How can South African municipalities respond to the challenges of sustainable electricity provision to urban households now and in the future?

Daniel William Kerr

MSc Energy and Sustainable Development

This dissertation is submitted in part fulfilment of the requirements of De Montfort University for the degree of Master of Science in Energy and Sustainable Development

Institute of Energy and Sustainable Development

Faculty of Technology

September 2018

Abstract

This dissertation aims to investigate urbanisation in Sub-Saharan Africa, specifically South Africa, and the challenges of sustainable electricity provision to the urban domestic sector. The work also aims to investigate how municipalities in South Africa can respond to the challenges presented by increasing rates of urbanisation and urban population growth, and the attendant impacts this will have on domestic electricity consumption. This dissertation focuses on both population growth and electricity consumption growth in two South African cities: Cape Town and Polokwane. A mixed methodology is used to investigate urban population growth and electricity consumption growth: quantitative modelling using the Long-range Energy Alternative Planning (LEAP) tool, developed by the Stockholm Environment Institute, as well as Microsoft Excel, was used to determine the growth in population in both cities through to 2030 from a baseline of 2012 for Cape Town, and 2011 for Polokwane, disaggregated by household income bracket. This is supplemented by qualitative analysis of the policy and regulatory frameworks that exist for electricity provision in the country, and case studies of previous electrification programs. By using estimated per-income-bracket monthly electricity consumption totals, this can then be translated to electricity consumption, and projections for the growth in electricity consumption through to the 2030 end-point are also produced. Finally, the modelling exercise captures rates of informality in the domestic sector in both cities and produces total formal and informal household numbers for the baseline year, as well as 2020 and 2030. Three scenarios were investigated: a business-as-usual scenario, a high population-growth scenario, and a demographic change scenario. The business-as-usual and high-growth scenarios both assume that the demographics of the city will remain consistent through to 2030, with current and increased levels of population growth respectively. The demographic change scenario assumes a move from lower-income brackets to higher-income brackets in the population of both cities. In terms of results, all three scenarios show a significant increase in domestic electricity consumption, and overall urban population. The high-growth scenario shows the largest increase, with an additional 22.7% consumption over business-as-usual levels by 2020, and 58.7% by 2030, in Cape Town, and a 27.5% increase by 2020, and 72.0% increase by 2030 in Polokwane. The demographic change scenario shows a smaller increase over business-as-usual levels. Informality is set to rise in magnitude under all three scenarios, but by less under the demographic change scenario, as expected. From this analysis, municipalities will need to respond to increases in urban populations by investing in greater electrification and formalisation efforts if these growing populations are to be adequately serviced, as mandated under the Sustainable Development Goals, particularly SDG7. This can be achieved by greater cooperation and knowledge exchange between municipalities, as well as between municipalities and the national electricity utility. Finally, future research in this area should focus on improving the sustainability of electricity provision to South African urban areas; the expansion of urban services provision to informal settlements, and the financing of electrification in urban areas of the country.

Contents

List of Figures

List of Tables

Introduction – Electricity, Population Growth and Informality

Developing countries, such as South Africa, are experiencing rapid population growth, and an equally rapid growth in urbanisation rates. Predictions from the World Bank suggest that by 2030, 50% of the Sub-Saharan African population will live in cities, challenging the common assumption in development practice of rural solutions to rural problems being a necessity (Rafei, 2014). This dissertation aims to determine how municipalities in developing country cities can respond to the challenges of growing populations and the resulting growth in electricity demand. In addition to the growth in electricity demand in the formal sector, informal households will be included in the analysis, as informal population growth is also predicted to increase in line with urbanisation increases in the region. The methodology used in this dissertation will focus on modelling urban population growth in two cities in South Africa, Cape Town and Polokwane. Cape Town has been selected as one of the primary cities of South Africa and is expected to undergo significant population growth in the near future as one of the economic hubs of the country. Current urbanisation research for Sub-Saharan Africa suggests that the majority of population growth expected in cities in the region is to occur in small- and medium-size cities, or cities under 1 million people in the coming decades (Satterthwaite, 2017). As such, the second city selected is Polokwane, one of the country's many secondary cities. The contrast between average incomes and municipal budgets between the two cities is expected to lead to contrasting approaches and challenges regarding municipal population growth and urban service provision.

The population growth models will be forecast through to 2030, from a baseline of 2012 for Cape Town, and 2011 for Polokwane. The baselines were selected as the most recent year for which reliable population figures are available, as the most recent country-wide census occurred in 2011. 2030 was selected as an end-point for the models to give a medium-term outlook on population growth in the coming decade, and to determine if current policies and programmatic responses in place are appropriate for the challenges facing the municipalities. Population growth in these models will be linked to electricity consumption by dividing growth into household income brackets and making informed assumptions about average household electricity consumption per income bracket, enabling the models to also predict electricity consumption growth through to 2030. Finally, growth in informal settlements will be modelled by assuming rates of informality remain at the same level as the baseline years and projecting these levels forward to 2030.

Three scenarios will be used for this analysis: a business-as-usual scenario, where population growth remains at current levels through to 2030; a high-growth scenario, where population growth rates remain at a higher level or increase, and a demographic change scenario, where household incomes increase, and households move from lower-income brackets to higher-income brackets. This last scenario is based on current research suggesting that middle-income populations in Sub-Saharan Africa will increase substantially in the coming decades as economic development continues, and the scenario aims to capture the effects this will have on electricity consumption and the prevalence of informal households.

The models suggest that even under a business-as-usual scenario, population growth and consequently electricity demand are both set to markedly increase in the two target cities through to 2030. This will present a number of challenges to the municipal authorities responsible for electrification and electricity service provision in Cape Town and Polokwane: higher population growth rates mean a larger required investment in new electricity infrastructure to service expanding household numbers, while also meaning increased municipal revenue from formal electricity services. For both Cape Town and Polokwane, an increase in the number of informal households is predicted in line with population growth rate, presenting additional challenges in servicing these new informal households with formal electricity services: settlement morphology challenges and the prevalence of illegal electricity connections in informal settlements both contribute to a challenging socio-technical situation for municipal authorities in providing formal electricity services.

The main goal of the analysis of these models is to determine the scale of challenge facing municipalities in providing electricity services and electrification, and how municipalities across South Africa and in the wider region can respond to these challenges. Greater investment and increases in municipal electricity department budgets are an obvious starting point, but sustainability considerations must also be taken into account, particularly given the goals South Africa has signed up to under the United Nations Sustainable Development Goals, and Goal Seven (ensuring access to affordable, reliable, sustainable and modern energy for all) in particular. This will require a new approach to electrification, determining appropriate solutions to the challenges faced in cities, and considering both on- and off-grid systems, as well as sustainable energy systems. Integrating sustainability concerns, and ensuring reliable, affordable access to modern energy solutions, will require new and updated policy and regulatory frameworks, and greater collaboration between municipal and national governments, and national institutions such as ESKOM, the parastatal electricity utility. Finally, capacity within municipal governments for electrification and electricity provision is key, and capacity-building and knowledge exchange activities will be key to ensuring appropriate solutions for problems are implemented across the gamut of urban contexts in the country.

Aims, Objectives and Research Questions

This dissertation has three main aims: to model and therefore estimate the growth in urban populations in South African cities through to 2030; to model and estimate the growth in electricity consumption in the domestic sector that this population growth entails, and to estimate the growth of informal settlements (specifically informal households) in South African cities through to 2030. The objectives that result from these aims are to create a model of urban population growth in South African cities in the coming decades, and create a robust model of how electricity consumption in the domestic sector relates to population growth. Finally, an estimate of how informal household numbers will grow with relation to formal household numbers will be determined. The main research question of this dissertation is “How can South African municipalities respond to the challenges of sustainable electricity provision to urban households now and into the future?” Secondary research questions include how informal settlement growth relates to formal population and household growth in South Africa, and how electricity consumption growth in the domestic sector is linked to urban population growth in cities in the country.

Literature Review – South African Urban Contexts and Electrification Challenges

South African Urban Context

According to the World Bank, as of 2017, South Africa was approximately 65% urbanised. The country contains a number of major urban areas, including the large cities of Cape Town, Johannesburg and Durban, as well as a number of smaller urban areas such as Port Elizabeth, Nelson Mandela Bay and Polokwane. The country, similar to a number of Sub-Saharan African nations, has seen a rapid growth in its urbanisation rate over the last thirty years, and annual urban population growth as of 2016 was estimated to be 2.3%. There are a number of factors behind this relatively high urbanisation rate in the country: notably, population growth in the country is relatively high, at 1.61%, with young and elderly populations growing faster than others (Statistics South Africa 2017). In addition, rural-urban migration has been a contributing factor to the growth of cities in the country since the colonial era and continues to drive the growth of the country's urban areas. By 2030, the United Nations estimates that 71% of the country's population will reside in urban areas (Brand South Africa 2015, Pardee Center for International Futures 2018, Trading Economics 2018a, Trading Economics 2018b, Statistics South Africa 2017, World Population Review 2018).

Urban Services and Electricity

High levels of urban population growth in recent decades have strained the ability of municipalities to provide urban services to ever-increasing populations. While the official electrification rate of urban residents in South Africa stands at 94%, this figure may fail to capture the reality of access to electricity and the level of service that residents of urban areas have access to. In particular, the disparity in level of access between middle- and high-income populations and low-income populations presents a different reality of electricity access than the official figures suggest. Figures for the City of Cape Town for 2011, which will be analysed in greater detail later in this thesis, suggest that 89% of the low-income population had access to electricity, compared with 97-99% of the middle- and high-income populations of the city (City of Cape Town 2015). In addition, this figure fails to take into account the levels of electricity access in informal urban settlements, which have developed outside of the formal urbanisation structure of municipalities in response to urban population growth. Access to electrification data for these settlements is challenging, as are current estimates of the population living in urban informal settlements. Census data for South Africa was last compiled in 2011, and urban informal settlement growth rates have continued to rise since then.

Informal settlements are a niche case in the urban electrification and urban development policy space. These settlements exist outside of the formal urban services sphere, including the formal electricity provision sphere. Access to a formal electricity connection for these communities is often out-of-reach, either due to cost concerns (demographically, these settlements are typically low-income) or due to regulatory barriers to formalisation. These regulatory barriers can include distance to an existing formal electricity service point, as well as a lack of a formal address to apply for a formal connection (UN-HABITAT 2011, UN-HABITAT 2016).

Growth in Informality in Urban Areas of South Africa

Urban population growth, either through natural growth in populations or through rural-urban migration, has led to a significant growth in informality in urban areas of South Africa. The causes of rural-urban migration in Sub-Saharan Africa are well-documented: opportunities for employment and economic advancement, leading to a better quality-of-life, and enhanced access to services, are commonly-cited as factors affecting the decision to move from rural areas to urban areas. However, the ability of municipalities to formally service ever-growing populations in South Africa has not kept up with the urbanisation rates seen in recent decades, and the growth of urban informal settlements as a self-made solution for housing and living is a consequence of this lack of formal service availability. To gain an insight into the recent scale of prevalence of informal settlements, Statistics South Africa reported that as of 2014, 13.1% of households in urban areas of the country were classed as informal dwellings, and the proportion of the urban population living in informal settlements was estimated to be 11%. These figures, however, vary across the country, with the report stating that North-West and Gauteng provinces had the highest proportions of informal urban households (21% and 19%, respectively). While it is commonly assumed that urban informal settlement populations are poorer economically, an interesting facet of this report is that informal settlements in urban areas were occupied evenly by the bottom 80% of household income levels (quintiles 1 through 4) (Statistics South Africa, 2016, Space Syntax 2012).

Urbanisation Rate in South Africa and Growth in Middle-income Populations

The growth in population and subsequent growth in informal settlements are primary drivers for increases in electricity demand in the country. However, two other drivers also affect the potential for electricity demand in cities to rise: growth in the urbanisation rate of the country, and increasing levels of income, manifesting through an increase in 'middle-class' consumption patterns in the country.

Urbanisation rates in Sub-Saharan Africa generally are increasing, and a significant proportion of population growth in the region is set to be in small- and medium-sized cities. In addition, the continent's emerging mega-cities are continuing to experience high population growth. From 1990 through to 2030, modelling suggests that urban population growth is set to be strong in cities of all sizes, but particularly in small- and medium-sized cities, with less than 1 million people. This growth pattern may initially present opportunities for sustainability, however the mode of urbanisation seen in Sub-Saharan African cities tends towards sprawl rather than densification, presenting further challenges to municipal authorities in servicing growing spatial regions (Dodman et al 2017). South Africa is no exception to this: The City of Cape Town, for example, has seen significant increases in its overall land area usage in recent years (Horn, 2018). As more of the country becomes urbanised, urban electricity consumption patterns (in general greater than rural consumption patterns due to access and increasing incomes) are set to rise, increasing overall domestic electricity consumption in the country in a way not accounted for through natural population growth alone (Güneralp et al, 2014).

The third factor is increasing incomes: the economic pressures on rural populations that drive rural-urban migration are well-documented in a number of developing and transition country contexts (Brueckner & Lall 2015, de Brauw, Mueller & Lee 2014). In addition, a growing body of literature concerning the rise of the 'New African Consumer' and the growing global middle-class, particularly in Sub-Saharan Africa, suggests that incomes on the continent, and in South Africa, are set to rise, with a greater proportion of the population having access to more disposable income, and desiring the services that greater household incomes can provide. Increasing household incomes not only drive economic growth, but also drive consumption of resources, electricity included. As new consumers enter the middle-class income bracket, consumer goods ownership and household consumption of non-essentials (such as entertainment and media access) is set to rise, leading to an increase in overall household electricity consumption. As more consumers enter this bracket, driven by economic growth as well as policy, this is set to drive increases in overall domestic consumption in the country (McEwan, Hughes & Beck 2015, African Development Bank 2011, Deloitte 2013, Bhorat, Kharas & Pita 2017).

Previous Challenges & Responses to Electrification in Urban Settlements – A Review

The challenges facing municipal and national electricity authorities in electrifying urban settlements in Sub-Saharan Africa more widely, and South Africa specifically, are numerous. These challenges are particularly apparent when dealing with urban informal settlements. Urban settlement electrification in the formal urban sphere has developed well in South Africa in the post-apartheid era, with figures for 2015 suggesting that 94% of the urban population of the country had access to electricity (Trading Economics, 2018b). However, as the figures for the City of Cape Town show, there is still a disparity in access between income levels, and these figures may not capture the full reality of the urban electrification space due to factors like informality and informal/illegal access.

The challenges facing electrification authorities in addressing continuing urban electrification growth can be broadly grouped into technical, economic and policy challenges. Technical challenges and economic challenges are often interlinked, with the technical challenge of servicing growing populations in urban settlements being constrained by the economic challenges of meeting the cost of grid extension. Technical challenges are often seen when considering formal electrification of informal settlements. Informal settlements are often constructed at the periphery of formal urban spaces, and/or where land is available for settlement. This has led to settlement development in terrain that is challenging for electrification authorities to work in, such as hillsides and wetlands. In addition, given the history that exists in South Africa of a lack of electrification in informal spaces, informal/illegal electricity connections have become widespread as a method of gaining electricity services by the residents of informal settlements. These illegal connections pose both a technical and economic challenge to electrification authorities. Both municipal electricity authorities, and the national utility ESKOM, have previously proven unwilling to selectively electrify areas where illegal connections are the dominant mode of access, due to a perception that illegal connections would be more accessible thanks to more proximate access to formal electricity infrastructure. Blanket electrification alongside the removal of illegal connections is another option that has been used by both municipal authorities and the national utility, although this poses additional challenges in terms of financing larger-scale operations. Settlement morphology poses additional challenges to the blanket electrifications strategy: given the prevalence of informal settlements, and illegal connections, in challenging terrain, additional expenditure in terms of equipment and labour would be necessary to electrify these areas. Additional economic challenges can arise from the consumer side: revenue recovery and consumer willingness-to-pay can both pose problems to electricity authorities when deliberating the electrification strategy for informal settlements. Consumers that have previously been connected through an illegal electricity connection have been found to be less willing to pay for formal connections in the country, despite the increased quality and availability of service. This in turn affects revenue recovery for the electricity authority: formally-connected consumers not paying for the electricity service delivered to them will have an impact on the financial stability of the authority, and therefore affect operations and future development. As an estimate of the scale of the problem of electricity theft in South Africa, data from the Operation Khanyisa project, in partnership with ESKOM and the South African Local Government Association (SALGA) suggests a total of R20.2 million in lost annually by ESKOM and municipal distribution authorities due to non-technical losses (predominantly electricity theft) (Operation Khanyisa 2016, Bekker et al 2008, ESI Africa 2015, Smart Energy International 2017).

Governmental responses, both at a national and municipal level, have changed considerably in the last two decades in South Africa. The 2004 Breaking New Ground plan was the dominant government strategy for informal settlements and targeted the progressive eradication of informality and informal settlements in the urban landscape of the country. However, results of the Plan were mixed, and documents released at the beginning of the 2010s suggested a new policy approach to informality from national government, particularly with regard to electrification. These included the Energy White Paper of 2010, and specifically the Policy Guidelines for the Electrification of Unproclaimed Areas of 2011. The Energy White Paper for example, specifically included informal settlements in national electrification targets, and the 2011 Policy Guidelines were the first national government policy release specifically targeting urban informal settlement electrification (Lemaire & Kerr 2016, Government of South Africa 2004).

These policy guidelines have been applied at different levels throughout the country, in part due to the variances in governance structure of electricity provision within municipalities. The policy and regulatory framework for electrification in South African cities varies by municipality, due to whether the municipality has its own distribution utility (for example, in the case of Cape Town), or whether the municipality is directly serviced by ESKOM, the vertically-integrated parastatal utility (for example, in part in the case of Polokwane). A common approach between these two groups of municipalities is grid extension to informal settlements, with the installation of new distribution lines to the street-level and metered household connections. However, based on internal policies of municipal utilities and policies within the national utility, some variance in approach has arisen.

As part of the establishment of the context that exists regarding electrification of urban informal settlements in South Africa, and urban electrification more generally, two case studies will be used to highlight the variances in approach between municipalities in the country. The first is the Cape Town “backyarder” electrification project, aiming to electrify informal settlements sited on the property of other, formal dwellings on an individual basis. The second is the Johannesburg informal settlement electrification efforts undertaken by City Power in Johannesburg, the municipal electricity utility, which electrified informal settlements in the city based on criteria involving the suitability of their location, their prospects for grid extension in the immediate future, and the security and longevity of habitation at the location.

The City of Cape Town backyarder electrification project began initially in 2011 with three pilot projects, in the Factreton, Hanover Park and Langa areas of the city. As of 2018, the project has been extended to two further areas of the city: Parkwood, and Bonteheuwel. “Backyarder” dwellings in this context refers to informal households that are sited on land occupied by formal properties, either state-owned public housing or private properties. These informal households are supplied with basic utilities through the formal connections of the property on which they are situated, and the owners/occupiers of the formal properties commonly collect revenue from the informal households for these services. These services include electricity, but also extend to water services and waste collection. This presented a number of challenges, not only to the inhabitants of these informal households, but also to city utilities, particularly the Electricity Department. Interviews with backyard dwelling inhabitants showed that service to their household was routinely poor, and often absent for long periods of time after the informal connections to their property tripped or were overloaded. Issues also existed with the democracy of access and information provided to these households on electricity consumption: householders were commonly not informed of their consumption by the inhabitants of the formal property, or discouraged from using electricity altogether, despite paying over-market-price rates for their services. With regard to the Electricity Department, these informal arrangements put additional strain on network infrastructure in areas where this practice was common, resulting in the need for increased maintenance and component replacement, and therefore cost. Democracy of access was also a key priority for the department, in line with drives towards energy efficiency and responsible consumption: metering each household individually meant that the city could directly monitor each household’s consumption, as well as informing inhabitants of their consumption practices. In addition, these newly-formally-connected households could benefit fully from existing subsidies, such as the Free Basic Electricity program, intended for low-income and low-consumption households. Finally, with regard to public safety, the formalisation of these previously-informal connections significantly reduced electrocution and fire risks in these backyard dwellings (Government of South Africa 2004, South African Department of Energy 2003, Kotze 2017, Gaunt et al 2012).

The pilot projects and subsequent electrification projects were undertaken by the City of Cape Town Electricity Department and involved a selective electrification approach, in that the targeted areas had already undergone a formal, blanket electrification process, but new dwellings had emerged in the period following the formal process which required selective electrification. The project was also somewhat unique in that households that were electrified were already, to an extent, able to receive electricity services from the municipal distribution infrastructure, albeit via a third party (the formal household owner). However, in line with the goal of democratisation of electricity access built-in to the electrification programs, these households were each given individual metering points and registered as individual consumers, giving them greater status and rights under the existing electricity policy framework. Current information on the ongoing state of electrification projects is limited, however a new project in Kalksteenfontein was slated for 2017, and approximately R50 million had been set aside by the City of Cape Town Electricity Department for ongoing works in the electrification of backyard settlements for 2017 (Kotze, 2017, Shezi 2016).

As of 2017, City Power, the municipal electricity authority for Johannesburg, was including informal settlement electrification as part of their ongoing business plan through to 2021. For financial year 2017/18, targets were set to electrify 10,491 households in five informal settlements in the city, with plan to electrify another 4,200 as of 2018/19, and 3,991 as of 2019/20. The program overall is being funded by government grant funding from the Department of Energy, as well as through the Urban Settlement Development Grant programme. An interesting facet of this case study is that instead of a traditional, grid-only electricity supply to the informal households, these settlements will be electrified with a grid-tied hybrid arrangement using solar photovoltaics to self-generate some load, and feed back to the local grid in times of over-supply. This is in part due to national pressures on electricity supply, and due to City of Johannesburg officials advocating for alternatives to grid-supplied electricity in response to this. It also represents a more sustainable alternative to traditional grid electrification. City Power's own policy with regard to the electrification of informal settlements within its service area includes this commitment to partially meeting the electricity needs of settlements through solar PV, as well as a traditional grid connection. In addition to meeting the electricity needs of informal settlements through electrification, City Power also intends to provide new thermal energy supply sources to these households in the form of LPG distribution and appliance provision, as well as investing in energy efficiency measures.

The approach taken by City Power in Johannesburg to electrifying informal settlements contrasts with the approach taken by the City of Cape Town in that it is closer to a blanket electrification approach, involving removing existing illegal electricity connections, and creating new, formal infrastructure to the households individually in a wide area. These connections are not intended to supply the households solely, and householders are required under policy to be informed that the alternative energy sources (namely the per-household PV installations) will be required to supplement their grid connection. A significant community engagement process is also built-in to the electrification program to ensure that informal settlement householders are aware of this fact, to prevent overloading of the grid connection or local network (City Power Johannesburg 2015, City Power Johannesburg 2017, Moagi 2015).

Methodology

To achieve the aims and objectives of this research, a mixed methodology of quantitative modelling and policy and regulatory review and critical analysis will be used. For the quantitative modelling, two distinct methods will be employed: firstly, benchmarking of baseline years for population,

population growth rates and electricity consumption using existing literature, and secondly, forecasting through to an end-point year of 2030 using both the Long-Range Energy Alternatives Planning tool (LEAP) and spreadsheet modelling using Microsoft Excel. LEAP is an integrated, scenario-based modelling tool that can be applied to a wide variety of situations to determine energy policy and climate change mitigation responses and is widely used globally by thousands of organisations to create models for energy and climate change (Stockholm Environment Institute, 2018). This software was chosen partly for its flexibility and ease-of-use, and the familiarity of the researcher with the software, and partly to maintain consistency with the establishing baseline papers for the scenarios below, which also employed the software. Further modelling, where the LEAP software may be unnecessarily complex to use, will be completed using Microsoft Excel, specifically for determining household numbers under different population growth scenarios. These quantitative methods will be employed in addition to qualitative analysis of the existing policy and regulatory landscape for electricity in South Africa, and a critical analysis of existing policies and regulations will be employed to determine responses and recommendations to the outcomes of the quantitative analysis.

Projected Growth in Urban Population in South Africa through to 2030, and Projected Growth in Household Energy Demand

To determine the scale of the challenge facing electricity authorities in South Africa with regard to urban population growth and household energy demand growth, projections of the growth in urban population and the growth in households, as well as in energy demand from the domestic sector, need to be constructed. This analysis will enable the identification of the scale of the problem facing electricity authorities with regard to urban electrification, and inform the type of policy, technical and social responses needed to address the challenges.

A number of challenges exist in constructing an accurate model of population growth and household energy demand growth. To address these, some assumptions need to be made in order to simplify the analysis, not only to enable achievability in the timeframe of this work, but also to take into account the accessibility of accurate data on urban populations, household numbers, and current energy demand from households across the income spectrum in South Africa.

Two existing pieces of work will form the foundation of this analysis, being the LEAP technical reports for the cities of Cape Town and Polokwane, produced under the Supporting African Municipalities in Sustainable Energy Transitions project by the University of Cape Town Energy Research Centre. These reports both used the Long-Range Energy Alternatives Planning methodology, developed by the Stockholm Environment Institute, to examine the energy supply scenarios available to both cities through to 2040 in the case of Cape Town, and 2030 for Polokwane (McCall & Stone 2017, McCall & Stone 2015).

These reports will form the baseline of the model used in this research. The assumption that underpins this choice is that both Cape Town and Polokwane represent an indicative picture of the South African urban landscape. The analysis of Cape Town, as one of the major urban centres of the country, will allow for the analysis of how a primary city, and established urban conurbation, will develop into the future. The use of Polokwane is in some ways more relevant: Polokwane represents one of the country's many emerging urban centres, whose growth from existing projections is anticipated to be extremely strong into the future, posing significant challenges to the municipal authority in terms of wider urban services, as well as in terms of electricity. This is particularly relevant given the dimensions of urban population growth that international think tanks, such as the Cities Alliance, as well as the academic sector, predict through to 2050. Rather than growth being concentrated in Sub-Saharan Africa's existing and projected megacities, small- and medium-sized cities are expected to experience the bulk of urban population growth through to 2050 (Satterthwaite, 2017). The selection of Polokwane as a foundational example of South African urban population growth seems prudent in this context.

A baseline year of 2011 will be used for population statistics, as this is the most recent year that census data from the South African government is available. This is consistent with both McCall & Stone (2015) and McCall & Stone (2017) for Cape Town and Polokwane respectively. 2011 will also be used as a baseline year for household numbers in both cities. In order to acquire household numbers in light of projected population growth, household occupancy will be assumed to be at the same rate as the 2011 baseline through to 2030, the end-point of this analysis. Both Cape Town and Polokwane, as of 2011, had approximately 3.5 persons per household. The baseline figures for this are presented in Table 1:

City	Number of Households (2011)	Population (2011)	Pop/Household
Cape Town	1,068,574	3,740,026	3.50
Polokwane	177,991	628,999	3.53

Table 1: Baseline Household and Population Figures for Cape Town and Polokwane (McCall & Stone 2015, McCall & Stone 2017)

2030 has been selected as the end-point of this analysis in order to provide a medium-term picture of population growth and household energy demand growth. This 12-year horizon is short enough to allow for adequate planning based off the technical, social and policy context that exists in South Africa at present, while being sufficient to encompass the expected changes in urban context to a reasonable degree.

However, population growth is only part of the reason for conducting this analysis: the challenges facing municipal authorities in South Africa lie partly in the urban services space, such as housing, water and sanitation, and transport, but also lie firmly in the energy space, including in electrification and meeting electricity demand. To add to this population growth analysis, projections will be made regarding the growth in household energy demand, in line with population growth, through to 2030.

The baseline year for the household electricity consumption analysis will also be 2011 for Polokwane and Cape Town, in line with data presented in McCall & Stone (2015) and McCall & Stone (2017), although more recent data will be used where available for the two municipalities. In order to determine household consumption into the future, an average rate of household consumption for the municipalities will need to be found for the baseline year. Assumptions can then be made that this level of consumption per household in the municipalities will continue into the future or grow/decline according to demographic shifts or fuel consumption pattern shifts, according to the targeted scenario. Baseline data for Cape Town and Polokwane for total electricity consumption in the domestic sector, and consumption per household, is presented below:

Municipality/Year	Number of Households	Total Domestic Electricity Sales per annum (GWh)	Consumption per Household per annum (kWh)
Cape Town (2012)	1,096,399	3,859.3	3,520.01
Polokwane (2011)	178,001	561.4	3,154.04

Table 2: Baseline electricity consumption per household per annum for Cape Town and Polokwane (McCall & Stone 2015, McCall & Stone 2017)

From this baseline, we can see that Cape Town and Polokwane domestic consumers have similar levels of electricity consumption per annum on average. However, the assumption behind this calculation is that all households will have an even level of consumption, irrespective of household income, which does not represent the full reality of the situation. To determine a more accurate level of electricity consumption per household, it would be more appropriate to disaggregate the number of households by their income brackets. This disaggregation alone will not provide the data required, however, as it would still assume that, for example, 20% of the households would consume 20% of the electricity, equalling an equivalent per-household consumption figure.

To solve this, some assumptions can be made regarding the levels of household consumption of electricity based on income bracket. To begin with, the household number of both Cape Town and Polokwane will need to be separated into relative income brackets. Statistics South Africa uses four income brackets in their household income analyses: Low, Middle, High and Very High. This disaggregation has been used in McCall & Stone (2015) and McCall & Stone (2017) to determine the number of households in each income bracket for both Cape Town and Polokwane. These articles further disaggregate the low- and middle-income household brackets into electrified and non-electrified, based on Statistics South Africa survey data. This data also suggests high- and very-high income households as approximately 100% electrified in Cape Town, and these households are assumed to be totally electrified in this analysis. For Polokwane, three household groups are used, low, middle and high, based on the income distributions present in households in the city as of the 2011 census.

The disaggregation of households by income bracket for Cape Town and Polokwane for 2012 and 2011 respectively are presented below:

Cape Town (2012)

Income Bracket	Number of Households	Percentage of Total
Low-income Electrified	449,653	41.01%
Low-income Non-electrified	55,652	5.07%
Middle-income Electrified	288,187	26.28%
Middle-income Non-electrified	7,220	0.65%
High-income	220,705	20.12%
Very High-income	53,126	4.84%

Table 3: Number of households per income bracket for Cape Town (2012) (McCall & Stone, 2015)

Discrepancies in these household figures and the ones represented above can be attributed to the calculation of annual growth rates performed in McCall & Stone (2015). As the figures above differ from the predicted total household figure by less than 2%, the percentages presented above can be treated as relatively robust. For the rest of the electricity consumption analysis, the non-electrified low-income and middle-income households will be discarded, as they will not be contributing to the electricity consumption per household totals.

Polokwane (2011)

Income Bracket	Number of Households	Percentage of Total
Low-income	82,554	46.38%
Middle-income	55,847	31.38%
High-income	39,590	22.24%

Table 4: Number of households per income bracket for Polokwane (2011) (McCall & Stone, 2017)

As these figures are taken directly from the 2011 census data, the correlation between household totals and households per income bracket is accurate. However, the above figures assume a 100% electrification rate for households in Polokwane. To give a more accurate household figure for use in the following analysis, data from the 2011 census can be used to determine a broad electrification rate estimate for households in Polokwane. Households that use electricity for lighting were determined to be electrified for the purposes of the analysis of Cape Town in McCall & Stone (2015) and applying this methodology to Polokwane gives an overall domestic electrification rate of 87.4%. High income households, in line with the Cape Town analysis, are assumed to be 100% electrified. Adjusting the figures above to take this fact into account, the following table gives electrified and non-electrified household figures by income bracket:

Income Bracket	Number of Households	Percentage of Total
Low-income Electrified	72,152	40.53%
Low-income Non-electrified	10,402	5.84%
Middle-income Electrified	48,810	27.43%
Middle-income Non-electrified	7,037	3.96%
High-income	39,950	22.24%

Table 5: Number of households per income bracket for Polokwane (2011) adjusted for estimated electrification rate

The monthly household incomes used to define these brackets are presented below:

Income Bracket	Lower Bound (ZAR)	Upper Bound (ZAR)
Low-income	0	3,200
Middle-income	3,201	12,800
High-income	12,801	51,200
Very High-income	51,201	N/A

Table 6: Household income thresholds per bracket (McCall & Stone, 2015)

Both McCall & Stone (2015) and McCall & Stone (2017) can assist in informing the assumptions to be made regarding household electricity consumption per month based on income bracket. Low-income consumers in both Cape Town and Polokwane are assumed to use electricity predominantly for lighting only. The Free Basic Electricity policy can be used to inform consumption levels regarding this: this policy allows for consumption of up to 50kWh per month per household without charge for lighting, basic media access and basic water heating access for grid-connected systems (South African Department of Energy, 2003). Not all low-income households in the two cities will be eligible for free basic electricity, so a conservative estimate of 120kWh/month for the low-income household bracket will likely cover the majority of households. For the middle-income household bracket, the average consumption per household from the figures provided for 2012 for Cape Town and 2011 for Polokwane can inform the assumptions: if the average household in Cape Town in 2012 consumed 3,520.01kWh annually, and for Polokwane in 2011 3,154.04kWh, then monthly consumption figures of 292.5kWh (293kWh rounded) for Cape Town, and 262.83kWh (263kWh rounded) for Polokwane can be used. For high-income households, a figure of approximately 600kWh/month will be used, representing growing usage of appliances and ownership of appliances, as well as variety of appliances owned and end-uses of electricity. For very-high incomes, based on data from McCall & Stone (2015) for Cape Town, electricity as a percentage of household end-use decreases, as liquid fuel use for cooking rises. An estimate of around 1,000kWh per month, short of the doubling seen between medium- and high-income brackets, will be used for this analysis.

For the purposes of calibration of these assumptions, the figures will be used in conjunction with the derived 2012 and 2011 household numbers for Cape Town and Polokwane respectively, and compared to the reported total domestic electricity sales stated above:

Income Bracket	Baseline Number of Households	Household Consumption/Month (kWh)	Household Consumption/Year (kWh)	Total Electricity Consumption (GWh)
Low-income	449,653	120	1,440	647.5
Middle-income	288,187	293	3,516	1,013.3
High-income	220,705	600	7,200	1,589.0
Very High-income	53,126	1,000	12,000	637.5
Total Predicted				3,887.4
Total Actual				3,859.3

Table 7: Assumption calibration for baseline year of 2012 for Cape Town

Income Bracket	Baseline Number of Households	Household Consumption/Month (kWh)	Household Consumption/Year (kWh)	Total Electricity Consumption (GWh)
Low-income	72,152	120	1,440	103.9
Middle-income	48,810	263	3,156	154.0
High-income	39,950	600	7,200	287.6
Total Predicted				545.6
Total Actual				561.4

Table 8: Assumption calibration for baseline year of 2011 for Polokwane

From these tables, we can see that the assumptions made in terms of household consumption per month closely match up with observed total domestic consumption figures. For Cape Town, the assumptions over-estimate total consumption by roughly 0.7%, and for Polokwane, under-estimate by approximately 2.9%. These figures are within acceptable bounds of accuracy to continue.

Scenarios

Three scenarios will be considered in this analysis. A business-as-usual scenario will be the first, where population growth will continue in line with current rates, and household growth will be assumed to grow in line with population as defined above. A second scenario will consider higher population growth rates than current projections, in an effort to capture what challenges municipal authorities may face in the event of increased internal migration to urban areas or through increased natural population growth. Both of these scenarios will assume that the proportion of households in each income bracket remains the same through to 2030. A third scenario will consider a change in economic demographics of urban areas, and the emergence of a growing “middle-class” in urban settlements. Each of these scenarios will disaggregate population growth, based on the business-as-usual scenario, between lower, middle and upper classes in the populations of Cape Town and Polokwane based on household income. The demographic change scenario disaggregation is expected to capture not only expected changes in middle-class populations projected by national and international organisations (including Statistics South Africa and the Brookings Institute), but also the anticipated effect that this will have on household energy consumption, due to the close correlation between rising income levels and rising electricity (and energy more widely) consumption.

Finally, for each scenario, an estimation will be made of the growth of formal housing as opposed to the growth of informal housing, using initial figures for Cape Town and Polokwane presented in McCall & Stone (2015) and Housing Development Association of South Africa (2013). The proportions of formal and informal settlements in the cities will be assumed to stay the same or grow/decline as defined in the baseline studies, for the business-as-usual and high population-growth scenarios. The reasoning behind this is that the focus of this analysis is not the growth in population or number of informal settlements in the target cities, but the growth in electricity consumption and need for electrification in these settlements, which this assumption will be more relevant for determining (Housing Development Association of South Africa, 2013).

For the demographic change scenario, this assumption would not seem to be the most relevant, as a shift towards higher income brackets, in theory, should mean a shift towards formalisation of living conditions. The majority of papers regarding informal settlements in the current literature define these settlements as places in majority occupied by the urban poor, with poverty of inhabitants often used as a factor in defining whether a settlement can be classed as informal. However, analysis of the 2011 census data for South Africa by Statistics South Africa as part of the analysis of the General Household Survey (conducted from 2002 to 2014) suggested that informal households were occupied by a relatively even spread of income bands from quintiles 1 through 4, or in other terms, 80% of the total household income spread of the country. To bring together these two seemingly conflicting standpoints, a small shift towards formality will be built in to the demographic change scenario. This shift will be set at a 10% reduction in informal settlement numbers compared to the baseline for both cities.

Business-as-Usual Population Growth Scenario

In order to achieve accuracy in the population projection model, care must be taken when determining the rates of population growth used in the model for the business-as-usual scenario. These figures can be taken from McCall & Stone (2015) and McCall & Stone (2017) for Cape Town and Polokwane respectively, as the figures used in these reports follow closely the established knowledge from statistical bodies in South Africa (particularly Statistics South Africa and the respective regional governments) as to population growth in the years up to 2011 and projections for beyond. The business-as-usual projections for population for Cape Town are presented below:

Year	Population	Growth Rate per annum	Population per Household	Number of Households
2011	3,740,026	3.47%	3.50	1,068,574
2012	3,837,414	2.60%	3.50	1,096,399
2020	4,131,720	0.93%	3.50	1,180,486
2030	4,420,145	0.68%	3.50	1,262,893

Table 9: BAU population growth 2011-2030 for Cape Town (McCall & Stone, 2015)

Based on the projections used in McCall & Stone (2015), we can see that the annual population growth for Cape Town steadily declines through to 2030, from roughly 3.5% per annum to 0.68% per annum. This corresponds to a slowing growth rate in the number of households present in the city.

For Polokwane, the business-as-usual scenario will also follow the work of McCall & Stone (2017). This projection assumes a flat population growth rate of 1.58%, derived from the average population growth rate measured in the city from 2007 to 2011. In addition, while the Cape Town projection assumed a static household occupancy, the Polokwane projection assumes a steadily decreasing number of persons per household, following the trends observed from 2007 to 2011. 2007 household occupancy in the city was determined to be approximately 4.50 persons per household, which decreased to 3.53 persons as of the 2011 census. Through to 2030, this is assumed to further decrease to 3.00 persons per household. The projections for population growth and household growth for Polokwane are presented below:

Year	Population	Growth Rate per annum	Population per Household	Number of Households
2011	628,999	1.58%	3.53	178,001
2018	701,952	1.58%	3.25	215,985
2020	724,309	1.58%	3.20	226,347
2030	847,239	1.58%	3.00	282,413

Table 10: BAU population growth 2011-2030 for Polokwane (derived from McCall & Stone, 2017)

As stated above, the assumption used in the business-as-usual scenario is that the proportions of households in each income bracket in both Cape Town and Polokwane will remain the same through to 2030. These household projections by income bracket are presented below:

Income Bracket	Percentage of Total from Baseline	Baseline Year (2012)	2020	2030
Low-income Electrified	41.01%	449,653	484,139	517,935
Low-income Non-electrified	5.07%	55,652	59,920	64,103
Middle-income Electrified	26.28%	288,187	310,289	331,950
Middle-income Non-electrified	0.65%	7,220	7,774	8,316
High-income	20.12%	220,705	237,632	254,220
Very High-income	4.84%	53,126	57,200	61,193

Table 11: Number of Households per Income Bracket for Cape Town to 2030, rounded to the nearest whole number

Income Bracket	Percentage of Total from Baseline	Baseline Year (2011)	2020	2030
Low-income Electrified	40.53%	72,152	91,738	114,462
Low-income Non-electrified	5.84%	10,402	13,219	16,493
Middle-income Electrified	27.43%	48,810	62,087	77,466
Middle-income Non-electrified	3.96%	7,037	8,963	11,184
High-income	22.24%	39,950	50,340	62,809

Table 12: Number of Household per Income Bracket for Polokwane to 2030, rounded to the nearest whole number

Finally, for this scenario, the growth of formal housing as opposed to informal housing in the city should be investigated. As of 2011 (figures for which are provided in McCall & Stone (2015)), approximately 218,780 households in Cape Town could be defined as 'informal', with the remainder (849,794) being classed as formal housing. For Polokwane, McCall & Stone (2017) does not provide an overall proportion of households classified as informal. However, a 2013 study from the Housing Development Association of South Africa of Limpopo province suggests that as of the 2011 census, approximately 5% of households in Limpopo province (in which Polokwane is situated) lived in informal settlements, either in shacks or in backyard properties. Applying this to the 2011 households figure gives a total of 8,900 informal households, and 169,101 formal households.

Using the 2012 figures, we can see that approximately 79.52% of households in Cape Town were classified as formal dwellings as of the baseline year. Using these figures, the numbers of households can be derived for the two snapshot years of 2020 and 2030. The results of this are presented below:

Household Type	2012	2020	2030
Formal	871,922	938,793	1,004,328
Informal	224,477	241,693	258,565
Total	1,096,399	1,180,486	1,262,893

Table 13: Proportions of formal households and informal households for Cape Town to 2030 (McCall & Stone, 2015)

Using the figures presented by the Housing Development Association of South Africa, the overall numbers of informal settlements in Polokwane can be derived. Assuming these proportions stay the same through to 2030, the overall numbers of formal and informal households can be acquired for the snapshot years also. These figures are presented below:

Household Type	2011	2020	2030
Formal	169,101	215,030	268,292
Informal	8,900	11,317	14,121
Total	178,001	226,347	282,413

Table 14: Proportions of formal households and informal households for Polokwane to 2030 (Housing Development Association of South Africa 2013, McCall & Stone 2017)

Business-as-Usual Electricity Consumption Growth Scenario

Based on the population growth figures presented above and using the estimated average household consumption figures derived from end-use of electricity, a business-as-usual projection for the growth in electricity consumption in Cape Town and Polokwane can be produced. The household figures used in the below tables are based on the electrified households per income bracket only. Based on the household figures through to 2030 derived above, growth in consumption through to 2030 can be modelled. These results, with a snapshot at 2020 and 2030, are presented below:

Income Bracket	Number of Households (Baseline)	Number of Household (2020)	Number of Households (2030)	Estimated Monthly Electricity Use (kWh) per HH	Estimated Annual Electricity Use (kWh) per HH	Electricity Use Total for Baseline Year (2012) (GWh)	Electricity Use Total for 2020 (GWh)	Electricity Use Total for 2030 (GWh)
Low-Income	449,653	484,139	517,935	120	1440	647.5	697.2	745.8
Middle-Income	288,187	310,289	331,950	293	3516	1,013.3	1,091.0	1,167.1
High-Income	220,705	237,632	254,220	600	7200	1,589.1	1,711.0	1,830.4
Very High-Income	53,126	57,200	61,193	1000	12000	637.5	686.4	734.3
Total	1,011,671	1,089,260	1,165,298			3,887.4	4,185.5	4,477.7

Table 15: Business-as-Usual Electricity Consumption Growth from 2012 to 2030 for Cape Town

Income Bracket	Number of Households (Baseline)	Number of Households (2020)	Number of Households (2030)	Estimated Monthly Electricity Use (kWh) per HH	Estimated Annual Electricity Use (kWh) per HH	Electricity Use Total for Baseline Year (2012) (GWh)	Electricity Use Total for 2020 (GWh)	Electricity Use Total for 2030 (GWh)
Low-Income	72,152	91,738	114,462	120	1440	103.9	132.1	164.8
Middle-Income	48,810	62,087	77,466	263	3156	154.0	196.0	244.5
High-Income	39,950	50,340	62,809	600	7200	287.6	362.5	452.2
Total	160,912	204,165	254,737			545.6	690.5	861.5

Table 16: Business-as-Usual Electricity Consumption Growth from 2012 to 2030 for Polokwane

High-Growth Population Growth Scenario

For the high population growth scenario, the population growth rates for Cape Town and Polokwane will be modified to capture the potential expansion of population and households should population growth rates remain strong, in the case of Cape Town, or increase, in the case of Polokwane. For Cape Town, population growth rates for this scenario are assumed to remain at the level seen from 2011 to 2012, 2.6%. For Polokwane, in the decade up to 2020, population growth rates are assumed to remain at 1.58%, and then increase to 2.37% through to 2030, representing a 50% increase in annual population growth rate. These assumptions have been made in line with the literature presented above, in mind of the fact that primary cities, such as Cape Town, could continue to have strong growth, and that the growth rate of secondary cities, such as Polokwane, is likely to increase. Again, occupancy per household is assumed to correspond to the business-as-usual scenario, with a flat occupancy of 3.50 persons per household for Cape Town, and a variable occupancy of 3.53 persons per household in 2011, falling to 3.25, 3.20 and 3.00 in 2018, 2020 and 2030 respectively for Polokwane.

The results of this scenario are presented below for the two cities:

Year	Population Growth Rate	Population	Number of Households
2011	3.47%	3,740,026	1,068,579
2012	2.6%	3,837,267	1,096,362
2013	2.6%	3,937,036	1,124,867
2014	2.6%	4,039,399	1,154,114
2015	2.6%	4,144,423	1,184,121
2016	2.6%	4,252,178	1,214,908
2017	2.6%	4,362,735	1,246,496
2018	2.6%	4,476,166	1,278,904
2019	2.6%	4,592,546	1,312,156
2020	2.6%	4,711,952	1,346,272
2021	2.6%	4,834,463	1,381,275
2022	2.6%	4,960,159	1,417,188
2023	2.6%	5,089,123	1,454,035
2024	2.6%	5,221,440	1,491,840
2025	2.6%	5,357,198	1,530,628
2026	2.6%	5,496,485	1,570,424
2027	2.6%	5,639,393	1,611,255
2028	2.6%	5,786,018	1,653,148
2029	2.6%	5,936,454	1,696,130
2030	2.6%	6,090,802	1,740,229

Table 17: High population growth scenario for Cape Town to 2030

Year	Population Growth Rate	Population	Number of Households
2011	1.58%	628,999	176,685
2012	1.58%	638,937	179,477
2013	1.58%	649,032	182,313
2014	1.58%	659,287	185,193
2015	1.58%	669,704	188,119
2016	1.58%	680,285	191,091
2017	1.58%	691,034	194,111
2018	1.58%	701,952	215,985
2019	1.58%	713,043	219,398
2020	2.37%	729,942	228,107
2021	2.37%	747,242	233,513
2022	2.37%	764,951	239,047
2023	2.37%	783,081	244,713
2024	2.37%	801,640	250,512
2025	2.37%	820,638	256,450
2026	2.37%	840,088	262,527
2027	2.37%	859,998	268,749
2028	2.37%	880,380	275,119
2029	2.37%	901,245	281,638
2030	2.37%	922,604	307,535

Table 18: High population growth scenario for Polokwane to 2030

As with the business-as-usual scenario, the proportions of households in each income bracket are assumed to stay the same under the high-growth scenario. For comparison to the business-as-usual scenario, snapshots of the household distribution by income bracket are provided for 2020 and 2030 below:

Income Bracket	Percentage of Total from Baseline	Baseline Year (2012)	2020	2030
Low-income Electrified	41.01%	449,653	552,106	713,668
Low-income Non-electrified	5.07%	55,652	68,256	88,230
Middle-income Electrified	26.28%	288,187	353,800	457,332
Middle-income Non-electrified	0.65%	7,220	8,751	11,311
High-income	20.12%	220,705	270,870	350,134
Very High-income	4.84%	53,126	65,160	84,227

Table 19: Household numbers by income bracket for Cape Town under high growth scenario

Income Bracket	Percentage of Total from Baseline	Baseline Year (2011)	2020	2030
Low-income Electrified	40.53%	72,152	92,452	124,644
Low-income Non-electrified	5.84%	10,402	13,321	17,960
Middle-income Electrified	27.43%	48,810	62,570	84,357
Middle-income Non-electrified	3.96%	7,037	9,033	12,178
High-income	22.24%	39,950	50,731	68,396

Table 20: Household numbers by income bracket for Polokwane under high growth scenario

Finally, the proportion of informal and formal households for each city should be determined under the high population-growth scenario. To achieve this, as stated in the initial assumptions, the proportions of each type of housing will be assumed to remain the same at each snapshot point (baseline, 2020 and 2030). These proportions will be applied to the higher population figures for this scenario to determine the number of formal and informal households under this scenario. The results of this are presented below:

Household Type	2012	2020	2030
Formal	871,922	1,070,636	1,383,934
Informal	224,477	275,636	356,295
Total	1,096,399	1,346,272	1,740,229

Table 21: Proportions of formal households and informal households for Cape Town to 2030 under high growth scenario

For Polokwane, the same process can be applied, assuming that the 5% figure of informal households as a proportion of the total housing stock remains the same.

Household Type	2011	2020	2030
Formal	169,101	216,701	292,158
Informal	8,900	11,405	15,377
Total	178,001	228,107	307,535

Table 22: Proportions of formal households and informal households for Polokwane to 2030 under high growth scenario

High Population Growth Electricity Consumption Growth Scenario

As with the business-as-usual electricity consumption growth projection presented above, the estimated average electricity use per household per month, derived from the end-use of electricity by income bracket, will be used to estimate electricity consumption growth under the high-population growth scenario. Again, non-electrified households (which are assumed to remain an equivalent percentage of the total population) will not be used in the electricity consumption growth projection. For comparison to the business-as-usual electricity consumption growth projection, snapshots for 2020 and 2030 will be provided based on the high population growth figures. The projections for this are presented below for Cape Town and Polokwane:

Income Bracket	Number of Households (Baseline)	Number of Household (2020)	Number of Households (2030)	Estimated Monthly Electricity Use (kWh) per HH	Estimated Annual Electricity Use (kWh) per HH	Electricity Use Total for Baseline Year (2012) (GWh)	Electricity Use Total for 2020 (GWh)	Electricity Use Total for 2030 (GWh)
Low-Income	449,653	552106	713668	120	1440	647.5	795.0	1,027.7
Middle-Income	288,187	353800	457332	293	3516	1,013.3	1,244.0	1,608.0
High-Income	220,705	270870	350134	600	7200	1,589.1	1,950.3	2,521.0
Very High-Income	53,126	65160	84227	1000	12000	637.5	781.9	1,010.7
Total	1,011,671	1,241,936	1,605,361			3,887.4	4,771.2	6,167.4

Table 23: Electricity consumption growth for Cape Town under the high population growth scenario

Income Bracket	Number of Households (Baseline)	Number of Households (2020)	Number of Households (2030)	Estimated Monthly Electricity Use (kWh) per HH	Estimated Annual Electricity Use (kWh) per HH	Electricity Use Total for Baseline Year (2012) (GWh)	Electricity Use Total for 2020 (GWh)	Electricity Use Total for 2030 (GWh)
Low-Income	72,152	92,452	124,644	120	1440	103.9	133.1	179.5
Middle-Income	48,810	62,570	84,357	263	3156	154.0	197.5	266.2
High-Income	39,950	50,731	68,396	600	7200	287.6	365.3	492.4
Total	160,912	205,753	277,397			545.6	695.9	938.2

Table 24: Electricity consumption growth for Polokwane under the high population growth scenario

Demographic Change Population Growth Scenario

The third scenario in this analysis considers the eventuality that population growth remains steady, as under the business-as-usual scenario, but a demographic shift occurs in the municipalities under consideration. This demographic shift will be modelled as a move of lower-income consumers into middle-income brackets, a similar move of middle-income consumers into high-income brackets, and in the case of Cape Town, a smaller shift of high-income consumers into very high-income brackets. Some assumptions need to be made in this scenario to determine appropriate rates of demographic change between the income groups. Projecting the growth of middle-class populations is extremely challenging, partly due to uncertainties in measuring the existing number of middle-class populations due to issues with self-reporting and income assessment, and partly due to uncertainties in how national GDP growth in the future will affect income distribution among the population (University of Cape Town/IPSOS 2017, Businesstech 2018). Various reports have put the figure for the share of middle-class persons in South Africa as between 13.5% to 43.2%. A more accurate projection can be derived from Africa-wide figures from the African Development Bank, which suggest that as of 2011, 13% of the population of the continent could be defined as stable middle-class consumers, projected to rise to 43% by 2060 (African Development Bank, 2011). This represents an approximate growth rate of 4.5% per annum, assuming a stable growth rate. This figure will be used to determine the growth in middle-income consumers, and the growth in high-income consumers in both cities. For Cape Town specifically, a growth rate of half of this will be used to determine the move from high-income to very high-income consumers, based on the approximate income differences between the two bands defined by Statistics South Africa. To determine this growth rate, the percentages of households per income bracket from the baseline will be calculated to 2030 with this growth rate in mind, and these new figures applied to the overall household numbers to determine the new distributions. With regard to electrified and non-electrified households, the rate of electrification will be assumed to remain constant, so that electrified households will move between electrified income groups, as will non-electrified households (Africa Check 2018, UHY 2018, Bhorat, Kharas & Pita 2017).

To determine the effect that this demographic shift will have on electricity consumption, the specific shifts in demographics will first need to be projected. The percentages will be rounded to two decimal places for clarity. The results of this for Cape Town and Polokwane are presented below:

Income Bracket	Baseline Household Percentages	Percentages as of 2020 with growth rate	Percentages as of 2030 with growth rate
Low-income Electrified	41.01%	40.05%	38.80%
Low-income Non-electrified	5.07%	5.05%	5.02%
Middle-income Electrified	26.28%	26.51%	26.80%
Middle-income Non-electrified	0.65%	0.67%	0.70%
High-income	20.12%	20.74%	21.57%
Very High-income	4.84%	4.95%	5.09%

Table 25: Demographic change scenario household distribution by income for Cape Town

Income Bracket	Baseline Household Percentages	Percentages as of 2020 with growth rate	Percentages as of 2030 with growth rate
Low-income Electrified	40.53%	39.52%	38.21%
Low-income Non-electrified	5.84%	5.69%	5.51%
Middle-income Electrified	27.43%	27.62%	27.87%
Middle-income Non-electrified	3.96%	4.11%	4.29%
High-income	22.24%	23.05%	24.12%

Table 26: Demographic change scenario household distribution by income for Polokwane

Regarding the proportions of informal and formal settlements for the demographic change scenario, as stated above, a small shift of 10% towards formality will be assumed for this scenario, in an effort to consolidate the body of research suggesting informal settlements are predominantly occupied by lower income groups, and the research from Statistics South Africa suggesting an even spread of incomes between economic quintiles 1 through 4 in informal settlements. From the business-as-usual scenario, for Cape Town, informal settlements made up approximately 20.48% of households as of 2012, and for Polokwane, 5% as of 2011. Assuming a 10% reduction in these proportions, as of the snapshot years of 2020 and 2030, this means that informal settlements will make up approximately 18.43% of households in Cape Town, and 4.5% for Polokwane. Using these figures, the proportions of formal and informal households are presented below:

Household Type	2012	2020	2030
Formal	871,922	962,923	1,030,142
Informal	224,477	217,563	232,751
Total	1,096,399	1,180,486	1,262,893

Table 27: Proportions of formal households and informal households for Cape Town to 2030 under demographic change scenario

Household Type	2011	2020	2030
Formal	169,101	216,161	269,704
Informal	8,900	10,186	12,709
Total	178,001	226,347	282,413

Table 28: Proportions of formal households and informal households for Polokwane to 2030 under demographic change scenario

Demographic Change Electricity Consumption Scenario

Now that the percentages of households by income bracket for the two cities have been derived, these can be used with the business-as-usual household predictions for 2020 and 2030 to derive electricity consumption predictions per income bracket for the two snapshot years. The results of this are presented below:

Income Bracket	Number of Households (Baseline)	Number of Household (2020)	Number of Households (2030)	Estimated Monthly Electricity Use (kWh) per HH	Estimated Annual Electricity Use (kWh) per HH	Electricity Use Total for Baseline Year (2012) (GWh)	Electricity Use Total for 2020 (GWh)	Electricity Use Total for 2030 (GWh)
Low-Income	449,653	472,784	489,976	120	1440	647.5	680.8	705.6
Middle-Income	288,187	312,891	338,436	293	3516	1,013.3	1,100.1	1,189.9
High-Income	220,705	244,931	272,385	600	7200	1,589.1	1,763.5	1,961.2
Very High-Income	53,126	58,405	64,221	1000	12000	637.5	700.9	770.7
Total	1,011,671	1,089,011	1,165,019			3,887.4	4,245.3	4,627.3

Table 29: Electricity consumption scenario for Cape Town under the demographic change scenario

Income Bracket	Number of Households (Baseline)	Number of Households (2020)	Number of Households (2030)	Estimated Monthly Electricity Use (kWh) per HH	Estimated Annual Electricity Use (kWh) per HH	Electricity Use Total for Baseline Year (2012) (GWh)	Electricity Use Total for 2020 (GWh)	Electricity Use Total for 2030 (GWh)
Low-Income	72,152	89,457	107,912	120	1440	103.9	128.8	155.4
Middle-Income	48,810	62,518	78,705	263	3156	154.0	197.3	248.4
High-Income	39,950	52,189	68,119	600	7200	287.6	375.8	490.5
Total	160,912	204,165	254,737			545.6	701.9	894.3

Table 30: Electricity consumption scenario for Polokwane under the demographic change scenario

Analysis

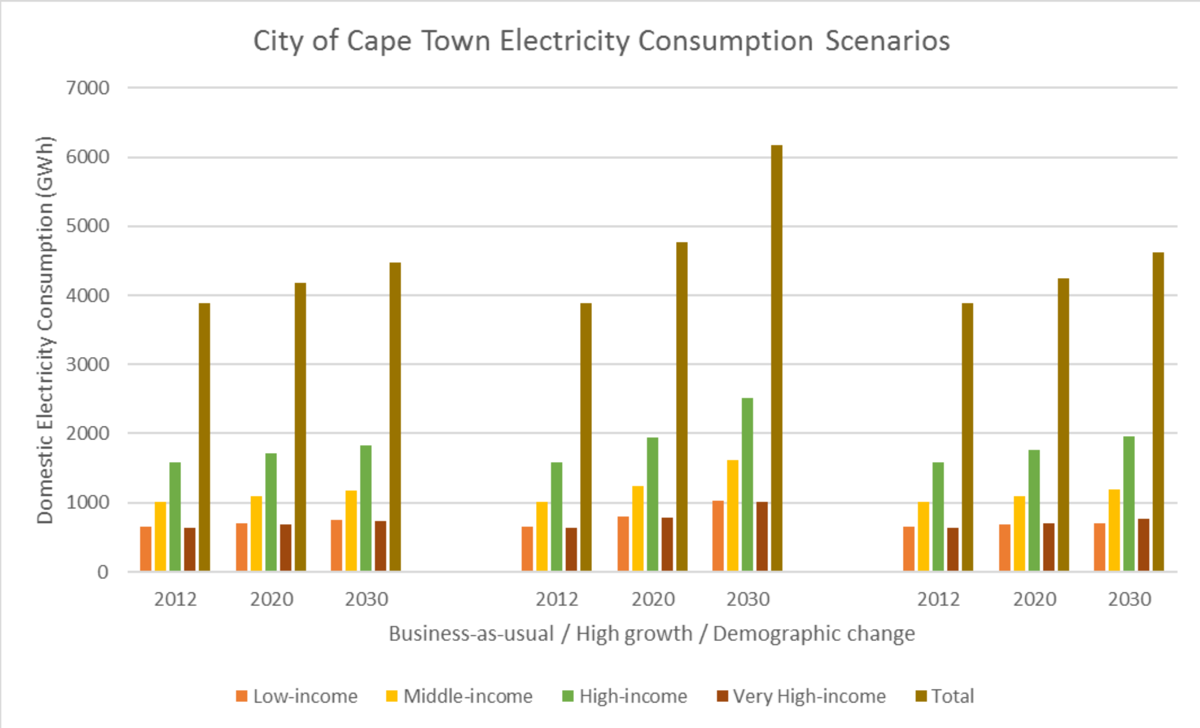

Figure 1: City of Cape Town Electricity Consumption Scenarios

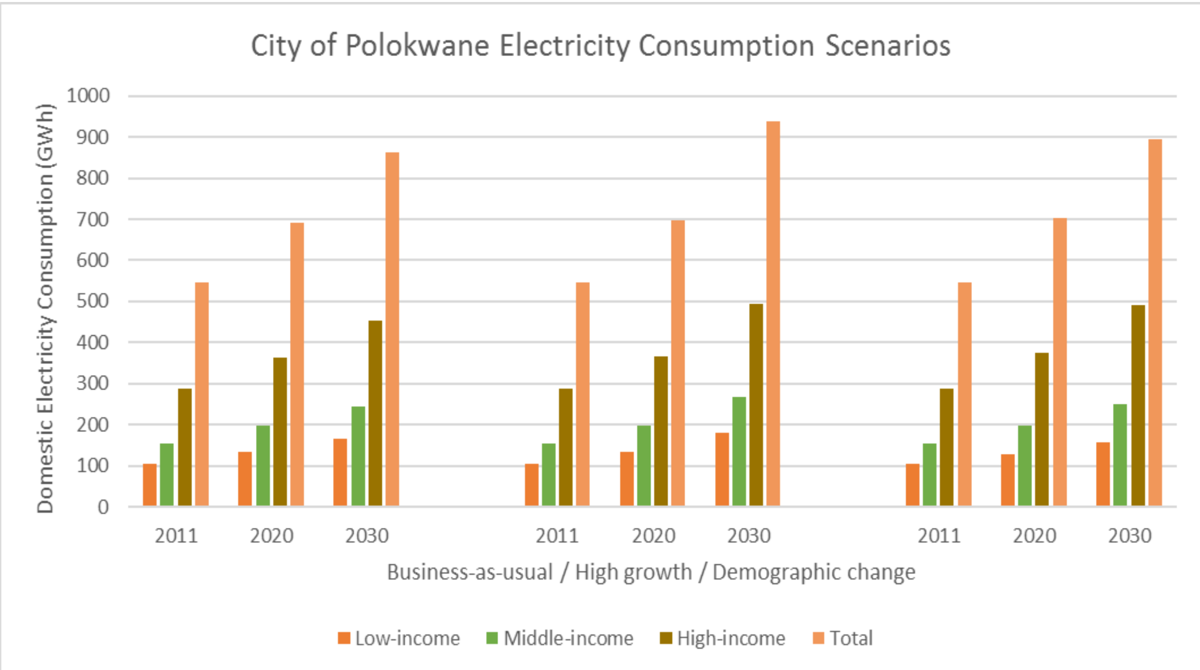

Figure 2: City of Polokwane Electricity Consumption Scenarios

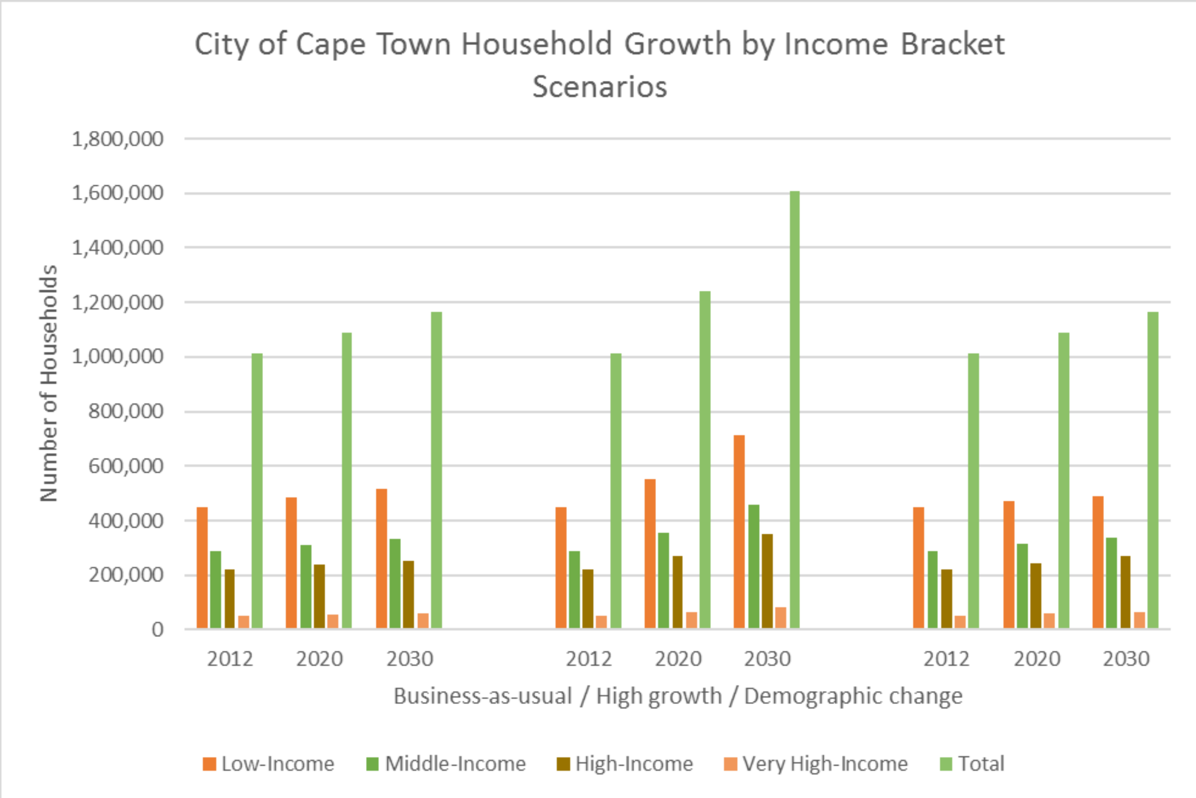

Figure 3: City of Cape Town Household Growth by Income Bracket Scenarios

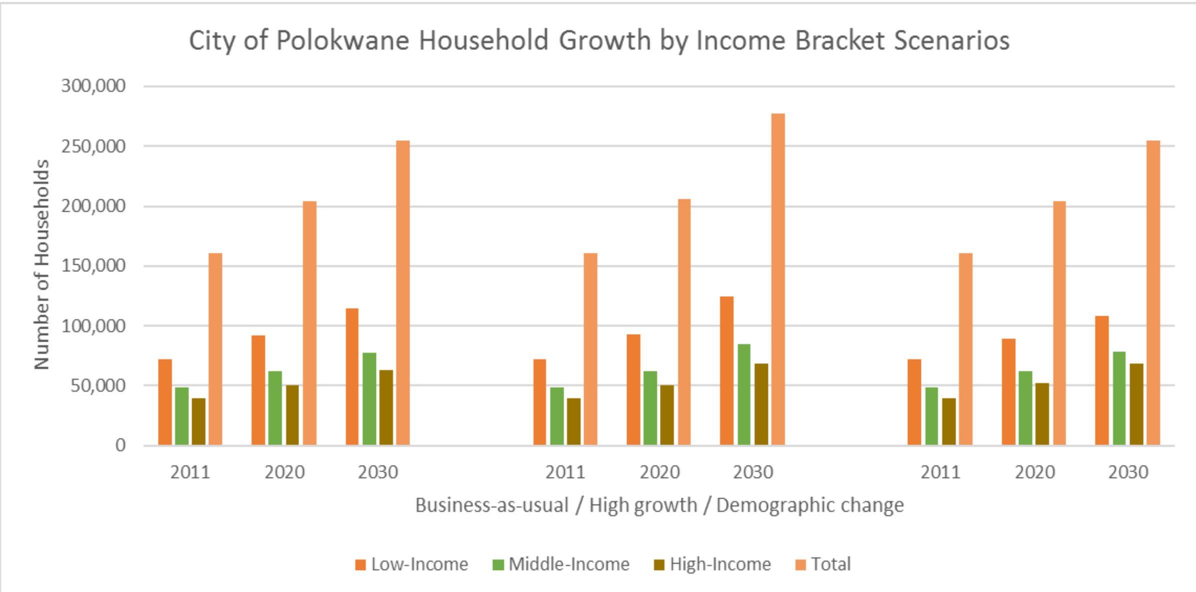

Figure 4: City of Polokwane Household Growth by Income Bracket Scenarios

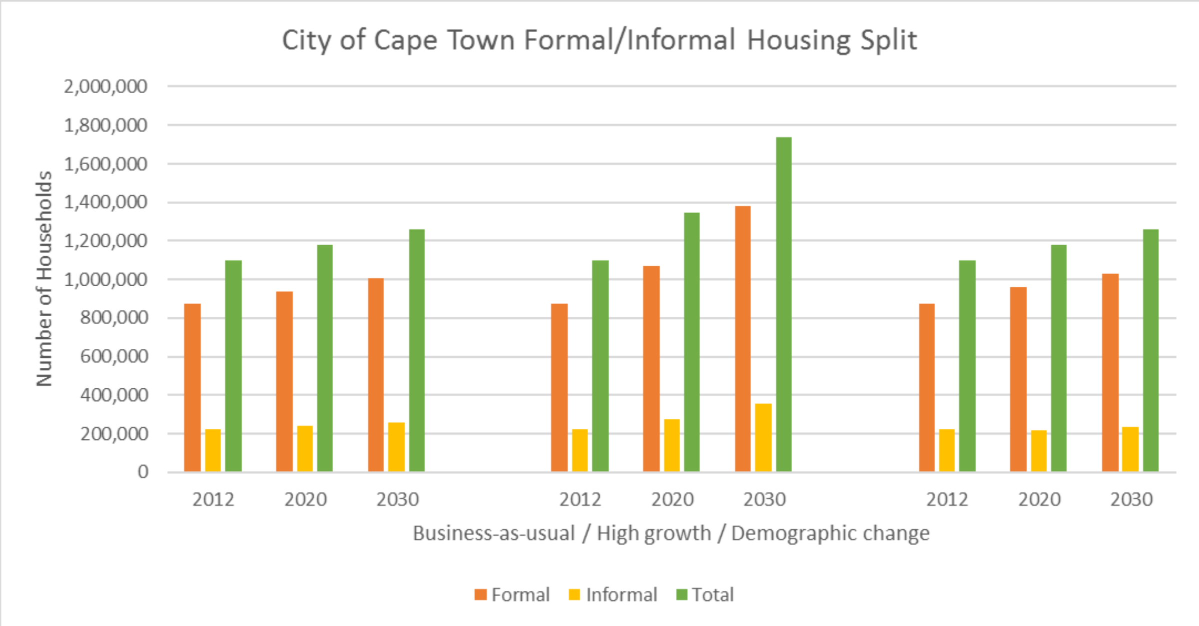

Figure 5: City of Cape Town Formal/Informal Housing Split

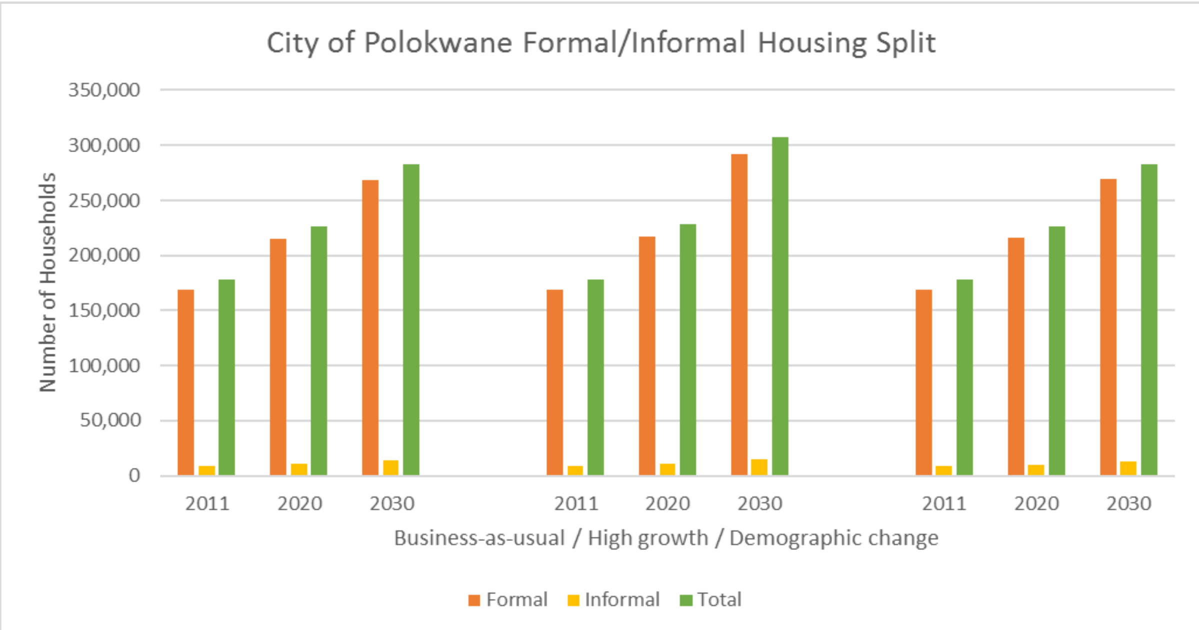

Figure 6: City of Polokwane Formal/Informal Housing Split

From the scenarios presented above, the scale of the challenge facing municipal governments in both Cape Town and Polokwane with regard to population growth and electricity consumption growth, as well as the need for continued and growing electrification efforts, is clear. The analysis of the scenario projections will be split between the two cities, and further between each scenario within the cities, as different challenges are likely to face primary cities such as Cape Town, as emerging cities such as Polokwane. This analysis will cover the projected growth in electricity consumption as a result of population growth foremost, and also consider the growth in electrified versus non-electrified populations, and the growth in informality in the target cities. The graphs above capture the results of the scenarios for electricity consumption growth, overall household growth per income bracket, and the formal/informal housing split.

Cape Town

The analysis of the projections for Cape Town should begin with the business-as-usual scenario, as a representation of the challenges facing the city under current population growth and electricity consumption growth projections from Government and academic sources. Cape Town's population is set to increase under this scenario to 4,131,720 by 2020, occupying 1,180,486 households, and to 4,420,145 by 2030, occupying 1,262,893 households. This represents an increase in population of 294,306 by 2020, and a further 288,425 by 2030, for a total of 582,731. Household numbers are projected to increase in line with this population increase, for a total household growth by 2020 of 84,087 over the 2012 baseline, and a further 82,407 by 2030, for a total of 166,494. In terms of electricity consumption growth, compared to a 2012 baseline of 3,887.3GWh of total consumption, by 2020 this is projected to rise to 4,185.5GWh, and 4,477.7GWh by 2030. This represents a total growth in electricity consumption of 298.1GWh by 2020, and 590.3GWh by 2030. In terms of a percentage growth, this represents a 7.6% growth by 2020, and a 15.2% growth by 2030, of consumption compared to the 2012 baseline. Broadly, the proportions of growth in electricity consumption are to be expected, given the slowing rate of population growth built-in to the Cape Town population growth model, leading to an electricity consumption growth rate slightly below what may have been expected if population growth remains consistent through the 2020-2030 period. Regarding the growth in informality in the city, the number of informal households is set to increase to 241,693 by 2020, and 258,565 by 2030 compared to the 2012 baseline of 224,477, assuming that rates of informality in the city (i.e. the proportion of formal and informal households) remains constant.

For the high population growth scenario, a significantly greater increase in the total population, as well as number of households and electricity consumption totals, can be seen. Under this scenario, Cape Town's population is projected to increase to 4,711,952 people occupying 1,346,272 households by 2020, and 6,090,802 people occupying 1,740,229 households by 2030. This represents a significantly greater population increase, and consequently household numbers increase, than predicted under the business-as-usual scenario, as expected. An increase in population of 874,538 by 2020, and 2,253,388 by 2030, is predicted under this scenario. This corresponds to an increase in the number of households of 249,873 by 2020, and a further 393,957 by 2030 for a total of 643,830. In terms of electricity consumption, this also shows a corresponding marked increase in comparison with the business-as-usual scenario, as expected. Domestic electricity consumption under this scenario is set to increase to 4,771.2GWh by 2020, and 6,167.4GWh by 2030, representing a growth of 883.8GWh by 2020, and an additional 1,396.2 GWH by 2030, for a total of 2,280.0GWh. These figures represent a percentage growth in electricity consumption of 22.7% by 2020, and 58.7% by 2030, compared to the baseline. In comparison to the business-as-usual scenario, an additional 585.7GWh of electricity consumption by 2020, and 1,689.7WGh by 2030, is expected in addition to the predicted growth defined in the above scenario. While this seems high on initial inspection, these figures broadly correspond to the reality that would be observed should population growth continue unabated in the city, particularly given the large increases predicted in higher-income bracket households, which, as shown in the projections above, constitute the majority of electricity consumption for the city. Compared to the business-as-usual scenario, the total number of informal households in the city is also projected to significantly increase, as expected, given population increases, and the assumption that rates of informality remain constant. As of 2020, 275,636 informal households are expected in the city, and 356,295 by 2030. This represents an additional 33,943 households compared to the business-as-usual scenario by 2020, and 97,730 by 2030.

For the demographic change scenario, as the population growth projection used is the same as in the business-as-usual scenario, this analysis will focus on the effects that changes in the demographic make-up of the city with regard to household incomes will have on electricity consumption, the overall changes in household numbers, and the changes in the informal/formal household division in the city. In terms of electricity consumption, the demographic change scenario predicts that as of 2020, domestic consumption will rise to 4,245.3GWh, rising again to 4,627.3GWh by 2030. Compared to the business-as-usual scenario, this represents an increase of 59.8GWh by 2020, and 149.7GWh by 2030. Percentage-wise, this represents an additional 1.4% to electricity consumption by 2020 compared to the business-as-usual projection, and an additional 3.34% compared to the 2030 projections. Regarding the overall change in household numbers, compared to the business-as-usual scenario, by 2020 an additional 2,602 middle-income households are expected, rising to an additional 6,486 by 2030. For high-income households, an additional 7,299 are expected by 2020, rising to 18,165 by 2030. Finally, for very high-income households, an additional 1,205 are expected by 2020, and an additional 3,028 by 2030. Proportional decreases in the number of low-income households, as well as a decrease in the number of non-electrified low-income households, and an increase in the number of non-electrified middle-income households, are also predicted under this scenario. Of these, the change in the number of electrified low-income household is most defined, reducing by 11,355 by 2020, and 27,959 by 2030 compared to the business-as-usual scenario. However, it should be noted that despite the demographic shift from lower to higher incomes, the number of low-income households is still projected to grow compared to the business-as-usual scenario, albeit at a slower rate than under that scenario. In terms of informality, the demographic change scenario predicts a reduction in overall informal household numbers, with 217,563 informal households as of 2020, and 232,751 as of 2030. This represents a reduction in overall informal household numbers of 24,130 by 2020, and 25,814 by 2030 compared to the business-as-usual scenario.

Polokwane

In line with the analysis for Cape Town, the numerical analysis of the results of scenarios for Polokwane should begin with the business-as-usual scenario. Under this scenario, Polokwane's population is set to increase to 724,309 people occupying 226,347 households by 2020, and 848,239 people occupying 282,413 households by 2030, compared to a 2011 baseline of 628,999 people occupying 178,001 households. These figures represent an increase in population of 95,310 by 2020, and a further 123,930 by 2030, for a total of 219,240. In terms of household numbers, 48,346 additional households are expected by 2020, and a further 56,066 by 2030, for a total of 104,412. Regarding electricity consumption growth, compared to a baseline of 545.6GWh as of 2011, Polokwane is expected to consume 690.5GWh as of 2020, rising to 861.5GWh as of 2030. This represents a growth of 144.9GWh by 2020, and an additional 171.0GWh by 2030, for a total of 316.0GWh. In terms of a percentage growth, these figures represent a growth of 26.5% by 2020, and 57.9% as of 2030. These growth rates are significantly higher than those seen in Cape Town above, which is to be expected given the stronger population growth rates used in the business-as-usual scenario for Polokwane compared to Cape Town. Finally, in terms of the growth in informality and the number of informal households in Polokwane under this scenario, the city is predicted to have 11,317 informal households as of 2020, rising to 14,121 as of 2030, compared to the estimated 2011 baseline of 8,900, assuming that the proportion of informal and formal households remains constant. There are a number of reasons behind the lack of informality seen in Polokwane compared to Cape Town, which will be discussed later in this analysis.

Similar to the scenario for Cape Town, the high-population growth scenario for Polokwane exhibits a significantly greater total population and number of households by 2020 and 2030. This is accompanied by a correspondingly greater overall level of electricity consumption. Under this scenario, Polokwane's population is expected to rise to 729,942 people occupying 228,107 households by 2020, and 922,604 occupying 307,535 households by 2030. This growth pattern is in line with current research on Sub-Saharan African urbanisation that predicts strong growth in small- and medium-sized cities through to 2030, with the population of Polokwane approaching the 1 million persons threshold by 2030. This represents a growth in population of 100,943 by 2020, and an additional 192,662 by 2030, for a total of 293,605.This corresponds to a growth in household numbers of 51,422 by 2020, and an additional 79,428 by 2030, for a total of 130,850. In terms of electricity consumption growth, this also shows the expected marked increase seen in the Cape Town high population growth scenario. Under this scenario, domestic electricity consumption in Polokwane is predicted to rise to 695.9GWh by 2020, and 938.2GWh by 2030, compared to the 2011 baseline of 545.6GWh. This represents an overall growth in domestic consumption of 150.3GWh by 2020, and an additional 242.3GWh by 2030, for a total of 392.6GWh. In terms of a percentage growth, this represents a 27.5% increase by 2020, and 72.0% increase by 2030. Predictably, this is higher than the percentage increases seen in the business-as-usual scenario, although less so by the 2020 snapshot than seen under the Cape Town high-growth scenario, or that may have been expected. This is likely attributable to the increase in population growth rates modelled under the high-growth scenario for Polokwane from 2020 onwards: by the 2030 snapshot, increases in electricity consumption far outstrip that seen under the business-as-usual scenario, which is in line with the expected outcomes of higher population growth. Finally, regarding the predicted change in informality under the high-growth scenario, the city is predicted to have 11,405 informal households by 2020, rising to 15,377 by 2030. This is predictably higher than what is seen for the business-as-usual scenario. In addition, the rise from 2020 to 2030 in overall numbers of informal households is expected: the increase in population growth rate built into the high population-growth model from 2020 to 2030 shows an increase in the overall number of households, and consequently the proportion of informal households, despite the reduction in overall household occupancy (from 3.2 persons per household to 3.0) by 2030.

Finally, the demographic change scenario for Polokwane exhibits similar characteristics to the same scenario for Cape Town. Again, this analysis will focus on changes in the informal/formal household division within the city, as well as changes in overall household numbers per income bracket and the effect that the modelled demographic change will have on electricity consumption. Under this scenario, total domestic electricity consumption is predicted to rise to 701.9GWh by 2020, and 894.3GWh by 2030. This represents an additional 11.4GWh of consumption by 2020, and an additional 32.7GWh of consumption by 2030. Compared to the business-as-usual consumption growth projection, this represents an additional 1.7% increase in electricity consumption by 2020, and an additional 3.8% increase by 2030. In terms of the overall change in household income division in the city, compared to the business-as-usual scenario, middle-income households are project to increase to 62,518 by 2020, and 78,705 by 2030, or an additional 431 household by 2020, rising to an additional 1,239 households by 2030. Regarding high-income households, these exhibit a slightly stronger growth, due to the move from middle-income to high-income projected under this scenario. High-income households are projected to increase to 52,189 by 2020, and 68,199 by 2030, or an additional 1,759 by 2020, and an additional 5,310 by 2030. As with Cape Town, the number of low-income households is set to fall under this scenario by 2,281 by 2020, and 6,550 by 2030. These figures all apply to electrified households only, as they are the household brackets considered under the electricity consumption growth projections for this demographic change scenario. Again, as with

Cape Town, it should be noted that low-income households are still projected to grow in absolute terms under the demographic change scenario. Finally, in terms of the number of informal households in Polokwane under this scenario, a modest decrease in overall numbers is predicted, due to the shift from low-income to middle- and high-incomes. As of 2020, this scenario predicts 10,186 informal households in the city, rising to 12,709 by 2030. This represents a reduction in overall informal household numbers compared to the business-as-usual scenario of 1,131 by 2020, and 1,412 by 2030.

Implications of the Analysis of the Models for Cape Town and Polokwane

From the quantitative analysis presented above, it is clear that both the cities of Cape Town and Polokwane will need to institute measures to address the growth in overall domestic electricity demand. Under the business-as-usual scenarios for both cities, electricity demand is projected to rise significantly, and more so for Polokwane compared to Cape Town. Cape Town's total domestic electricity demand by 2030 is projected to rise by 15.2% over baseline levels, and Polokwane's by 57.9%. These projected increases in electricity demand will have significant impact on the ability of the municipal electricity authorities in both cities, as well as the national utility in the case of Polokwane, to adequately service the populations with electricity. The differences in projections seen under the business-as-usual models for Cape Town and Polokwane have their roots in the differing challenges facing primary cities, such as Cape Town, and secondary cities such as Polokwane. Polokwane's domestic electricity consumption is set to increase at a much faster rate than Cape Town's due to the higher population growth rates modelled under the business-as-usual scenario: a significantly greater percentage-wise increase year-on-year leads to a greater overall increase in population, leading further to the stronger domestic electricity consumption growth seen in the model.

This trend also holds true for the high population-growth scenario and the demographic change scenario for Polokwane: both of these hypothetical scenarios show that Polokwane's domestic electricity consumption is set to far outstrip that seen in Cape Town as a proportion compared to the baseline years. This also applies to household numbers under the demographic change scenario: Polokwane's middle- and higher-income household groups are set to grow faster than comparable groups in Cape Town. However, this does not apply to population growth: at 58.8%, the overall increase in population in Cape Town compared to the baseline is higher than that seen in Polokwane (46.6%), despite the higher population growth rates modelled under the high population-growth scenario for Polokwane. This is likely attributable to the higher baseline population of Cape Town, and the greater overall magnitude of population growth that results from this.

Overall, the demographic change scenario produces much less extreme results regarding the growth in domestic electricity consumption than the high population growth scenario. This is to be expected: the foundation of the demographic change scenario is the business-as-usual scenario regarding population growth, however, overall domestic electricity consumption growth in this scenario is still less than may have been expected. This is likely due to the modest rates of population movement between income brackets used in the projection: these rates were derived from an estimate based on a number of projections of middle- and upper-class growth in South Africa in the coming decades, and as such can be seen as relatively robust. This implies that the solutions necessary for both municipalities in addressing the demographic change projections need to be less wide-ranging than if preparing for a high population-growth scenario and may fall within the remit of current measures to address the business-as-usual scenario.

Regarding informality, overall increases in the number of informal households present in Polokwane are significantly lower than those seen in Cape Town in all three scenarios presented above. This can be attributed to the efforts, both municipal and province-wide, of governments at a local and national level to reduce the number of informal households in both cities. Cape Town, and more broadly the Western Cape provincial government and national government, have to date focused on a policy of formalising services to informal households, over more traditional formalisation of housing stock and rights as seen in other provinces of South Africa, and indeed other Sub-Saharan African nations. The case presented above of the City of Cape Town backyarder electrification program is an example of this: services, in this case electricity services, to informal households were brought in line with the services provided to formal households. While this improves the quality of habitation of informal households, these households are still classified as "informal" by the city and contribute to informal settlement numbers in official statistics. Limpopo province, in which Polokwane is situated, has seen a significant growth in the provision of formal housing since the early 2000s, and as such as decline in occupants of informal settlements, as low-cost social housing was a priority in the housing development drive. This has been accompanied by a decline in traditional dwellings in Limpopo province due to rural-urban migration (Housing Development Association of South Africa, 2013). This is a broad outlook on informal settlement growth/decline in both cities: Western Cape province, and Cape Town specifically, has also seen efforts to formalise urban informal settlements in a more traditional sense, such as in the case of Joe Slovo informal settlement near Cape Town airport, which underwent an extensive formalisation campaign through the national Department of Human Settlements Integrated Reconstruction and Development Program (IRDP), beginning in 2005 (Sustainable Energy Africa, 2014).

Regardless of intent to formalise or relative formalisation of services, the growth in informal household numbers in Cape Town, and to a lesser extent in Polokwane, presents additional challenges to municipal and national electricity authorities over and above those seen in the formal household growth figures. Under the business-as-usual scenario for Cape Town, an additional 17,216 informal households are expected by 2020, rising to 34,088 by 2030, and bringing the total number of informal households over a quarter of a million in the same period. Given the existing nature of informal settlement growth in South Africa, these additional households are likely to follow a similar pattern of unplanned growth, leading to similar spatial challenges and challenges in urban form for electricity authorities as existing informal settlements in the city. While this challenge is smaller for Polokwane in terms of magnitude, an additional 5,221 informal households are expected by 2030 under the business-as-usual scenario. If these households are to be brought in line with formal households in the provision of services, efforts to either formalise services or formalise housing will need to be increased in line with informal household growth, which will require both additional capacity and additional financing from municipal or national authorities.

Responses: The Role of Municipalities in Addressing Electrification into the Future

The models and analysis above have set out the scale of the challenge facing municipal and national electricity authorities in meeting the demands of the domestic population regarding electricity services. Under the three scenarios set out, the scale of the challenge varies widely: both the business-as-usual and demographic change scenarios entail a significant growth in electricity demand from the domestic sector, as well as a rise in the number of informal settlements, which have traditionally been difficult to electrify and provide services to in line with formal settlements.

The high population-growth scenario above poses an even greater challenge in this regard. The question then remains: how can municipalities respond to the challenges of servicing ever-increasing domestic populations with electricity?

The responses to these challenges should be grouped by the type of household to be electrified (formal/informal) and will focus on the two municipalities considered in the analysis. As stated above, Cape Town and Polokwane were selected for this analysis to give a broad overview of the types of response available to municipalities of various sizes of city. In addition, as seen from the analysis, the challenges with regard to informality, as well as more formal population growth, vary between the two cities. Cape Town faces greater challenges in terms of the magnitude of population growth it is expected to undergo, as well as the projected increase in informality within the city. Polokwane in many ways faces a lesser challenge in terms of overall population growth and informal settlement growth but faces other challenges at a policy and administrative level, given the split between the local electricity authority and the national utility in responsibility for providing electricity services to the city's domestic consumers.

For the City of Cape Town, the municipal Electricity Department has responsibility for all distribution works carried out within the municipality. The Department has proven itself capable in the past of expanding electricity provision within the city, and the City itself is generally well-financed regarding municipal funds available for electrification works. With regard to informal settlement electrification, as shown above the Department has been a leader within the country in innovative approaches to formalising electricity services for informal households, and the drive towards democratisation of electricity access within the city has seen significant numbers of informal households brought onto the formal electricity grid. Considering these factors, the Department should be well-placed to meet the challenges presented in the business-as-usual and demographic change scenarios above regarding electricity demand growth. Formal housing growth in the city is generally accompanied by electricity grid extension for new properties, and the current financing arrangements for backyarder property electrification in place as of 2018 denote a continuing commitment to informal settlement electrification within the city, in line with municipal and national policy on the issue. Regarding the high population-growth scenario, it is reasonable to assume that current financing arrangements and levels of capacity within the Electricity Department in the city may not be sufficient to meet the significant increases in electricity demand, as well as the demand for electrification of new properties, and especially the growth in informal settlement residents and electrification of informal settlement households.

The high-growth scenario, more so than the other two, presents a number of specific technical challenges, as well as putting additional strain on the policy responses in place in the city regarding electrification. The technical challenges present themselves in the form of constraints on capacity, both human and financial, within the Electricity Department, to deliver the required additional infrastructure that the high-growth scenario will demand. Sustainability of electricity delivery is another concern in a technical sense under the high-growth scenario. Cape Town has, compared to the rest of the country, significant capacity for delivering sustainability projects, and a leading awareness of climate change and urban sustainability concerns. However, applying existing measures such as the provision of off-grid renewable energy systems to grid-inaccessible/inappropriate informal households, or the current promotion of self-generation or independent power production, to the scale of population growth seen under the high-growth scenario, may prove inadequate for meeting the scale of demand growth seen under the scenario.

Social responses in the city may be the key to addressing all three scenarios into the future. While existing measures may prove appropriate for the business-as-usual scenario, and with limited expansion, the demographic change scenario, a purely technical response would require dramatic increases in financing and human capacity within the Electricity Department to meet the demands of the high-growth scenario. Social and policy responses may be helpful in addressing this, particularly in energy efficiency, and specifically electrical efficiency. Demand-side management and reducing overall per-capita electricity consumption is something that has been on the political agenda in South Africa in recent years, given the country's comparatively high per-capita electricity and energy consumption rates compared to similar nations. Improving the electrical efficiency of the appliance stock in the city would reduce overall household consumption and mean that a more limited level of technical response would be necessary to meet increasing demand. More social responses such as behavioural change in households could also be targeted as a non-technical means to reducing demand: encouraging households to use less energy through simple behavioural change measures such as switch-off campaigns and policy responses such as energy-efficient appliance subsidies could have a significant impact on the city's ability to meet its growing electricity demand. Indeed, Cape Town already has experience within the municipal government in encouraging behavioural change in the populace due to the ongoing drought in the city, and Western Cape province more widely, prompting the municipal government to encourage the populace to use less water through behavioural change. This existing experience could be applied to the domestic electricity sector to achieve these goals.

Regarding formal electrification in Polokwane, responsibilities for electrifying new properties in the city are divided between the municipality and ESKOM. As such, the municipality can only have direct influence over the areas that it has responsibility for electrifying, although successful projects in these areas could have influence over the national utility to adopt differing electrification methods in the areas of the city it has responsibility for. Polokwane is relatively less prosperous in terms of overall revenue than the City of Cape Town, and as such has lower overall funding in place for electrification works and services provided by the municipal electricity department. At present, it appears that for formal electrification works, there is little to no collaboration between the municipality and ESKOM, which is an area that could be improved upon. This will be particularly relevant when addressing edge-case areas at municipal district boundaries, especially if settlement lines extend across municipal boundaries. Due to these factors, the municipality may need to be prepared to increase the budget for formal electrification works to meet the demands of the growing populace through to 2030, as defined under the business-as-usual and demographic change scenarios. Both of these scenarios predict strong growth in domestic electricity demand, far outstripping the growth in demand seen in Cape Town, and as such the financial and capacity arrangements to address this growth will need to be proportionally larger. This also applies to the high-growth scenario: Polokwane's population is set to be just under 1 million as of 2030 under this scenario, a 32% increase compared to the 2011 baseline. This is a dramatic change in population and will involve a similarly huge increase in electricity demand. Contingencies will need to be put in place to increase municipal funding for electrification works to service these demands should population growth remain strong. The proposed municipal budget for Polokwane through to 2020 shows that the City is taking these concerns seriously: tariff increases in line with those recommended by the national electricity regulator will mean an additional 30% revenue collected year-on-year through to 2020 compared to the FY2016/17 budget, and the proposed budget for new electrical infrastructure works is set to rise by 24% over the same period. Finally, in terms of informality, the challenge facing Polokwane municipality is actually lesser than that facing Cape Town, due to the provincial and national government works over recent decades to formalise housing in Limpopo province. The current policy and regulatory framework in place for both ESKOM and the municipality should be appropriate to service the growth in informality predicted under all scenarios in the city.

Conclusions and Recommendations for Future Research

This dissertation has analysed the possible scenarios for population growth and electricity demand growth in two South African cities: Cape Town and Polokwane. Three scenarios have been projected through to 2030 for both cities: a business-as-usual scenario, where population growth and electricity demand growth continues as per current projections; a high population-growth scenario, where growth remains strong and, in some cases, increases in the cities, and a demographic change scenario, where the division of household incomes in the cities moves from lower income brackets to higher income brackets. These scenarios were projected to an end-point of 2030, to give a medium-term overview of the challenges facing the two cities. In addition to the growth in population and growth in electricity demand, a division of households into formal and informal households was conducted for both cities, and the growth in informal households modelled to 2030.

From the scenarios presented, even under a business-as-usual scenario, cities such as Cape Town and Polokwane, and their equivalent settlements across the country, will face significant challenges in meeting the electricity demand needs of the domestic sector in the coming decades. Significant population growth, through both natural population growth and rural/urban migration, will lead to increases in domestic electricity demand that will need to be met by increased electrification, and increased electricity service provision. Primary cities such as Cape Town face different challenges in this regard than growing secondary cities such as Polokwane: magnitudes of population growth in Cape Town are projected to be significantly higher under all scenarios than with Polokwane, but percentage-wise increases in Polokwane are set to be higher than for Cape Town. These factors present differing technical challenges: Cape Town, with its current policy and governance framework, has sole responsibility for electricity distribution within the city, and as such capacity and financing for the municipal Electricity Department will need to grow to meet the increases in demand seen under the scenarios. Polokwane will face different challenges: negotiating electrification rights with the national utility, ESKOM, and determining interconnection between ESKOM-operated areas and municipality-operated areas will create regulatory challenges under all growth scenarios, particularly in edge-case areas between service regions. In addition, capacity to meet technical challenges in a sustainable manner in secondary cities such as Polokwane is traditionally lower, and as such greater increases in both human and financial capacity than those seen in primary cities such as Cape Town may be necessary.

This dissertation has solely focused on the demand-side of electricity, and on only one sector: the domestic sector. As such, there is significant scope for future work in this area: broadening the projections for demand growth to include other sectors of the urban energy services sphere, such as the commercial/industrial sector, transport and municipality self-consumption, could provide greater insight into the necessary requirements for energy demand growth into the future. As a demand-side focused work, this dissertation has not commented on the need for electricity generation to meet the growing needs of supply. Meeting electricity demand growth in a sustainable manner on the supply-side is a huge potential area of work, particularly given the rise in new forms of sustainable electricity generation in South Africa in the form of independent power producers, complementing ESKOM's electricity generation infrastructure. This work on domestic electricity demand, complemented by potential future work on broader energy-consuming sectors, could help in building a more complete picture of electricity demand in urban areas of the country going forward, informing the planning of new generation infrastructure in the country. The financial aspects of servicing growing populations with electricity, and the financial capacity increases needed to implement electrification programs to extend connections to new populations, are also an area for future research.

The methodology used in producing the scenarios for the two South African cities is cross-applicable to a variety of other contexts and is not unique to South Africa. When considering the growth of primary cities in South and South-East Asian contexts, for example, a similar methodology to that used for the Cape Town projections, and lessons from the City of Cape Town Electricity Department in how to address the challenges that present themselves, could be applied. Further research could be therefore focused on broadening the picture in South Africa to cover other primary cities, such as Johannesburg or Durban, or on applying the methodology used in this dissertation to other country contexts, and comparing and contrasting the results of the modelling exercise to see if the technical and social responses produced for the South African context have any cross-applicability to other developing country contexts.

Finally, this dissertation has to an extent focused on the need for electrification in urban informal settlements, and the growing challenges that present themselves when considering informality in the domestic sector in South Africa. This is not a uniquely South African phenomenon: across developing country contexts, informality is a growing issue, and responses in the South African context could potentially be used to inform future work in other developing countries, particularly those in similar positions in Sub-Saharan Africa, as well as countries in Latin America and the Caribbean, and South and South-East Asian nations. Informality in the socio-economic structure of developing countries is a complex problem: decades of under-service and lack of access to formal urban services, not just electricity, has led to parallel systems of economic and social development in informal settlements.

Conceptualising these settlements as complex systems may be a viable starting point for further research into the potential responses of municipal and national governments to the challenges that informality poses to these institutions. Informal settlements in themselves exhibit significant complexity in their operation, with a wide range of factors affecting the social, economic and technical nature of the settlements and the evolution of these factors. These settlements are also rapidly-changing contexts, which respond rapidly to various external influences on a social, technical and economic scale. Electricity is also not the only consideration in these settlements: the gamut of urban services exhibit similar levels of complexity in their provision in informal settlements, including water and sanitation provision, emergency service access and services, and access to municipal transport within the city. As these settlements also exist in a typically grey legal area, and sometimes in areas that are in violation of national and local laws, security of habitation is another key concern in these systems, which leads to their precarity, and contributes to their complexity.

A variety of methodologies could then be used to analyse the complexity of these informal systems. One such approach is a multi-level stakeholder analysis, where networks of stakeholders are determined and their influences on various aspects of the socio-economic system in informal settlements are analysed. This approach has seen some use in the South African context in the past to conceptualise informal settlement electricity services, and how access to electricity services is interrelated with other urban services and formalisation needs, such as formal housing rights, land rights and formal addresses (Runsten, Nerini & Tait, 2018). Another approach that could be used to analyse informal settlements in a complexity science framework is agent-based modelling. Originally arising from computer science, agent-based modelling has seen growing applications in the social sciences as a method of conceptualising complex systems with multiple influences and interactions between stakeholders. These stakeholder "agents" can be used within the model to simulate the dynamics of the system under various external and internal influences and determine emergent behaviours within the system. Agent-based modelling has a number of advantages over a more traditional stakeholder analysis approach, particularly in that the methodology can more easily identify behaviours in systems that exhibit non-independence between actors in the system. Agent-based models are typically constructed using software, and once constructed, can be interrogated for various outcomes. An applicable use of such a model regarding informal settlements would be determining the most appropriate policy levers and programmatic responses for providing an urban service (such as electricity) to an informal settlement.

Overall, it is clear that a number of challenges face cities in developing countries in providing electricity services to their populations in the coming decades. In a context of growing concern over climate change and the need for increased sustainability of energy supply, particularly electricity supply, this dissertation has aimed to provide an overview of the potential growth of electricity demand facing South African cities across the scale of urban area seen in the country, and highlight the potential challenges facing municipalities in meeting this electricity demand in a stable, reliable and sustainable manner.

References

AFRICA CHECK (2018) FACTSHEET: Measuring South Africa's (black) middle class. Available at: https://africacheck.org/factsheets/factsheet-measuring-south-africas-black-middle-class/ [Accessed 30.08.18]

AFRICAN DEVELOPMENT BANK (2011) The Middle of the Pyramid: Dynamics of the Middle Class in Africa. Available at: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/The%20Middle%20of%20the%20Pyramid_The%20Middle%20of%20the%20Pyramid.pdf [Accessed 30.08.18]

BEKKER, B. et al. (2008) South Africa's rapid electrification programme: Policy, institutional, planning, financing and technical innovations. *Energy Policy*, 36, pp. 3125 – 3137

BHORAT, H., KHARAS, H. & PITA, A. (2017) Africa's expanding middle class. Available at: https://www.brookings.edu/podcast-episode/africas-expanding-middle-class/ [Accessed 30.08.18]

BRAND SOUTH AFRICA (2015) South Africa plans for mass urban migration. Available at: https://www.brandsouthafrica.com/governance/government/south-africa-plans-for-mass-urban-migration [Accessed 30.08.18]

BRUECKNER, J.K. & LALL, S.V. (2015) Cities in Developing Countries: Fueled by Rural–Urban Migration, Lacking in Tenure Security, and Short of Affordable Housing. In DURANTON, G., HENDERSON, V. & STRANGE, W. (eds) Handbook of Regional and Urban Economics. Volume 5. Amsterdam: North Holland Publishing Co./Elsevier, pp 1399-1455

BUSINESSTECH (2018) This is how big South Africa's middle class really is. Available at: https://businesstech.co.za/news/finance/229307/this-is-how-big-south-africas-middle-class-really-is/ [Accessed 30.08.18]

CITY OF CAPE TOWN (2015) Cape Town State of Energy 2015. Available at: https://africancityenergy.org/uploads/resource_22.pdf [Accessed 30.08.18]

CITY POWER JOHANNESBURG (2015) Electrification and Energy Solution for Informal Settlements Policy. Available at: http://sustainable.org.za/uploads/resources/resource_56.pdf [Accessed 30.08.18]

CITY POWER JOHANNESBURG (2017) Business Plan 2017-2018 Final. Available at: https://www.citypower.co.za/city-power/Annual%20Reports/2017%20-2018%20Annual%20Business%20Plan.pdf#search=informal%20settlements [Accessed 30.08.18]

DE BRAUW, A., MUELLER, V. & LEE, H.K. (2014) The Role of Rural–Urban Migration in the Structural Transformation of Sub-Saharan Africa. *World Development*, 63, pp. 33-42

DELOITTE (2013) Deloitte on Africa: The Rise and Rise of the African Middle Class. Available at: https://www2.deloitte.com/content/dam/Deloitte/au/Documents/international-specialist/deloitte-au-aas-rise-african-middle-class-12.pdf [Accessed 30.08.18]

DODMAN, D. et al (2017) African Urbanisation and Urbanism: Implications for risk accumulation and reduction. *International Journal of Disaster Risk Reduction*, 26, pp. 7-15

ESI AFRICA (2015) City of Cape Town's backyarder project. Available at: https://www.esi-africa.com/city-of-cape-towns-backyarder-project/ [Accessed 30.08.18]

GAUNT, T. E. et al (2012) Informal Electrification in South Africa: Experience, Opportunities and Challenges. Available at: http://cityenergy.org.za/uploads/resource_116.pdf [Accessed 30.08.18]

GOVERNMENT OF SOUTH AFRICA (2004) "Breaking New Ground": A Comprehensive Plan for the Development of Sustainable Human Settlements. Available at: http://abahlali.org/files/Breaking%20new%20ground%20New_Housing_Plan_Cabinet_approved_version.pdf [Accessed 30.08.18]

GÜNERALP, B. et al (2017) Urbanization in Africa: challenges and opportunities for conservation. *Environmental Research Letters*, 13(1). Available at: http://iopscience.iop.org/article/10.1088/1748-9326/aa94fe [Accessed 30.08.18]

HORN, A. (2018) Letting go: Evaluating spatial outcomes and political decision-making heralding the termination of the urban edge in Cape Town, South Africa. *Land Use Policy*, 78, pp. 176-184

HOUSING DEVELOPMENT ASSOCIATION OF SOUTH AFRICA (2013) Limpopo: Informal Settlements Status (2013). Available at: http://thehda.co.za/pdf/uploads/multimedia/HDA_Limpopo_Report_lr.pdf [Accessed 30.08.18]

KOTZÉ, B. (2017) Servicing backyard dwellings with electricity in the City of Cape Town. In *CIGRÉ Southern Africa 8th Southern Africa Regional Conference. Cape Town, South Africa, 14-17 November 2017.* Available at: http://www.cigresa-events.co.za/symposium/2017_post_documents/papers/Session%204%20Universal%20Access/P4.02_%20Servicing%20Backyard%20dwellings%20in%20the%20City%20of%20Cape%20Town%20_%20B%20KOTZE.pdf [Accessed 30.08.18]

LEMAIRE, X. & KERR, D. (2016) Informal Settlements: Electrification and Urban Services. Available at: http://samsetproject.net/wp-content/uploads/2017/10/SAMSET-UCL-Informal-Settlements-Electrification-and-Urban-Services-Dec-2016-1.pdf [Accessed 30.08.18]

MOAGI, P. (2015) Electrification of informal settlements in Johannesburg. In *Proceedings of the 25th AMEU Technical Convention 2015. Johannesburg, South Africa, 4-7 October 2015.* Available at: http://www.ee.co.za/wp-content/uploads/2015/11/AMEU-Convention-2015-p92-98.pdf [Accessed 30.08.18]

MCCALL & STONE (2015) Energy Scenarios for Cape Town: Exploring the implications of different energy futures for the City of Cape Town up to 2040. Available at: http://samsetproject.net/wp-content/uploads/2016/02/Cape-Town-LEAP-technical-report-2015.pdf [Accessed 30.08.18]

MCCALL & STONE (2017) Polokwane LEAP Model Technical Report. Available at: http://samsetproject.net/wp-content/uploads/2016/02/Polokwane-LEAP-model-technical-report-SAMSET-format-1.pdf [Accessed 30.08.18]

OPERATION KHANYISA (2016) Fact Sheet. Available at: http://www.operationkhanyisa.co.za/wp-content/uploads/2016/06/Operation-Khanyisa-Fact-Sheet.pdf [Accessed 30.08.18]

PARDEE CENTER FOR INTERNTIONAL FUTURES (2018) Country Profile, South Africa. Available at: http://www.ifs.du.edu/ifs/frm_CountryProfile.aspx?Country=ZA [Accessed 30.08.18]

RAFEI, L. (2014) Africa's urban population growth: trends and projections. Available at: https://blogs.worldbank.org/opendata/africa-s-urban-population-growth-trends-and-projections [Accessed 30.08.18]

RUNSTEN, S., NERINI, F.N. & TAIT, L. (2018) Energy provision in South African informal urban Settlements - A multi-criteria sustainability analysis. *Energy Strategy Reviews*, 19, pp. 76-84

SATTERTHWAITE, D. (2017) The impact of urban development on risk in sub-Saharan Africa's cities with a focus on small and intermediate urban centres. *International Journal of Disaster Risk Reduction*, 26, pp. 16-23

SHEZI, L. (2016) Cape Town to spend R50mil to connect backyard dwellers to power grid. Available at: https://www.htxt.co.za/2016/09/26/cape-town-to-spend-r50mil-to-connect-backyard-dwellers-to-power-grid/ [Accessed 30.08.18]

SMART ENERGY INTERNATIONAL (2017) Analysis: Electricity theft in South Africa. Available at: https://www.metering.com/features-analysis/electricity-theft-south-africa/ [Accessed 30.08.18]

SOUTH AFRICAN DEPARTMENT OF ENERGY (2003) Guidelines for the introduction of Free Basic Electricity Service. Available at: http://www.energy.gov.za/files/households/guidelines_electricity_freebasic_2003.pdf [Accessed 30.08.18]

SPACE SYNTAX (2012) Slums and informal settlements: An evidence-based approach to sustainable upgrading and development. Available at: http://www.spacesyntax.com/wp-content/uploads/2012/03/Space_Syntax_Informal-settlements-brochure.pdf [Accessed 30.08.18]

STATISTICS SOUTH AFRICA (2016) GHS Series Volume VII: Housing from a human settlement perspective media release. Available at: http://www.statssa.gov.za/?p=6429 [Accessed 30.08.18]

STATISTICS SOUTH AFRICA (2017) Mid-year population estimates. Available at: http://www.statssa.gov.za/publications/P0302/P03022017.pdf [Accessed 30.08.18]

STOCKHOLM ENVIRONMENT INSTITUTE (2018) LEAP: Introduction. Available at: https://www.energycommunity.org/default.asp?action=introduction [Accessed 30.08.18]

SUSTAINABLE ENERGY AFRICA (2014) Joe Slovo, Cape Town: Sustainable low-income settlement densification in well located areas. Available at: http://samsetproject.net/wp-content/uploads/2016/02/Joe-Slovo-Informal-Settlement-Upgrade-Case-Study-South-Africa_FINAL-1.pdf [Accessed 30.08.18]

TRADING ECONOMICS (2018a) South Africa – Urban population growth (annual %). Available at: https://tradingeconomics.com/south-africa/urban-population-growth-annual-percent-wb-data.html [Accessed 30.08.18]

TRADING ECONOMICS (2018b) South Africa - Access to electricity (% of urban population). Available at: https://tradingeconomics.com/south-africa/access-to-electricity-percent-of-urban-population-wb-data.html [Accessed 30.08.18]

UHY (2018) The world's fastest growing middle class. Available at: http://www.uhy.com/the-worlds-fastest-growing-middle-class/ [Accessed 30.08.18]

UN-HABITAT (2011) Global Report on Human Settlements 2011: Cities and Climate Change: Policy Directions. Available at: http://www.citiesalliance.org/sites/citiesalliance.org/files/CA_Images/UNH_GRHS2011_CitiesClimateChange.pdf [Accessed 30.08.18]

UN-HABITAT (2016) Urbanization and Development: Emerging Futures – World Cities Report 2016. Available at: http://wcr.unhabitat.org/wp-content/uploads/2017/02/WCR-2016-Full-Report.pdf [Accessed 30.08.18]

UNIVERSITY OF CAPE TOWN/IPSOS (2017) Sub-Saharan middle class: R1.3tn per month and growing. Available at: https://www.news.uct.ac.za/article/-2017-05-26-sub-saharan-middle-class-r13tn-per-month-and-growing [Accessed 30.08.18]

WORLD POPULATION REVIEW (2018) South Africa Population 2018. Available at: http://worldpopulationreview.com/countries/south-africa-population/ [Accessed 30.08.18]