, South Africa relied more on international products and skills and spent less resources on the generation of new local knowledge and innovation. The country's own skills would have further developed inventions, which would be transformed into innovative products and skills. It would have been a critical condition to deepen national technological capabilities, which would have contributed to successful leapfrogging. The linear approach to quick supply-side solutions was hard to defend as more inclusive relationships between the stages of technical progress would have resulted in a non-linear process with feedback between its processes of technical change. Stakeholders knew well enough that if socio-technical change in FL was not conceptualised as a gradual process that involved different stages of progress, there could be failures in adoption of the relevant technologies and systems.

Inclusive growth and development, incorporating a broader range of stakeholders, long-term policy commitments and redirection of funds for a low-carbon path did not exist from the start. Critical drivers of change in energy technologies that were relevant to all countries and had a role to play in all stages of technical progress (although the nature of it can change) were research and development (R & D) and capacity deployment. More inclusive policies (that would consider the requirement for broad correspondence between the process of technical change and the main R & D activities) were missing. These included basic research, applied research and development. The lack of more focused funding prevented basic research (invention and early stages of conception) and technology to mature through diffusion stages fostered by research and development (R & D). In addition, the knowledge and learning by doing gained from manufacturing, scale-up in production and utilisation was too limited to allow for sustained technical transformation of society and economy. Furthermore, the lack of local technological improvements would inhibit cost savings in the manufacture and installation as well as saving costs on exchange rates and import taxes. Box 5.2 provides the plausible costs for PVs and incentives.

Box 5.2 Renewable energy costs

The backcasting denoted less ambitious time frames for installation of renewables than the FL pathway required. This was evident in the approximate 30% of homes in 2030 that generated their own energy with net metering and REFIT. In the same year, the smart grid design allowed for increasing domestic connection of PVs to benefit from feeding energy back into the grid and receiving an income from the surplus. It was only by 2020 that municipalities and Eskom introduced a system to install net metering for the homeowner to benefit from payments for surplus power to the grid based on installation certification. Although the backcasting preferred that all types of PV installation prices would become substantially more affordable over time, the Delphi forecast that PV on grid installation prices would be reduced by 22% by 2050. **Figure 5.2** shows the PV price reduction over time, following the current path of development.

Government's financial incentive mechanisms were referred to for installation of renewables in both the Delphi and backcasting data and showed some similarities. The Delphi referred to rewards such as rebates that would end by 2020, whereas subsidies for renewables and net metering for REFIT, would remunerate homes that supplied electricity to the grid from relevant renewable technologies, starting from 2020. Also, government-guaranteed and regulated low-interest loans for certain energy saving installations would start by 2020. The backcasting further referred to subsidies and tax incentives as motivators for retrofitting existing homes.

If by 2030, PV penetration in the FL pathway had already stabilised, it would mean that between 2020 and 2025, rapid diffusion would have occurred. As a precedent, if cell phones, which became affordable and out-diffused virtually any other technology in the world, had taken 25 years to reach maturity, it was unlikely that expensive renewables would diffuse at a similar rate or better. To indicate the time forecast for renewables to diffuse, **Figure 5.2** indicates the BAU cost reduction trends of PVs.

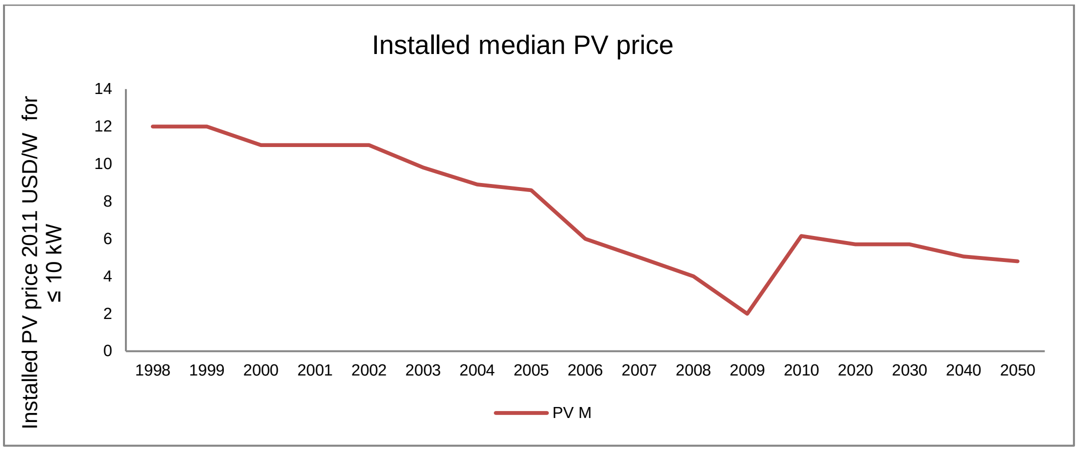


Figure 5.2 Trend in installed PV prices

With a forecast of PV cost reductions of 22% by 2050, the disruption caused by government in the FL pathway would not have resulted in socio-technical change without a concerted effort to ensure co-evolutionary transformation on all market levels. Due to the early stage of development of the energy efficiency and renewable energy market, many middle-income households refrained from installing the systems and passively waited until the industry had developed greater experience and knowledge. Many of these transformations in the supporting conditions were discounted/disregarded by the linear-focus on change and growth in the use of renewable energy technologies with emission reduction is a primary goal.

As demand for renewable technologies increased due to the strict policy requirements, there was a slowdown in improving the service quality and cooperative partnerships between actors, which adversely affected service (utility scale market) of the installation of renewables for the whole life cycle of the technology. Between 2010 and 2030, the economic system was still hanging on to so-called “material” goods and values, which implied a focus on the production process mainly having to do with material goods. South Africans increasingly showed that there was a need for localised manufacturing, and a service economy that was less "materialistic" than the classical industrial revolution period, where the production process was mainly dependent on material goods. This required that the "non-material" became more important and was related to the notion that a higher degree of education was an essential prerequisite of proper production and after-sales service.

When referring to renewables, there were not many actors involved in ensuring the quality and durability of the product requiring relevant skills, such as the developer, ECs, operation and maintenance by EC, project owners and utilities (generators/transmitters of the renewable energy and who would also be responsible for upgrade and maintenance of the required smart-grid). The lack of knowledge, skills and service from the service sector on renewables resulted in a decline in adoption between 2030 and 2050 for the middle-income group. Box 5.3 provides the plausible localisation scenarios.

Box 5.3 Plausible localisation scenarios

The forward-thinking concepts of a service economy were preferred in the backcasting. By 2040, the interaction between manufacturers and customers became more intimate than before, leading to early involvement and co-creation with customers (customisation). This was also a way of serving customers throughout the whole life cycle of a product, involving the usage phase and afterwards – "sale of use" rather than "sale of product". Business models and organisational culture would shift fundamentally. Industry reputation became an important attribute requiring product certification as an indicator of quality – including durability and embodied energy (recycling, reusing and dismantling products). With the event of localisation taking priority, international relationships for trading were also improved by curtailing barriers to make exchange of products easier when and if required.

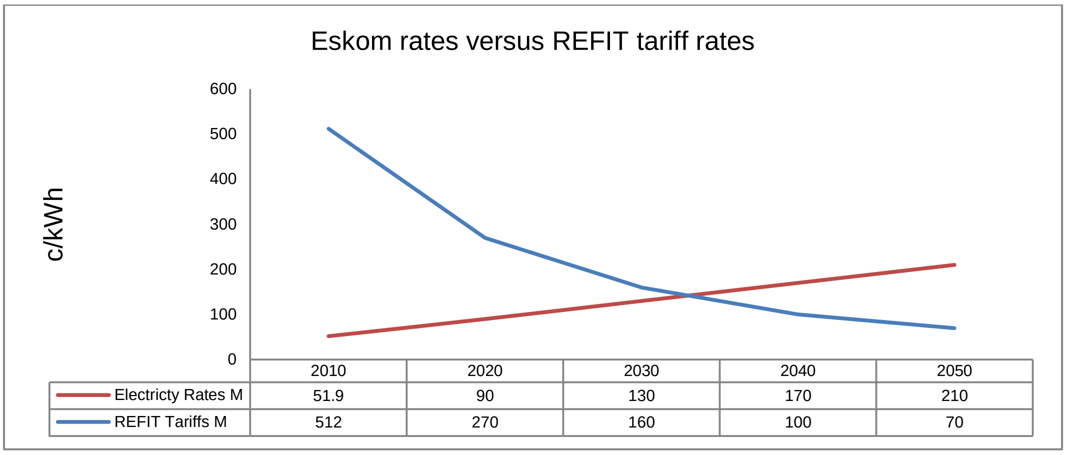
Renewables, such as rooftop PVs, were not aligned with, or in principle, supported throughout the government decision-making process, and therefore lacked adequate policies. The legislative framework of the PV rooftop environment was vast and complex and did not include entities such as DOE, NERSA, Science and Technology, Municipalities, Eskom and South African Bureau of Standards (SABS). Many policies related to small-scale rooftop PVs were not adequately reviewed for the long term in relation to connections, installations, investment support, operating support and public buy-in and education, and therefore faced the risk of not being systematically prioritised nationally in order to accelerate the reduction of CO_2 emissions by homes in the long term.

Although homesumers were forced to install renewables such as PVs, there were benefits in electricity cost savings and they were drawn by financial benefits that feed-in tariffs could provide. These REFIT, however, regressed over time, as did incentive programmes with no other backup plan. Due to the FL CO_2 reductions in the earlier period between 2016 and 2030, the purchase price of renewable technologies decreased marginally for a small local renewable market in the country as compared with the majority of imported products. This motivation is substantiated by the plausible REFIT tariff data provided in Box 5.4.

Box 5.4 Plausible REFIT tariffs

The backcasting intended the REFIT scheme to be a motivator, but did not intend reliance on this scheme over the long period. As shown in **Figure 5.3**, Delphi data indicated that when comparing electricity rates with feed-in tariffs in c/kWh, the former would be higher than the latter by 2050. This implied that not much income would be obtained from REFIT between 2030 and 2050, should electricity rates be higher and therefore not be fitting as a motivator for installing PVs.

Figure 5.3 illustrates how Eskom rates compare to REFIT tariffs as these two aspects affect the likelihood of supporting them.



	2010	2020	2030	2040	2050
Electricty Rates M	51.9	90	130	170	210
REFIT Tariffs M	512	270	160	100	70

Figure 5.3 Eskom rates versus REFIT tariffs as per BAU trends

The BAU trend for REFIT tariff indicates that its benefits as a motivator is not a long-term solution. Other mechanisms would have to be implemented in the FL pathway to ensure uptake/adoption of renewables such as localisation, technology advancement and behaviour-change.

5.2.4 Lawful individuals

<u>Accelerating factors</u>. Under this pathway, homesumers were adopting renewables to comply with the regulatory requirements imposed on them and were therefore primarily reactional. As abiding citizens, they followed processes to install bi-directional meters and PVs from a list of service providers that government approved. This required being less concerned with matters related to energy usage and left all in government's hands to regulate the climate change challenge. They did not have to think of making changes to habits or reflect on how lifestyle changes could possibly contribute to living a more holistic low-carbon lifestyle. This was merely a method of solving the problem of load-shedding and electricity tariff hikes. After installation of micro-generation technologies, homesumers were content that electricity could now be used as before, continuing with usual habits, and even purchasing more goods with costs saved. After the short warranty period expired, homesumers were

maintaining the technology at their own cost, taking full responsibility for any arising usage problems.

Inhibiting factors. The demand-side requirements that were neglected related to the necessary collaborative processes between technologies and human behaviour. Between 2010 and 2030, citizens were passive bystanders who reacted to the authority of government. They were hardly included in the innovation process in a manner that would improve technology uptake and its durability. Micro-generation interventions were also hardly accompanied by complementary policies on behaviour at the micro level. Unless “non-rational” influences on energy-use behaviour and choices are factored into policy-interventions, people may not just maintain, but could even increase their energy consumption, even in the face of economic disincentives such as cost escalation.

Policies or programmes to promote innovation or diffusion of low-carbon technologies and infrastructure that lacked an understanding of how humans interacted with such technologies were likely to fail in terms of best practice in installation and use thus reducing potential CO_2 emissions reduction. While the policy emphasis was on providing financial incentives and regulations to promote micro renewable energy systems, including capital cost support and most recently the REFIT, not much attention wasfocused on how or even why the technologies were prioritised and used. There were some indications that the uptake of micro-generation technologies by middle-income households would prompt pro-environmental behavioural changes, but they also “locked-in” unhelpful practices, as the uptake was not accompanied by consciously-understood behaviour-change. There was also a risk that middle-income households could increase energy use after installing micro- generation technologies, if they believed that their energy source was now “green” and they could therefore use as much as they liked. Box 5.5 confirms the mindset of citizens.

Box 5.5 Mindset of citizens and the risk of increased “green-energy” consumption

In the backcasting, the groups concurred that at present, people sometimes did the right thing and sometimes not, admitting to weakness of will to making changes voluntarily. If this was the case, not much behaviour change would have occurred in the short term, which was critical in driving the required rate of change to achieve 80% CO_2 savings through making good choices, complemented by appropriate habits and lifestyles. Perceptions of comfort were based on adopting social success and what was known at the time, leaning heavily towards consumerism. Behaviours were still entrenched in unconscious and frequent bad habits or routines, rather than rational decisions. This was seen as particularly relevant to energy behaviours, due to the legacy of energy “invisibility” up to the 21st century, which needed a drastic turnaround and mindset change.

5.3 Back-loading (BL) pathway

5.3.1 Late commitment

Accelerating factors. The South African government tended to think climate change was not an African problem as they believed that the highest energy-consuming countries that were the cause of this climate catastrophe were the developed countries. Furthermore, when the state committed itself to the Conference of Parties (COP) 17 initiatives in 2011 and the COP 21 initiatives in 2015, the conditions were that carbon mitigation targets would be achieved only if they were financially and technically supported by developed countries. Owing to other priorities, more reliance was placed on developed countries, which is why commitment occurred at later stages between 2030 and 2050. From a magnitude perspective, there was a steep rise of CO_2 emissions between 2015 and 2030, following a BAU route, and from 2030 onwards to 2050, there was suddenly a steep decline in CO_2 emissions from 36.4 Mt CO_2 to 5.2 Mt CO_2 with a reduction of 31.2 Mt CO_2. In the BL pathway, government was well aware of climate change issues, but being a problem of the future, it did not compel urgent attention.

Inhibiting factors. The BL pathway was unlikely to be the adopted pathway due to procrastination delaying government commitment and wasting time rather than taking full national responsibility for climate change mitigation. Generally, this involved a situation where two sets of preferences, long- and short-term, were caught up in a perpetual conflict. The relevant trade-off in the case of climate change was between the well-being of future generations versus that of people who are alive now. This type of decision-making, to solve problems that required altruistic leadership traits, became more difficult for developing countries where basic needs had not yet been satisfactorily met. It was understandable for government that economic growth remained the central political priority, but the kind of growth that it was seeking to generate was not aimed at solving core issues. Moreover, ingrained behaviours were extremely resistant to sustained change and transformation. However, slow gradual action would have made it easier for both current and future generations.

Perhaps the worst penalty resulting from the country's procrastination was the lack of citizens' support, as many assumed that their authorities had been protecting them. When the consequences of climate change struck and became the new normal, or a sudden change in leadership occurred by 2030, the changes would be of a magnitude larger than one could manage. Accordingly, citizens did not understand why, all of a sudden, their rights were curtailed and their taxes went through the roof because their government suddenly came to a realisation of what should be done – instead of having prepared everybody and everything over time.

5.3.2 Delayed heavy-handedness

Accelerating factors. The BL pathway's heavy-handed approach had similarities and differences in relation to the FL scenario in that the relevant periods, when this occurred, gave rise to different effects. With government committing more fervently to climate change mitigation efforts, at around 2030 it had the advantage of having more time to plan for funding of R & D, commercialisation and incentives. Similar to FL, the plan was to force citizens to comply with stringent policies to implement renewable energy, of which PV was a viable option. However, this would be applied through rational choice and consumer preference models promoting pro-environmental behaviours by providing people with the right information, financial incentives and upfront product designs. This was a linear model, with most of the changes being instigated by the supply-side.

Inhibiting factors. The framework for this pathway was based on the primary notion of leaving BAU momentum to prevail until it was too late to make meaningful/rectifiable changes. By rationally weighing up the costs and benefits of its approach, government thought it would resolve the problems on climate mitigation. However, this was a narrow approach that tended to marginalise cultural and demand-side aspects, and also lacked more dynamic orchestration of change on multiple levels. The BL pathway co-ocurred with heavy-handed tactics, which did not allow any freedom of choice under an authoritarian "order seeking" government. Regulators had often chosen some kind of command-and-control regulation, by which they persistently disregarded free choices and market-based options and allowed people little flexibility in promoting environmental goals.

Academics, policy experts and business leaders had been searching for alternative ways to induce changes in a more liberal way that would allow freedom of choice for more positive outcomes. It would have been more desirable to investigate how choices could be made at different levels of consciousness to be able to decide on the best approach to induce change for a given situation, context or personality – preferably using a combination of methods.

Choices could be made easier by capitalising on the “bounded rational” nature of human decision-making through, for example, soft nudging. This could have been done in a way that was more rewarding to people and thus less punitive. “Nudging”, is a form of progressive paternalism; it is paternalistic in that it assumes to know what is good for you (e.g. to save for a pension or avoid being knocked down), but it is liberal in the sense that it merely nudges you towards these objectives (e.g. by making the pension a default you could opt out of, or by painting “look left” at crossings), while leaving the choice in the citizen’s hands.

Nudging could have changed the environment in such a way that people would change their behaviour, but it would not have changed people at any deeper level in terms of attitudes, values or motivations. In this respect, nudging creates what psychologists call “first-order change” rather than “second-order change”. One could have included more transformative behaviour change interventions that uses reflexivity as a tool to inculcate the self-aware autonomy that the population at large now requires to meet the demands of the modern world. This would have implied more intrinsic awareness of a situation and understanding of what was happening and what the implications would be in order to have wanted to make changes for the better.

In the case of “nudging”, it was possible to guide people into certain forms of behaviour by offering simple, although apparently irrelevant cues. It turned out that if certain objects were made visible and salient, people’s behaviour could be responsively influenced. For example, mere exposure to the scent of an all-purpose cleaner had proven to make people keep their environment cleaner while they ate. In view of the unsuccessful onedimensional approach of coercion and the many other softer progressive options available that allowed more flexibility in finding solutions in overcoming systems inertia in a diverse cultural society, it was less likely that the force and punishment mechanism would be the predominant condition under which complex changes would be pursued.

This section argued that coercion and the rational choice approach were not sufficient for overcoming systems inertia, especially where changes in a complex socio-economic system in middle-income homes required dynamic orchestration of changes at multiple levels. Owing to these shortcomings, the BL pathway was deemed to be less likely to be adopted. Box 5.6 provides the plausible data for the backcasting and Delphi methods on the balance required between authoritarian and progressive approaches.

Box 5.6 Balance between authoritarian and progressive approaches

The backcasting concurred that when it comes to making changes, the stakeholders preferred factors such as carrots and/or sticks and the extent to which they motivated lifestyle change. Most people lacked the motivation to make energy behaviour changes or only sometimes did so, allowing indoor routines and habits to dominate over economically “rational behaviour”. By providing a combination of coercion, nudges and reflexivity, this had a greater effect on making more lifestyle changes, whether rationally or more intrinsically. This resulted in government shifting priorities with a balance between inducement and enforcement through equal weighting on the sticks and the carrots that contributed to cultivating a lifestyle sustainable for all.

5.3.3 Servicing shortcuts

Accelerating factors. It was only after BAU trends continued until 2030 that Government began to realise with increasing evidence what the benefits of achieving low-carbon homes would be. Consequently, they also understood that economic development could be addressed through sustainability principles and low-carbon initiatives. Political leadership committed to such plans only came into effect after 2025. In this period, there was time for resource planning and funding for R & D and commercialisation. In addition, policies could have been developed and partnerships created for incentive programmes that could motivate the uptake of renewables, especially where energy efficiency standards for new homes would not achieve the deep CO_2 emissions reduction in the FL periods by 2050.

Inhibiting factors. The time delay had undesirable outcomes as far as cost and affordability were concerned. Macro-economic conditions were such that home prices increased cumulatively by 2050; thus it would have made more sense to have started with a renewables boost sooner. Should the costs of installing PVs have decreased over time owing to PV’s cost reduction potential, as it matured, it might have made sense to install PVs in the same period as in the BL pathway. It was also likely that late implementation of cheaper PVs would not have been a stronger motivator should incentives have regressed over time. Homesumers would have had to install low-carbon technologies themselves in addition to paying more for homes. Moreover, more stock at a later period would require vast PV interventions that would increase incentive costs to the country, even though PV prices would come down. Box 5.7 provides the plausible scenarios for financial drivers.

Box 5.7 Plausible scenario for financial drivers

The backcasting data showed that there were divided opinions about the financial drivers that would be required for promoting the uptake of low-carbon technologies. On the one hand, people did not rely too much on incentives to install PVs, albeit government would still provide some incentives in terms of magnitude or time. Renewables such as PVs were also accepted as being affordable if the investment was justified on the basis of a life-cycle costing payback period. Emphasis was placed on true democracy to allow for more flexibility in energy use as well – if one wanted to pay more for using more energy, that option was there as well.

Owing to the uncertainty of the national budgets available in the future, it was decided that it would be better for more costly (upfront costs) technologies and packages to be implemented for different lifestyle models if they were justified on the basis of payback periods without necessarily becoming incentivised.

The Delphi consensus-building method indicated that incentives would possibly be required for installation of PVs over and above generation incentives such as REFIT.

Introducing a micro-generation energy boost required adequate time and funding not only for R & D, but for the service sector's commercialisation, monitoring and evaluation processes. This would have ensured local production, knowledge and skills, maintenance and technology advancement, and hence smoother uptake thereof. For this BL pathway, there was a lack of time for following through with the outcome of monitoring technology during the uptake phases of the micro-generation technologies; behaviour change initiatives (especially in pursuit of pathway-corrections) were not planned for. Usually, more informed data towards the end of the technology adoption process made enhancements possible and prolonged the cycle of uptake, or allowed for the declining process or perhaps the beginning of new inventions. This would have allowed for reinvention, which occurred as a result of an adopter wanting to make modifications or improving on the performance. More participation of users in order to allow for customisation and hence more rapid uptake was not included. Further, there would be a stage where the technology adoption was confirmed; if not followed through (the stage), it still had the potential to be declined. The pathway would not be chosen as there were inadequate path correction opportunities, given the limited period between 2030 and 2050 once evaluation and feedback became available.

Inhibiting factors. The challenges faced by low-carbon technologies can also be exacerbated by the potential of high-carbon technologies to become increasingly competitive, whether through falling fuel costs (for example, if larger discoveries of shale gas proved to be extensively exploitable at low market cost), through improvements in their characteristics or via increased regulatory protection or barriers to entry of competing alternatives. The tendency of improvements in existing technologies − to be stimulated by competition from new technologies − was known as the “sailing ship” effect or the “last gasp” effect. In such case, these circumstances should have been identified earlier for the better performing low-carbon technologies to incorporate these highly competitive market conditions and build the necessary enthusiasm, technology, infrastructure and forms of organisation and institutions, to prevail over the established high-carbon technologies with less potential. This would require political vision, skill and determination in the face of high levels of socio-technical and economic risks and uncertainties. If monitoring and evaluation are not incorporated in the process of low-carbon technology uptake, the risks are high that high-carbon technologies could be locked-in the system and make it even harder to allow for beneficial innovations to prevail.

If the process of monitoring the uptake was not followed through to also include how the technology affected behaviour, there would be a risk that improved efficiency would not lead to the level of demand reduction that a simple calculation would lead us to expect. This perverse outcome, known as the “rebound effect”, could have taken several forms. Direct rebound effects could have occurred when consumers spent the money they saved owing to their uptake of energy-efficient appliances to use more energy, or used an appliance more often. Indirect rebound effects could have occurred when consumers spent the money they saved from energy-efficient goods or services on yet additional energy-intensive goods or services. Economic rebound effects could also have occurred when energy-intensive goods became more competitive, thus increasing demand for them. These were all risks that could have become realised as a result of long delays reinforcing bad habits/behaviour even further. Therefore, due to the risks of rebounding because of unattended behaviour-change, there could have been more constraints contributing to the BL pathway not being chosen by stakeholders.

5.3.4 Path-dependant individual behaviour

The lifestyle that allowed for the BL pathway adoption at the time was one that led to path-dependant habits, which compared with FL, but were even more deeply entrenched. Along this path, the only changes made were the interventions on mainly the supply-side between 2030 and 2050, forcing the uptake of renewable technology such as PVs, which at the time was the only way to get a large number of individuals to adopt micro-generation technologies. This reduced the responsibility for making changes at the household level and allowed homesumers to continue their relentless pursuit of status through displays of material goods. The middle-income group were incentivised, which made passive/reactionery adoption easier as it reduced the payback period and also benefitted from the REFIT intervention. Sudden changes in lifestyle were not necessary, especially when it came to having to make further intrinsic changes.

Inhibiting factors. Because of the cost of living being a major driver of change and the reality of strict enforcement of PVs for which incentives became fewer over time, living a low-carbon lifestyle became a necessity. In the BL pathway, homesumers had to reduce CO_2 emissions further due to the BAU pathway prevailing till 2030. Subsequently, it would be necessary to revert to values calculated to maintain a standard of living that would provide a decent life. In material terms, this could head in the direction of a more egalitarian society, which provided the basics for people to live well and participate in society. Much of the “over-consumption” that one associated with consumer lifestyles, including the relentless pursuit of status through displays of material goods, would be reduced. At the same time, the intention was to protect the requirements for a decent life, and there were some indications that with less competition and fewer material burdens, well-being in such a society may even improve.

Furthermore, the low-carbon technologies were not living up to the homesumer’s standards and were excluded from the innovation and reinvention stages which would have included modifications according to homesumers’ needs. With consumers insufficiently prepared to rely on more intrinsic values and make voluntary changes, as well as not having an input to the customisation of products, the BL was unlikely to be the chosen pathway.

5.4 Less-likely pathways conclusion

The FL pathway will not be chosen owing to the rapid and forced uptake between 2010 and 2030, which did not allow for adequate planning for R & D, localisation and behaviour-change. The pathway required a longer time for path correction owing to slow R & D, but because of a steady decline in adoption in that period and stock increasing, carbon reduction was not decreasing at a steady rate anymore. As a result of the heavy-handed supply-side enforcement and impediments to an orchestration of change on multiple levels, there was a lack of citizen participation that therefore did not allow for modification of technologies and did not entrench more intrinsic behaviour-change. Behaviour change would be required possibly to live a more modest lifestyle in view of the cost of living and especially the resource/environmental cost of materialistic/consumerism lifestyles.

Similarly, the BL pathway could not be adopted as the procrastination in implementing changes that occurred between 2030 and 2050 reinforced systems inertia thus hindering the orchestration of change on multiple levels. This prevented adequate time for monitoring and evaluation, and the confirmation of adoption of renewable technology to allow for path correction on time. Some inhibiting factors that contributed to the pathway not being adopted were heavy-handed tactics, insufficient resources and funding for knowledge and skills, lack of monitoring and evaluation, and participation in behaviour change initiatives. Owing to the BAU pathway prevailing till 2030, behaviour changes were the most difficult to pursue, thus further entrenching bad habits.

CHAPTER 6

MORE-LIKELY PATHWAYS

6.1 More-likely pathways introduction

The pathways appraised in this section were more likely to be chosen in the South African context because of the predominant accelerating factors within the provided workable (more pragmatic) pace that reduced CO_2 emissions. These were the even-loading (EL) and middle-loading (ML) pathways characterised by a slower rate of technology adoption and deeper-reaching behaviour-change. The final ML pathway would most likely be chosen by South Africa due to the carefully considered accelerators that would ensure attaining 80% carbon reduction by 2050. The slower uptake of low-carbon technologies was mainly due to systems inertia principles, whereby any change in a complex socio-technical system for low-carbon technologies used in average-sized homes required systematic orchestration of changes at multiple levels.

Socio-technical transitions steered the framework for structuring the conditions under which the pathways occurred. There were similarities and differences with the previous chapters regarding the circumstances under which the more-likely pathways occurred. What differed was that the accelerating and inhibiting conditions were structured directly under the different MLA levels, including:

- the macro level of governance incorporating government, institutions and infrastructure that develop policies and strategies;
- the meso level of supplying services to the individual, including manufacturers, suppliers and contractors; and
- the micro level of individuals and their lifestyles and behaviour.

The necessary conditions for the hypothetical pathways more likely to be chosen by stakeholders are provided. Accelerators which boosted the momentum of the uptake of relevant low-carbon technologies over the specified time horizon are provided; this can be seen in a positive or negative context. Should an accelerator be seen in a negative context, it is subsequently motivated as an inhibitor due to its inability to adequately uphold its effectiveness to warrant it being the chosen pathway. Inhibitors were also the factors that supported the reasons why a relevant condition would not be chosen by South African stakeholders owing to its constraining of socio-technical advancement.

As with the previous chapter, cross-referencing has been systematically applied without over-burdening this chapter with numerous citations to literature as was done in the first three chapters. The conditions were substantiated by selected exemplar Delphi and backcasting data (as reported in Chapter 4) that have been "abstracted" in boxes. The boxed text is the supporting data that is separated from the main unboxed/main text that focuses on the conditions that led to the pathways. Only key characteristics of a relevant pathway were verified with cross-checked data from Chapter 4 in order to prevent repetition. The final preferred ML pathway that would most likely be chosen by South Africa will be validated by the boxed text, consisting of selected backcasting strategies (why the pathway occurred), of Chapter 4. All the pathways were written in the past tense providing the conditions that allowed the 80% CO_2 emissions reduction to have occurred starting from the future to the present.

The pathways were compared with a typical s-shape technology diffusion journey in terms of the Diffusion Innovation Theory (DIT), whereby there was a defined start, middle and end phase. Although the pathway was shown as one continuous line/process, this does not preclude non-linear events occurring according to the MLA framework, including reiteration of cycles that would reflect the dynamic technology diffusion patterns. The cycles would be steered by key forces that could induce or deter change at different levels.

6.2 Even-loading (EL) pathway

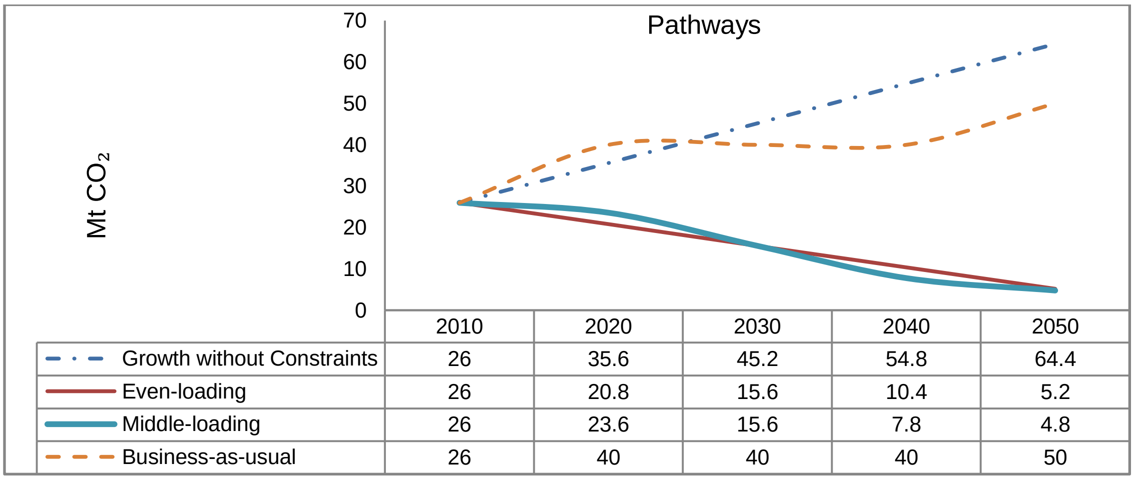
6.2.1 Long-term government commitment

Accelerating factors. The state learnt that short-sightedness does not provide the results required for achieving solutions (involving levers such as technology, markets, policies and lifestyle) to the complex problem of transitioning from a high-carbon to a low-carbon society. Instead, government began to develop a more comprehensive vision, insisting on long-term sightedness instead of short-sightedness in the planning and delivery of governmental responsibility for societal growth and development. It was recognised that short-sightedness would cause mediocrity, dependence and confusion. For this EL pathway, the strategy was to set a long-term carbon reduction target for the household sector of 80% by 2050, with interim targets every five years. Although government's approach was to break down a complex problem, it was focused on reinforcing the ongoing transitioning that was already gaining momentum.

6.2.2 Governmental gradualism

Accelerating factors. Political change was achieved in small incremental stages (governmental gradualism) rather than abrupt strokes that brought about reforms in CO_2 emissions mitigation. Gradual changes accumulated with improvements on existing systems, which did not require sudden discontinuities, but instead, built even momentum in technology diffusion and social change. Initially, short-term goals were formulated and implemented, while ensuring they remained connected to the long-term goal. The rate of gradual change was influenced by the quality of leadership, which steered the country towards a shared vision of deep carbon reductions. This influenced the extent of the required change in momentum for overcoming systems inertia in a complex socio-technical system at multiple levels.

Government was setting clear and consistent targets realised through the enforcement of policies (technical regulations) for existing and new homes of the middle-income group by 2050, as required by science (determined by research of Intergovernmental Panel on Climate Change). Between 2010 and 2050, a consistent reduction was achieved from 26 Mt CO_2 to 5.2 Mt CO_2. **Figure 6.1** provides the graphs for the EL and ML pathways.



	2010	2020	2030	2040	2050
Growth without Constraints	26	35.6	45.2	54.8	64.4
Even-loading	26	20.8	15.6	10.4	5.2
Middle-loading	26	23.6	15.6	7.8	4.8
Business-as-usual	26	40	40	40	50

Figure 6.1 More-likely pathways – Even-loading (EL) and middle-loading (ML)

A longer period to attain the target was allowed; less CO_2 needed to be reduced by homes, which made the target more attainable. It became more important to focus on existing but evolving low-carbon technologies in the South African market, such as SWH and other common interventions. This would equate to SWHs and other renewables (to a lesser extent) providing carbon-neutral energy, and the commonly accessible energy efficiency interventions reducing heating and cooling loads through design measures, especially related to the building envelope. The regulations for low-carbon interventions in existing and new homes were stringently enforced by municipalities/regulators. Regulators even charged a penalty fee for non-compliance with low-carbon regulations for exceeding the minimum requirements. Incentives were also instituted to motivate homesumers who wanted to reduce more than the required minimum carbon reductions through carbon neutral-renewable technologies.

Inhibiting factors. Whereas long-sightedness had its advantages, it depended greatly on how inclusive the orchestration of changes was under a softer, “paternalistic” government that induced gradual change. The quality of government leadership over time was inconsistent and inhibited sustained transformational changes. Political adversaries and cynics exploited uncertainty of long-term problems to their advantage. This is a typical example of how people discounted future risks.

By undermining “slow problems” (the effects of climate change do not manifest for decades) and focusing mainly on the existing standards, thus leading to inconsistent incremental changes, people faced the risk of becoming too complacent with the status quo. Gradual change threatens to undermine more drastic public policy and collective change where major change requires a combination of innovation and substitution (invention). Usually, people tend to be more sensitive to changes that occur quickly and ignore changes that happen gradually. Finding a balance between making gradual and making more radical changes becomes critical in overcoming disinterest and thus ensuring more sustainable changes.

6.2.3 Service sector moderate resources

Accelerating factors. To attain the set targets incrementally, government invested in least-cost interventions such as those included in home and solar-water-heating low-carbon technologies. Solar water heaters (SWHs) were a fairly mature technology, although research and development (R & D) still continued in the country, providing scope for saturating the market. This required funding for developing quality infrastructure for SWHs. The infrastructure included the development of testing laboratories and certification bodies, along with the supporting organisations for accreditation, inspection, installer training and standards development. Most of the alternative technologies already in the market were evolving into mature technologies. The quality of these alternative products improved and diffused more easily, thus improving accessibility and servicing.

Inhibiting factors. There was a lack of R & D in newer low-carbon technologies to allow for more radical change in the long term. Within the learning processes of technical change, the main R & D activities needed to include basic research and applied R & D, which were not well provided for. Basic research occurred at the invention stage (the early conception stages of a technology), which was the slowest part of the pathway and normally showed a definite lag followed by shorter lags. This lag was the stage when invention or innovation of technologies was relevant in addressing a gap in the market with large potential for acceleration in adoption. At the research stage, structured/regular workshops should have been held with heterogeneous groups of actors representing a niche technology market on multiple levels to plan out the process of improving the scale-up of the intervention/adoption. These actors/participants needed to be representatives from government, services and technology supplier companies as well as policymakers, researchers, industry professionals, consultants, manufacturers, suppliers, agents and communities who would have to provide equal input and have the opportunity to influence change. The workshops would also have considered the end-user of a technology, as well as the availability of funding. Setting clear goals and considering the status-quo inertia would make it possible to develop scenarios and choose the best possible pathway to provide the momentum to overcome such inertia in the system over a longer period.

Technologies at different stages of maturity had different learning-by-research and learning-by-doing curves. As technologies matured, applied R & D became more relevant to the innovation and diffusion stages of technical progress relative to the invention stage, especially during the early stages. Although the knowledge gained from learning-by-doing from the manufacturing process, scale of production and utilisation were also important sources of technical progress, there was not adequate time allowed for initial research to include the invention and innovation of emerging low-carbon technologies, such as small-scale renewables. The backcasting method confirmed the significance of R & D as depicted in Box 6.1.

Box 6.1 Accommodating research and development in the pathway

The backcasting results reinforced that R & D was completed for the successful adoption of technologies addressing people’s needs with regard to materials and renewable technologies. The quality of materials became increasingly important with attributes that showed that materials were environmentally friendly and more durable. A proper planning stage occurred for ten years for a comprehensive and integrated renewable energy grid design for a system that allowed for a diverse energy mix to have occurred by 2020. This included resources, funding, commercialisation, covering research and developing knowledge and skills. Systems were designed that bore in mind interrelationships that enhanced a nested level of smartness. By 2020, interconnectedness became more pronounced. The uptake of renewables for homes surged. Smarter manufacturing techniques led to desirable smart homes, combining advanced smart technologies with eco-friendly technologies, which was what the middle-income group aspired to have. Research was funded by private institutions, government or international donors to study low-carbon eco-villages, which would enhance social structure, induce cost savings, reduce carbon emissions and maintain a good standard of living Entrepreneurs introduced new product models and architects led in designs of modular system typologies. Modular systems and designs obtained brand names that became desirable objects.

The pathway did not define the point when critical mass was attained, which was at the point before major acceptance and uptake, implying that enough individuals in a system had adopted an innovation such that further rates of adoption of the innovation of the innovation became self-sustaining. The adoption occurred because of more mature technologies not requiring additional periods of exposure as compared to newly emerging innovations. Therefore, less communication was required in the early stages of innovation of the EL pathway. Opinion leaders and their intermediaries found it easier to influence other leaders on the uptake to a point of influencing enough people for reaching the critical mass.

Monitoring and evaluation of the technology uptake and behaviour change processes of innovation along the EL route would have made it possible to identify where improvements needed to be made. More enhanced data availability towards the end of the technology adoption process made enhancements/upgrades possible and thus intensified the cycle of uptake, or even allowed for the process of decline and perhaps, the beginning of new innovations. From the services sector level, innovation would have become successful for a renewable energy system if there was a rich combination of good-quality products, sound/reliable installations and proper operations and maintenance over the system’s life cycle. However, in order for the latter to work, training and certification of practitioners would have had to be prioritised.

Reinvention is the degree to which an innovation changed or was modified by a user in the process of adoption and implementation. An innovation is not necessarily invariant during the process of diffusion, and adoption of innovation is not necessarily a passive role of just implementing a standard template of a new/improved idea. Many adopters want to participate actively in customising an innovation to fit their unique circumstances. Innovations diffuse more rapidly when they can be reinvented, subsequently changing behaviour and thus becoming more sustainable. Plausible reinvention required by homesumers as established in the backcasting method is provided in Box 6.2.

Box 6.2 Homesumer preferences

The backcasting clearly favoured modular smart eco-homes in eco-villages (as a lifestyle choice model that reduced costs) and pre-manufactured homes customised to homesumers' needs to fit their unique situations. By 2030, at least 30% of new homes were smart prefabricated eco-homes, which had been introduced by 2020.

In the Delphi, a pattern of housing growth was forecast following historic trends, with the likelihood of apartments experiencing most growth, followed by detached bricks-and-mortar, and then cluster homes.

The consequences of the adoption or rejection of an innovation had to be considered and monitored more closely, as this was the stage where attitude and behaviour change could be reflected. Although the adoption of an innovation followed a linear process, all innovation processes were viewed to be reiterative or cyclic due to potential for reinvention.

6.2.4 Adoption or rejection at individual level

Accelerating factors. The decision process experienced by an individual (or other decision-making unit) consisted of acquiring the knowledge of an innovation, the formation of an attitude toward the innovation, the decision to adopt or reject, and the implementation and post-implementation experience of the adoption of the new technology. This last decision stage of the user-process was where confirmation occurred, which was when individuals sought reinforcement of an innovation decision that had already been made, but could reverse the previous decision if exposed to conflicting messages about the innovation, which can occur along any development process. The evolving technology (e.g. SWH) and alternative energy interventions had been in the market long enough to allow for not having to take extra precautionary measures (such as monitoring and evaluation) in order to ensure proper market adoption and saturation with the products.

Inhibiting factors. There is a high risk of rejection of evolving technologies (such as SWH) and even more so of emerging renewable technologies (such as PV) should there be less research funding or servicing in the operation stage. Research funding and servicing in the operation stage are essential factors for such carbon-neutral technologies to be adopted more widely and thus promoting independence from the conventional electricity grid. These risks lie in the weak understanding of preferable attributes that a technology needs to possess, owing to homesumers not being meaningfully involved in the decision-making process. In addition, motivation programmes should have been implemented by government and the service sector for individuals to become more aware of the need to make responsive changes voluntarily.

6.3 Middle-loading (ML) pathway

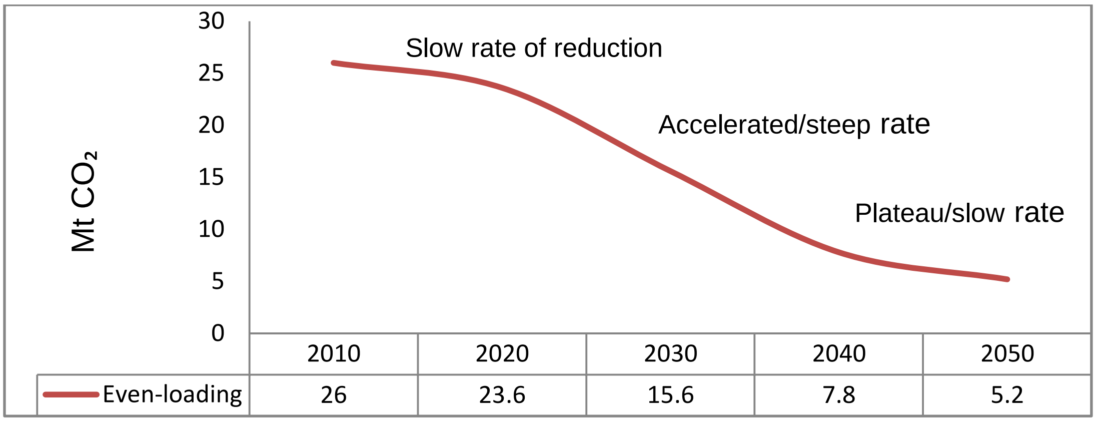
6.3.1 Invention and innovation accelerators

Transformational leadership. In the ML pathway, government realised that transformational leadership was required in order to articulate a vision that described a better future and was congruent with the deeper values of the citizens. The leaders' personal examples served as a model of the kind of behaviour required to attain the vision, which was held to be important for the achievement of a long-term orientation and longer-term goals. To lead by example required the capacity to develop and communicate a vision which was attractive and motivating for a diverse range of actors, and which all collaboratively pursued. This required actors working together to define and develop their relationships not just as issues of influence and leadership, but also on how to keep the momentum going till the vision is attained. Having a shared, overarching goal or vision of the future ensured a shared frame of reference for government, which made it easier for other actor groups and individuals to reflect on effectively with regard to their roles. Transformational leaders aided this process by regularly discussing the goal with the citizens (clarifying/enhancing a shared vision and leadership commitment), and thus stimulating reflexivity in an indirect way. Linking transformational leadership with softer nudging approaches proved to be ideal in ensuring that changes were made more holistically in response to complex societal issues.

The approach that clearly caught the zeitgeist was “nudging”, which became a wide-ranging term to cover any change in the environment that affected behaviour as informed by behavioural science. From a government and leadership perspective, this led to the philosophy of “progressive paternalism” on which nudging was based, which constantly addressed the risk of merely defaulting to paternalistic patterns. The deepest problem with nudging was that it was not transformative enough. Nudging changed the environment in such a way that people responsively changed their behaviour, but it did not change people at a deeper level in terms of attitudes, values or motivations. In this respect, nudging created what psychologists called first-order change rather than second-order change. It was held that, even though individuals may have been imperfect decision-makers, they still possessed more information than government rule-makers. It was further argued that if government started manipulating decision-making processes, then individuals would not necessarily continue their commitment to learning how to think for themselves. This was thought to be a result of technical solutions targeting discrete measurable problems. Adaptive challenges, on the other hand, required changes in attitudes and perspectives, not just behaviours, and could be addressed only by the people themselves through a reflective mindset. The difference between a technical and adaptive solution can be illustrated by the following example. Individuals paying extra for carbon offsetting represent a technical solution to GHG emissions reduction, as is the case of raising taxes on flying, while getting people to fly less often for environmental reasons constitutes an adaptive challenge.

What was lacking in behaviour change approaches, however, was a holistic model that recognised that our controlled (conscious deliberations) and automatic (unconscious behaviour, choice architecture and nudging) systems were intertwined and mutually reinforcing. A new approach that is reflexive was followed because it was a form of learning – learning not only about what might be done, but also why and how it is to be done. Reflexivity is not a term commonly used in everyday language, and a simple way to describe it is “self-awareness in action”. While “nudge” and “think” rest on an unhelpful dichotomy between controlled and automatic mental processes, the “steer” approach tries to align strategies for behaviour change with human nature. People have the ability to regulate social relations, where “social” refers to human interactions and the related norms, biases, mores and institutions. This approach, which considers the more holistic scientific view of human nature and people’s perceptions, helps to foster the transformative learning we need in order to make significant and enduring changes to our behaviour particularly in support of CO_2 emissions reduction in homes.

A transformation along the hypothetical pathway in terms of magnitude showed that most CO_2 reductions of 15.8 Mt CO_2 occurred between 2020 and 2040. The first decade between 2010 and 2020, and the last decade between 2040 and 2050, however, showed a slow decrease of 2.4 Mt CO_2 and 2.6 Mt CO_2. **Figure 6.2** provides the graph for the ML pathway.



	2010	2020	2030	2040	2050
Even-loading	26	23.6	15.6	7.8	5.2

Figure 6.2 Most-likely pathway – Middle-loading (ML)

<u>Relocalising research through funding</u>. A condition for the ML pathway to be adopted was a focus on localisation, which prioritised systematic diffusion and adoption of low-carbon technologies and behaviour-change. Shortages in local carbon-neutral products and skills required inventions and innovations to be pursued more earnestly. It was sensible to place emphasis on those technologies that drew on the most abundant resources and consequently tended to be cheaper than those that required scarcer resources. However, South Africa had to decide where this balance occurred in a way that would meet its basic food, energy and housing needs primarily from its own resources. For example, in the case of PVs and energy storage, most of the parts could be manufactured in the country and innovation could contribute to finding new and more efficient ways to innovate/improve on such low-carbon products/technologies.

Transformation occurred in the middle-income group housing sector, for which greater government and business funding for R & D in basic and applied research was attained between 2010 and 2020. This funding ensured that development and economic growth could happen in the niche of low-carbon technology areas such as renewable energy technologies, material sciences, appliances, LEDs, social sciences and modular housing systems, with more focus on local resources. At the same time, there were products best produced by a few companies operating at a global level because of increasing returns to scale. Therefore, local and global economies were sensitively factored into the vision in a complementary manner. In the process of transformation, the aim was to get a better balance between the two-level economies. Between 2010 and 2020, the global sourcing was dominant, and therefore scales were weighted to make them eventually tilt the local way. The backcasting findings substantiated the condition for funding in research and product development through strategies depicted in Box 6.3.

Box 6.3 Funding and finance

The backcasting findings indicated that research was funded by bodies relevant to the study of low-carbon technologies and eco-villages, which enhanced social structures, induced cost savings, reduced carbon emissions and maintained a good standard of living. Alternative funding mechanisms were planned and sought from international donors and multilateral organisations willing to sponsor worthwhile low-carbon projects, such as the Kreditanstalt für Wiederaufbau (KfW) and the International Finance Corporation (IFC) for incentive programmes. The Department of Science and Technology as a regulator collaborated with relevant departments such as Environmental Affairs, Development Bank of South Africa, Economic Development and National Treasury and improved programmes related to research including the housing sector. This allowed incentive programmes to be developed that provided motivation and assistance with upfront costs for low-carbon technology interventions. However, it was in the best interests of the government or the service sector to introduce sustainable incentives for low-carbon technologies that would utilise funds from, for example, carbon tax schemes and shorten payback periods to homesumers. To transit to a low-carbon society, South Africa fundamentally pursued the design of a comprehensive and integrated energy system. The relevant bodies that were responsible for these initiatives from 2015 onwards were the Department of Energy and the state-owned enterprises such as Eskom and NERSA.

It was inevitable that linkages between research organisations and firms nationally and internationally were strengthened within a “glocalisation” approach (adjustment of products to local culture with an improved balance between local and global economies), which resulted in acquiring more knowledge, funding and partnerships. Skills deployment and communication skills became an integral part of the research programme, and also improved coordination in sharing of learning, which united government, science and technology management. The direction of research was enhanced through the distinction between those who were responsible for the regulatory framework affecting all institutions with R & D as a primary mandate and the line departments who set objectives and budgets of these institutions within the framework of the visioned goal and responsive pathway.

The transition from invention and innovation to the diffusion stage was crucial for technical progress. Theory informed policies, and empirical evidence could improve the process and contribute to better allocation of technology promotion funds between R & D and capacity deployment across technologies. Part of the capacity-building included monitoring the R & D strategy and the action plan by government as a fundamental process to evaluate progress in terms of clear high-level national goals to steer responsive changes in research.

Transformation required the inclusion of all actors within the macro, meso and micro levels of a technology market niche/space, as defined under the definitions in Chapter 1 and their interactions between processes. The interrelationships between actors entail a non-linear, coevolutionary/coevolving process with a more iterative, feedback model where actors hold centre stage. Transformation engendered a better understanding of what drove individuals and communities into making behaviour changes and also improved technology uptake through research. Research teams collaborated on the best ways forward from a socio-technical perspective in order to ensure the diffusion of low-carbon home interventions. Feedback was provided to research organisations on preferences of homesumers, who also became part of the innovation programme. Through adequate commitment, funding was attained for the supply side and the demand side interventions. These funds also made it possible to obtain insight into behaviour change in a holistic model that provided rewards for improved uptake of a new technology by individuals, communities and organisations. Initiatives that combined multiple interventions were more effective than those that used only one intervention at a time. They involved a combination of antecedent interventions such as having linkages with a network of experts and incorporated communication tactics with consequent interventions such as feedback and rewards.

Carbon-mitigation goal orientation became an important aspect when involving actors from multiple-levels of a technology niche market. Local sustainability drove the goals that required local services and local production, enhancing individual, community and regional autonomy through self-service, disintermediation (reduction in the use of intermediaries between producers and consumers), and mass customisation. Findings from the backcasting method provided the preferences that became the mechanisms to achieve the carbon targets, as summarised in Box 6.4.

Box 6.4 Setting production goals

A renewed belief in the importance of community, pressing environmental concerns and cost consciousness were moving people away from top-heavy, centralised and controlled forms of consumerism towards one of sharing, aggregation, openness and cooperation. By 2040, people were increasingly inspired by creative and entertaining designs through the best product brands for individuals to live a decent life that would work for the socio-economic and environmental goals, and make every day living easier with factors including comfort, durability, user-friendliness, privacy and collaboration in eco-village co-housing. Between 2030 and 2040, communities became more aware of environmental issues and preferred materials that could breathe, absorb CO_2, be recycled and reused, dismantled, were biodegradable and had characteristics of biomimicry with R&D initiatives working in collaboration with research institutions and the service sector.

In terms of the product type, preferences for goods and services were not formed just on the basis of price, but also on product attributes and their brands, and the value of these for consumers. Consumer-customised homes led the trend without increasing costs, making the customer the focal point and promoting a service orientated economy. Research institutions intensified efforts to develop new products at more affordable prices. Buyers in different technology niches set trends. New niche technology markets stayed abreast of underperforming mature products as diffusion of technological innovations of new low-carbon technologies required interactions between role players such as entrepreneurs, firms and research institutions and communities, which became easier by 2040. By 2030, preferences of the middle-income group included the durability and benefits of smaller more affordable and desirable objects. The design systems at that point needed to bear in mind interrelationships that enhanced a nested level of smartness, e.g. increased uptake of the smart car became part of the smart grid and the smart car batteries worked for the smart grid. From 2018 onwards, it became necessary to promote more low-carbon technology production through localisation.

Planning for commercialisation. Between 2010 and 2020, this became a critical issue for research institutions or firms attempting to profit from innovation by translating new technologies into products, processes and services, and selling them into the newly emerging market niches. For many new technologies, commercialisation implied scaling up from prototype to volume manufacturing, and committing greater resources to marketing and sales promotion. Typically, the cost of commercialisation activities far exceeded that of R & D. Research and development and product design comprised approximately one quarter of the cost to introduce a new product to the market. What was taken into account was that researchers or firms avoided developing innovations to the prototype stage that often did not become fully commercialised because of the lack of financial and managerial resources. Open innovations were licensed to other firms, sold off in the form of a divestiture or simply passed on at zero cost.

Service provider's decision-making. In order to improve localisation, firms, entrepreneurs and manufacturers played an important role in the commercialisation and uptake of technology across the product life cycle. In the diffusion of technology, there was constant movement from product/service inception to full adoption, but what made this holistic process different was the timing which involved an orchestrated interaction between external forces, actors, linkages, skills, communication and resources in order to fully exploit the emerging market niche/opportunity.

Decisions to commercialise new technology were made by government or entrepreneurs to whom a prototype was passed, but who were closely linked to characteristics of the innovation system in which the entrepreneur operated. The constant pressure and tension in the market with different technologies at different stages of innovation diffusion contributed to the tactics for each niche market player. Imposing additional external pressures (e.g. macro-economic) created dynamic shifts that provided the opportunity to direct the market towards the low-carbon pathway. Ultimately, the time of uptake was critical and was governed by two key drivers which were the rate of incremental learning and the systems' resistance to switching between equilibria (when an old and new technology co-exist). Many factors played a significant role in the servicing sector transformation and government's decision-making process to commercialise an innovation. Companies ventured to optimise on profitability of a new venture, taking into account the ability to protect or obtain intellectual property; the degree of existing or anticipated competition; the size and profitability of possible markets and the cost of manufacturing; linkages with all role players; social marketing initiatives, communication tactics; development of agents; and knowing what the individual and community consumers aspired for (both in terms of products and experiences). They also evaluated their ability to harness necessary complementary assets – such as other technologies needed to make their innovation more useful, or capabilities in the manufacturing, marketing and distribution needed for success, and the degree to which the technology fitted in with the company's general business plan.

Communication networks. The networks were no longer linearly orientated, but instead followed different approaches for different niche markets. Researchers or agents had regular personal or collective interactions with the service sector and individuals, which further catalysed interest and commitment). This was facilitated through initial workshops, which included heterogeneous groups of participants to allow for a more interactive process of development. Other interconnected individuals and organisations were linked by responsively articulated flows of information which potentiated multiple network links in a communication structure. Each individual key player possessed a personal network consisting of a set of other individuals to whom the focal individual was linked within network relationships. The focal individual's behaviour was determined, in part, by information and influence communicated by other members of the individual's personal network. Participants' views on the interactions required between researchers and manufacturers are provided in Box 6.5.

Box 6.5 Research interactions

Firms in the servicing sector and government formed partnerships or persuaded manufacturers to commit to producing a technology. Manufacturers needed to review the prospects, starting from the workshop stage. Evaluating the potential of producing a technology included many factors such as involving all role players in a niche market, securing funding from internal and external sources, determining their ability to develop or gain access to manufacturing equipment and supplies, and establishing the size of potential markets. Without fitting networks (suppliers, agents, marketing, incentive programmes, etc.) to support their efforts, firms could not be assured of gaining returns from their investments, and status-quo rivals with better support networks would be able to capture the market. This was why pioneers in a new market often had to close their businesses, allowing imitators with better financing, infrastructure and strategy to win.

Individuals and research. In addition to the performance and costs of a technology, researchers investigated the needs and preferences of homesumers at the basic research, applied research and development stages in order to improve on the design of services/product, and improve uptake of an invention or innovation. This included not only the technology’s attributes, but also the required behaviour change programmes. At an early stage, firms involved their change agents and social marketers in approaching innovators and communities and getting them adopt the new technologies/products.

The knowledge stage started with the “innovation-decision” process, which commenced when the individual (or other decision-making unit) was exposed to an innovation’s existence and therefore gained an understanding of how it functioned. Instead of individuals and communities being passive bystanders and merely waiting for an innovation to mature, there would have been prior interaction right from the conceptual design stage. This would increase the acceptability of a design, thus addressing specific needs and making it more relevant to, for example, the middle-income group. Marketing of new products started at an early stage in order to prepare homesumers about the innovative interventions to come, focus on the relevance to the individuals' needs and be consistent with the individuals' attitudes, emotions, values and beliefs. Individuals needed to be exposed regularly to innovation messages and reflexivity workshops. More tactical approaches to communication were required once the majority became aware of the innovation in order to gain additional/updated knowledge. Thus, knowledge of an innovation created motivation (curiosity) to learn more about it and instilled a deeper awareness of the need for change and, ultimately, adopt the relevant low-carbon technology.

The likelihood of earlier adopters being a small group was great, as they were the ones who first got to know about the invention or innovation. This group had to approach the 2.5% threshold of all the potential adopters before self-reinforcing diffusion could be achieved. These were the people who were involved in the initial research (whether individuals or communities) and those who were willing to be the first to try the innovation themselves as they were venturesome, interested in new ideas and felt part of the process to which they contributed. Only limited incentivisation for the innovation was needed to appeal to these early adopters.

6.3.2 Rapid uptake process

Governance interventions:Technical and adoption techniques.
Government played a critical role in influencing innovations and energy-use behaviours. This role in turn encouraged technology adoption both directly, through regulation, and indirectly, by addressing structural influences on energy-use between 2020 and 2030 (e.g. through policies affecting growth/markets, cultural values, income distribution, social structures and institutional practices).

By that stage, economics theory acknowledged that government intervention would be necessary to correct market failures, provide public goods to pursue particular social or environmental goals. Typical policy instruments included basic information on the costs and benefits of production and consumption choices, price signals and incentives, including taxes and rebates to encourage or discourage certain technologies, regulations that made certain technologies, goods, services or behaviours compulsory or illegal, and direct provision of public transport or other infrastructure services (such as installing energy-efficient measures and conditions for public procurement). Elements of the evolving policy framework in South Africa included improved building regulations, appliance labelling, certification of homes, renewable energy obligations, electricity market reform, feed-in tariffs, town planning improvements and incentives. All these interventions had a diverse impact on energy choices at a local level, as well as on distributional strategies.

Over the years, however, theory shifted to an increased focus on the role of government in mitigating climate change by persuading and steering rather than forcing people to adopt desirable behaviours through regulation; encouraging a sense of personal responsibility and greater partnership between service-users and providers; and supporting communities (and other actors) to reduce energy-use. “Nudge” theory, (derived from behavioural economics), had been influential in this instance as well as reflexivity. It recommended influencing behaviour by altering the context in which people made choices, rather than directly regulating behaviours, such as through rewards, prompts and options. However, non-regulatory or regulatory measures used in isolation were often unlikely to be effective. Usually, the most effective means of changing behaviour at a population level was to use a range of policy tools, both regulatory and non-regulatory. Boxes 6.6 and 6.7 provide findings from the backcasting method on changes made in relation to governance issues.

Box 6.6 Governance issues

By 2025, an improved quality of leadership emerged which started steering towards transformation, whereby economic viability was apparent as was the shifting of priorities to sustainable living in solving problems. Policies on lucid information changed the way people behaved. Some changes were made intrinsically and willingly through the impact of education, media and social media and induced taking more responsibility. Experts, educators and “believers” who spread the word through media and social media were more vigorously achieved by the Green Building Council of South Africa (GBCSA), government, firms and entrepreneurs from 2020. These campaigns usually accompanied new policy development.

Government placed much greater value on embodied awareness and supported forms of reflective practice from 2025 onwards, such as mindfulness programmes that help people regain some control over what they do with their attention. At the neuroscientific level, it is accurate to divide our brains into a controlled system and an automatic system, in which our automatic and largely unconscious behaviours are supplemented and informed by occasional conscious deliberation. Social reinforcement was sought for a new habit to become easy, and achieved through establishing places to practise these and people to teach them or work with. For this new-found habit to be socially endorsed it would also require social rewards and incentives. While social support continued to help keep control of our attention, mindfulness also taught us to pay attention to the processes through which we reach decisions.

Humans are easily nudged by other humans, and strategies on how this type of nudging happened started in 2017. For different cultures to pull together, government rigorously implemented its policies on carbon reduction goals. This was an important government initiative primarily driven by Department of Energy (DOE) and Department of Environmental Affairs (DEA), as people underestimated the importance of the future compared with the attraction of short-term gains. Other motivators that assisted with behaviour change initiatives, even if only for a short period, were government, private sector and international donors through the introduction of subsidies and rebates to incentivise good behaviour. Softer carbon taxes were imposed for extreme situations, but it was preferred to give people the choices of having to pay more or introducing carbon trading schemes to help move towards carbon neutral emissions reductions.

Box 6.7 Governance issues

The Sectional Title Management Bill 2009 under the Department of Human Settlements reviewed parts of the bill to include improvements to the Homeowners Association and corporate body on intentional communities, such as co-housing that promoted collaboration.

Town planning focused on nodal and growth corridors, where smart eco-villages were strategically placed. This included integration schemes on both public and private urban developments for inner city regeneration such as including mixed-use development; preventing urban sprawl and developing on green fields; densification models supported by public spaces with greening of all open spaces; the Department of Environmental Affairs facilitating and coordinating different departments that will work together to ensure proper land-use planning for new zoning models for eco-villages; and improving cooperative planning to integrate smart eco-villages that will be serviced and assimilate new forms of mass transit. This involved the Integrated Urban Development Framework (IUDF) responding to various infrastructure challenges through regulatory tools such as the Development Bill.

Services sector management: Processes, practices and interactions.

Change agents were required as intermediaries to contribute to the process of change required by the service sector. During the various adoption phases of technology, economies of scale were more evident during the early years but gradually weakened over time. However, network interactions and effects were important during all phases of technology take-up and entailed workshop feedback as well as change agents fast-tracking this process. Both research institutions and service-provider firms involved change agents to facilitate a process of effective communication.

The workshop facilitators and change agents had to apply communication tactics that worked more effectively such that the approach became specifically tailored to the unique needs of the target groups. In the context of research, targeting required a process of customising the design and delivery of a communication programme based on the characteristics of the intended stakeholders. Whilst the workshop facilitators comprised researchers or consultants, actors in many different occupations fitted the definition of change agent who amongst others include teachers, consultants, public officials and sales-people. All of these change agents provided a communication link between the resource system with some kind of expertise and client/homesumer. One main role of a change agent was to facilitate the flow of innovations from a change agency to an audience or client-systems. Change agents usually possessed a high degree of expertise regarding the innovations being diffused.

Innovation characteristics comprised various attributes of the new technology which expedited uptake and adoption. The obvious determinants of new technology adoption were the benefits received by the user and the adoption of the costs. Emerging technologies such as solar power were a good example of showing limited progress in technical change and cost relative to other technologies which in turn constrained their market opportunity and diffusion. As a result of these limitations, diffusion of the emerging technologies had been slow and they took quite sometime to gain a noticeable share of the energy mix. Adoption did not take place the instant the benefits equalled costs, but were delayed until benefits were far above costs, thus providing another reason why diffusion may have been rather slow. There was considerable scope for cost reduction in emerging technologies over time through learning by doing and learning by research, which were prioritised for faster diffusion.

Even though the costs of an innovation influenced its uptake, this would be short-lived where effects of other attributes were not considered. The process of adoption of an innovation could be ascribed to several characteristics of the innovation itself such as the benefits it provided, its nested level of smartness and compatibility with existing systems, visibility in the market, price, trial ability to test out the product first, emotional and cultural connection, ability to reduce uncertainty, after-sales service and perceived complexity.

The services sector in this context was more closely associated with the concept of a service economy, which in essence was linked to the value of a product or service in terms of its performance or result over time. During the classical economic revolution, the value of products could be identified essentially with the costs involved in producing them. In contrast, the notion of value in the service economy shifted towards evaluation of costs in terms of the results obtained in utilisation. The whole life cycle of a product, therefore, became part of the product for which services were provided owing to the increasing complexity of the low-carbon technologies entering the market. This would provide assurance of the risks involved and the skills required for the durability of the technology over its lifespan.

Behaviour change approaches: Combining interventions. Recently there had been convergence with the merits of behavioural psychology factors and advances in neuroscience that played a significant part in maintaining momentum in the rate of technology adoption. A combination of multiple behaviour change interventions proved to be more effective than single interventions in isolation. Combining both transformational leadership and liberal paternalistic principles could ensure that nudging and reflexivity remained relevant along the pathway. The knowledge gained placed emphasis on both the technical and adaptive-behaviour responses.

The way people were nudged to low-carbon technology behaviour became a vital part of social-cultural transformation. Improved consumption feedback to householders grew markedly, not least because of rising fuel prices and environmental concern, but also because of the development of smart/sub metering (this made accurate and more frequent bills simpler to produce and dispatch) and home energy displays, possibly using smart/sub meters with various functions that could be tailored to household circumstances. Providing user-tailored and practical feedback or direct guidance on efficiency measures tended to give better results than technological interventions in isolation. Norm-appeals had also been shown to influence attitudes and behaviours especially when incorporated into messages or when community leaders were engaged in the promotion of the desired behaviour-change.

From a reflexivity perspective, people’s behaviour were shaped by various altruistic values, such as pro-social and environmental values, rather than purely self-interest concerns. For example, appealing to people to install insulation only on the grounds of money saving could have led to them using the resultant cost-savings to increase consumption of other goods or services which could lead to the “rebound effect”. Relevant practices and messages from leaders and the media prioritised the approach of appealing to the people’s deeper values. Preferences for goods and services were not formed just on the basis of price, but also on product attributes and their deeper significance for the consumers.

Although individual and community actions were constrained by external influences (macroeconomics), they were still able to moderate these wider influences. Such influences were also diminished through initiatives such as setting up bulk-buying programmes to influence prices, helping residents negotiate with landlords, and ensuring that energy-efficiency programmes reached diverse stakeholder groups. Such programmes therefore reduced local inequalities, encouraged new practices and social norms, developed alliances to press for legislative changes, and disseminated good practice, among other approaches. As a result communities were able to pull together towards mitigating the rebound effect. Energy-efficiency programmes were more effective in reducing overall demand for energy services and improving energy-use practices, including the use of alternatives such as car sharing, cycle lanes and better public transport.

Nudging people to make a commitment appeared to be an effective tool towards promoting behaviour-change. Evidence suggested it was more effective when made by an individual rather than a group, written rather than verbal, public rather than private, and involving a more specific rather than a general goal. Combining commitments with feedback appeared to be particularly effective.

Social marketing involved the application of marketing knowledge, concepts, and techniques on order to achieve social instead of commercial or economic objectives. It sought to influence people to change their behaviours voluntarily through providing public information or advertising campaigns, informed by insights from psychology, sociology, economics, neuroscience and anthropology, and could be accompanied by complementary interventions. The strengthening of individual agency and group capacity (whether motivation, confidence, knowledge or skills) was an important, but sometimes neglected, ingredient for successful behaviour-change strategies.

Government, local authorities and non-governmental organisations (NGOs) adapted social-marketing principles such as framing and market segmentation in their campaigns to change attitudes, mindsets and behaviour. The intention was also to focus campaigns and social-marketing messages more consistently on activating altruistic rather than self-interest motives as a way of securing deeper-rooted transformational change. Campaigns, in conjunction with implementation of new policies, proved to be more effective than one intervention in isolation. The backcasting findings substantiated the interventions required for behaviour-change, as outlined in Box 6.8 and illlustrated in **Figure 6.3**.

Box 6.8 Changing behaviour through collaboration

Making intrinsic changes will be a gradual process to some homesumers, while others will be affected by enforcement and external influences. Adaptation to new purchasing patterns due to external forces such as cost of living became evident; increased rentals, dual-income families and housing models induced collaborative sharing. Education, media and practices will play a critical role in appealing to people’s emotions by using nudging and instilling reflective techniques. Possibly, the manner in which people change their lifestyles will influence values by putting into effect the concept of collaboration and collaborative consumption, which trumps all other approaches regarding values. This can be initiated by redesigning estates with stronger social cohesion principles where possible. Facilities were shared that served the need for slightly smaller homes in a community. This was guided by findings from research institutions, industry researchers, the Department of Education, professionals in the industry and the Green Building Council.

Figure 6.3 Example of a smart eco-village cohousing project by White Design Architects, LILAC, Bramley, West Leeds, UK, 2013 (Haines, 2013)

Market persuasion required proper communication for the successful diffusion of innovation. Innovation firms did not only have to develop renewable energy technologies and produce renewable energy systems, but also had to put immense effort towards shaping the market through getting individuals to participate in the product development and education of consumers in increasing their perceived risk.

Certain decision processes on the demand side equally affected the degree of adoption. For the rapid adoption period the relevant stages of forming an opinion of the innovation were experienced. These opinions could be formed on varying scales of adopter groups, which required unique approaches to ensure uptake/adoption by the majority. The knowledge stage (involving consensus) was followed by the decision stage followed with technology implementation stage and finally the approved technology and confirmation stage. These stages possibly included reiteration and reinvention until proven suitable for a specific user group.

The second process was the knowledge and consensus stage, when an individual made a positive contribution towards the innovation, thus and reducing the possibility of rejection. The individuals shaped their attitude at this stage after they had been exposed to the innovation. The degree of uncertainty about the functioning of the innovation and social reinforcement from others (such as colleagues and peers) affected individuals' opinions and beliefs about the innovation. With carefully planned communication strategies about who to involve initially and then about product performance, coupled with financial and service plans, the degree of uncertainty could have reduced over time.

During the decision stage of the innovation-decision process, the individuals chose to adopt or reject the innovation. While adoption referred to the full use of an innovation as the best course of action available, rejection meant not to adopt an innovation. The innovation decision process could be accelerated by vicarious trial as well as more intimate contact with individuals or the community. However, rejection remained a critical possibility at every stage of the innovation-decision process. The two types of rejection were active rejection and passive rejection. In an active rejection, individuals tried an innovation and thought about adopting it, but later decided not to adopt it. In a passive rejection, the individuals did not think about adopting the innovation at all. If all reasons for rejection were considered from the outset, strategies could mitigate risk of potential rejection.

At the implementation stage, an innovation was put into practice. However, owing to the innovation's novelty, some degree of uncertainty was involved in the diffusion process. Uncertainty about the outcomes of the innovation could still have persisted as a problem at this stage. Thus, the implementer (homesumer) may have needed technical assistance from change agents and others to reduce the degree of uncertainty about the consequences. Technical assistance would become essential during the monitoring and evaluation period on the supply side, which was part of the after-sales service, which thus required a more intimate relationship with the implementers.

Reinvention usually happened at the implementation phase and therefore constitutes an important part of this stage. Reinvention was the degree to which an innovation was changed or modified by a user in the process of its adoption and implementation. It could be either part of an invention or an innovation (process of developing an existing idea further). The more reinvention took place, the more rapidly an innovation was adopted and became embedded into common practice. This was followed by the final confirmation stage.

Adoption in the context of this study did not mean a passive adoption. It meant adoption owing to an ongoing dynamic interaction throughout the process in technology uptake and/or making voluntary behaviour changes. Where a large group of individuals were potential adopters in the technology uptake process, there was a sequential increase in the uptake of technologies and/or behaviour-change. After the research stage of an invention, when a prototype had been developed, there was a stage of early adoption before the critical mass threshold could be reached.

Before rapid adoption could take place, early adopters, comprising about 13.5%, had the highest degree of opinion leadership among the adopters' categories. Normally, early adopters had higher social status and financial liquidity, a more advanced education and were more socially progressively oriented than late adopters. This would differ in terms of the focus groups who were the participants benefitting from possible incentive programmes. They were more discreet in adoption choices than the innovators.

Early "majority" adopters, comprising 34%, followed and had good interaction with other members of the social system, but they did not have the leadership attributes of early adopters. However, their interpersonal networks were still important in the innovation diffusion process. Following those were the "late majority" adopters, comprising 34%, and included one third of all members of the social system who waited until most of their peers adopted the relevant innovation. Although they were sceptical about the innovation and its outcomes, economic necessity and peer pressure eventually led them to adopt an innovation. To reduce the uncertainty of the innovation, interpersonal networks of close peers persuaded the late majority to adopt it. By then, the late majority felt it was safe to adopt the innovation.

6.3.3 Stabilisation and decline

The final stage of the pathway represented a decline in the adoption rate or even signified a reinvention which started a new cycle according to which the path averaged out to a longer and slower adoption period. The market became saturated at the final stage of the innovations' life cycle, after which a new innovation or improved innovation started to take its place.

Consistence in governance. Research and monitoring**.** Government and private research groups followed through all monitoring and evaluation processes of technologies along the diffusion path until all faults were addressed. This included regular research workshops and feedback links on the progress of a technology to reach maturity. Communication links were maintained on multiple levels of a technology’s niche market, and consistent strategies developed to ensure the technological innovations matured effectively. This included the provisions made for research and funding, skills development and resources until the stabilisation and decline stage of a product. It was critical for government policies to develop programmes and projects involving a combination of technical and socio-economic adaptive solutions that changed the environment in such a way that facilitated people to change their behaviour, and also change people at a deeper level in terms of attitudes, values and motivations.

Services ensuring maturity of technologies. Removing faults**.** At the end of the adoption pathway, technological innovations diffused in a self-reinforcement manner, which implied having reached a point of stabilisation. Any type of niche market would need to reach this goal, but some technologies such as emerging, reviving and evolving technologies took longer than mature technologies that entailed “locked-in” inertia. As the technology matured, its length of use ensured that most of its initial faults and inherent problems were addressed or reduced by secondary innovation cycles. Technology adoption stabilised in cycles, which also entailed monitoring and reinventions before reaching final maturity.

The advantage of emerging technologies was that if it was a better performing innovation with all the low-carbon attributes and preferred characteristics, it got adopted in the market more quickly relative to old, existing and/or mature technologies that were becoming rapidly obsolete. Inventions and innovations changed the whole use paradigm and choice architecture in the market. The services sector was able to embed communication with all sectors, involve media, promote education, develop skills and build more intimate relationships with implementers (homesumers) until final maturity of a niche market was reached.

Individual confirmation stage. After innovation-adoption decisions had been made at the confirmation stage, homesumers looked for support for their decision from earlier adopters and also had to be nudged and needed to reflect in order to maintain voluntary decisions and action as well as to prevent bad habits from rebounding. This decision therefore remained at risk of being reversed if the individuals were exposed to conflicting messages about the innovation. Discontinuance could have occurred at this stage, but under this ML pathway, homesumers were satisfied with the performance as their needs for additional/confirmatory support were met through nudging or they became motivated to make more intrinsic and voluntary/deeper-value changes towards behaviour-change.

6.4 More-likely pathways conclusion

Stakeholders knew well enough that long-sightedness as a government responsibility would provide improved development and growth. However, if long-term goals were not holistic to include all traction-influencing factors that would ensure sustainable technology adoption, the possibility of the EL pathway being chosen would be slim. Through long-sightedness, goals were achievable, but at a gradual and moderate pace. The evidence lay in the advantages of gradual change of existing technologies that could systematically diffuse into the renewable energy niche market. The lack of research and innovation, and not allowing time to monitor and evaluate the progress of technology diffusion, limited the degree to which an innovation changed or was modified by a user, which increased the risk of limiting its adoption and optimisation.

On the other hand, the ML pathway would be the most likely pathway chosen based on its more transformational and holistic approach, starting from a leadership level that allowed the transition from high-carbon to low-carbon middle-income homes. The pathway followed the route of successful technology diffusion in terms of ensuring a suitable adoption tempo through defined phases. This path was closely characterised by dynamic equilibrium, which occurred when the rate of change in a social-cultural system kept pace with the system’s ability to cope with the adoption of related innovations. The three main phases were depicted by invention and innovation (starting phase); rapid uptake (middle phase); and the stabilisation (end phase) in which an orchestration of change occurred on multiple levels of society and economy and aimed towards a successful socio-technical transition to low-carbon homes. This pathway is more resonant with accelerating and inhibiting factors thus allowing it to be adopted and optimised whilst still allowing time for monitoring and steering for pathway corrections by 2050.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The final chapter aims to give meaning to the findings of the research through revisiting the previous chapters with a refreshed interpretation. The core insights from the findings are captured across the study's categories of motivation and objectives, theoretical/conceptual frameworks and sub-findings. The categories are organised such that the initial section recapitures the research objective, question, sub-questions and working hypothesis as related to the pathways. The findings are then reconnected to the theoretical/conceptual frameworks (all cross-referenced for content in previous chapters) of the literature underpinning the study. Finally, sub-findings are framed and the process of consolidation to overall findings and recommendations are then captured. The concepts are categorised in the following order: Objectives of the Study; Connections to theoretical framework; Key sub-findings; Consolidation of overall findings; and Recommendations.

7.2 Motivation and objectives

The main question and sub-questions were structured around pursuing a likely pathway to an 80% CO_2 reduction (as required by science) by South African middle-income homes. Chapter 4 established the vision of how an 80% carbon reduction for the middle-income homes sub-sector was achieved by 2050, but still needed to address the main question, which is to establish the pathway that could attain this desirable future state. To track the pathway that stakeholders would choose for the country, a framework consisting of less-likely and more-likely pathways was developed in order to serve as a method of comparing pathway options. Thereafter, more insight was provided by answering the sub-questions on what needed to change in the Delphi/business-as-usual (BAU) pathway by a certain time horizon; why these changes along the BAU pathway would occur; how the mechanisms manifested could have achieved the changes; and who the agents of change could be. These pathways entail socio-technical changes which deal with both lifestyles as well as physical changes (technological interventions) to actual homes.

The methodological framework falls primarily under futures studies and empirical transitioning to the low-carbon homes sub-sector and includes the forecasting and backcasting methods. Using a dual-method approach, the Delphi method characteristically assumed the causal BAU pathway. which provides a benchmark for the transitioning required through the anchoring backcasting method. The nature of the backcasting method was to establish the most likely pathway that achieved the 80% reduction. The backcasting followed a process of initially developing visions, after conceptualisation of the transition pathways was undertaken. Alternative pathways were analysed based on the multiple-level actors (MLA) perspective as reinterpreted from related transition theories on the multiple-level perspective (MLP).

7.3 Theoretical/conceptual frameworks

To answer the main research question as well as the sub-questions, the study was contextualised within futures studies, involving prospective thinking with empirical transitions providing an analytical framework. The study does not overburden the analysis chapters with references back to the literature, but instead draws together the insights from the literature appraisals completed in Chapters 2 and 3. In particular, futures studies aim to discover or invent, examine and evaluate and propose possible, probable and preferable futures. To attain a likely pathway a transitions model was used to provide co-evolutionary perspectives on multiple levels of technology market dynamics.

The study uses visions in the initial stage of a backcasting mini-charrette approach in the form of narrative descriptions. The aim is to be both plausible and desirable. Such studies tend to be rhetorical rather than analytical. Their role was not to analyse or predict the future; but rather the strength of the approach is that such studies expand the possibilities considered, and create a shared picture of what the desirable future state could be. Visions can be referred to as scenarios; the study used “inductive scenarios” through interpretation of data, trends and other material by a core or expert group. More specifically, a “normative” approach to scenario-building encourages a preferred/desirable vision of the future and outlines different “pathways” from the goal to the present involving “backcasting”. A major difference between visions and backcasting is that backcasting is not only about developing a vision, but also about developing pathways on how to achieve those visions eventually. In this study, visions are a state rather than a method, which are anchored within the backcasting method and its pathways. The development of pathways to the future has been the subject of future studies for a long time, especially through the development of scenarios.

Authors held that backcasting was dependent on forecasting, which becomes an important step within the backcasting process. Backcasting studies began with generating images/visions of the future and creating scenarios that fulfil the targets expressed in the desirable future vision while concurrently developing Delphi forecasts. The desirable future vision was then compared with the Delphi/BAU pathways in order to determine the extent of changes required to attain the desirable future state. Combining backcasting and forecasting is beneficial for the development of transition pathways towards carbon reduction emissions. According to

Diffusion Innovation Theory (DIT), the rate of accumulative adoption can be diffused over time in a pattern that resembles an s-shaped curve. The theory also affirms that there are three main stages for an innovation to be adopted starting with the period of rapid growth, after which an innovation’s rate of adoption will gradually stabilise and eventually decline with the possibility of facilitating new innovation cycle.

It was further established that good scenarios constitute transition pathways. There were even connections made between normative backcasting pathway scenarios (what should happen) to the more recent development of “transition studies”. Within the transitions literature (Section 3.4.2), the concept of a “pathway” is explicitly to recognised. Pathways seek to develop well-established technological and economic scenario-building techniques by focusing on the co-evolutionary dynamics between actors and technological infrastructure in the transition processes. In this study, scenarios and visions are used in the context of a future state instead of a method anchored within the backcasting pathways method. Pathways indicate a link between backcasting and transitions. Moreover, there is more of a linkage between backcasting and TM than socio-technical change, although both fall under the MLP. This is due to arguments on the differences between backcasting and transition studies in that backcasting does not assume that the roots of transitions are in socio-technical niches. It only assumes that desirable future visions, and pathways potentially leading towards such desirable futures, can be developed. Rather, it presupposes that both vision development and pathway development contain processes of higher order learning in which participants learn not only about preferable futures and their contradictions, but also about the present, about each other, about barriers and incentives, about the change agents, and about how to improve the future vision in order to make it more appealing and resilient. In this context where substantial and more structured changes to be made in the future, associations had been made with theories related to transitions and its analysis framework in innovation. More recent frameworks used for analysing system innovation are the innovation systems (IS) approach and the socio-technical transitions approach. These perspectives developed from exchanging ideas and sharing most of the innovation concepts. The socio-technical transition approach was an overarching term that included the MLP and multi-phase model, transition management (TM) and strategic niche management (SNM). The last two approaches emerged partly from MLP and had a more normative and governance-orientated focus for supporting radical innovations and system transformations. The MLP research emerged partly from historical studies of system changes and evolutionary economics. The approach was conceived in a societal context that was broader than the IS approach. A central theme was the recognition of the co-evolutionary development of technologies, institutions and social and economic sub-systems. The MLP posits three levels to aid in the understanding of transitions. These are landscape (macro-level), regimes (meso-level) and niches (the micro-level) as defined under Section 3.4.2 of Chapter 3.

The strength of the MLP approach was that transitions could be explained by the interplay of stabilising mechanisms at the regime level, combined with destabilising pressure from the landscape level and radical innovations at the niche level. In particular, the breakthrough of innovations was dependent on multiple processes in the wider context of regimes and landscape. Some researchers perceived weaknesses in the MLP typology, arguing that the conceptual levels could not be applied empirically, that the agency identified is neglected, and that the approach places too much emphasis on technological niches as the principal locus for regime change. A major issue is how backcasting studies relate to socio-technical transition studies. In socio-technical transition studies, and especially in the multiple-level perspective (MLP), future visions are also used to orient transition processes. In contrast with backcasting, socio-technical transitions assume, in their conceptual model, that innovations occur in niches, which then may grow to destabilise the incumbent unsustainable socio-technical regime. To address these arguments, the study holds that for change to occur along a path of technological uptake and behaviour change, co-evolutionery/non-linear market pressures should exist but be directed by what is pragmatic for a relevant country or community. Therefore, accelerating and inhibiting factors with different timing for each level were investigated under the conceptualised less-likely and more-likely pathways.

For this approach in the study, the transitions framework for the analysis of pathways was guided by a strategy of embedding interactions between the macro, meso and micro levels. Fostering socio-technical change requires an understanding of the status of a technology in the market as well as and its agents/actors for a specific country or economy. Initially, a system has to be in a state of disequilibrium in order for change to occur ad subsequently that can lead to a new state of equilibrium whereby all level interactions are aligned. This starting point of innovation manifests across the historical dynamics of transitions such as from the horse-drawn carriages to automobile transport systems of today. A pathway aims to achieve technology uptake/adoption following the key stages of innovation which constitute of radical uptake and stabilisation. The strategy that guided the analysis was based on the timing and severity of an interaction as characterised here below:

- Conceptualisation and elaboration of four contrasting pathways, preferably representing alternative rates/timing and degree of change to attain a desirable future state of 80% CO_2 emissions reduction in the middle-income homes sub-sector. This would preferably be agreed upon by the participants of the backcasting charrette but in this study, due to time and costs constraints was only completed independently subsequent to analysis of mini-charrette data.

- For each pathway, the timing will guide the interacting conditions that would have led to the desirable future state.
- In context of South Africa, on the three levels (macro, micro and meso) for each pathway, establish the accelerating and inhibiting forces/factors that will lead to the desirable state.
- Due to accelerating and inhibiting factors that can differ for each level, the most pragmatic conditions representing a specific pathway scenario are chosen for a certain technology or behaviour change outcome. For example, government coercion could have resulted in pressure that created momentum for disruptive change in the services sector within a certain time-period, but there could also have been another disruptive force stemming from any of the other levels for technology uptake or behaviour-change. The timing and pressure exerted by a level can depend on the socio-economic status of a country.
- Compare the conditions for the BAU pathway to establish the extent of change required towards a transformation of status-quo and related BAU as a complex dynamic problem.
- Finally, the most-likely pathway that would attain the envisioned the envisioned desireable future state would then be chosen for the country.

7.4 Sub-findings

The first sub-question to be answered was: What needed to change in the Delphi/BAU pathway to steer a more likely pathway? The Classical Delphi was used whereby the main significance was to predict/forecast empirically-quantified data bassed on reducing complex propositions down to simple observations and validated by means of consensus-building amongst participants who were selected as experts in their selective fields. For the Delphi, due to its empirically determined data approach, only linear data on individual lever categories of technology, policies, markets and lifestyles were derived. The predominant change that would have to occur in the Delphi was the CO_2 emissions reduction trajectory related to electricity consumption. The BAU forecasts that there will be a CO_2 emissions increase from 40 Mt CO_2-eq in 2010 to 50 Mt CO_2-eq in 2050 thus implying a 25% growth in CO_2 emissions by 2050. This reflects a lower level of emissions when compared to growth without constraints (GWC), but still demonstrated the need for a substantial CO_2 emissions reduction in order to align with the envisioned goal. Although CO_2 emissions reduction were predicted from technologies such as lighting, appliances, space heating and water heating, trends would not cause any substantial changes in CO_2 emissions reduction in the long term. Even though costs of relevant renewable technologies decreased, the Delphi predicted that costs would negatively affect the buying power of homesumers, as prices of technologies and homes perpetually increase because of inflation, transport costs, production, raw materials and importations.

The above outcomes indicate that what was lacking and needed to be factored into the trajectory trends was the co-evolutionary development of technologies, institutions and social and economic subsystems. The BAU scenario did not factor in structural forces/pressures which confronts/addresses systems inertia thus hindering the orchestration of change at multiple levels. Another important change that needed to occur would be to address the irrational behaviour of homesumers especially through engendering change in the deeper social values of a people/society.

The second sub-question to be answered was: Why could the “what” have occurred, within the specified period along the pathway? This Delphi outcome could have occurred for reasons that are closely aligned with the inhibiting factors under pathways as analysed in Chapter 5. Should renewable technology such as on-grid and stand-alone PV become lifestyle trends by 2020, then technology will have been taken up by early adopters or the majority, but without making a substantial difference in carbon reductions by 2050. The Delphi BAU pathway, however, followed a similar trajectory to the back-loading (BL) pathway until 2030 after which their pathways diverged.

The links between the Delphi and less-likely BL pathway were identified according to the inhibitors and accelerators in the MLA market levels of governance, R& D, services sector, and individuals/communities that would foster socio-technical transitions. Government played a critical role in the South African context by influencing innovation and energy-use behaviour-change. This role, in turn, encouraged technology adoption both, directly through regulation, and indirectly, by addressing structural influences on energy-use.

A crucial inhibitor between 2010 and 2020 of the BAU pathway was that the South African government was delaying commitment to CO_2 emissions reduction goals as they thought climate change was a developed country issue. The country committed to COP17 under 21 emissions reduction initiatives on the condition of being financially and technically supported by the developed countries. Developing countries focussed their funding on meeting basic needs symptomatically instead of adopting and applying sustainability principles that could address the root causes of the global problems. From 2020 onwards, the pathway plateaued because although certain low-carbon technology policies such as rebates, appliance labelling and feed-in tariffs, were introduced at the macro level, they were not sufficient to make the disruptive/structural changes that would have led to the 80% CO_2 emissions reduction goal in middle-income homes. Instead, only an insignificant minority would adopt on-grid and stand-alone PV even though PV on grid installation prices declined by 22%; feed-in tariffs were lower than electricity prices; and appliance labelling reduced its carbon significantly by 50% by 2050. Even though there were cleaner technologies, lower costs and smaller homes, there would be a net increase in energy consumption.

The significant carbon increase from 2040 indicated many missing pieces in the systems innovation framework. The Delphi/BAU does not focus on systems-interactions (between governance, R&D, the services sector and the individuals/communities) necessary to streamline the co-evolutionary process of the innovation systems framework as analysed in Chapter 6. The strength of the Delphi analysis was to highlight the spontaneous initiatives from the technology supply sector and related policies. The critical accelerators which are missing in the pathway were the R&D interventions such as funding, local technology advancement, commercialisation, service sector partnerships, and skills improvements. In the services sector, there was a need for life-cycle servicing strategies, monitoring technology uptake, reinvention, change agents and intrinsic behaviour-change stimulation. Communities and individuals lacked advocacy, reflective action and reinventing products. These interventions would have assisted with improving technology advancement, developing local capacity, improving services, providing information and promoting reflexivity and reflectivity towards the required deeper/structural change for transitioning.

The carbon increase was also as a result of a perverse outcome, known as the “rebound effect”, which could have taken several forms. Direct rebound effects could have occurred when consumers spent the money they saved (as a result of energy-cost savings) owing to their uptake of energy-efficient appliances to use more energy, or use an appliance more often. Indirect rebound effects could have occurred when consumers spent the money they saved from energy-efficient goods or services on on other categories of energy-intensive goods or services. These were all risks that could have become realised because of long delays in taking action, causing unresponsive habits to be entrenced even further. The contemporary lifestyle that allowed for the BL pathway adoption was one that led to path-dependant habits.

The Delphi approach assumed that all individuals base their decisions on rational calculations, act with rationality when choosing, and aim to increase either pleasure or profit. Therefore, the additional assumption was that providing homesumers with the low-carbon technologies, basic regulations, incentive programmes and information would lead to rational choices and decisions that will guarantee that carbon reduction goals are achieved. This type of thinking falls under one of the more classical economic theories, known as the rational choice theory (Section 2.3.2). Arguments against the rational choice theory (such as those espoused under behavioural economics or prospect theory), are based on the idea that individuals do not always make rational utility-maximising decisions but very often make make non-rational decisions. Rational choice theory provides a limited view of the individual (as a consumer) as it is well understood now that it disregards other psychological and social aspects of being human. It does not include the origins, nature or validity of people's preferences (why they want what they want) or how such "wants" developed or evolved over time, and it has little to say with regard to our understanding of habitual energy-use behaviours.

The third sub-question to be answered was: How could the mechanisms manifested have achieved the required changes and from whom? Following the BAU trajectory, necessary interventions would have been required to ensure the successful uptake and adoption of technologies as well as voluntary behaviour-change. These would be the interventions that achieved the 80% carbon reduction for the new and existing homes, as provided in Appendix B7 (see page 347), in the middle-income home sub-sector. Socio-technical transition interventions addressed the crucial problem of affordability and shifts in behaviour. Accelerating factors exerted pressure in the MLA market levels (macro level – governance, meso level – service sector and micro level – individuals) along a technology pathway of innovation (2016-2020), rapid uptake and adoption (2020-2040) and stabilisation (2040-2050). A concerted effort was needed to be made by all role-players at all market levels in order to have achieved the 80% CO_2 emissions reduction in the middle-income homes sub-sector by 2050. In this study, it is assumed that the macro level initiated moderate pressure on the meso and micro levels for actors to modify their direction of development paths for technology innovations that were not sufficiently matured yet. Considering that most South African citizens do not have the will to make voluntary changes, some greater force would have had to initiate and induce disequilibrium in the stable system and thus catalyse the required changes.

Between 2016 and 2020, improved quality of leadership was critical in realising the economic viability of shifting implementation priorities to sustainable living in order to solve problems. Leadership by example was required in order to develop and communicate a vision which would be attractive and motivating to the diverse range of actors. Transformational leaders aided this process by setting CO_2 emissions reduction goals and by clarifying/enhancing a shared vision while also demonstrating leadership commitment.

At this time, a useful intervention by government was to start focussing on localisation and glocalisation, which prioritised systematic diffusion and adoption of low-carbon technologies and related behaviour-change. Shortages in local carbon-neutral products and skills required inventions and innovations to be pursued more earnestly. Parliamentary and donor funding in public and private sector R & D organisations ensured that development and economic growth happened in the niche of low-carbon technology areas such as renewable energy technologies, material sciences, appliances, LEDs, social sciences and modular housing systems, with more focus on local resources. It would be inevitable that linkages between research organisations and firms nationally and internationally became strengthened, which resulted in acquiring more knowledge, funding and partnerships. The transition from invention and innovation to the diffusion stage is crucial for technical progress. Systematically informed policies based on empirical evidence improved the process and contributed to better allocation of technology promotion funds between R & D and capacity deployment across technologies. Part of capacity-building included monitoring the R & D strategy and government's action plan as a prerequisite to steering progress in relation to the high-level national goals in order to mould the necessary change in research.

In the rapid low-carbon technology uptake and adoption phase between 2020 and 2030, government and private sector played a vital role in influencing innovation and energy-use behaviour. This role, in turn, encouraged technology adoption both directly (through regulation) and indirectly (through structural influences on energy use). Typical policy instruments included basic information on the costs and benefits of production and consumption choices; incentives and rebates; taxes; regulations prohibiting or enforcing certain technologies; and behaviour-changes coupled with related infrastructure services such as installing energy-efficient measures and conditions for public procurement. Elements of the evolving policy framework in South Africa included improved building regulations, appliance labelling, certification of homes, renewable energy obligations, electricity market reform, feed-in tariffs, town planning improvements and incentives. Rewards/incentive programmes assisted with upfront costs for low-carbon technology interventions. However, it was in the best interests of the government and/or the service sector to introduce sustainable incentives for low-carbon technologies that would utilise funds from channels such as amongst others carbon tax. Softer carbon taxes were imposed for extreme situations, but it was preferred to give people the choices of having to pay more or opt for carbon trading schemes to help the move towards carbon neutral emissions lifestyles and homes.

Over the years, however, theory shifted, with increased focus on the role of all market actors such as government, firms, manufacturers and entrepreneurs towards mitigating climate change. This was accomplished by persuading and steering rather than forcing people to adopt desirable behaviour through regulation; encouraging a sense of personal responsibility and greater partnership between service users and providers; and supporting communities (and other actors) to reduce energy-use.

The Sectional Title legislation was reviewed to include improvements to the Homeowners Association and corporate body sections, by encouraging intentional communities such as co-housing that promoted collaboration. Change agents were required as intermediaries to contribute to the process of change required by the service sector. However, network effects and interactions remained crucial during all phases of the technology take-up and required workshops for feedback channels and change agents to fast-track the process. Both research institutions and service-provider firms involved change agents to facilitate a process of effective communication. Targeting in the context of research required a process of customising the design and delivery of a communication programme based on the characteristics of the targeted audience/actors.

The processes followed by the service sector for emerging technologies between 2020 and 2040 were considered. In order to ensure cost reduction over time, learning by doing, and learning by research became a priority for faster diffusion. Whereas the costs of an innovation influenced its uptake, this would be short-lived if the effects of other attributes were not systematically factored into the dynamics. Although the process of adoption of an innovation could be ascribed to many characteristics as provided in Chapter 6, the services sector in this context was more closely associated with the concept of a service economy, which in essence was linked to the value of a product or service in terms of its performance or result over time. The whole life cycle of a product, therefore, became part of the reconceptualised product around which services were provided, owing to the increase in complexity of the low-carbon technologies. This provided assurance of the risks involved and the skills required for ongoing/reliable performance of the technology over its lifespan.

Combining both transformational leadership and liberal paternalistic principles ensured that nudging and reflexivity tactics were relevant along the pathway. The knowledge gained placed emphasis on both technical and adaptive behaviour solutions. The way homesumers were nudged towards low-carbon technologies and behaviour was a vital part of the transformation. Improving consumption feedback from householders grew markedly, not least because of rising fuel prices and environmental concerns, but also because of the development of smart/sub metering (which made accurate and more frequent bills simpler to produce) and home energy displays, possibly using smart/sub meters with various functions that could be tailored to homesumers needs. Providing user-tailored and practical feedback or direct guidance on efficiency measures tended to give better results than single interventions. Norm-appeals had also been shown to influence attitudes and behaviour when incorporated into messages or when community leaders were engaged to promote the desired behaviour-change.

Although individual and community actions were constrained by external influences (macroeconomics), they were still able to moderate/counter-influence pressures. Such influences were diminished through initiatives such as setting up bulk-buying programmes to influence prices, helping residents negotiate with landlords, and ensuring that energy-efficiency programmes reached the relevant group networks. These programmes therefore reduced local inequalities, encouraged new practices and social norms, developed alliances to press for legislative changes, and disseminated good practice, among other initiatives. Communities were able to pull together and find a solution to mitigate the rebound effect. Energy-efficiency programmes were more effective as a result of reducing overall demand for energy services and improving energy-use behaviour practices, including using alternatives such as car sharing, cycle lanes and better public transport. Community-based social marketing through service providers fostered the spread of sustainable behaviours by selecting the specific behaviours that needed to change; identifying barriers and benefits; developing strategies; and collectively piloting implementation and evaluation. Making intrinsic changes was a gradual process to some homesumers, while others were more affected through enforcement and external influences. New purchasing patterns due to external forces, such as the cost of living, brought about adaptation consisting of increased rentals, dual-income families and housing models induced collaborative living.

Between 2040 and 2050, the final stage of the pathway represented a stabilisation in adoption or even signified a reinvention which started a new cycle according to which the path averaged out to a longer and slower adoption period. The more reinvention took place, the more rapidly an innovation was adopted and became deeply embedded into every day behaviour on practices. The market became saturated at the final stages of life cycle, after which a new innovation or improved innovation could take its place. Government and private research groups followed through all monitoring and evaluation processes of the technologies along the diffusion path until all the gaps had been addressed.

Any market niche would need to reach this goal, but some technologies such as emerging, reviving and evolving technologies took longer compared to the mature technologies that underpinned the “locked-in” inertia. As the technology matured, its length of use ensured that most of its initial faults and inherent problems were addressed or mitigated through secondary innovation cycles (mini-cycles within the larger-cycle). The advantage of emerging technologies was that a better performing innovation with all the low-carbon attributes and preferred characteristics would be adopted in the market more quickly relative to old existing mature technologies that were becoming rapidly outdated.

The fourth sub-question to be answered was: Who could be responsible for making the changes in order for the “what” to occur? To complement the interventions required to make the required changes, it was necessary to identify the agents of change, as they would have to make the required changes become realised. In order to avoid overloading the section with all the names of key actors/role-players they have been captured more systematically in **Table 7.1** below.

Table 7.1 Summary of critical actors and interentions under the prioritised ML pathway

Co-evolutionary innovations system actors and functions of a niche market					
Multi-level actors in multi-level spaces			**Interventions**		
No.	Level	Actors	Invention/Innovation (2016–2020)	Technology uptake and behaviour change (2020–2040)	Saturation/Decline (2040–2050)
1.	**Government**	• **Relevant government depts. and state-owned enterprises, including policymakers:** • Departments: Science and Technology, Education, Economic Development, Finance, Public Services and Administration, Trade and Industry, Human Settlements, Social Development, Energy, Transport, Public Works, Health, Environmental Affairs, Rural Development • National Treasury, municipalities, NERSA, Eskom, professional councils, SABS, National Regulator of Compulsory Specifications (NRCS), Development Bank of South Africa	• Transformational leadership and progressive paternalism • Holistic behaviour change model • Nudging and reflexivity • Technical and adaptive solutions • Controlled and automatic systems • Steering approach • Long-sightedness and goal setting • Research and funding for localisation	• Resource mobilisation • Persuading and steering • Altering the context in which people chose and mindfulness • Combine regulatory and non-regulatory interventions • Ardent coordination, facilitation, participation and feedback workshops between all role players and individuals • Learning by research through monitoring and evaluation	• Feedback workshops • Reinvention of technology • Communication links • Transformational governance consistency • Technical and adaptive solutions • Enabling an environment • Education and information of agents • Continuation of reducing uncertainty
2.	**Services sector**	• **NGOs, firms, manufacturers, distributors and suppliers:** • Professional institutions • South African organisations, e.g. The Green Connection • International donors from various countries; multilateral organisations such as the World Bank, IFC, etc. • Entrepreneurs, consultants, professionals, contractors • Generators, independent power producers, banks • Small-scale and large-scale manufacturing entrepreneurs • Small-scale and large-scale distributing entrepreneurs • Small-scale and large-scale supplier entrepreneurs	• Heterogeneous interactive workshops and mapping • Basic and applied research on innovations for individual and community needs • Strengthening linkages • Macro-economic external pressures • Motivation, skills development and deployment • Commercialisation for "glocalisation" • Theory-informed policies and empirical evidence • Resource mobilisation • Intermediaries and change agents • Reinforcing linkages and partnerships	• Feedback workshops • Change agents as intermediaries • Network effects and tactful communication • Learning by research and learning by doing • Compatibility with existing systems, visibility, trial ability, emotional and cultural connection • Service-orientated economy • Skills development and deployment • Resource mobilisation • Monitoring and evaluation on progress at individual and community levels	• Technology niche multiple-level actors • New technology breakthroughs • Reinvention or new invention for individuals' needs • Service economy practices • Agents on information and education • Rate of technological maturity • Cyclic technology diffusion • Monitoring, evaluation and reinvention

2.	**Services sector**	• **NGOs, firms, manufacturers, distributors and suppliers:** • Professional institutions • South African organisations, e.g. The Green Connection • International donors from various countries; multilateral organisations such as the World Bank, IFC, etc. • Entrepreneurs, consultants, professionals, contractors • Generators, independent power producers, banks • Small-scale and large-scale manufacturing entrepreneurs • Small-scale and large-scale distributing entrepreneurs • Small-scale and large-scale supplier entrepreneurs	• Heterogeneous interactive workshops and mapping • Basic and applied research on innovations for individual and community needs • Strengthening linkages • Macro-economic external pressures • Motivation, skills development and deployment • Commercialisation for "glocalisation" • Theory-informed policies and empirical evidence • Resource mobilisation • Intermediaries and change agents • Reinforcing linkages and partnerships	• Feedback workshops • Change agents as intermediaries • Network effects and tactful communication • Learning by research and learning by doing • Compatibility with existing systems, visibility, trial ability, emotional and cultural connection • Service-orientated economy • Skills development and deployment • Resource mobilisation • Monitoring and evaluation on progress at individual and community levels	• Technology niche multiple-level actors • New technology breakthroughs • Reinvention or new invention for individuals' needs • Service economy practices • Agents on information and education • Rate of technological maturity • Cyclic technology diffusion • Monitoring, evaluation and reinvention
3.	**Individuals**	• **Individuals and communities:** • Homeowners in detached homes, clusters and flats • Small-scale or large-scale communities	• Strong participation in research • Technology attributes and behaviour-change programmes • Innovation decision process – knowledge stage • Earlier adopters	• Psychological and neuroscience theories • Learning, unlearning and adaptivity • Combination of behaviour-change involvement • Both socio- and technical interventions • Reinforcing choices and motivation • Active participation and feedback • Practices, messages for more embodied awareness	• Confirmation stage • Nudging and reflexivity for voluntary changes • Prevent reversing decision • Strong support and relationships • Monitoring, evaluation and feedback • Ensure positive feedback to other communities

7.5 Consolidation to overall findings

The 80% CO_2 emissions reduction goal for the South African middle-income homes sub-sector was taken from Intergovernmental Panel on Climate Change (IPCC) research on the urgency of limiting warming to below 2°C emissions reduction of 80% below 1990 emission levels by 2050. Even as a developing country, South Africa has a high per capita CO_2 emission level which is closer to that of developed countries, and if no transformative climate change action is taken now, will be responsible for two thirds of the global emissions by 2030, compared with one third in 1990, owing to economic development. The aim of the mini-charrette method was to ascertain how this target can be achieved in the country especially give that if the Delphi BAU trajectory was to be followed, South Africa would have increased its emissions by 10 Mt CO_2 by between 2016 and 2050.

To ascertain how these targets can be attained, a multiple-method approach was chosen in order to deal with the complex problems relating to futures-thinking. The primary purpose of futures studies is to uncover images of possible, probable, and preferable futures that enable people to make informed decisions about their lives. This study established what was possible and preferable by using the Delphi and backcasting methods based on complementary theoretical frameworks. At the backcasting charrette, visions of a desirable future state were developed and pre-analysed following good-practice process and using coding technique in order to obtain sufficient congruence amongst participants. The data were then analysed further based on the conceptualised framework comprising more-likely and less-likely pathways and guided by using the socio-technical transition approach which included a reinterpreted MLA perspective. One could argue that if the backcasting participants (including homesumers) had developed the pathways themselves and managed to to reach sufficient congruence, the findings would have been more plausible. Even so, it can be contended that follow-ups and monitoring spin-offs could have led to richer outcomes.

Backcasting and socio-technical transitions have not been linked in previous studies due to their inherent disciplinary differences on how to develop the outcome. Although they share similarities on pathways they are dissimilar on the way they are developed and their related outcomes. The findings of this study corroborate the claims that backcasting vision entails processes of higher order learning which involve preferable futures, including many levers of change, whereas socio-technical transitions such as the MLP recognise co-evolutionary development of technologies, institutions and social and economic sub-systems.

This study provides an interesting perspective on how backcasting could be combined with transition pathways in order to provide the benefits of both higher order learning and system transformation insights, which in essence, can cause pressure to destabilize the present unsustainable socio-technical regime. In the MLP, the regime level (meso) comprises the structures that represent current practices and routines, including the dominant technological rules and new technological and social innovations. In the study’s reinterpreted MLA perspective, there is no regime level as such, and it presupposes that all three levels of macro, meso and micro can exert pressure from any level. Governance and other external pressures (e.g. macro-economics) in the form of accelerating or inhibiting forces, could be exerted on the services-sector and community in order to create enough momentum within a certain time period and thus overcome system inertia.

Regarding the lack of will to make voluntary changes in South Africa, the backcasting stakeholders suggested a more heavy-handed approach to induce necessary energy-use behaviour-change. However, this was contrary to literature findings, which suggested a more transformational approach that is more holistic with better outcomes in the long term. For example, “nudging theory” refers to changing the environment (choice-architecture) in order to nudge people in the right direction through a combination of interventions. The environment could be changed by prompts that could guide people into certain forms of behaviour through linkage to new/innovative policies. Other nudges could include improvements in the feedback processes to consumers through better information and disclosure of products with interesting designs that entice people to procure them directly or access their related services as facilitated by the service-sector. It is critical to focus more earnestly on transformation in people, thus making more intrinsic changes which could be guided by reflexivity theory principles and based on policies/programming to support more mindful action for the deeper/ structural change required to sustain the CO_2 emissions reduction goal.

7.6 Recommendations

The study has substantiated on the socio-technical transition pathways that South African policy makers may want to pursue in order to attain the CO_2 emissions reduction target in the middle-income homes sub-sector and thus steer the country into a desirable future state that would work for all its citizens as well as for humanity in general. A sector that emitted high levels of CO_2, but had not yet been systematically studied, was prioritised for the study in order to facilitate a new focus on technology and behaviour change pathways for middle-income homes. From a broader perspective, the country had been experiencing energy shortages, load-shedding and electricity tariff hikes since 2008, and is still in transit towards finding effective solutions that would ensure all citizens have sustainable access to clean energy sources. However, in the midst of climate change problems, and a recent severe drought and extreme weather events in South Africa, the dependency on coal-fired power stations has resulted in per capita CO_2 emissions which are 43% higher than the global average.

Should electricity supply need to grow by 4.4% per year, CO_2 emissions from electricity-generation would more than double in the next 20 years. These issues among other sustainability concerns, provided the impetus to find cleaner energy-supply solutions that would mitigate the catastrophic effects of climate change.

In Chapter 1 it was explained how this study's carbon reduction pathways compare with the current South African GHG emissions trajectory. A change in mitigation targets was considered at the Copenhagen Conference, whereby South Africa, in a loose commitment, confirmed undertaking mitigating actions more closely aligned with those of developed countries. In 2011 South Africa communicated, as defined in national policy (DEA, 2011: 27), a peak, plateau and decline GHG emissions trajectory range. South Africa's GHG emissions peak in the period 2020 to 2025, plateau for up to ten years after the peak and from 2036 onwards emissions will decline in absolute terms. Referring to the same database (DEA, 2014: 62), the residential sector has a mitigation potential of 20% of CO_2 emissions reduction for the sub-sector by 2020, 29% by 2030 and 46% by 2050, which is slightly lower than the previous trajectory pledge. This National GHG Emissions Trajectory Range may be reviewed in the light of monitoring and evaluation results, technological advances or new science, evidence and information. The present study focused attention on the required time for a technological innovation to diffuse and behaviour change to occur. In contrast, this study's chosen ML pathway suggested a 22% CO_2 emissions reduction target by middle-income-group homes by 2025, until an 80% reduction was reached by 2050. This implies a higher reduction target required for homes in the sub-sector and could call for a review of residential policies for CO_2 emissions reduction targets. The ML pathway CO_2 reduction targets were based on available statistics between 2009 – 2012 (more recent data was not available) and recommend that a follow-up study be completed based on updated statistics possibly including commissioned data, specifically for the residential sub-sectors.

Most government departments would have to play their part in amending policies for the residential sector – this can also mean a group of government departments working more collaboratively. These departments would be responsible for policies on socio-technical advancement in localisation, glocalisation, manufacturing, R&D, performance regulations, intrinsic behaviour changes, service economy, new home owners association, townplanning, carbon tax, incentive programmes and energy infrastructure. Furthermore, the services-sector should conceptualise and implement company policies on life cycle servicing, communication skills, change agents, social marketing, R&D, monitoring and incentive programmes. Communities would enhance social cohesion and advocate for social/community models that can enhance a quality of life desired by most individuals and meaningfully contribute to responsive technological innovations. One could argue that although the programmes have demonstrated the technical and economic potential for climate change and mitigation adaptation policies, they have not yet in practice laid out what implementation requires in terms of national and international agreements and regulations. Designing an environment (choice architecture) that provides social cues/nudging in order to change behaviour could be an interesting design and social challenge for subsequent/further studies.

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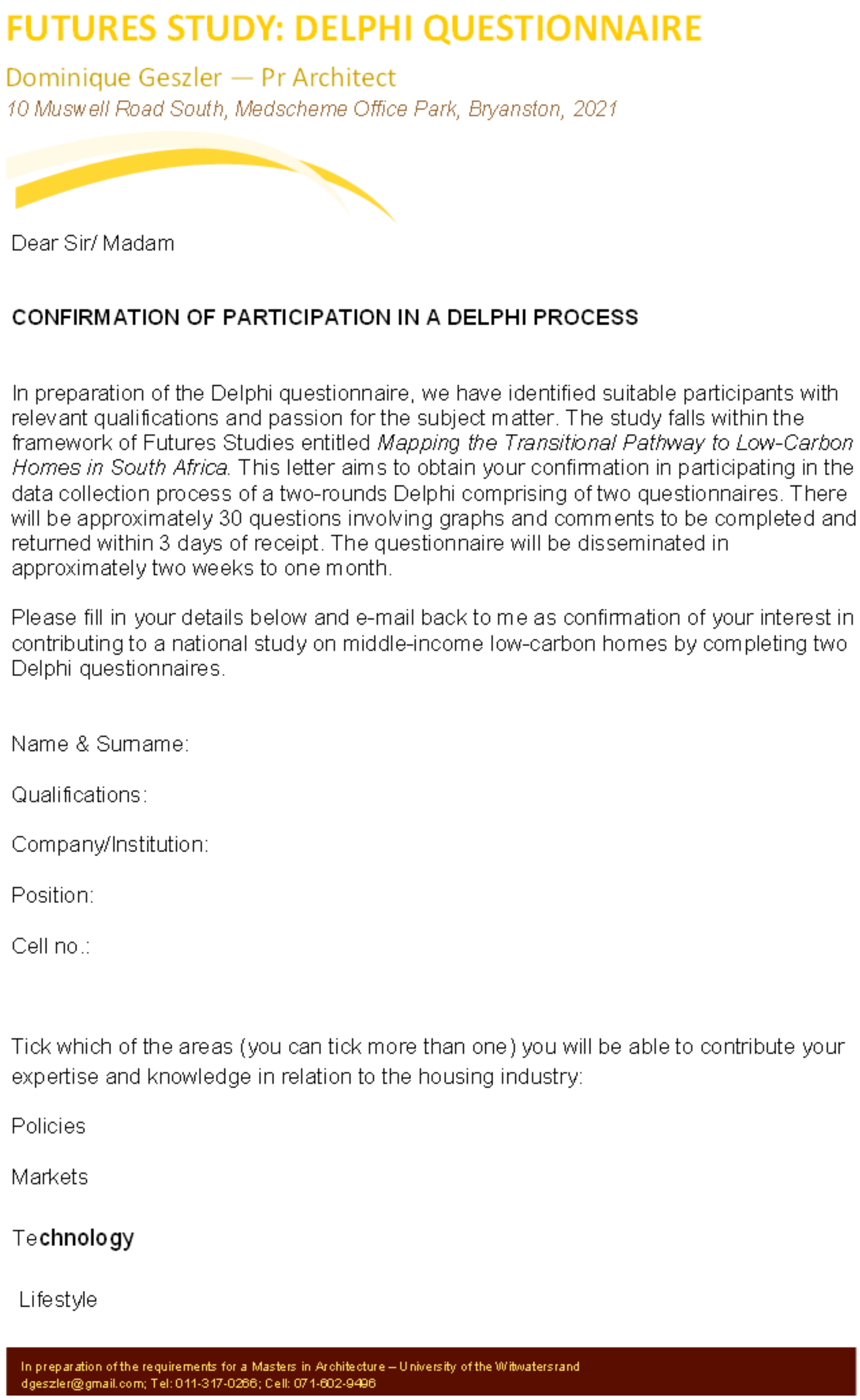
APPENDIX A DELPHI METHOD TOOLS

A1 Delphi letter



FUTURES STUDY: DELPHI QUESTIONNAIRE

Dominique Geszler — Pr Architect
10 Muswell Road South, Medscheme Office Park, Bryanston, 2021

Dear Sir/ Madam

CONFIRMATION OF PARTICIPATION IN A DELPHI PROCESS

In preparation of the Delphi questionnaire, we have identified suitable participants with relevant qualifications and passion for the subject matter. The study falls within the framework of Futures Studies entitled *Mapping the Transitional Pathway to Low-Carbon Homes in South Africa*. This letter aims to obtain your confirmation in participating in the data collection process of a two-rounds Delphi comprising of two questionnaires. There will be approximately 30 questions involving graphs and comments to be completed and returned within 3 days of receipt. The questionnaire will be disseminated in approximately two weeks to one month.

Please fill in your details below and e-mail back to me as confirmation of your interest in contributing to a national study on middle-income low-carbon homes by completing two Delphi questionnaires.

Name & Surname:

Qualifications:

Company/Institution:

Position:

Cell no.:

Tick which of the areas (you can tick more than one) you will be able to contribute your expertise and knowledge in relation to the housing industry:

Policies

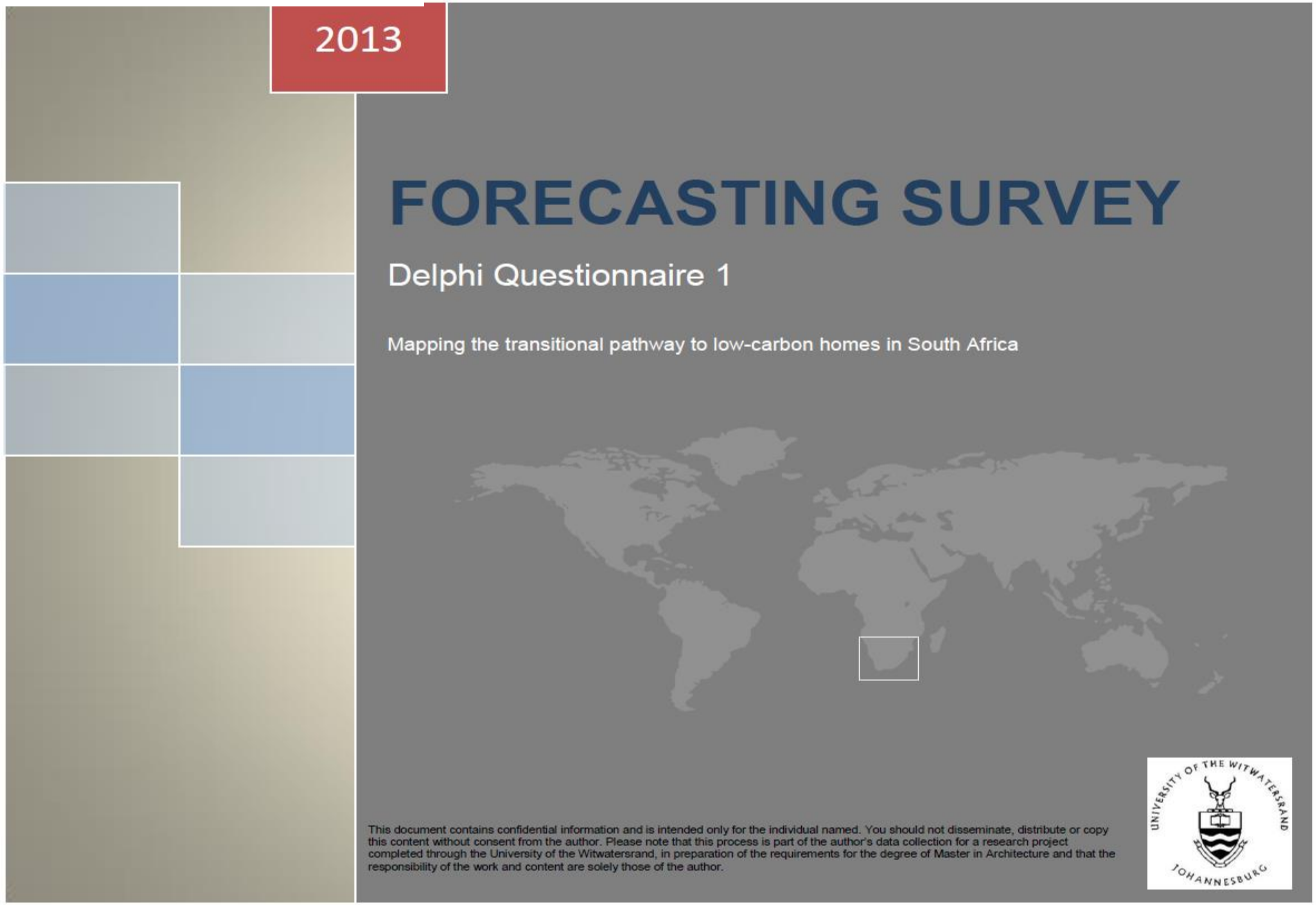
Markets

Technology

Lifestyle

In preparation of the requirements for a Masters in Architecture – University of the Witwatersrand
dgeszler@gmail.com; Tel: 011-317-0266; Cell: 071-602-9496

A2 Questionnaire



2013

FORECASTING SURVEY

Delphi Questionnaire 1

Mapping the transitional pathway to low-carbon homes in South Africa

This document contains confidential information and is intended only for the individual named. You should not disseminate, distribute or copy this content without consent from the author. Please note that this process is part of the author's data collection for a research project completed through the University of the Witwatersrand, in preparation of the requirements for the degree of Master in Architecture and that the responsibility of the work and content are solely those of the author.

SECTION A: INTRODUCTION TO QUESTIONNAIRE

1. Research Details

Background

This Delphi Survey is carried out as part of a postgraduate study in Architecture at the University of the Witwatersrand entitled *Mapping the transitional pathway to low-carbon homes in South Africa.*

The study aims to investigate the improvements required to map out the transition to low-carbon homes along a future pathway. Mapping data will be obtained from the themes related to the current technology trends and its influencing policies, markets and lifestyles in order to establish the extent of mitigation in greenhouse gas emissions by 2050. However, the expert can include other probable technologies in the future, if it can be well substantiated, due to technology innovation diffusion. A case study example on technology innovation diffusion is attached to the questionnaire.

To respond to the question: “What will happen on condition that the likely development unfolds?”, the Delphi technique is used to forecast the future. The “Delphi” is characterised as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem. It is mainly characterised by its ability to predict what is going to happen in the future on a current path of development using known current technology trends and its historic data in South Africa.

The most widespread type of dwelling unit is the bricks-and-mortar structure on a separate stand or yard, and the market trends are led by the highest energy consuming category of 80–220m² in medium-sized homes. An average sized home of 130 m² can be used for quantifying purposes of the questionnaire. Technologies for these homes have been identified that are, according to Eskom, the current high consuming technology trends in homes and its remedial counterpart.

Process

Distinguishing features of the Delphi process include well-prepared questionnaires and controlled information feedback to determine group consensus. This Delphi process will comprise of two rounds and two questionnaires, of which this is the first.

Questionnaire 1**:** Will obtain all the likely trends in technologies and their influencing policies, markets and lifestyles with the aim of ascertaining likely low-carbon home trends by 2050.

Questionnaire 2**:** Will evaluate the trends in questionnaire 1 and provide new trends to be validated.

Informative: Final results will be provided to the participants.

Analysis

Responses are compiled according to the questions' 50% probability using medians and quartiles or standard deviations. Confidence levels are also required to be filled in for each question which will contribute to validating the answers.

Questions

The questionnaire is divided into 4 main sections i.e. Technologies, Markets, Policies and Lifestyles. Questions are asked that require identifying the year of occurrences of a particular trend and questions are asked that need to be quantified, followed by a comments box. For the graphs an example of a likely extrapolated extension is indicated, which the respondent must confirm or change. The 4 main groups are distinguished through different colours: Technology (grey); Markets (blue), Policies (yellow) and Lifestyles (brown).

Definitions

Trends: The continuance of a predominant general pattern of a variable (technologies, markets, policies, lifestyles) over a period of time based on past data.

2. Participants Details

Fill in all the required particulars below from 2.1 to 3.1.

2.1 Full name:

2.2 Profession:

2.3 Qualifications:

2.4 Company/Institution:

2.5 Position:

2.6 Area of expertise:

2.7 No. of papers completed and its relevant field of knowledge:

2.8 Land-line tel.:

2.9 Cell phone:

3.0 Fax:

3.1 E-mail:

SECTION B: DELPHI QUESTIONNAIRE 1

Indicate in which years the following technologies will become predominant trends influenced by either policies and/or lifestyles. If you think that both can influence the technology trend, mark the relevant years next to policies and lifestyle when it will become a trend and remain a trend thereafter. Should you think only one is relevant, leave the other option empty. In the comments box, you must provide reasons for your choices and include other relevant technology trends.

An EXAMPLE of how to fill in the Technology section is given below.

No. Technology		***2010***	***2020***	***2030***	***2040***	***2050***	***Confidence Level 1–4***
Indicate when the technology will most likely become a trend due to policies	***i) Policy***				***X***	***X***	***2***
Indicate when the technology will most likely become a trend due to lifestyles	***ii) Lifestyle***			***X***	***X***	***X***	***2***

No. ***COMMENTS: example***

Key assumptions*: Policies = Poor political leadership; GDP of 1% in 2050; High costs unaffordable to import, etc. Lifestyle = Voluntary adoption due to moral reasons, etc.*

Other key developments *(uncertainties): Policies = Change in SA's incentive structure; technology advancement in insulation properties, etc. Lifestyle = Greener preferences.*

Other Typologies: *Insulation "x" will become a trend from 2030 onwards due to innovation diffusion & affordability, etc. Key Assumptions: Policies = Stringent Building Code Lifestyle = Choose this technology due to cost- and performance effectiveness.*

TECHNOLOGY

TECHNOLOGY CHOICES

Active Technologies

Heating and Cooling

			2010	2020	2030	2040	2050	Confidence Level 1–-4
1.	**Gas, radiant, convection and panel heaters**	**i) Policy**						
		ii) Lifestyle						

The **heater panel** is a whole room heater, which is mounted 21 mm from the wall. Heat is mainly generated behind the heater, which leads to an efficient updraught of heat circulated in the room. The principle of natural convection applies whereby 90% of the heat comes from the back of the panel and 10% is radiated from the front. These heaters have a low energy usage of 400 W/h (288 kWh/month) and low costs. Locality heaters, for example, use 1000 W/h to 3000 W/h (Du Pont 2013, pers. comm., 25 February).

1. **COMMENTS:**

Key assumptions:

Other key developments (uncertainties):

Other technologies:

		2010	2020	2030	2040	2050	Confidence Level 1–4
2. Heat Pumps	**i) Policy**						
	ii) Lifestyle						

Heat pump: This is a device that uses a small amount of energy to move heat from one location to another. Two types are mostly used, the split type and integrated type. They are usually used to heat water of which the domestic type uses 3.2 kW, but can be used for space heating and cooling. A heat pump utilises 1 unit of energy and yields 3 units of energy. Heat pumps can have energy savings of up to 67% (Willis 2012, pers. comm., 28 November).

2. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

	Renewables		2010	2020	2030	2040	2050	Confidence Level 1–4
3.	**PV on grid**	**i) Policy**						
		ii) Lifestyle						
4.	**Wind on grid**	**i) Policy**						
		ii) Lifestyle						

PV on-grid: The behind the meter photovoltaic on-grid connected (grid-tied) that is smaller than 10 kW. There are roof- and ground-mounted, and track-type modules. There are crystalline and thin-film PV systems of which thin-film modules are typically lower priced than crystalline modules per watt, but less efficient. Thin-film modules, however, degrade faster. Homes use mainly roof-mounted types of less than 5 Kw (Barbose *et al.*, 2013:28).

Wind on-grid: Small wind turbines of 100 kW or less are used. Wind power is one of the most mature renewable technologies in the world and is still growing rapidly, particularly in developing countries. A small turbine can be tied to the electricity distribution system and reduce consumption, e.g. 10 kW produces 170–1 800 kW and reduces the bill by 50% (IRENA, 2012:9).

3 & 4. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

	Appliances		2010	2020	2030	2040	2050	Confidence Level 1–4
5.	**Fridges with ratings**	**i) Policy**						
		ii) Lifestyle						
6.	**Gas stoves**	**i) Policy**						
		ii) Lifestyle						

Fridge: A top fridge and bottom freezer is a typical refrigerator in South Africa. In 2007, the KGN range consumed 392 kWh with an energy efficiency class of A. In 2013, this range consumes 327 kWh with an energy efficiency of A+. The efficiency of this appliance is improving with time (Dreyer 2013, pers. comm., 25 February).

Gas Stove: As one of the energy-efficient cooking appliances, the gas stove is more energy efficient to use and is making a steady comeback. Depending on the costs of gas and electricity, in the USA the energy used by a gas stove is 0.112 therm. in an hour and costs USD 0.07 compared with an electric stove/oven using 2 kWh in one hour costing USD 0.16 (CEC, 2013).

5 & 6. **COMMENTS:**

Key assumptions:

Other key developments (uncertainties):

Other technologies:

	Lighting		2010	2020	2030	2040	2050	Confidence Level 1–4
7.	Compact fluorescent lighting	**i) Policy**						
		ii) Lifestyle						
8.	Light emitting diodes	**i) Policy**						
		ii) Lifestyle						

CFL: Miniature versions of the full-sized fluorescents, but do not flicker. These lamps use 75% less electricity than ordinary incandescent fixtures and last longer. A compact fluorescent bulb uses 27 watts of electricity that is the same light output as a 100-watt incandescent bulb (Ecogeekliving, 2013).

LED (light emitting diode)**:** Tiny lights produced by moving electrons in a semiconductor. There is no burning gas or filament and they are therefore more durable and produce little to no heat. They are very resistant to weather and also energy efficient. LEDs use 1/50 of the energy of a standard bulb, last 10 times longer and need to be changed only after 15 years. They are still not as versatile in traditional light fixtures and are more expensive than CFLs (Ecogeekliving, 2013).

7 & 8. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

Passive Technologies

Envelope

	Standard insulation		2010	2020	2030	2040	2050	Confidence Level 1–4
9.	Mineral fibre	**i) Policy**						
		ii) Lifestyle						

Mineral Fibre: Glasswool is made from silica sand to which 80% recycled glass and fluxing agents are added and then melted to 1 100 ˚C in an electric furnace, and then conditioned in a gasfired forehearth. By adding binding products, fibres are formed and gathered in a mat form and cured in an oven to the required thickness and density. This insulation can save up to 21% on the energy bill. Other types of mineral wool insulation are fibrous stonewool with thermosetting phenol/formaldehyde resin. Mechanical properties such as thermal conductivity in W/mK at 60 kg/m^3 is 0.033 and a 80 kg/m^3 is 0.033 (Isover, 2013).

9. **COMMENTS:**

Key assumptions:

Other key developments (uncertainties):

Other technologies:

	Heating and Cooling		2010	2020	2030	2040	2050	Confidence Level 1–4
10.	Solar water heaters	**i) Policy**						
		ii) Lifestyle						

A **SWH** delivers hot water using solar energy that heats a collector on the roof. Mostly 300 litres are installed to replace 2 or 3 conventional geysers.

An indirect system is essential for South Africa due to the freeze conditions in winter and about 87% of the country suffers from high calcium water. Between the vacuum and the flat-plate collectors, the flat-plate seems to be more popular as the water can easily boil. Severe hailstorms damage the collectors in the southern hemisphere (Harper 2012, pers. comm., 4 December).

10. **COMMENTS:**

Key assumptions:

Other key developments (uncertainties):

Other technologies:

	Renewable Energy		2010	2020	2030	2040	2050	Confidence Level 1–4
11.	PV off-grid	**i) Policy**						
		ii) Lifestyle						
12.	Wind off-grid	**i) Policy**						
		ii) Lifestyle						

PV off-grid: An off-grid PV system, also called a stand-alone system, is designed to provide electricity to a home or business without drawing on supplemental power from the electricity utility. These systems consist of a PV array, control and safety equipment, a battery bank and usually an inverter. The Fraunhofer Institute for Solar Energy (ISE) had developed an energy management system, which optimises the use of electricity produced by a concentrated photovoltaic system and minimising expensive batteries (Sonlight Power, 2013).

Wind off-grid: Systems not connected to a local utility supplier are known as "off-grid" systems. A hybrid system that uses both PV panels and a wind turbine will make a good complement to provide minimum interruptions in power to a home that is off grid. However, it is practical to utilise wind when power speed in the area is at least 9 mph (4.0 m/s). In the case of an emergency, off-grid systems must have an engine generator on hand (Southwest Windpower, 2013).

11 &12. **COMMENTS:**

Key assumptions:

Other key developments (uncertainties):

Other technologies:

	Fenestration		2010	2020	2030	2040	2050	Confidence Level 1–4
13.	Coated/ insulated/tinted glass	**i) Policy**						
		ii) Lifestyle						
14.	Double glazing	**i) Policy**						
		ii) Lifestyle						

Low e-glass has a pyrolytic hard metallic coating, which is embedded into the glass during the molten stage of manufacture. For a better performance, the low-emissivity glass can be used in double-glazed units and can be toughened or laminated. For comparison, normal single glazing has a U-value of 5.8; low-emissivity glass has a U-value of 3.6 Wm^2 °C and low-emissivity glass in a sealed insulated glass unit (SIGU) has a U-value of 1.9 W/m^2 °C. There is almost 40% less energy lost with the low-emissivity product compared with clear glass (Mccoys, 2013; National Glass Distribution, 2013).

Double glazing will be used in more extreme cases to achieve improved U-values. Usually, the double glazing will comprise one clear glass panel, air space and a low-e glass panel and provides an improved U-value if in a sealed unit of 1.9 W/m^2 °C. The SIGU unit shows 67% less energy lost than clear glass (Mccoys, 2013; National Glass Distribution, 2013).

13 &14. **COMMENTS:**

Key assumptions:

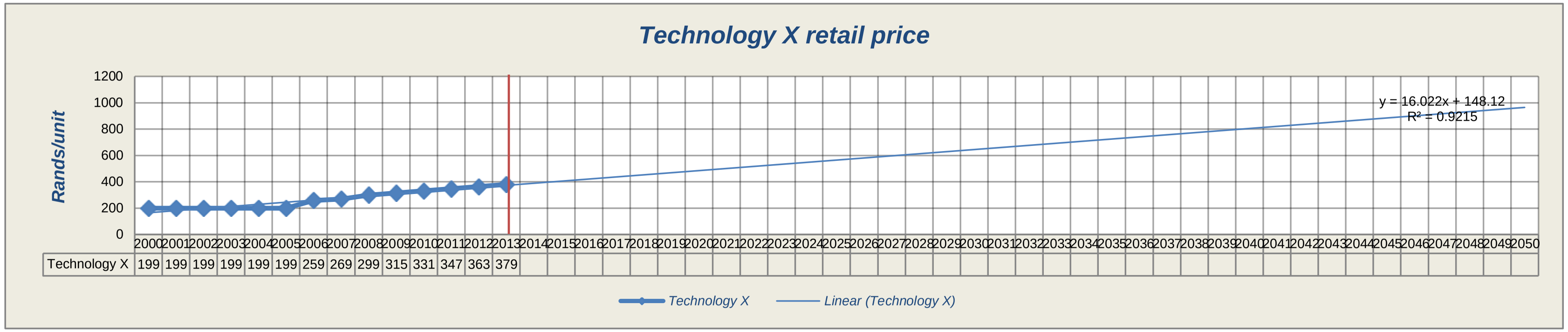
Other key developments (uncertainties):

Other technologies:

TECHNOLOGY ENERGY TRENDS

For each of the graph trends, indicate your trend line/extension in the box below the graphs for 2010, 2020, 2030, 2040 & 2050 that you think are likely to be more accurate in the unit measurement of the graph variable. Provide your comments on the key assumptions for your extensions and other key developments (uncertainties) that you think will probably result in major revisions to the graphs. The principles of answering the graph questions apply to all the graphs although the given example refers more to “markets”.

An EXAMPLE of how to fill in the graph sections is given below. This example relates to “markets”:



Indicate your extension figures of the graph more likely to occur in the boxes, or, if you agree with the proposed graph then mark the “agree” box with a cross. Your figures must be according to the relevant graphs’ unit measurement, e.g. Rand/unit or MtCO₂, etc.

Agree	***2010***	***2020***	***2030***	***2040***	***2050***	***Confidence level 1–4***
	331	*400*	*550*	*700*	*850*	*3*

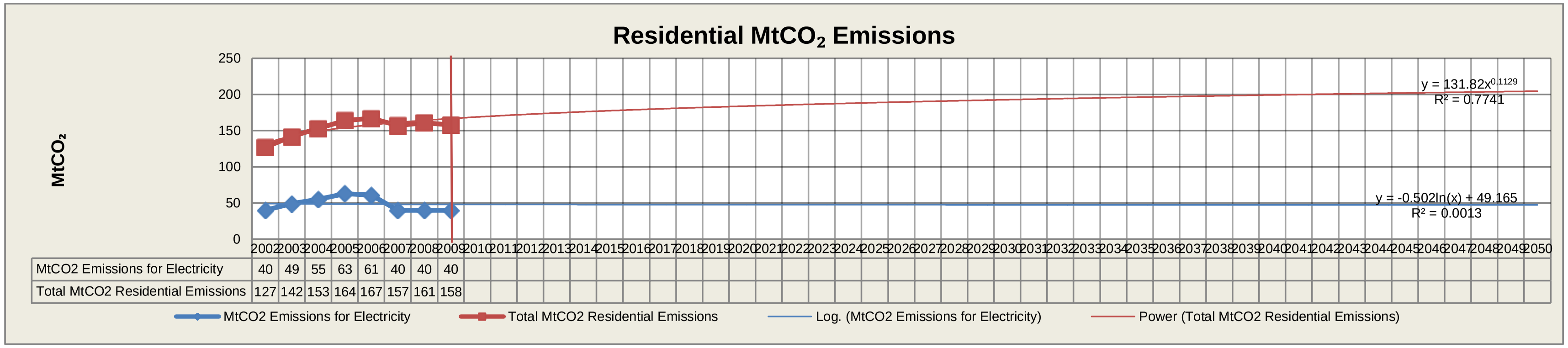
No. ***COMMENTS: example***

Key assumptions: *Slow increase of x% over time due to increases in the exchange rates, labour costs, production costs, raw material costs*

Other key developments (uncertainties): *Growth of rates could increase more drastically if alternative technologies become dominant*

Other technologies: *If you have indicated another technology in the “technology choices” section above, provide the graph extension prices in this part of the comments section, e.g. (R/unit) 250 in 2010, 300 in 2020, 450 in 2030, 500 in 2040, and 800 in 2050*

15. Residential CO_2 emissions – electricity



(StatsSA, 2012:30 –38)

	Agree	2010	2020	2030	2040	2050	Confidence level 1–4
Total residential $MtCO_2$ emissions							
Residential $MtCO_2$ due to electricity							

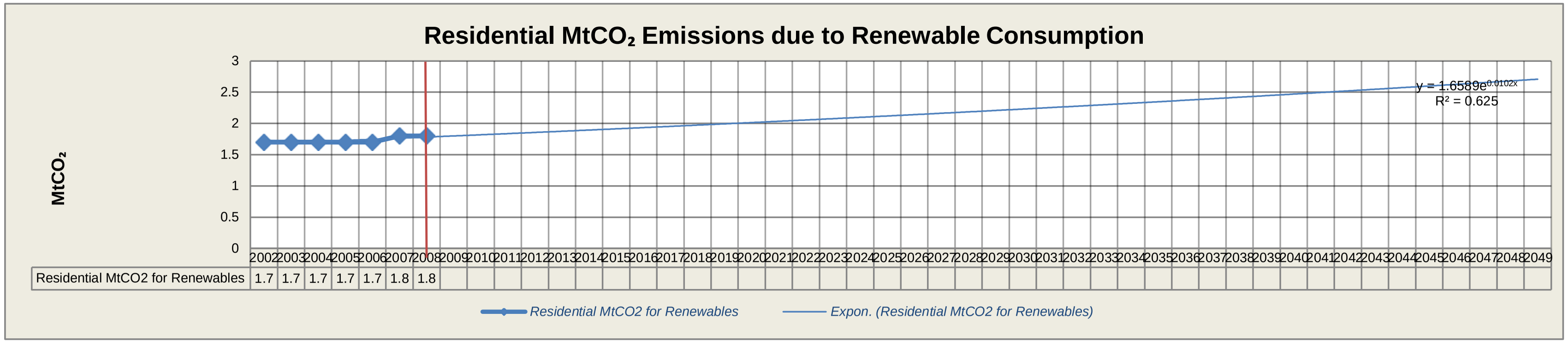
Statistics of energy use in South Africa are limited and often contradictory. For these purposes, the energy accounts from StatsSA have been used. However, the General Household Surveys from StatsSA indicate that electricity comprised 61% in 2002 and 66% in 2011 of the total energy consumption by source type. Of the total energy used, renewable energy consists of 1–10%, coal 1–8% and petroleum products 20–23%. To convert a unit of energy consumption to a unit of carbon emission the following conversion factors are used: 1 GWh = 3.6 TJ; 1 TJ = 0.278 GWh and 1 TJ = 278 tCO_2 (StatsSA, 2012:30 –38; CIDB, 2009:27).

15. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

16. Residential CO_2 emissions – renewable energy



(StatsSA, 2012:30– 38)

Agree	**2010**	**2020**	**2030**	**2040**	**2050**	**Confidence level 1–4**

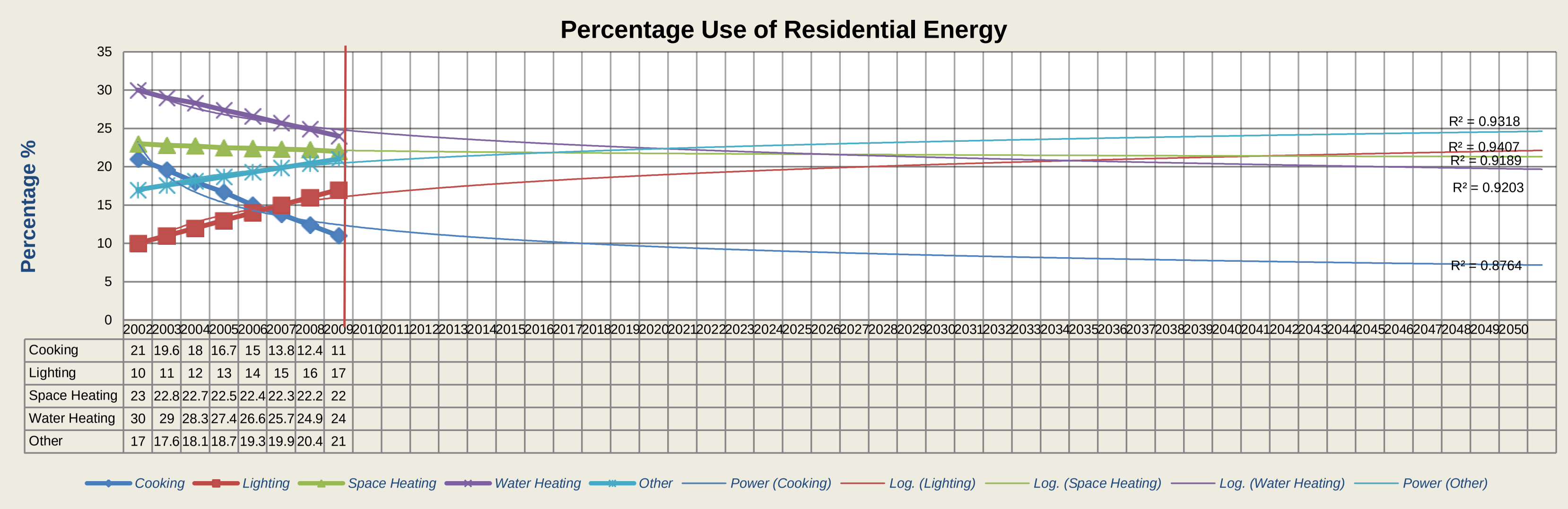
A smaller proportion of the $MtCO_2$ emission is attributable to renewable energy consumption. The renewable energy statistics are contradictory and have for these purposes used the energy accounts from StatsSA. However, the General Household Surveys of StatsSA indicate that renewable energy as an energy source type comprises 1–10% of the total and is in conflict with the figures in this graph of which renewables constitute 40% of the total. To convert a unit energy consumption to a unit of carbon emission, the following conversion factors are used for renewable energy: 1 GWh = 1.1 TJ; 1 TJ = 0.93 GWh and 1 TJ = 93 tCO_2 (StatsSA, 2012:30 –38; CIDB, 2009:27).

16. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

17. Percentage use of residential electricity – middle/high income



	2002	2003	2004	2005	2006	2007	2008	2009
Cooking	21	19.6	18	16.7	15	13.8	12.4	11
Lighting	10	11	12	13	14	15	16	17
Space Heating	23	22.8	22.7	22.5	22.4	22.3	22.2	22
Water Heating	30	29	28.3	27.4	26.6	25.7	24.9	24
Other	17	17.6	18.1	18.7	19.3	19.9	20.4	21

(CIDB, 2009:30–38)

	Agree	2010	2020	2030	2040	2050	Confidence level 1–4
i) Cooking							
ii) Lighting							
iii) Space heating							
iv) Water heating							
v) Other							

Percentages of energy use data in households are derived for the year 2001 and 2008 to ensure reasonable consistency. The electricity usage trends are showing a gradual consumption increase in lighting and other areas, whereas the consumption trends for cooking, space heating and water heating is indicating a gradual decrease over time (Haw and Hughs, 2009: 40; CIDB, 2009:29–30).

17. COMMENTS:

Key Assumptions:

i) Cooking:
ii) Lighting:
iii) Space heating:
iv) Water heating:
v) Other:

Other key developments (uncertainties):

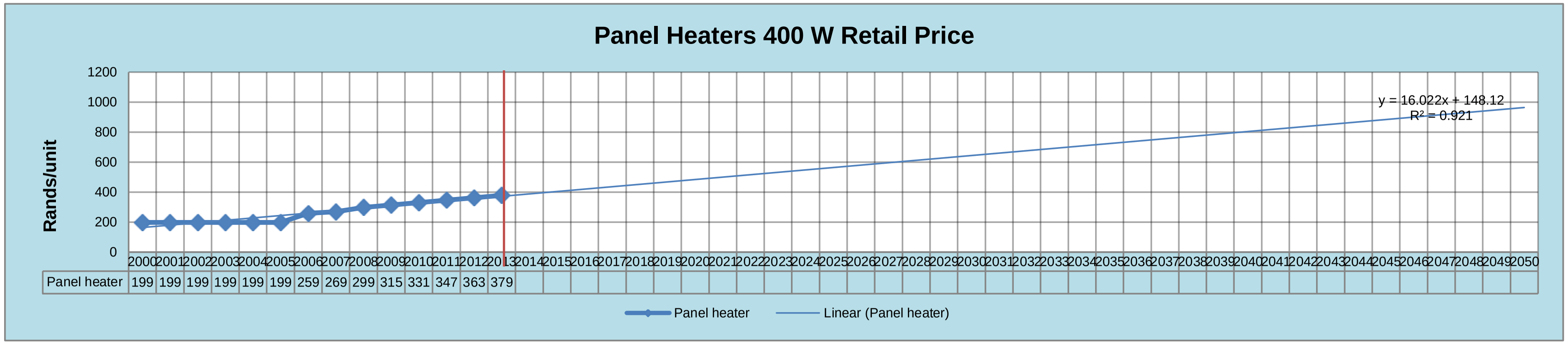
i) Cooking:
ii) Lighting:
iii) Space heating:
iv) Water heating:
v) Other:

MARKETS:

Active Technologies

Heating and Cooling

18. Space heaters



(Du Pont 2013, pers. comm., 25 February)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

When the product first emerged, real prices were kept low and consistent. When the product became popular, prices went up, but retail store buyers demanded prices be kept below R300.00 in 2008. Labour cost increases (MEIBC), production costs, raw material costs and its exchange rates resulted in the increase from 2008 onwards.

(Du Pont 2013, pers. comm., 25 February)

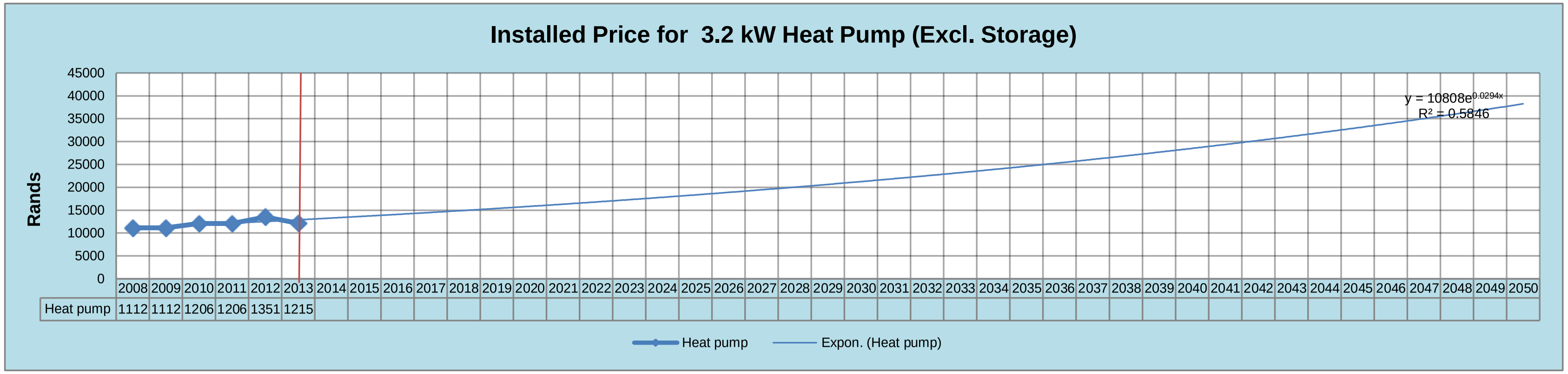
18. **COMMENTS:**

Key assumptions:

Other key developments (uncertainties):

Other technologies:

19. Heat pumps



(Willis 2012, pers. comm., 28 November)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

As a result of the product being imported, exchange rates and inflation influence the costs. Domestic heat pump water heaters are 3.2 kW. A gradual increase in the real costs is evident (Willis 2012, pers. comm., 28 November).

19. COMMENTS:

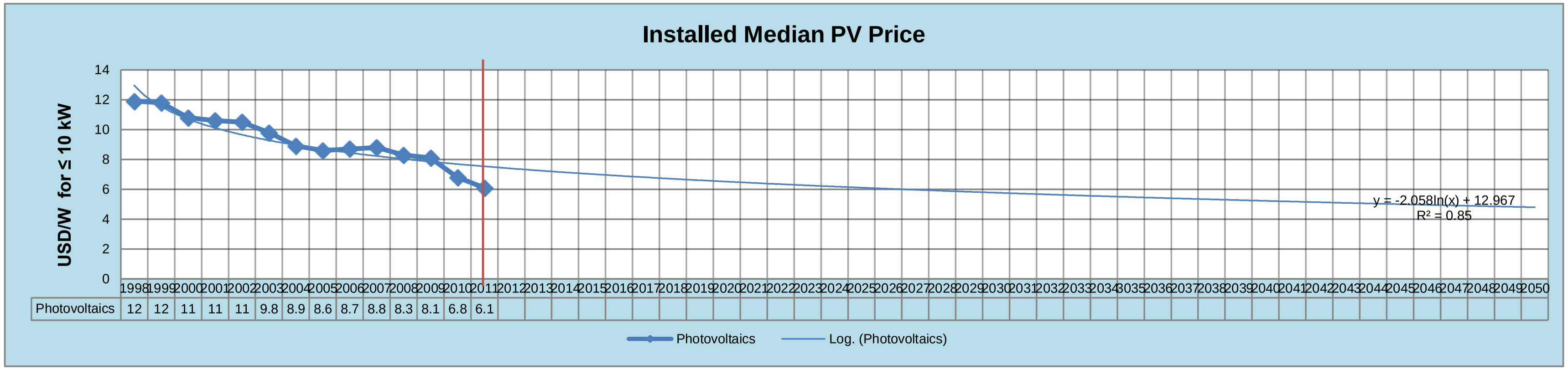
Key assumptions:

Other key developments (uncertainties):

Other technologies:

20. Renewables

PV on-grid: with REFIT



(Barbose, Darghouth and Wiser, 2012:28)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

The overall decline in total installed nominal prices was primarily attributable to a reduction in non-module costs. Within the past few years, however, module prices have declined at a much faster pace than the non-module costs, and as a result, non-module costs have grown in terms of their relative share of the total system costs.

The shift in the cost structure has heightened the emphasis within the industry and among policy makers on reducing non-module costs and business process soft costs (Barbose, Darghouth and Wiser, 2012:28).

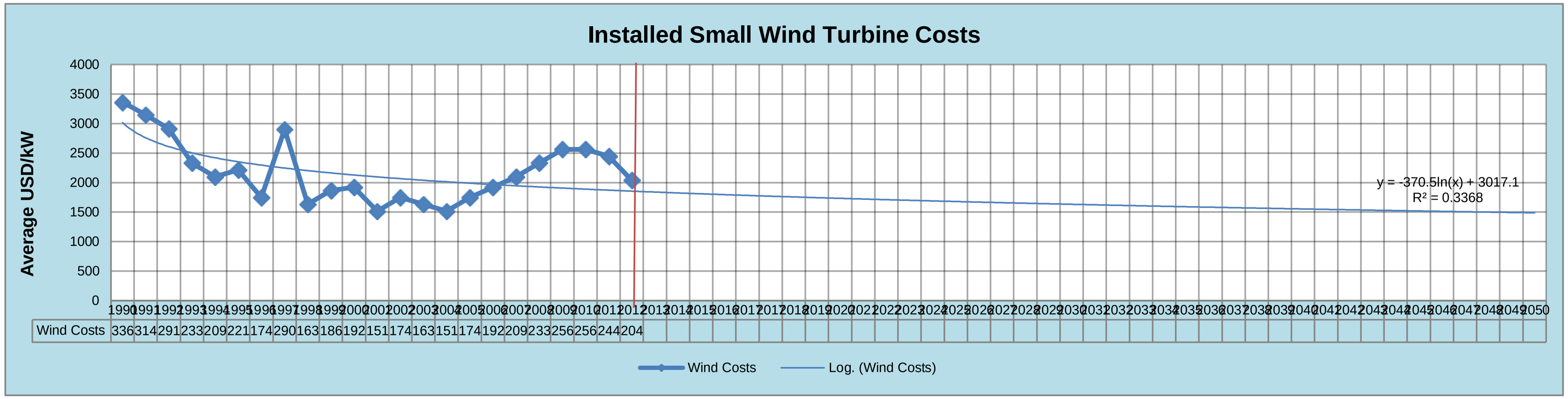
20. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

21. Wind on-grid: with REFIT



(DOE, 2012:34)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

The first four drivers of cost include labour costs, warranty provisions, turbine manufacturer profitability and turbine design and size (endogenous). The other three exogenous drivers include change in the commodity price of raw materials, energy inputs to manufacturing processes and the exchange rate (Bolinger and Wiser, 2011:6).

21. COMMENTS:

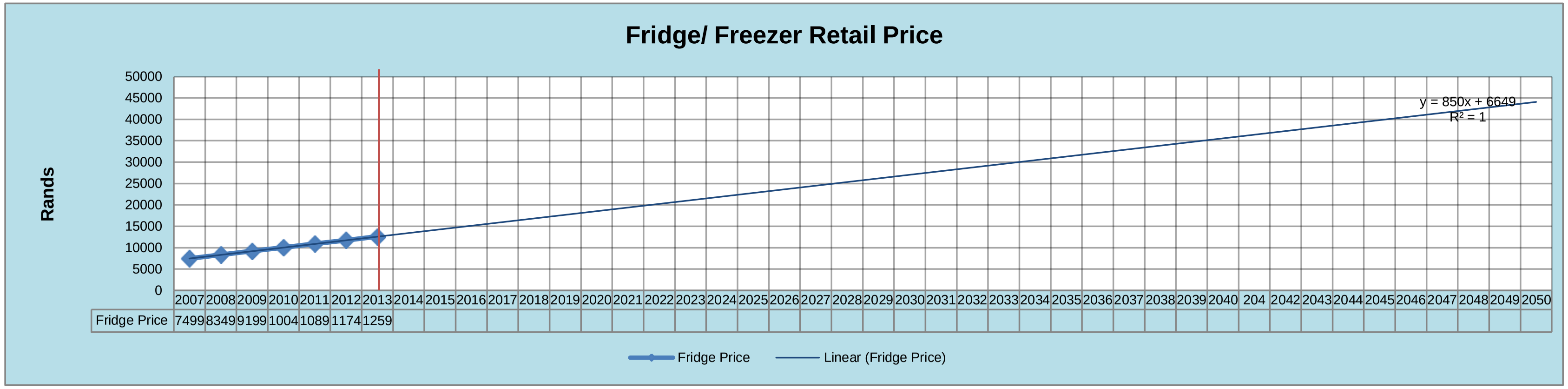
Key assumptions:

Other key developments (uncertainties):

Other technologies:

22. Appliances

Fridges with ratings



(Parker 2012, pers. comm., 25 February)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

The rise in prices is due to added costs of efficiency technology. The two variables that cause the rise in prices are cost mark-ups and economies of scale in the production of higher efficiency units. Real prices though, are falling. Also, note that appliances are mostly imported and that inflation also has an impact on the real price (Dale et al., 2009: 597–605).

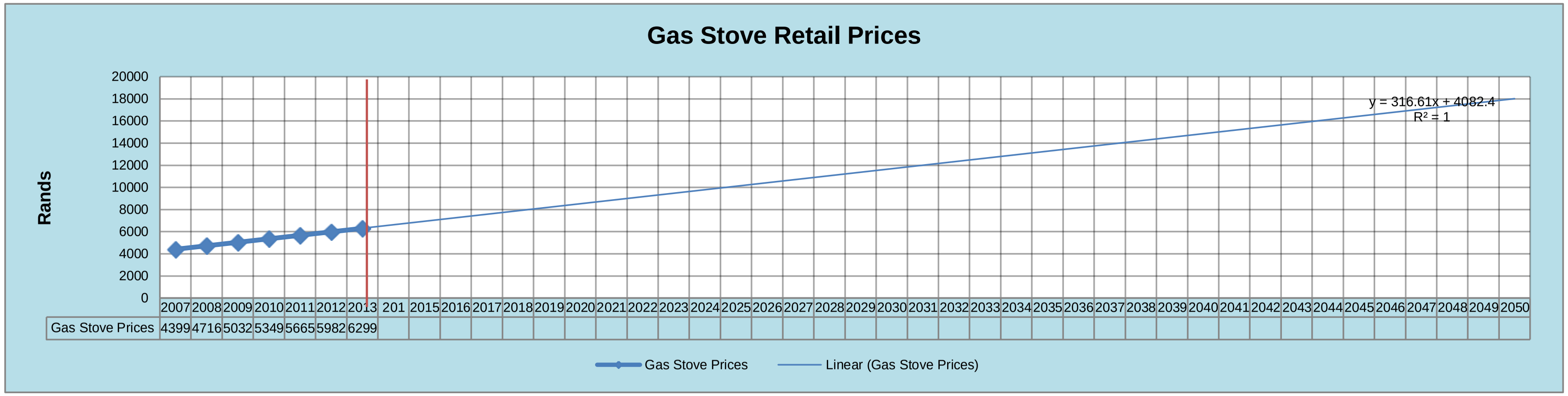
22. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

23. Gas stoves



(Parker 2012, pers. comm., 25 February)

Agree	**2010**	**2020**	**2030**	**2040**	**2050**	**Confidence level 1–4**

The rise in prices is caused by the added costs of efficiency technology. The two variables that cause the rise in prices are cost mark-ups and economies of scale in the production of higher efficiency units. Real prices are falling. Also, to be noted is that appliances are mostly imported and that inflation has an impact on the real price (Dale et al., 2009: 597–605).

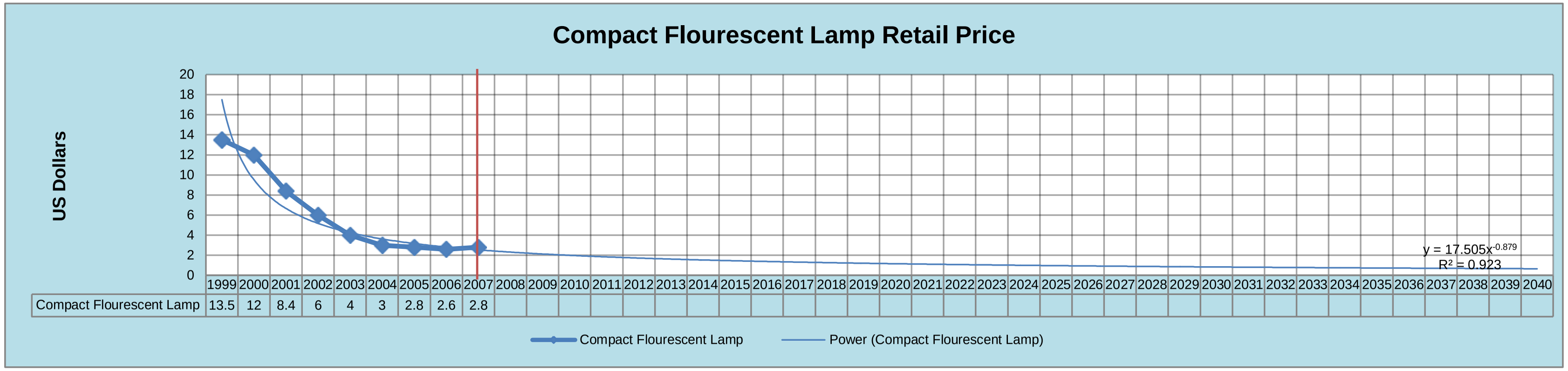
23. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

24. Compact fluorescent lamps



(Cadmus Group, 2009)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

Compact fluorescent lamps maintain a cost and light output advantage over the LED counterpart. The market for luminaire and lighting system control is primarily driven by new installations. Many countries have provided incentives and South Africa has distributed them for free. Although the trend shows a cost decrease, the competition could reduce sales and increase the cost trend. The lamp prices for the imported products are influenced by exchange rates plus 20% import duties and inflation (Botman 2012, pers. comm., 16 January).

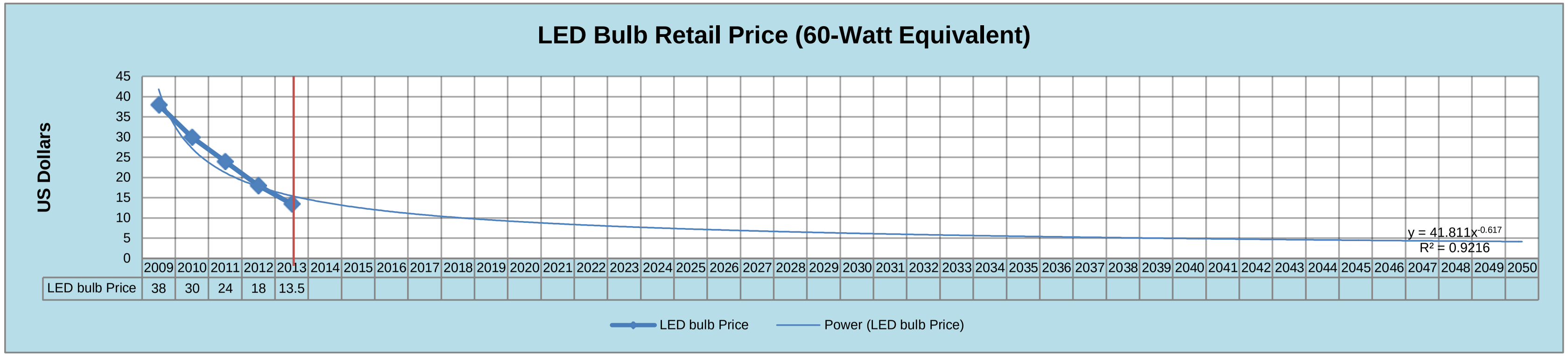
24. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

25. Light emitting diodes



(Cleantech, 2011)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

LED still leads the energy efficiency and longevity categories. Accelerated uptake is driven by a shorter payback time due to faster decline in prices. In some countries, the LED lamps are expected to become competitive with CFLs as soon as 2015, which will further speed up the transition from CFLs to LEDs. South Africa will be providing rebates competitive with CFLs as soon as 2015, which will further speed up the transition from CFLs to LEDs (Mckinsey and Company, 2012).

25. COMMENTS:

Key assumptions:

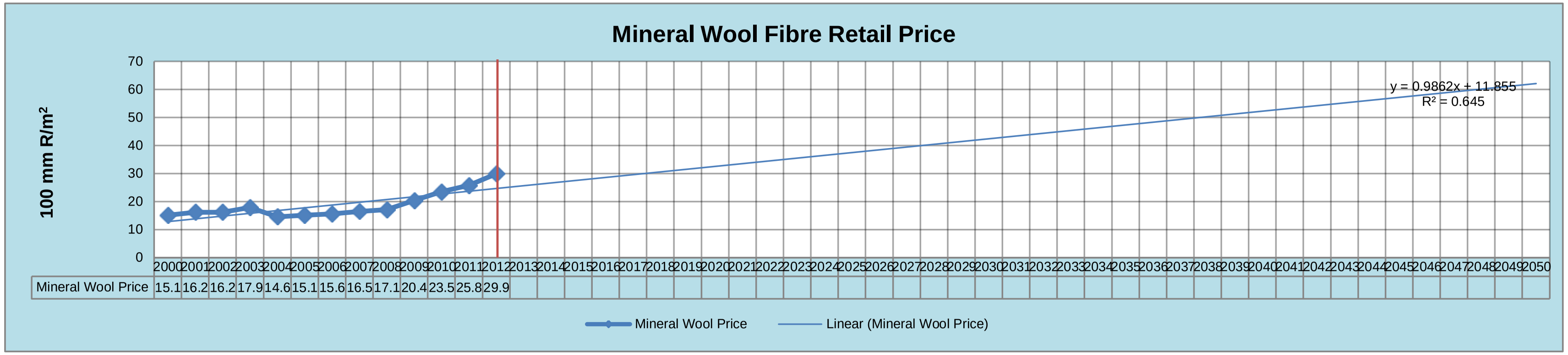
Other key developments (uncertainties):

Other technologies:

Passive Technologies

Envelope

26. Mineral fibre



(Osten 2012, pers. comm., 28 May)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

The higher average price increases shown for recent periods are as a result of the big price hikes we have experienced in electricity and inflation increases.

South Africa has 7 local manufacturing sites. The graph above indicates a consistent gradual price increase (Osten 2012, pers. comm., 28 May).

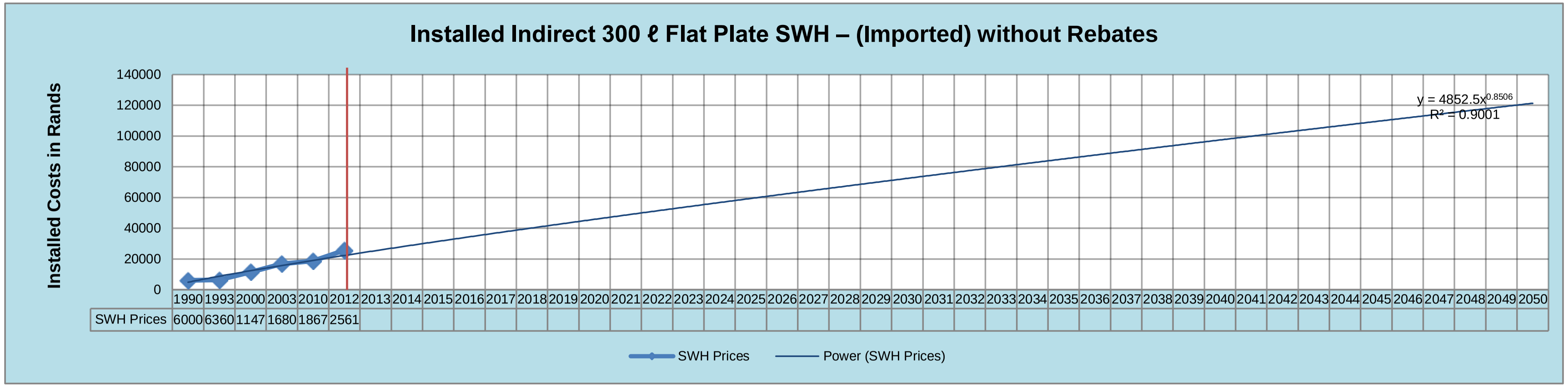
26. **COMMENTS:**

Key assumptions:

Other key developments (uncertainties):

Other technologies:

27. Solar water heaters



(Harper 2012, pers. comm., 4 December)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

There are both locally produced and imported solar water heaters. For the imported products, prices are inclusive of inflation and exchange rates. Installation charges change according to the ease, difficulty and hours required for labour (Harper 2012, pers. comm., 4 December).

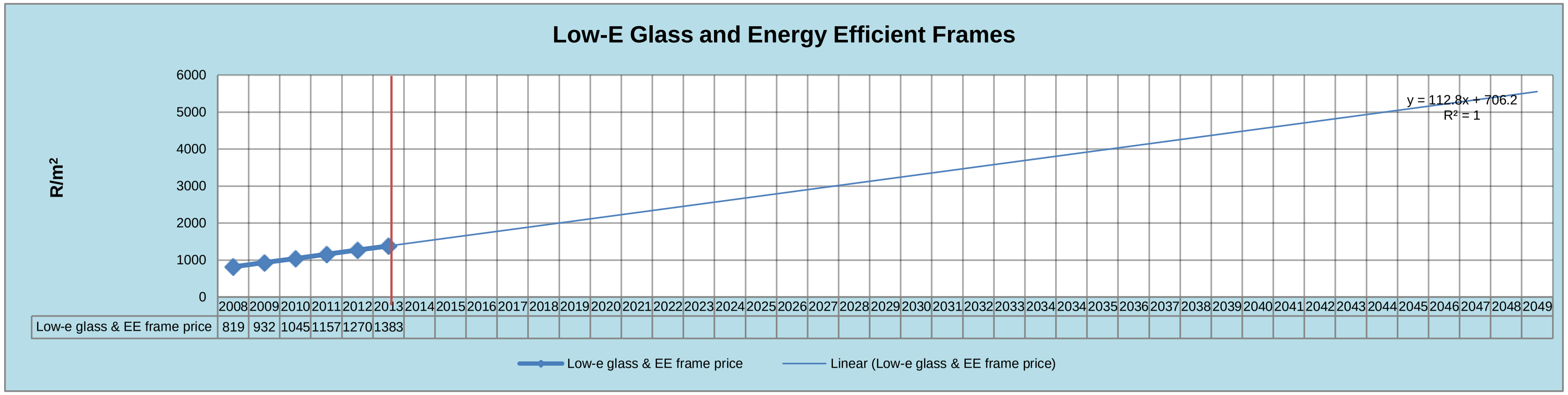
27. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

28. Fenestration



(Walton 2013, pers. comm., 19 February)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

The low-e glass includes the energy efficient frame and the 40% labour costs. Other additional costs are due to inflation, transport, production, raw material and importation (Walton 2013, pers. comm., 19 February).

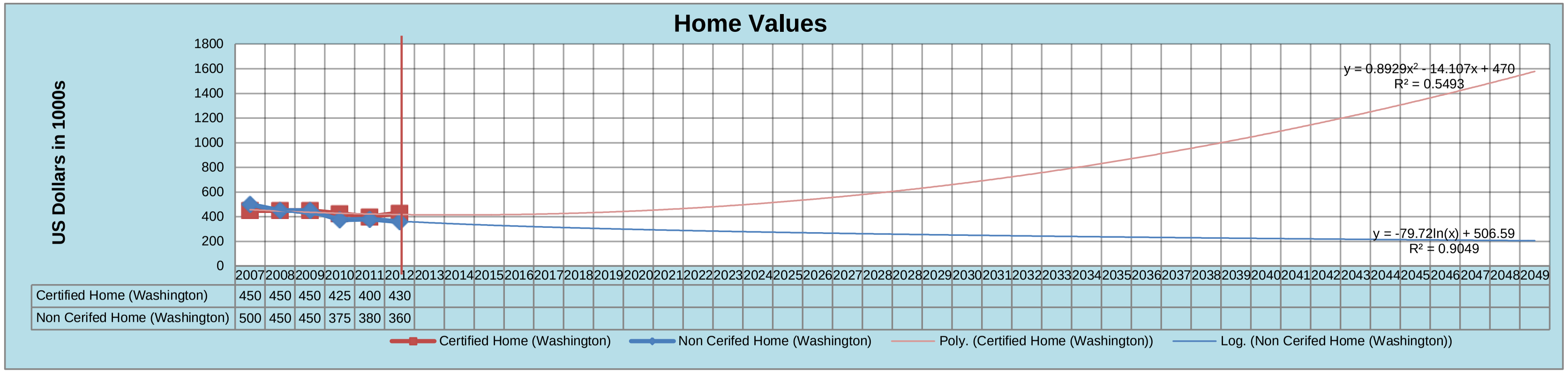
28. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

29. Home value



	2007	2008	2009	2010	2011	2012
Certified Home (Washington)	450	450	450	425	400	430
Non Cerifed Home (Washington)	500	450	450	375	380	360

(Greenworks Reality, 2013)

	Agree	2010	2020	2030	2040	2050	Confidence level 1–4
South African home values in Rand							

Environmentally certified new homes in King County (Washington) sell for more per square foot than non-certified homes. The selling prices are medians for Environmentally Certified Homes or Green Certified Homes, Energy Star or LEED Homes. The home sizes stretch from 162 m² to 218 m². The graph indicates that the price gap between certified and non-certified homes will increase over time (Greenworks Reality, 2013).

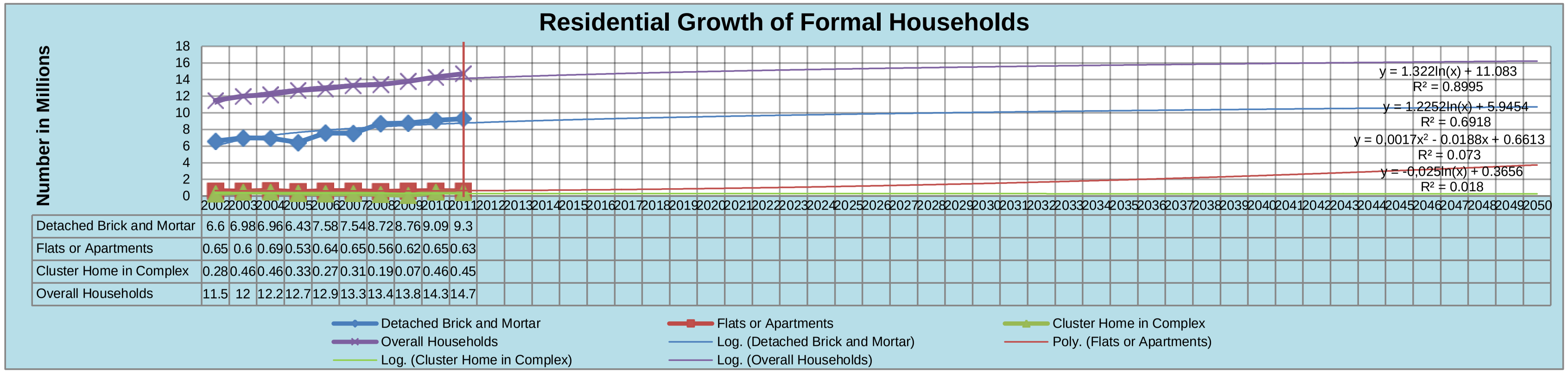
29. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

30. No. of Houses



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Detached Brick and Mortar	6.6	6.98	6.96	6.43	7.58	7.54	8.72	8.76	9.09	9.3
Flats or Apartments	0.65	0.6	0.69	0.53	0.64	0.65	0.56	0.62	0.65	0.63
Cluster Home in Complex	0.28	0.46	0.46	0.33	0.27	0.31	0.19	0.07	0.46	0.45
Overall Households	11.5	12	12.2	12.7	12.9	13.3	13.4	13.8	14.3	14.7

(StatsSA, 2010)

	Agree	2010	2020	2030	2040	2050	Confidence level 1–4
Overall households							
Brick and mortar detached homes							
Flats or apartments							
Cluster homes in complexes							

The table was constructed considering the population in 2050 of 49.4 million to 52 million (www.sdnbd.org) due to HIV. The trend was dampened to reflect the population growth in South Africa (StatsSA, 2010).

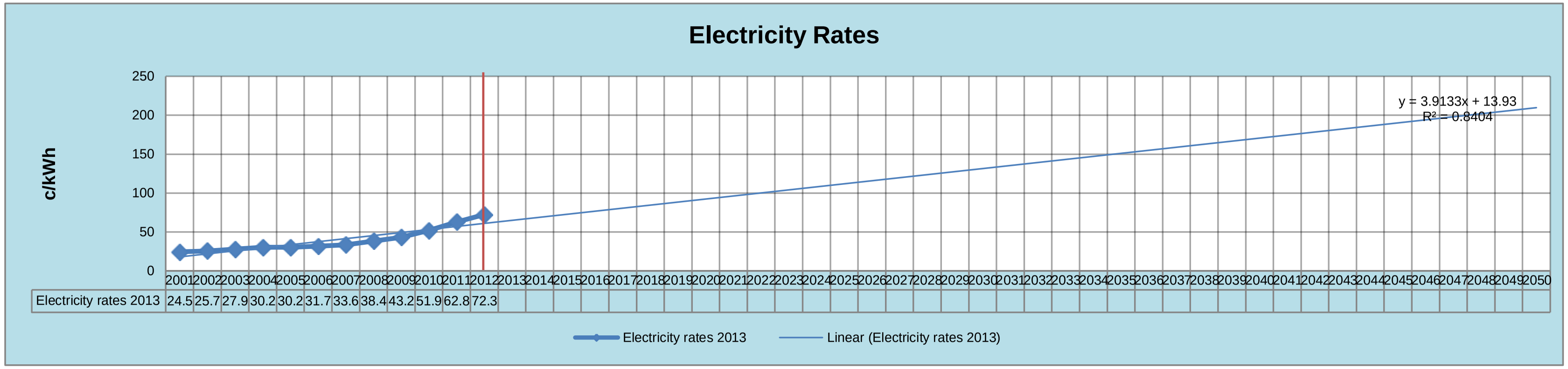
30. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

31. Electricity



(ESKOM, 2013)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

These trends indicate a gradual increase of tariffs to the homeowner over time. The electricity price was kept artificially low for many years as part of South Africa’s industrial policy. Eskom was therefore unable to build up reserves to sufficiently cover the costs of maintenance, replacement and new capacity. NERSA ruled that municipalities are allowed to increase their electricity prices by only 15–16% each year and above inflation (HSRC, 2013).

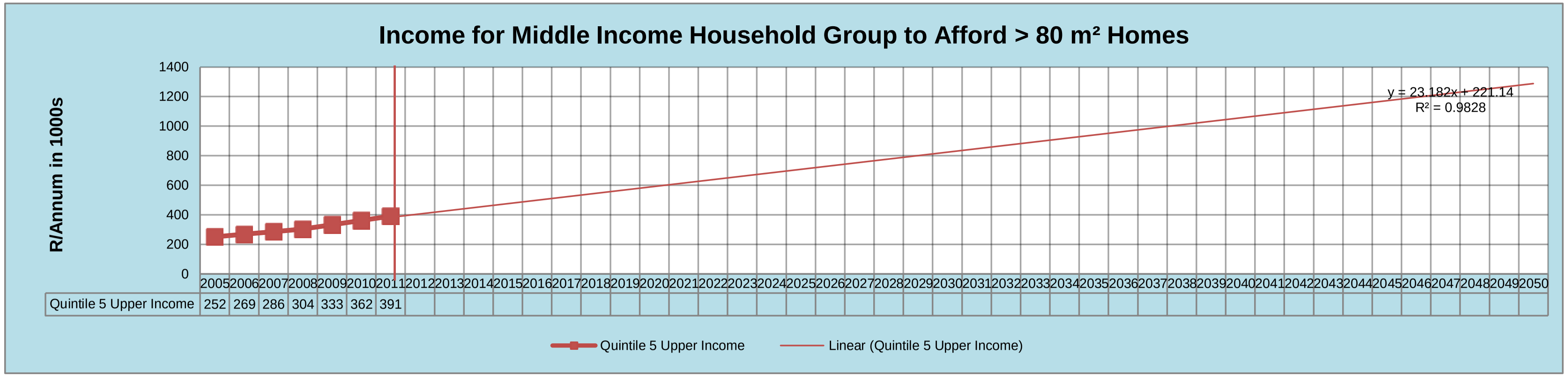
31. COMMENTS

Key assumptions:

Other key developments (uncertainties):

Other technologies:

32. Household income



(StatsSA, 2010)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

The income is determined from StatsSA and has focused on the income groups that can afford a home between 80 m² and 220 m², i.e. quintiles 4 and 5. There is a steady increase in these income groups, which are influenced by inflation at 5.4% in January 2013 (Kopi 2013, pers. comm., 4 March).

32. COMMENTS

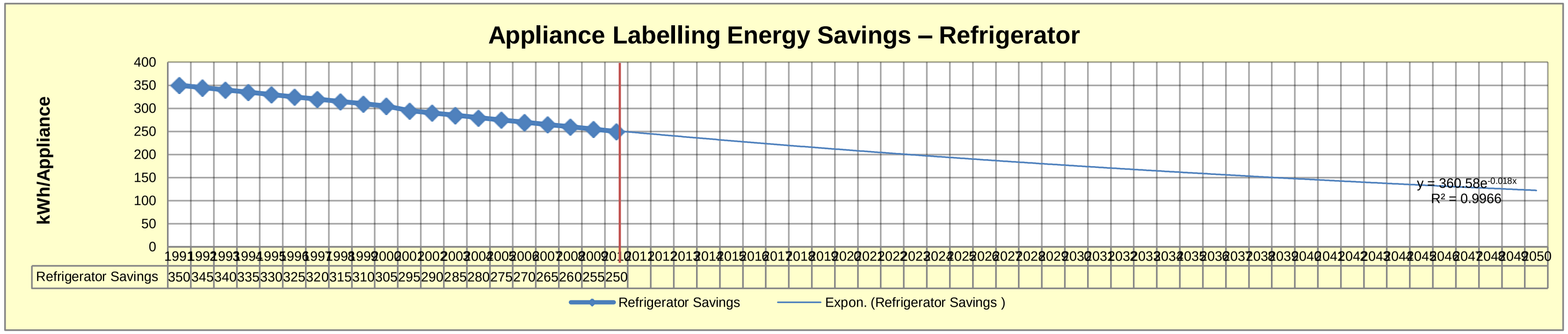
Key assumptions:

Other key developments (uncertainties):

Other technologies:

POLICIES

33. Appliance labelling



(Fraunhofer ISI, 2012:19)

Agree	2010	2020	2030	2040	2050	Confidence level 1–4

The specific electricity consumption of most of the major household appliances in Germany decreased considerably between 1991 and 2011, thus improving the energy efficiency considerably. Of all the energy savings measures in Germany, household appliance labelling (ENVKV) has shown the highest CO_2 reduction of -6 millions of tons of CO_2 between 1998 and 2010 (UBA, 2007).

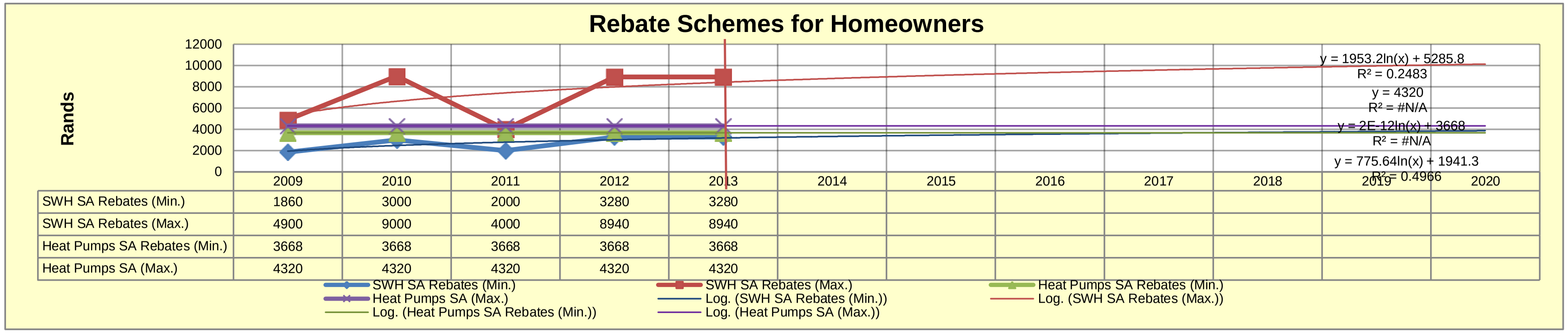
33. COMMENTS

Key assumptions:

Other key developments (uncertainties):

Other technologies:

34. DSM rebates



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
SWH SA Rebates (Min.)	1860	3000	2000	3280	3280							
SWH SA Rebates (Max.)	4900	9000	4000	8940	8940							
Heat Pumps SA Rebates (Min.)	3668	3668	3668	3668	3668							
Heat Pumps SA (Max.)	4320	4320	4320	4320	4320							

(Anel 2012, pers. comm., 1 December)

	Agree	**2010**	**2020**	**2030**	**2040**	**2050**	**Confidence level 1–4**
Min. SWH rebates							
Max. SWH rebates							
Min. heat pump rebates							
Max. heat pump rebates							

The incentives for SWHs and heat pumps were launched in 2009. In 2010, the SWH rebates increased, reduced again in April and increased again in 2012 to compensate those who locally produce more. This rebate programme, according to Eskom, is likely to run for the next 5 years until the market has been adequately stimulated and energy savings achieved. Savings on the electricity bill can be between 30% and 40%. From 2008 to 2011, 156 000 claims were made for SWHs, resulting in national energy savings of 60 GWh/annum. Rebates for heat pumps are aimed at installing 65 858 units to save 128 MW (Anel 2012, pers. comm., 1 December).

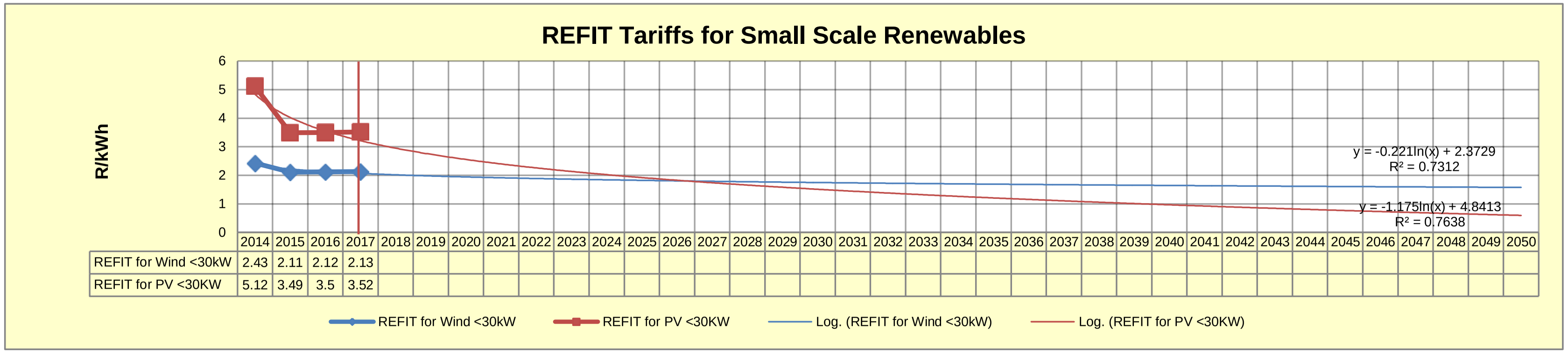
34. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

35. REFIT for small scale renewables



(NERSA, 2011)

	Agree	2010	2020	2030	2040	2050	Confidence level 1–4
REFIT for Wind							
REFIT for PV							

Feed-in tariffs (FIT) are a policy mechanism designed to accelerate investment in renewable energy technologies. Producers of renewable energy are paid a set rate for the electricity they produce in terms of the size of the installation. Roof-mounted tariffs for homes are higher than ground mounted at ± 10 euro cents/kWh higher – if following Germany. FIT often include "tariff degression", a mechanism according to which the price comes down over time. SA's FIT started in 2009 to motivate the production of 10 TWh per year. This will include cost of generation plus profit (DB, 2012).

35. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

36. **There are other model policies not currently implemented, indicate which policies will most likely be implemented, contributing to carbon reductions and/or cost reductions in South African homes and by what year.**
Provide the answers including the reasons in the comments box below.

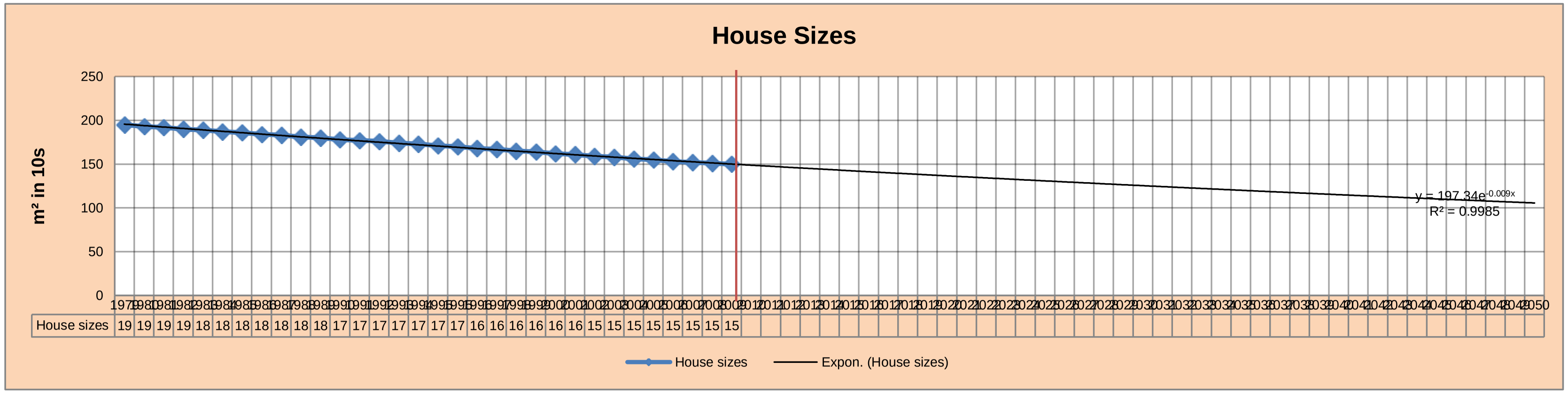
36. COMMENTS

Other future policies that will be implemented along the timeline to 2050 to reduce CO_2:

Other policies that will be implemented along the timeline to 2050 to reduce costs:

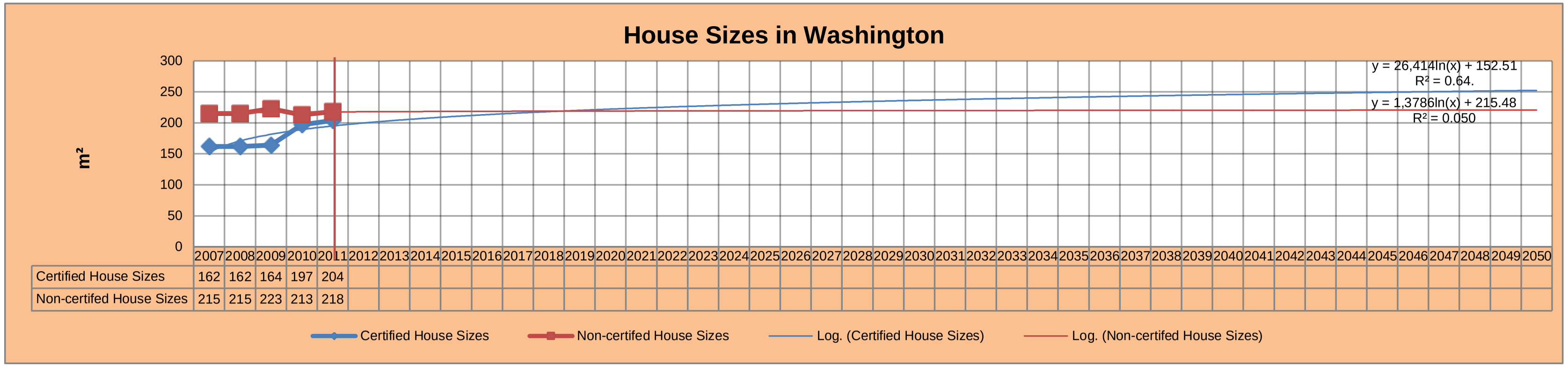
LIFESTYLES

37. Home sizes: South African – without energy efficiency



(Loos and Kellerman, 2011)

House sizes in Washington (certified and non-certified)



(Greenworks Reality, 2013)

	Agree	2010	2020	2030	2040	2050	Confidence level 1–4
South African low-carbon home sizes							

Two graphs are indicated: one for South Africa and one for Washington. The graphs for both South Africa and the USA indicate that the homes for non-energy-efficient homes are becoming smaller. The trends in the USA, however, indicate that certified homes are becoming larger over time (Greenworks Reality, 2013).

37. COMMENTS:

Key assumptions:

Other key developments (uncertainties):

Other technologies:

Technology Lifestyle

38. **Which other lifestyle/behaviour changes will most likely occur that affect technology choices, what are they, and by what year? Provide the answers, including the reasons, in the comments box below.**

38. **COMMENTS**

What are the other lifestyle or behaviour changes?:

Which technologies will be implemented due to behaviour or lifestyle changes given above and why?:

In which year will the technology be implemented along the timeline to 2050 i.e. 2010, 2020, 2030, 2040 and 2050?:

THE END

Thank you for completing Questionnaire 1. The results will be provided in Questionnaire 2 for you to validate. Please send the filled in questionnaire to both dominiqueg@nhbrc.org.za **and** dgeszler@gmail.com **within the next 3 days**

A3 Delphi participants list

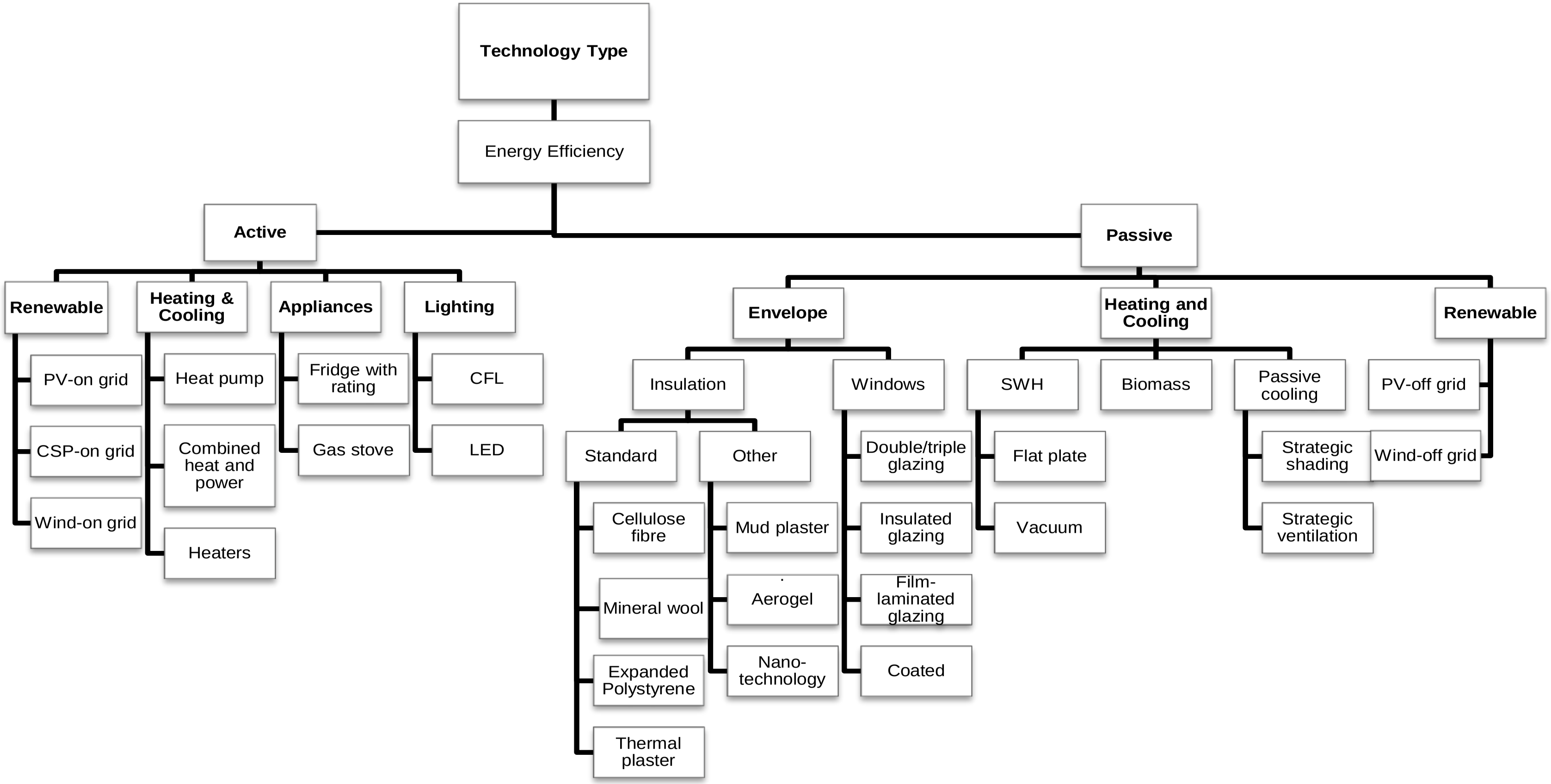
Final Delphi participants list						
No.	**Group**	**Stakeholder**	**Organisation**	**Province**	**Method**	**Confirmed**
1	Markets/Lifestyles	Hendrik Viveiros	GBCSA	Western Cape	Delphi	x
2	Policies	Dr Sheffie Gange	Energy Research Centre	Western Cape	Delphi	Withdrew
3	Technologies/Policies	Prince Ferris	Eskom	Gauteng	Delphi	x
4	Technology/Policies	Lenee Beckman	Energy Research Centre	Western Cape	Delphi	x
5	Technologies/Markets	Dr Brennan Joanes	CSIR/Consulting Engineer	Gauteng	Delphi	x
6	Policies/Lifestyles	Dr Jim Macdonald	CSIR/Sustainability	Gauteng	Delphi	x
7	Policies/Lifestyles	Christofer Hexner	Carbon Neutral Approach	Gauteng	Delphi	Not Q2
8	Technologies/Markets	Noe Thavaneswaran	St Gobain Construction	Gauteng	Delphi	x
9	Technologies/Markets	Steven Ferme	Agama Energy	Western Cape	Delphi	x
10	Technologies	Eden Ernest	Greenplan Consultants	Western Cape	Delphi	Withdrew
11	Technologies	Antoine Stephanos	Energy Research Centre	Western Cape	Delphi	x
12	Lifestyles	John Cramer	Osglo Architects	Limpopo	Delphi	x
13	Lifestyles/Technologies	Geno Fior	KMH Architects	Gauteng	Delphi	x
14	Markets	Thomas Schor	PentadQS	Gauteng	Delphi	Withdrew
15	Technologies/Markets	Darom Waniewski	Talani Quantity Surveyors	Gauteng	Delphi	x
16	Lifestyles	Arch Ens	TJ Architects	KwaZulu-Natal	Delphi	x
17	Technologies/Policies	Jan Loots	Ecocentric	Gauteng	Delphi	x
18	Technologies	Leonard Beckman	Sutherland Engineering	Gauteng	Delphi	Withdrew

A4 Delphi method process

Stage	Item description	Method process
Preparation	**1. Identified current trends.**	12/2012
	Determined the trends in lifestyles, policies, technologies and markets.	Guided by relevant literature.
	2. Identified sources for historic data.	01/2013
	Collected secondary data from different sources for extrapolations.	Collected data from local and international manufacturers, research institutions, regulatory bodies and academic literature.
	3. Prepared first questionnaire.	02/2013
	Prepared qualitative questions on the technology trends and quantitative data (time-series extrapolations to 2050) on the market, policies and lifestyle influences to establish technology CO_2 mitigation and cost effectiveness.	Divided the questionnaire into four sections/themes (technologies, policies, markets and lifestyles), of which the relevant sections determined the following. 1. When the technology will be a likely trend on a designated timeline to 2050 due to policies or lifestyles. 2. What the % mitigation of a technology will be in terms of its % reduction to the 100% overall consumption. 3. What the probable trends will be over time, generating various initial time-series extrapolation graphs for markets, lifestyles and policies based on secondary historic data. 4. What the reasons were for the provided data and its associated causal forces that could be responsible for the trends for each section. 5. What the other probable technology trends would be by asking open-ended questions. 6. How confident their responses were by assigning a CL of 1 to 4 for each question. 7. Completed a case study on technology innovation diffusion that was e-mailed to respondents together with the questionnaire.
Planning	**4. Designed the format of questionnaire.**	03/2013
	Designed the type of questions, layout, length, dissemination and analysis.	Decided how the questionnaire would be disseminated and filled in, and provided clear guidelines of how to fill it in.
	5. Invited approx. 18 participants.	04/2013
	Identified prospective organisations and/or experts nationwide and prepared invitations.	Phoned, e-mailed and obtained confirmation of participation e.g. confirmation letter in Appendix A1 (see page 281). Ensured there were two experts on a reserve list.
	6. Contacted participants before dissemination.	05/2013
	Stayed in contact and followed up when necessary.	Ensured mechanisms for soliciting were in place.
Conducting Delphi	**7. Disseminated questionnaire 1.**	06/2013
	E-mailed to 18 experts.	1. Used the e-mail method to send questionnaire 1 to each participant. 2. Respondents filled in questionnaire 1 electronically in MS Word format.

		3. Ensured that the filled-in questionnaire was returned within three days, although some took longer to respond. 4. Followed up if there was no response within three days to determine the status. 5. Received feedback from 14 respondents.
	8. Evaluated questionnaire 1.	07/2013
	Analysed questionnaire 1.	1. Estimated the quartiles, medians and the CLs. 2. Constructed new graphs with median results, lower quartiles and upper quartiles. 3. Included a summary of comments. 4. Completed questionnaire 2 to test validity by reiteration.
	9. Disseminated questionnaire 2.	08/2013
	E-mailed to 13 experts (one pulled out of the 14 respondents in Round 1).	1. Contacted each participant before dissemination. 2. Ensured that the filled in questionnaire was returned within five days and kept track of those who submitted later. 3. Included reserves.
	10. Evaluated questionnaire 2.	11/2013
	Analysed questionnaire 2.	1. Estimated the quartiles, medians and CLs to complete new graphs. 2. Estimated the medians, quartiles and the CL. 3. Summarised the comments, using a coding technique. 4. Sent participants the final results.

A5 Technology categories



APPENDIX B: BACKCASTING METHOD TOOLS

B1 Backcasting method process

Stage	Item description	Method process
Preparation	**1. Developed narratives for the backcasting in 2050.**	03/2013
	Defined the future by creating preliminary visions. Assumptions were made on the energy usage and cost implications for the narrative.	1. Developed two storylines for comparison, i.e. Hybrid society with deep carbon cuts (80%) and with moderate cuts (50%). 2. Mapped an overview of the storylines for each designated year on a timeline to 2050. 3. Made certain assumptions, e.g. stock, income, home size, etc. as part of the narrative.
	2. Decided on the steering committee.	03/2013
	Planned on how the charrettes would be managed.	1. The budget determined how many people could be part of the organising, managing and facilitating processes, in the event, the researcher would do all the latter tasks.
Planning	**3. Ascertained approx. 12 interested stakeholders for each charrette.**	04/2013
	Identified prospective organisations and/or experts and non-experts individually.	1. Solicited the participants, i.e. phoned, e-mailed and obtained confirmation from participants who represented an industry. 2. Aimed at approaching a cross section of stakeholders. 3. Identified two stakeholders for the reserve list. 4. Identified a manageable number of stakeholders.
	4. Finalised budget and expenditure.	04/2013
	Worked within available budget.	1. Ensured that the venue, equipment, supplies, exhibits, flight and transport requirements were affordable.
	5. Made logistical arrangements to conduct charrette.	05/2013
	Determined suitable venues for conducting the charrettes.	1. Ensured that the choice of venue locations were accessible. 2. Booked a venue in Pretoria and Cape Town at least one month in advance. 3. Planned for hotels that provided the following facilities: projectors, flip charts, recording material, lunches and break away spaces. 4. Ensured that the venues for conducting the charrettes were affordable, i.e. less than R500 per person.
	6. Prepared for charrette material.	06/2013
	Completed an agenda and presentation.	1. Developed an agenda that clearly stated the goals (see Appendix B6 (see page 332)). 2. Included the welcome and introduction.

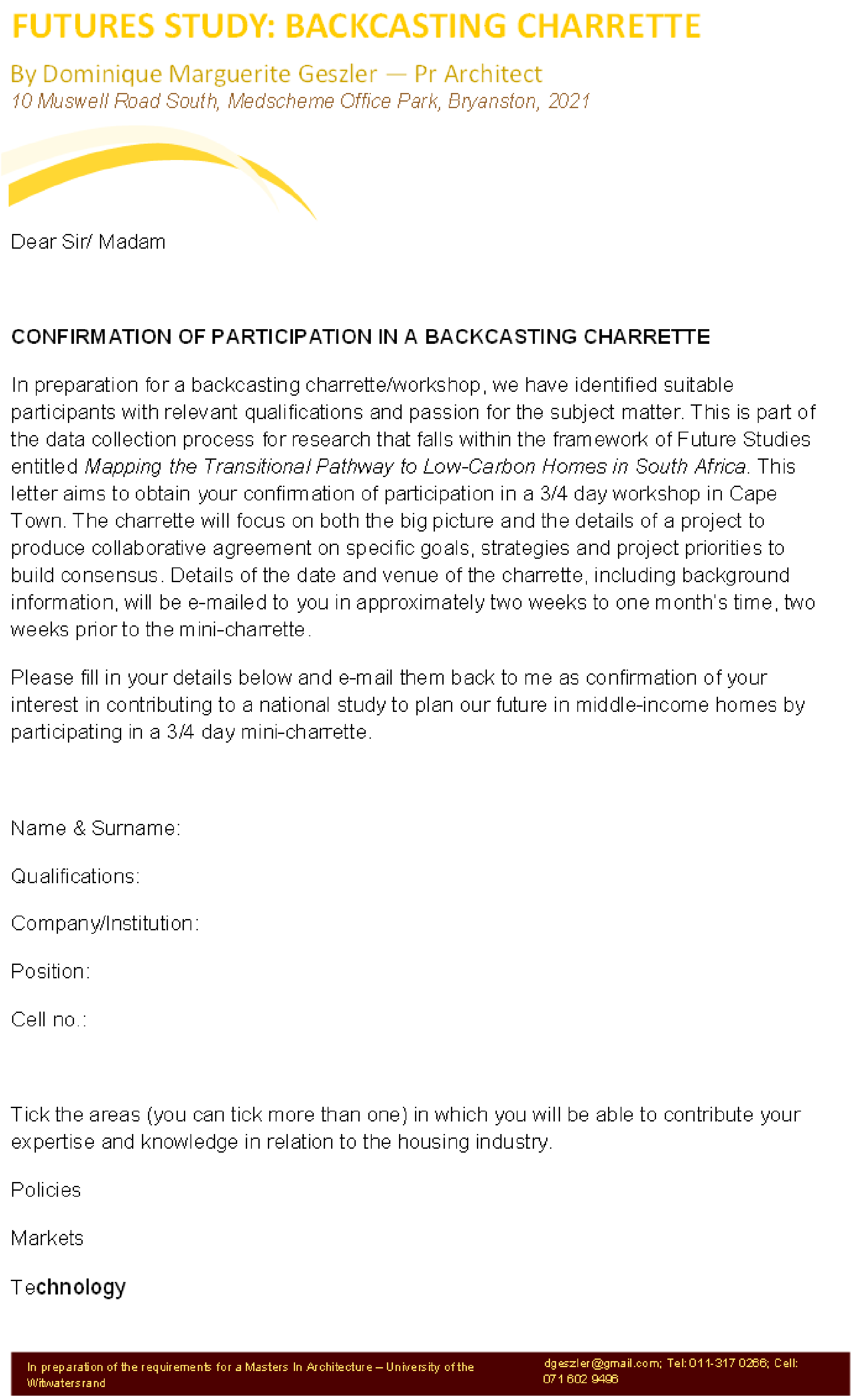
		3. Prepared the overview and technical presentation.
	7. Prepared participant packages.	06/2013
	Included basic items in the participants' packages.	1. Prepared packages that included the following items: final agenda, project information (narratives), presentation, and participant's notebook.
	8. Sent an invitation to stakeholders who confirmed their interest.	06/2013
	Sent all participants the invitation, background information and agenda.	1. Contacted each participant before dissemination. 2. Besides the agenda and invitation, included the narrative/storyline and what to prepare.
Conducting mini-charrette	**9. Checked and verified arrangements for the venue.**	07/2013
	Ensured that the arrangements made were in order the day before the event.	1. Visited the facility. Checked supplies and materials plus logistical arrangements.
	10. Proceeded with the event according to the programme.	07/2013
	Ensured the three-quarter day event was conducted according to plan.	1. Arranged with hotel reception to guide participants to venue. 2. Checked that the meeting room was arranged properly and all equipment was functioning. 3. Checked that the room was set up properly and that there were two tables (for two groups of 6 to 8 people) prepared for break-away sessions. Groups were predetermined. 4. Began with the opening session, i.e. introduction, goals, structure of charrette. 5. Described project and charrette expectations with presentation, i.e. goals, project description, project visions/storyline and issues. There was information that would not overwhelm the participants. 6. Created breakout groups. 7. Followed successful charrette practices, such as consistency in breakout group assignments, groups preparing a summary for the report-out session, taking photos of each breakout group and presentation, groups summarising work on flip charts to present, voice recording the charrette, setting performance goals and arriving at a consensus.
	11. Completed a final report.	08/2013
	Obtained inputs from participants for the final report.	1. Compiled a final report on the event and results. 2. Circulated a draft to include participants' comments, additions and corrections.

B2 Backcasting charrette participants lists

Charrette participants list for the Western Cape			
No.	**Group**	**Stakeholder**	**Organisation**
1	Technologies/Lifestyles	Deborah Kingston	City of Cape Town
2	Markets/Lifestyles	Dr Amanda Dawkins	Consolidated Carbon Solutions Africa
3	Markets/Policies	Dirk Hoop	GM Quantity Surveyors
4	Technologies	Edward Prince	Ecosolution Engineers
5	Lifestyles	Karin Skoon	Bear Architects
6	Technologies	Howard Maines	WWS Engineers-Electrical
7	Technologies	Conrad van Stade	WWS Engineers-Mechanical
8	Policies	Jackie Giotini	Jackie Giotini Architects
9	Lifestyles	Jack Harpen	Jack Harpen Architects
10	Policies/Lifestyles	John Sterning	Sustainability Institute in Stellenbosch
11	Markets	Brent Edwards	Bureau of Economic Research in Stellenbosch

Charrette participants list for Gauteng			
No.	**Group**	**Stakeholder**	**Organization**
1	Technologies/Policies	John Thorby	Eskom
2	Policies/Technologies	Prince Moetisi	City of Johannesburg
3	Technologies	Hans Boom	CSIR/Renewables
4	Markets/Lifestyles	Dr Hendrik Mansard	AECOM Quantity Surveyors
5	Policies/Lifestyles	Brenda Denneman	Shades of Green
6	Lifestyles	Isabel Graham	NDH Architects
7	Lifestyles	Claudia Fleece	City of Johannesburg
8	Technologies	Greg Hampton	Eco-relevance
9	Technologies	Jack Bream	Eco-relevance
10	Lifestyles	Dando Olawa	Legacy Architects
11	Markets/Lifestyles	Patricia Horn	ARDOM Quantity Surveyors

B3 Backcasting charrette letter



FUTURES STUDY: BACKCASTING CHARRETTE

By Dominique Marguerite Geszler — Pr Architect
10 Muswell Road South, Medscheme Office Park, Bryanston, 2021

Dear Sir/ Madam

CONFIRMATION OF PARTICIPATION IN A BACKCASTING CHARRETTE

In preparation for a backcasting charrette/workshop, we have identified suitable participants with relevant qualifications and passion for the subject matter. This is part of the data collection process for research that falls within the framework of Future Studies entitled *Mapping the Transitional Pathway to Low-Carbon Homes in South Africa*. This letter aims to obtain your confirmation of participation in a 3/4 day workshop in Cape Town. The charrette will focus on both the big picture and the details of a project to produce collaborative agreement on specific goals, strategies and project priorities to build consensus. Details of the date and venue of the charrette, including background information, will be e-mailed to you in approximately two weeks to one month's time, two weeks prior to the mini-charrette.

Please fill in your details below and e-mail them back to me as confirmation of your interest in contributing to a national study to plan our future in middle-income homes by participating in a 3/4 day mini-charrette.

Name & Surname:

Qualifications:

Company/Institution:

Position:

Cell no.:

Tick the areas (you can tick more than one) in which you will be able to contribute your expertise and knowledge in relation to the housing industry.

Policies

Markets

Technology

In preparation of the requirements for a Masters In Architecture – University of the Witwatersrand

dgeszler@gmail.com; Tel: 011-317 0266; Cell: 071 602 9496

B4 Invitation to charrette

PLEASE NOTE THAT THIS EVENT IS PART OF THE AUTHOR'S DATA COLLECTION FOR A RESEARCH PROJECT COMPLETED THROUGH THE UNIVERSITY OF THE WITWATERSRAND, IN PREPARATION OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN ARCHITECTURE AND THAT THE RESPONSIBILITIES OF THE WORK AND CONTENT ARE SOLELY THOSE OF THE AUTHOR

UNIVERSITY OF THE WITWATERSRAND
JOHANNESBURG

MAPPING THE TRANSITIONAL PATHWAY TO LOW-CARBON HOMES IN 2050

INVITATION TO THE CHARRETTE WORKSHOP – WC

TIME: 9H45 TO 16H30 **DATE: 04/07/2013**

VENUE: SPIER

Preparation for the Workshop:

1. The objective is to determine the improved policies, markets and lifestyles that influence the choice of technological options and combinations to be able to reduce carbon emissions by 80% in the year 2050.

2. Carefully study the attached Storyline for the year 2050 and analyze the parts relevant to your field of knowledge (technologies, policies, markets and lifestyles) for inputs at the charrette.

3. Attached are the Storyline and the Agenda

PRESENTED AND FACILITATED
BY DOMINIQUE GESZLER
PR ARCHITECT

Contact person: 011-317 0266
or 071 602 9496

Contact person e-mail:
dominiqueg@nhbrc.org.za and
dgeszler@gmail.com

VENUE ADDRESS: R310, STELLENBOSCH - SEE ATTACHMENTS FOR DIRECTIONS OR SEE WEBSITE AT WWW.SPIER.CO.ZA

FOR QUESTIONS OR COMMENTS E-MAIL US AT DOMINIQUEG@NHBRC.ORG.ZA OR CALL 011-317 0266 OR 71 602 9496

B5 Charrette agenda

AGENDA

Three-Quarter Day Mini-Charrette – 11 July 2013

High-Performance Outcomes

9:45–10:00	*Breakfast*
10:00–10:30	Welcome, introductions, expectations and goals
10:30–11:15	High-performance process and issues: Presentation
	1. Background
	2. Predesigned vision/storyline
	3. Predesigned analysis
	4. Goals and actions of groups
11:15–11:45	Q&A on project-specific issues
11:45–12:00	*Tea Break*
12:00–1:00	Breakout groups
	Two groups of 6–8 people per group
	Groups are made up of multidisciplinary team members
1:00–1:45	*Lunch*
1:45–2:30	Breakout groups
	Compile summary of outcomes
2:30–3:45	Report back of groups
3:45–4:30	Reporting out

B6 Categorised charrette narratives

WESTERN CAPE CONSENSUS

1. LIFESTYLE – Voluntary changes

1.1 Approach

There was overall consensus that the 80% carbon reduction target for homes can be achieved by 2050. To accomplish this from a voluntary perspective, the groups’ preferences for 2050 rested mainly on the concept of collaboration. Expanding on this concept, they believed that it could be an idealistic goal if other issues were not addressed, such as the massive inequalities and cultural differences. They further pointed out that anything was possible if everybody worked towards the same goals. However, they commented that making changes quickly would require mandatory requirements. Voluntary changes were not disregarded and could − to a certain extent − be envisaged, but the participants noted that the changes could be made only within the choices available and within the flexibility of policies. Although the group thought of desirable ways of living, it was emphasised that perceptions of comfort would be perceived differently in 30 years from now relative to what we perceived it to be today. It was emphasised that there would be higher levels of family planning as education improved, leading to better control of population growth – a major driver of any future economy.

1.2 Mindset and values

The group preferred the forward-thinking concepts of collaboration and collaborative consumption. This included systems, the re-appreciation of the commons, social cohesion and social capital that will strengthen a sustainable society. They felt that, in future, there will be more collaboration on a neighbourhood scale, meaning neighbourhoods will pull together and get a new form of modern social cohesion (communities, villages, cities and high-rise). They referred to collaboration taking different forms, whereby services will be provided in dense cities as well as in the countryside, e.g. institutions that provide services for a vegetable planting scheme. Ideas from the broader perspective alluded to people belonging to multiple overlapping communities as opposed to the insular idea, e.g. a community could be based around one's education or family. Although examples were given relating to voluntary changes being made, they would be more closely linked to available choices. There was talk about the focus shifting from a nuclear family to a more connected "community" family, as well as returning to values that encompassed sharing in a community sense, e.g. if the grandparents looked after the children, the children looked after the older generation. These communities consisted of compact convenient homes with a social focus in a community. Some lifestyle changes that the group foresaw in the future were healthier lifestyles, bicycle riding and preferences for smaller apartments, driven by increasing construction costs and energy costs. Participants' expectations were that in 40 years, as focus shifted towards global survival, this would cause a local shift towards a need for a community-focused lifestyle.

1.3 Land use

In terms of future growth, they envisioned nodes, where smart villages will be strategically placed along growth corridors. This type of development will put less pressure on road and transport infrastructure. The current growth pattern needed to be promoted more vigorously. Although the participants noted the virtues of high density, which were proven everywhere in terms of choices (as density increased choices increased), there will need to be support of public spaces and a mix of infrastructure services to be able to make those choices. New forms of decentralised infrastructure services could have a major implication for the type and form of future development. Respondents stressed that these villages will have to be properly serviced and that there will have be a new form of mass transit. Smart village-type thinking will be throughout the city at all scales, developing into a nested level of smartness. Medium-density and three-storey walk-up buildings would be an ideal compromise between density and lifestyle. High-rise buildings will probably continue to be the central city building typology.

Not everyone will be able to move from their current homes to new carbon-efficient developments. Therefore, everybody will have to reduce the carbon footprint of current residential areas. Employees should try to move nearer to the workplace, buy smaller vehicles or use public transport. Electric cars or green cars were currently very expensive and few could afford them. Changing from a large petrol vehicle to a small diesel vehicle meant 52% less carbon emissions. Other sources of energy − such as biomass fuels − could reduce future emissions.

The emergence of a new working model could influence the support of higher-rise living, whereby people will be working more from home, requiring less office space.

1.4 Life and household

Participants' vision highlighted the move from a production economy to a service economy, ending up with new models, and certain models becoming stronger than others − like the plug-and-play object, which could be leased out and then became a driver as a model until ultimately, the object became a smart home. The group believed that fuel shifting and modes of changing ownership models will drive South Africans. The big mindset change needed by middle-income households, but something everybody currently still seemed to shy away from, was sharing resources, e.g. cars, power tools/chainsaws, lawnmowers, etc. to reduce the number of appliances having to be bought. However, while this would reduce appliances bought, it would not reduce the energy needed to apply them.

Participants imagined that a new form of collaboration on a neighbourhood community level would emerge, comprising units, which would build cities. These community units will be in the new form of eco-villages and different forms of homeowners associations. The form of the village envisaged will be shaped by more compact and convenient homes, where resources will be shared and emissions reduced. Facilities could be shared that would serve the slightly smaller homes in a community. Partcipants emphasised that the forms of collaboration were not restricted, allowing people to collaborate in any street or in any city in the form of, for example, shared laundry facilities, cooking facilities, crèches, car pools, etc. For low-carbon homes to become affordable to the homeowner, they felt that society will head towards different economical models; there will be a pattern shift towards rentals and also dual-income families.

They all had similar ideas regarding the issue of free time and that it will be interpreted differently from today’s interpretation. Some ideas related to people having to work more as technologies surrounded them more, but having more freedom of choice regarding when they would work, breaking away from current structure. They believed that currently, people worked towards acquiring luxuries, but, in future, people will have more time and money to spend on their community.

They touched on future concepts, for example seeing more green areas such as green roofs, green walls, and tight and productive spaces that produced food. They took into account that green walls, etc. will be difficult to maintain and will call for homeowners to be schooled in this or there will have to be companies who maintained such features. They envisioned that there will be an increase in urban farming through tightly-controlled hydroponics, which will be part of the smart home.

1.5 Technology choices

Prefabricated smart homes were expected to be built off-site and manufactured in a controlled environment. This smart home will be small, compact, simple and affordable − a “sexy object” because it will be a desirable object. Because it will be an object which can be dismantled, it will be something that will lead a trend. Comments were made on the interconnectedness that was evident in the smart home getting plugged into the smart grid and the smart grid developing into a matrix of smart villages. This will include the interposing role of the smart car in the form of an electrical vehicle that can be parked in the smart home − mobility will be there for those who can afford it. This car will also contribute to the smart grid as the smart car batteries work for the smart grid.

Other modes of production would have to lead alternative trends. For extended modes of prefabrication, there will be high-rise coming off a standardised framework and pods that are just plugged in. Labour will become increasingly regulated in a controlled environment of factories. The accuracy or workmanship of prefabricated homes will call for a highly skilled labour. Essential attributes of materials will include the ability to breathe, which implies that the materials must be cooler in summer and warmer in winter. Pre-manufactured materials must be able to perform to such an extent that they will be able to absorb CO_2. A new generation of structural insulating panels will be made with natural insulating materials. Cement will not necessarily be used as the main structural form, as there could be new technologies that allow for lighter and less energy-intensive structures. The advantage of prefabrication was pointed out to be its very high level of “dismantle-ability”, which was a big buzzword. This will facilitate reuse as the structure can be taken apart and components reused. The best wall formats will prevail and standardisation will come through − after which monopolies fall away. Local sourcing was something they felt offered obvious cost benefits. To address the issue of reinforcing a sense of identity, they decided on a high level of customisation similar to cell phones. This will come through a factory that will deal with mass and offer a massive array of ideas from which to choose. Identity will be achieved through choice and numbers within the limits of a specific module. There will be consistency of the style, so there will be cohesion of style within the relevant module. However, they recognised that some people might opt for the traditional approach.

There was talk about autonomy being around the corner, resorting to a plug-in for a backup system. PVs covered the home for only eight hours a day and the energy will have to be stored in an economical way. Although people were aware of most of these materials, the materials properties and performance will improve over time.

1.6 Markets

Participants believed that there will be a shift with the current financing models and mechanisms for mortgages, where the market will switch to increased rentals − not because the demand will be lower for outright purchases/ mortgages, but because the availability of funds for the market will be lower. The responsibility of ensuring the building will be green will rest rather on the owner than the property developer/tenant who could possibly be a key role player in sourcing development finance through the IDC and the Development Bank to promote “greening”. The tenants will have power in that they will demand to live in an environment that has a much greener footprint or fewer emissions, which will be a type of shared incentive.

By 2050, they believed most South Africans will not be able to build their own homes and make them green with the new technologies − even if these become a bit cheaper. Therefore, sharing and renting will make it easier to have a green home that will provide 80% savings on greenhouse gases. People living in very large homes will be taxed more. This confirmed the perception that it will become too expensive for the vast majority of people to aim for the current lifestyles.

The current high rate of unemployment will require a return to a global production economy from the neo-liberal/unregulated financial economy of 1938−2008. As industrialisation will mature in the developing world, a shift towards a service economy will be facilitated. Developed service economies will start, at some level, to support relative resource decoupling − leading eventually to sustainable desirable steady-state economies.

2. POLICIES – Mandatory changes

2.1 Politics

The big mindset change will have to be led by government setting an example. Education was highlighted as an important component in consummating change, e.g. educating enforcers and bringing sustainability of life into schools and universities as a subject. Even though today's children learnt about climate change, recycling, energy saving and organic vegetable gardens in the school subject Life Orientation, this needed to be extended to create a change in the mindset of the new generation.

2.2 Land use and cities

Many areas of improvement in town planning were ascertained, and examples were given. Mixed-use development will have to be brought in, including shared common areas, shared laundries and shared facilities, which could extend to gyms, swimming pools, gardens, walkways, cycle paths, etc. City centres will have to include high-rise and mixed-use buildings, where people will be able to live, work and play possibly all within one building. Town-planning schemes must change to allow for different setbacks/boundaries as this will determine the shape of buildings. There must be a structure relating to how collaboration will be dealt with on all levels, including town planning. Development on urban edges will need to be controlled quite tightly to prevent urban sprawl. However, it will be much easier to develop on open land (green fields). New densification laws will be required by increasing the number of units on a site.

When enforcing “green” planning and building, it will be important to maintain a balance between the buildings and nature. Regulations must be put in place to ensure a certain percentage of greening per building or paved area. Other proposals related to high-rises incorporating greenery in the form of a standard garden that reduced overall power supply, and strict enforcing of open edges. To be able to maintain a balance between the buildings and nature, participants suggested that for “X” amount of bricks one must plant “Y” amount of greenery.

Other town-planning legislation discussed proposed shared walls between properties, relaxed boundaries, appropriately planned road layouts and north-facing layouts. People will have to have various options regarding building layouts on sites.

2.3 Technologies

It was believed that fuel-shifting will become apparent in the form of localised central power generation, hot water generation, space heating and cooling, and food processing extended to communities. They raised the point that there could still be an overall centralised system and that Eskom will be there, with nuclear power possibly being part of the national grid. However, there was strong resistance to the proliferation of nuclear plants owing to the extreme potential hazard to people posed by nuclear fallout or waste. Nuclear energy may be low carbon, but it has long-term negative consequences.

However, the participants confirmed that there would be localised generation and, if South Africa opted for smart homes, people would prefer solar panels and wind farms, etc. They also added that, for big commercial buildings, South Africa will definitely pass laws on the implementation of the grid system, but homes will still be excluded for some time. The reason for the Eskom grid implementation lagging behind was explained to be the fact that safety measures were not in place and that the grid was still politically controlled. Eskom’s focus will shift more to distribution rather than distribution plus generation. Generation was where more private producers will enter the market. While economies of scale support centralised energy generation, this was not centralised at national level, but at neighbourhood level and decentralised at national level.

A point was made that it would have taken years longer to get everybody to comply if it were not for energy efficiency regulations (SANS 10400 XA) and for prompt action, as there had to be mandatory requirements in place. This will include technical requirements such as appliances that will have to be limited to the highest efficiency through its relevant policies.

Mention was made of ways existing homes could reduce energy as they form the majority stock. Replacing 40 W to 60 W compact fluorescent lamps (CFLs) with 5 W LED lights will reduce the electricity consumption to 1/8 (12.5%) and 1/12 (8%) respectively of what the electrical consumption was. Geysers were well-known to use a lot of energy and homeowners should at least install a geyser blanket and geyser-wise meter to switch it on only during certain times. PV panels facing north and installed at the correct angle will reduce electrical consumption drastically.

2.4 Markets

The group alluded to mechanisms, such as taxes and rebates, to incentivise good behaviour, and implemented carbon tax to “decentivise” bad behaviour. They said it will be imperative to have accurate reporting and transparency of energy consumption; this will include naming and shaming. Other means of coercion were mentioned, such as increasing the power costs at peak periods. Efficiency regulations would also have to be enforced at a certain level for resale purposes (quality and value) through an energy-rating certificate. Similarly, there could not be laws prohibiting the size of house per person. The group did not disregard incentives to motivate homeowners, such as softer financing schemes in the form of interest rates and subsidies linked to building efficiency. Incentives could also come from businesses that were affiliated with household financing and insurances. For technology to be more affordable, the group proposed that one would have to introduce rationing of power, which could work in the form of a type of carbon credit card.

The group recognised that materials and products should rather be manufactured locally and the import of products limited – something that would also be beneficial for job creation and economic growth. Another point raised concerned enforcing how long a patent and copyright was in place, to open up monopolies.

GAUTENG CONSENSUS

1. LIFESTYLE – Voluntary changes

1.1 Approach

The group mentioned that when it came to making voluntary changes to reduce greenhouse gas emissions, there was still no continuity, collective action or pulling together on living low-carbon/sustainable lifestyles. They highlighted the fact that there will be a changed mindset and aspirations only among the next generations from 2030. Hence, everybody should focus more on how the target reduction could be achieved more realistically.

Partcipants agreed that the target reduction in greenhouse gases for homes would easily reach 80% from a technological perspective, if not more by 2050. The carbon mitigation in the sector could reach a 10% reduction by 2020. However, homes were commented on as being the main catalysts for general change and improvements in other sectors.

1.2 Life and household

The possibility of more communal type living was referred to, which included sharing resources. A renewed belief in the importance of a community, pressing environmental concerns and cost consciousness were moving South Africans away from top-heavy centralised and controlled forms of consumerism towards one of sharing, aggregation, openness and cooperation. It was added that communal living will comprise smart homes and smart communities by 2050. This would be attributable mainly to the technological capabilities. Inputs were made on collaborative ways of living and that if practised in a way that improved access to services and goods, for the majority this could help bridge cultural divides, especially considering principles of “Harambee”, “Stockfel” and “Ubuntu”, which were a common practice in a number of cultures in South Africa. They foresaw that the average home will be only slightly smaller than today and densification will occur close to and in cities. People would still have the option, though, to live further out, and live in larger homes, but they would have to manage their own electricity supply. Comments were made that people would be prepared to trade off smaller living spaces for the enjoyment of bigger parks. There did not seem to be a preference for high-rise homes as South Africans wanted greenery and space around them. A point was made that, if the top-income scale set the trend of not having to live in large homes, then everyone else would also trade down.

1.3 Technology choices

All confirmed that technologies were not an issue as, in 2050 all the technologies that South Africans wanted would be there. Even if renewable energies were already here, the technologies would really only be implemented with gradual improvements by 2050. Views were that technologies in 2050 would be unrecognisable relative to what South Africa had now, and others acceded to the technologies being different and that that there would be no issue with achieving zero energy. In principle, they agreed that technology was going to improve tremendously in the next decade in terms of being more efficient and intelligent.

In 2050, smart homes and smart communities will be more widespread. For this to occur, it was critical to note that the technologies that will make it happen were already there, with improvements along the way. The participants concurred that by 2030, smart homes will be the norm and, by 2050, all community houses will feature these technologies. The technologies referred to that were the key to eliminating the use of fossil fuels were renewables. Technologies that will be utilised, according to the participants, will be concentrated renewable energy sources such a hydrogen fuel cells, natural gas, solar farms, biogas for CHP, and cogeneration using garbage. For distributed generation, one would rather look at lots of small plants below 1 MW adding power to the grid. One could comfortably run a house on a 5 kW renewable source. The participants believed that in 2020, there would already be a diverse energy mix that would include different types of renewables. Other technologies would include integrated IT management systems that worked with sensors, e.g. lights automatically switching themselves on and off. The value of insulation, particularly in retrofits, was questioned and whether it was worth spending lots of money on, whereas there would probably be a business case for new homes.

Although there was mention of bricks and mortar still leading the trends in a greener way, others thought that there would be a change in the leading technology owing to an already existing shift to lightweight steel construction, partially because of the costs. Others mentioned that prefabrication would increase, especially in the lower-income sectors. The way forward was the ability to reuse and recycle, with prominence given to dismantling being the order of the day.

1.4 Markets

Owing to uncertainty regarding the national budgets available, it was decided that it would be better for more costly (upfront costs) technologies and packages to be implemented if they were justified on the basis of payback periods without necessarily incentivising such application.

2. POLICIES – Mandatory changes

2.1 Politics

This group conferred predominantly on government coercion as the main facilitator of change to effect deep cuts in carbon. They felt that government had to have a heavy-handed approach, top down to mitigate carbon emissions. Hence, the prevalence of policies and standards that would force people to make changes promptly, as long as government would be people-orientated, listened to people and put policies in place. They emphasised that it was vital for government to offer incentives, policies related to the “carrots and sticks”, to ensure changes and motivate individuals, especially within a less-enabling environment.

According to the participants, there would have to be an education drive across generations that government should lead. The whole process of education would have to start now and continue right up to 2050.

2.2 Land use

It was pointed out that densification policies should be in place now, which would include residential and green spaces, and achieve a balance of built versus green areas. The City of Johannesburg’s town planning division already had these policies in place and it remained a matter of implementation.

Between 2030 and 2050, there would be continued densification, and the group foresaw a complete public transport infrastructure in place.

2.3 Technology

Although it was agreed that most energy-related technology policies existed, they still needed to be implemented. Successful mitigation of carbon would mean that homeowners would have to drastically increase the level of energy they could generate in their own homes through means such as PV panels, bio-digesters, etc. Net metering would have to be implemented, as in other countries, to benefit from REFIT, but would require a new type of meter. Homeowners would require a renewable certificate to be able to offset power against electricity costs. There would then be decoupling of their own energy use versus their own energy generation.

On a national level, all undesirable energy-consuming items would have to be removed, e.g. incandescent lamps, two-bar heaters, and energy-wasting technology should no longer be allowed to be used, manufactured or sold. Another mechanism identified that would support the drive to ensure that people would follow a low-carbon life was communication via social media and peer comparisons.

2.4 Markets

The participants emphasised that, from 2015 onwards, the whole procurement system would need to change to facilitate a green economy. The procurement system was currently hampered by the Public Finance Management Act (PFMA) provisions. Furthermore, applying for funding for electrification projects would have to become easily accessible. Critical emphasis would be on localisation and it was recognised that as South Africa became more demand-driven, the country would have to build factories manufacturing technologies. This would add other advantages, such as creating green jobs. By 2050, most people would be off-grid and many homes would be smart by being able to manage energy automatically (e.g. switching off lights). Technology innovation diffusion would bring relevant technologies into the country.

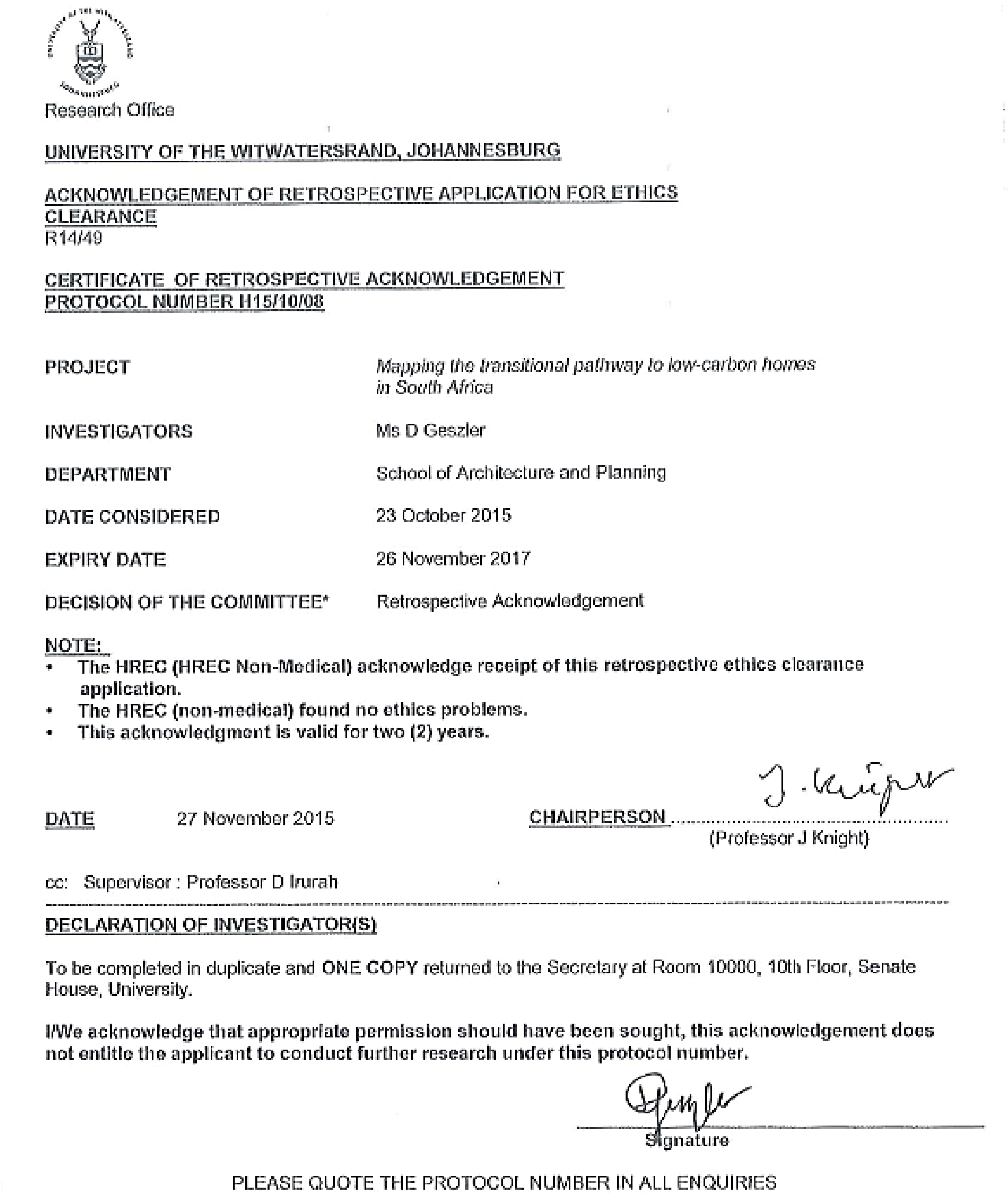
Other ways of motivating the chances of achieving low-carbon homes were raised. By 2020, there would be some sort of domestic energy-rating scheme in place, and a green star rating would increase the resale value of one’s home. Carbon taxes should also be enforced. The more fossil fuel one used, the more carbon tax one would pay. Even if the product was not affordable, incentives would counter such an expense.

B7 Housing stock and energy usage

The “middle-class” market included a wide range of property. The banks’ average was derived from properties that were 80–400 m^2, and costing less than R2.2 million (Rust, 2006:26). To calculate the total housing stock for this group, the Construction Industry Development Board, or CIDB, (2009:16) held that these houses were above 80 m^2 and consisted of 37% of the total housing stock. It was further assumed that from the population of 49.8 million people in 2010 (StatsSA, 2010:6) and 65.5 million people in 2050 (United Nations, 2015:22) an additional 15.7 million citizens will require new homes. Should there be an average household size of 3.9 people (StatsSA, 2010:7), then, for an additional 15.7 million people between 2010 and 2050, an additional 4 million new homes will be required. If 37% were above 80 m^2 then 1.48 million new middle-income homes could be required. If the existing housing stock was 10.21 million units in 2010 (StatsSA, 2010:94), then 37% of these would be above 80 m^2, equalling 3.78 million existing homes. This will lead to 1.48 million new homes plus 3.78 million existing homes, equalling a total of 5.25 million formal middle-income homes between 2010 and 2050.

The average energy consumption of an average-sized house for a mid-income in 1990 was approximately 9 300 kWh per year (Mathews *et al*., 1999:505–514). This energy consumption is taken as equivalent to 100% fossil fuels (coal converted to electricity) in 1990 and 2010, and hence carbon emissions from which reductions need to be made. Carbon-neutral energy sources such as renewable energy (PVs) can reduce these carbon emissions consisting of the amount of energy used.

C1 Retrospective ethics clearance certificate



Research Office

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

ACKNOWLEDGEMENT OF RETROSPECTIVE APPLICATION FOR ETHICS CLEARANCE
R14/49

CERTIFICATE OF RETROSPECTIVE ACKNOWLEDGEMENT
PROTOCOL NUMBER H15/10/08

PROJECT	*Mapping the transitional pathway to low-carbon homes in South Africa*
INVESTIGATORS	Ms D Geszler
DEPARTMENT	School of Architecture and Planning
DATE CONSIDERED	23 October 2015
EXPIRY DATE	26 November 2017
DECISION OF THE COMMITTEE*	Retrospective Acknowledgement

NOTE:

- **The HREC (HREC Non-Medical) acknowledge receipt of this retrospective ethics clearance application.**
- **The HREC (non-medical) found no ethics problems.**
- **This acknowledgment is valid for two (2) years.**

DATE 27 November 2015

CHAIRPERSON J. Knight ....
(Professor J Knight)

cc: Supervisor : Professor D Irurah

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10000, 10th Floor, Senate House, University.

I/We acknowledge that appropriate permission should have been sought, this acknowledgement does not entitle the applicant to conduct further research under this protocol number.

Signature

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES