Small Scale Embedded Generation (SSEG) in Cape Town:

A case study on the impact of Cape Town's SSEG regulation.

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Declaration

I, Dominic Oliver, know the meaning of plagiarism and declare that all of the work in the dissertation, save for that which is properly acknowledged, is my own.

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Abstract

In recent years, the rapidly diminishing costs of renewable technologies have rendered solar photovoltaics (PV) price competitive at a range of scales. Globally, there has been an increasing proliferation of distributed renewable generation embedded within the electricity network, called Small-Scale Embedded Generation (SSEG). Yet, while such decentralised technologies have taken a central role in discussions on energy transitions in the Global North, their implications in the Global South remain poorly documented. In South Africa, the convergence of a legacy energy system, supply issues, rising electricity prices, and growing environmental awareness as well as rapid urbanisation and persistent poverty is presenting a set of compound challenges for government at all levels and threatens the transition to a sustainable, low-carbon energy system.

This study investigates the implications of SSEG on Cape Town's energy transition and assesses the drivers and impacts of regulatory responses. The study adopts a multi-level perspective on socio-technical transitions deployed at the municipal scale to explore the role of SSEG in a just and sustainable energy transition. This was done along three dimensions using an environmental justice framework proposed by Cock (2004), wherein a green agenda refers to environmental conservation, a brown agenda represents energy impacts on quality of life and development, and a red agenda represents social justice and equality. Achieving a just transition will require attention to each of the three agendas in this framework.

Using data from a desktop analysis, policy review and ten semi-structured interviews to investigate the case of Cape Town, the study found that the impacts of SSEG are dependent on the contextual landscape within which this transition is situated. Regulation of SSEG is largely the result of municipal attempts to protect its financial ability to fulfil developmental mandates. Recent regulatory developments have resulted in several unintended consequences which have reduced the extent to which green energy is equitably distributed across the municipal grid, and failed to mitigate revenue impacts of SSEG, and consequently the ability of municipalities to continue developmental agendas.

National landscape pressures from increasing electricity prices and continued load-shedding are driving SSEG uptake. In response to these pressures, and municipal regulation, SSEG has adapted to new niches and battery technologies have become increasingly prevalent. Left unregulated SSEG will continue to threaten the financial viability of municipalities and the extent to which the ongoing energy transition in South Africa will be just and equitable.

This study contributes to an emerging social-science research agenda into socio-technical transitions and addresses the limited consideration of the implications of disruptive technologies and their regulation at the city regime scale in the Global South.

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List of Abbreviations

AMEU	Association of Municipal Electricity Utilities
ANC	African National Congress
CoCT	City of Cape Town
DA	Democratic Alliance
DoE	Department of Energy
DME	Department of Minerals and Energy
DMRE	Department of Mineral Resources and Energy
ECSA	Engineering Council of South Africa
EG	Embedded Generation
EPC	Engineering, Procurement and Construction
ERA	Electricity Regulation Act
FBE	Free Basic Electricity
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GHG	Greenhouse Gases
HD	High Demand
IBT	Inclining Block Tariff
IEA	International Energy Agency
IPP	Independent Power Producer
IRP	Integrated Resource Plan
kWh	Kilowatt-hour
LCOE	Levelised Cost of Energy
LD	Low Demand
MEC	Mineral-Energy Complex
MLP	Multi-level Perspective
MVA	Megavolt amperes
MWp	Megawatt peak
NEP	National Electrification Programme
NERSA	National Energy Regulator South Africa
OPT	Off-Peak Time
PT	Peak Time
PV	Photovoltaic (Solar)
RDP	Reconstruction and Development Programme
RED	Regional Electricity Distributor
REI4P	Renewable Energy Independent Power Producer Procurement Programme
RSA	Republic of South Africa
SALGA	South African Local Government Association
SAPP	Southern African Power Pool
SS	Small-Scale
SSEG	Small Scale Embedded Generation
SSI	Semi-Structured Interviews
ST	Standard Time
ToU	Time of Use

1. Introduction

This thesis investigates the impacts of solar photovoltaic (PV) small-scale embedded generation (SSEG) in Cape Town, the development and implications of regulatory responses, and its impact on municipal development functions.

Since the 1973-1974 oil crisis and subsequent formation of the International Energy Agency (IEA) the relationship between energy consumption and human development has faced increasing scrutiny. Following publication of '*The limits to growth*', global awareness of energy consumption's environmental impact increased (Meadows et al., 1972). Countries began to recognise the requirement for a shift towards alternative energy, increased energy efficiency[1], longer-term policy, and environmental consideration (IEA, 2020a).

Global energy production currently accounts for two thirds of total yearly Green House Gas (GHG) emissions (IEA, 2020b) and global demand is expected to rise over the next 40 years, largely due to rapid development in industrialising countries (Hammond and Pearson, 2013). In its 2020 World Energy Outlook, the IEA highlights, "emissions must fall 40% by 2030 on the path to 2050 neutrality": resulting in global warming of 1.65 degrees (IEA, 2020b). A peak in global emissions is necessary. Accordingly, attempts to address climate change must focus on energy.

Societies around the world have failed to dramatically reduce carbon emissions and are now plagued by a complex 'dual crisis' (García-García et al., 2020). Humanity has surpassed four of the planetary boundaries proposed as ecological limits[2] (Rockström et al., 2009), whilst global poverty and inequality remain persistent, and millions still live below internationally agreed minimum standards of health care, housing, income, and energy (Raworth, 2012;2017).

The requirement to reduce global emissions, whilst simultaneously addressing the needs of some four billion people who remain excluded from the benefits of a fossil-fuel based system, has caused widespread acceptance of the necessity to transition to a sustainable energy system (Solomon and Krishna, 2011; UNFCCC, 2015; Sovacool, 2016). For Grubler (2012:8), "the need for the 'next' energy transition is widely apparent as current energy systems are simply unsustainable on all accounts of social, economic and environmental criteria". Whilst the nature and implications of this 'new energy paradigm' remain contested, the substitution of fossil-fuels will be crucial to achieving a low-carbon energy system (Fouquet, 2010).

The conventional electricity utility model, based on centralised transmission, generation and distribution is subject to significant challenge from disruptive technologies and the rise of the producer-consumer ('prosumer') of electricity (Sioshansi, 2014; Baker and Phillips, 2019). Disruptive technologies are innovations, which, if scaled, may disrupt the network architecture of the electricity system (Verbong and Geels, 2010). Such disruptions include rapid renewable energy generation deployment, distributed generation, smart and flexible power systems, and advances in information and communication technologies (Baker and Phillips, 2019).

Renewable energy prices have been falling, rendering them increasingly competitive with fossil-fuels (Yang et al., 2020). For solar photovoltaics (PV), generation cost per kWh has declined over 95% since the 1970s (Kaylak et al., 2018). In 2019, 119GW of solar capacity was added worldwide, leading the IEA to label solar PV "the new king of electricity" (IEA, 2020b:34).

[1] In production and consumption.

[2] Climate change, biodiversity loss, nitrogen and phosphorous loading, and land conversion.

The scalability of PV makes it competitive across market sectors and has resulted in rapid uptake (Nordholm, 2020). However, the lasting impacts of PV on energy systems worldwide remain unclear (Yang et al., 2020).

Transition from a fossil-fuel based energy system to a low-carbon one built on 'green' technologies will necessitate momentous shifts in infrastructure, governance, practices, policies, cultural meanings, and behaviour, and will re-configure the geographies of producing, consuming, and storing energy (Grubler, 2012; Geels, 2014; Sovacool, 2016). Social implications of transition may be substantial, either exacerbating or addressing current energy injustices (Haas and Resch, 2008).

Limiting environmental decline while addressing entrenched socio-economic problems is therefore a key challenge (García-García et al., 2020). For the IEA, "promoting sustainable development and combatting climate change have become integral aspects of energy planning, analysis and policymaking" (IEA, 2020a:1). Energy has been included within the Sustainable Development Goals (SDGs). Energy transition should not just represent a transition from fossil-fuels, but from the injustices of the fossil-fuel based energy system (Nordholm, 2020). Accordingly, Grubler (2012) calls for increased urgency of policy-making and research on policy outcomes. This research responds to this call.

This study focuses on the role of PV SSEG within energy transition in the Global South. SSEG is the production of energy at sites where it is consumed, and forms part of a trend towards increasingly decentralised generation with potential to disrupt current energy regimes (Filipova and Morris, 2018). PV may trigger fundamental sector restructuring involving increased distributed generation, shifting use patterns, infrastructures, and social behaviours (Yang et al., 2020). Although, the impact of SSEG is still manifesting itself on power markets worldwide, there is limited research on the impact of attempts to regulate these technologies, especially in the Global South and at the local level.

Most of the extensive research into PV has favoured the Global North (Pillot et al., 2019). Research into the Global South is skewed towards Asian economies, with limited focus on Africa (Holstenkamp, 2019). The impacts of disruptive technologies and the implications of regulatory attempts are poorly documented in the Global South (Baker and Phillips, 2019). To date, there has been no qualitative assessment of the impacts of SSEG regulation in South Africa. Using Cape Town as a case study, this study addresses these gaps in the context of SSEG.

Persistent poverty and inequality can determine the possible trajectories of energy transition and pathways towards sustainable development in the Global South (Murphy, 2015). Research on PV in Africa has largely ignored the situated nature of energy transitions (Brunet et al., 2018). Current energy transitions literature has downplayed the political and economic complexities of the energy sector for a more techno-economic and managerial approach (Baker and Phillips, 2019). Social implications are rarely considered (Sovacool, 2014), but will be crucial in determining their management, particularly in the Global South where poverty remains systemic. Accordingly, Murphy (2015) calls for transitions research within such contexts to focus not only on environmental benefits, but on the potential for new technologies, policies, and practices to influence sustainable development.

This research responds to calls for increased social-science research into energy transitions (Sovacool, 2014). Situated between literature on energy transitions, multi-level governance, and energy justice, it contributes to the newly emerging literature on social-science transition research and develops an understanding of the implications of SSEG on a just and inclusive sustainable energy

transition. The study adopts the environmental justice framework proposed by Cock (2004), which focuses on green, brown, and red agendas within policy-making: achieving a just transition requires attention to each of these agendas. The green agenda references environmental conservation, mitigating climate impacts and promoting intergenerational equity. The brown agenda attends to energy impacts on quality of life, livelihoods, development, and poverty alleviation. The red agenda represents social justice and equality in electricity access. The agendas-based framework is adopted in evaluating SSEG in Cape Town to accentuate sustainability issues within an ongoing energy transition.

Using Cape Town as a case study, the research investigates attempts to regulate disruptive technologies in the Global South. It contributes to addressing the limited consideration of transitions in the Global South, at subnational scales within socio-technical transition research. While decentralised and disruptive technologies are often presented as a panacea for low-carbon inclusive energy transition, the reality in Cape Town is different. The South African context differs significantly from that of the Global North and municipal governments face a range of complex challenges and objectives. This research aims to understand the implications of SSEG in Cape Town as well as the drivers for and consequences of regulation attempts in ensuring a just and inclusive sustainable energy transition.

1.1 Background

The City of Cape Town is one of South Africa's legislative capitals with a population of approximately 4 million (CoCT, 2017a). When Apartheid[3] ended in 1994, to address persistent inequality and segregation, South African municipalities were mandated to facilitate local poverty alleviation and improve access to service delivery, acting as developmental local governments. Electricity access was included within the constitution and has become central to enabling socio-economic development (RSA, 1996; Mayr et al., 2015). Decentralised governance gives municipalities control over electricity distribution within their boundaries.

In Cape Town, electricity provision is divided between the CoCT municipality (75%) and Eskom (25%), the monopolistic state-owned utility (Dubresson and Jaglin, 2017). In South Africa's energy system, municipalities act as distributors, purchasing electricity from Eskom and reselling it to consumers (Bellos, 2018). The CoCT boundaries and distribution areas are shown in Figure 1. AECI is a South African chemicals group with former production facilities in Cape Town.

[3] a period of legislated racial segregation between 1948-1994 (Venter et al., 2020).

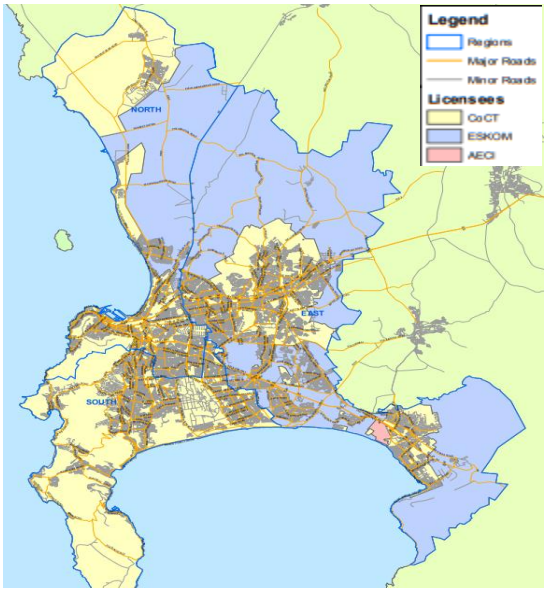

Figure 1 CoCT municipal boundaries and distribution areas. Source: CoCT (2020a).

The CoCT municipality has attempted to improve living standards and provide essential services at affordable rates (Swilling, 2010). It has outlined its priorities of economic inclusion, excellence in basic service delivery, mainstreaming service delivery to informal settlements, building integrated communities, and ensuring operational sustainability (CoCT, 2017a). Notwithstanding, the legacy of the Apartheid era is still visible in persistent inequality and geographical segregation (Lemanski, 2007; Swilling, 2014). Addressing this legacy is a key mandate of the CoCT.

To support the provision of basic services for all, the CoCT has implemented tariff structures to subsidise electricity provision and service delivery for those in need, from electricity sales revenue. The contribution of electricity sales to CoCT revenue was historically around 10%, before rising to 15% by 2003 (Dubresson and Jaglin, 2017).

In recent years, growing environmental awareness, rising electricity prices, falling PV costs, and continued energy insecurity have provoked a rise of SSEG in Cape Town. SSEG refers to the generation of electricity under 1MW at residential, commercial, or industrial sites where electricity is also consumed (CoCT, 2017d). In Cape Town, SSEG has grown quickly in the absence of coherent policy frameworks and now presents a series of complex challenges for municipal government.

1.2 Problem Statement

Attempts to regulate SSEG in South Africa are relatively recent. The CoCT has attempted to accommodate the growing prevalence of SSEG within its distribution network. Registration of connections has been a legal requirement since the 2017 '*Electricity Supply: Amendment By-law*', which revised the 2010 '*Electricity Supply By-Law*', but non-compliance is commonplace. In 2018, to address persistent illegal connection and non-registration the CoCT announced a deadline of July 2019 to register SSEG systems: installations not registered after this deadline would be disconnected and owners fined. Over a year later, it is pertinent to investigate the drivers and impacts of SSEG regulation in Cape Town, to understand its implications on a just and sustainable energy transition. Investigating a range of stakeholder perceptions and positions on these drivers and impacts helps to understand the implications of SSEG regulation on each of the framework agendas.

1.3 Aims and Objectives

The aim of this research is to explore the implications of SSEG on Cape Town's energy transition and assess the drivers and impacts of regulatory responses in order to inform the direction of South Africa's Energy Transition. The study utilises a multi-level perspective at the municipal scale to explore the role of SSEG in a just and sustainable energy transition and assess the implications of SSEG on each of the red, green, and brown agendas.

This research is guided by the following question:

What are the implications of SSEG and municipal policy on a sustainable and just energy transition in Cape Town?

To develop this question, five sub-questions were identified:

How have landscape and regime pressures affected the niche of SSEG in Cape Town?

What are the drivers of SSEG regulation at the municipal level?

How does regulation of SSEG affect municipal agendas (brown, green and red)?

How has the energy supply crisis affected SSEG?

How has SSEG influenced the municipalities capacity to fulfil its developmental mandate?

Correspondingly, the following research objectives were identified:

Explore the landscape and regimes in Cape pressures Town.

Identify the drivers of municipal level SSEG regulation.

Assess the impacts of regulation on municipal agendas.

Determine how the energy supply crisis has impacted SSEG.

Investigate whether SSEG has influenced the municipalities capacity to fulfil its developmental mandates.

Evaluate the effectiveness of the agendas framework for exploring local energy transition.

1.4 Thesis Outline

Chapter 2 provides a review of relevant literature on PV, energy transitions, distributed generation, the role of cities in transitions, and the multi-level perspective on socio-technical transitions adopted. It includes an outline of the agendas-based framework adopted.

Chapter 3 offers an overview of the research methods, techniques adopted, study limitations, and ethical concerns.

Chapter 4 provides a contextual analysis of South Africa's energy landscape.

Chapter 5 presents the growth of SSEG given the South African context, its implications on municipalities, and national SSEG policy.

Chapter 6 presents the findings in Cape Town.

Chapter 7 discusses the implications of these findings relating to the research questions and conceptual framework and suggests areas for future research.

Chapter 8 concludes the study, providing a summary of the implications of these findings.

2. Literature review

This chapter explores the key concepts, theories and research gaps related to the research problem. It begins by outlining the growth of PV. It explores research on socio-technical transitions, energy transitions, their drivers, and the scale at which they occur. It outlines the multi-level perspective adopted in this study and investigates the challenges posed by increasing decentralisation within energy systems. Lastly, it outlines an agendas-based framework for investigating the impacts and drivers of SSEG regulation in Cape Town, used to investigate SSEGs role on a just and sustainable energy transition.

2.1 The rise of renewables

Until recently, renewable energy market growth was driven by international frameworks such as the Kyoto Protocol[4] (Pillot et al., 2019). Such agreements triggered decades of innovation and investment which have rendered renewable technologies increasingly technologically feasible and financially viable at a range of scales (Riahi, 2015; Hermanus, 2017).

Transition from fossil-fuels to renewables has become widely accepted as the most cost-effective means to reduce GHG emissions and meet environmental targets (Haas and Resch, 2008; Fouquet, 2010).

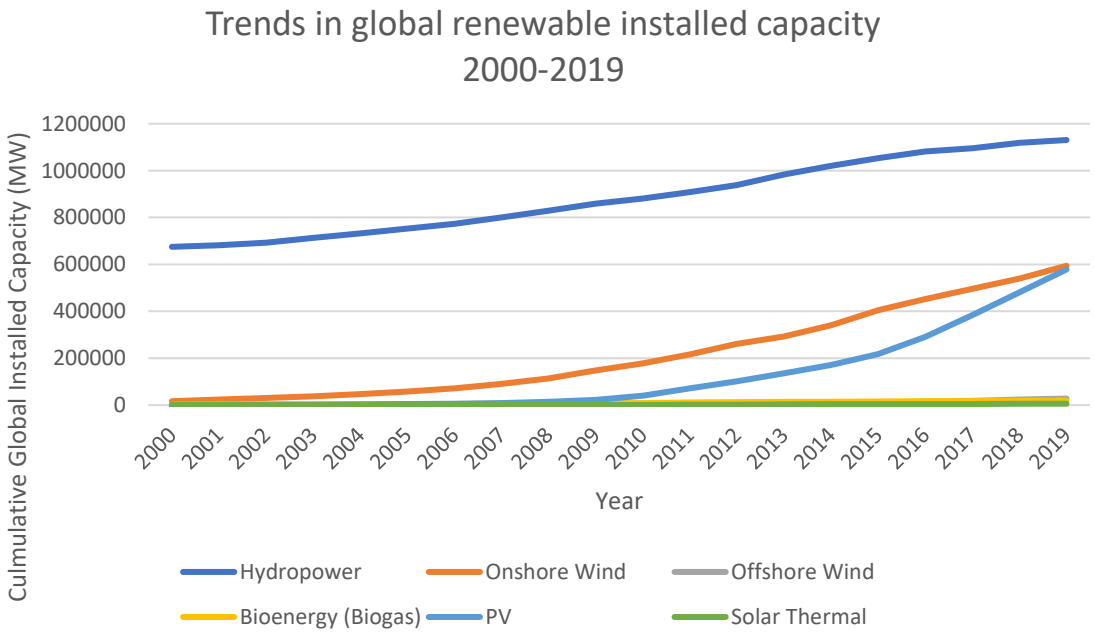

Figure 2 Trends in global renewable installed capacity: 2000-2019. Source: IRENA (2020a).

Using IRENA data, Figure 2 highlights the rapid growth since 2000 of PV capacity, which now represents more than 25% of total global renewable installed capacity. By 2030, 57% of global energy supply will come from renewable energy sources (IRENA, 2020a).

The price of PV modules has fallen 80% between 2009-2017, rendering it price-competitive with new coal-fired power stations in many countries (ERC, 2017). Figure 3 depicts levelised cost of energy (LCOE) for utility-scale PV between 2010-2019.

[4] endorses "research on, and promotion, development and increased use of, new and renewable forms of energy" (United Nations, 1998:2).

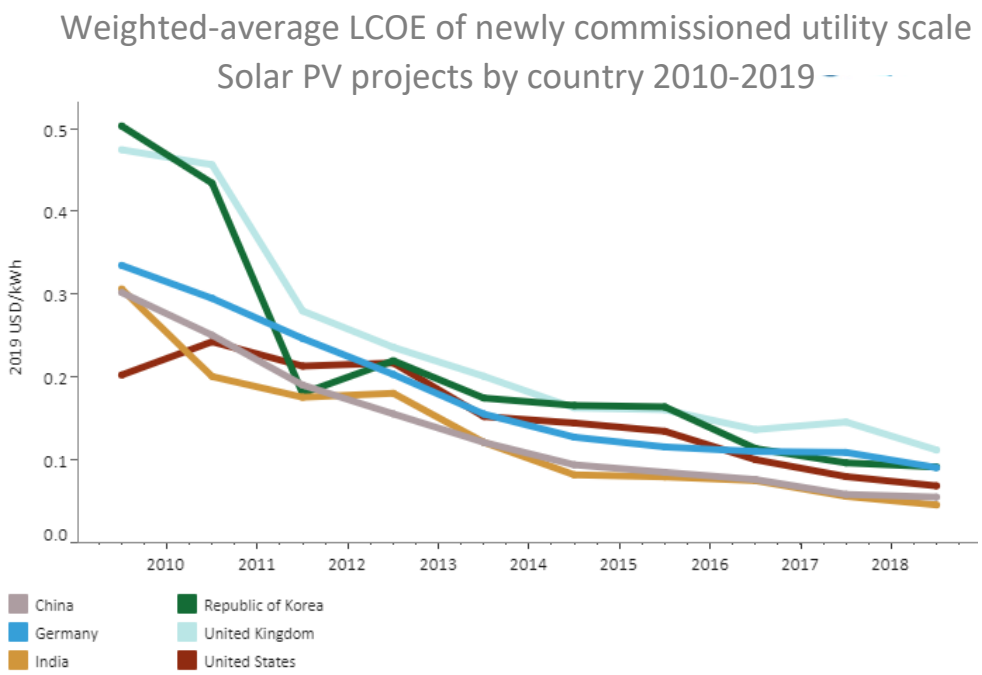

Figure 3 Weighted-average LCOE of newly commissioned utility-scale solar PV projects by country 2010-2019. Source: IRENA (2020b).

As PV cost falls, it is worth noting similar tendencies in lithium-ion battery storage. These are often installed alongside PV to offset its diurnal generation shortcomings. Between 2010-2019 the unitised capital cost of lithium-ion batteries fell 89% (BloombergNEF, 2020). The falling cost of lithium-ion batteries opens opportunities for either grid-tied or off-grid PV applications.

Finally, forecasts of PV uptake have often underestimated growth (ERC, 2017). The IEA World Energy Outlook provides a good example of this. Figure 4 plots IEA yearly projections against actual uptake. The growth of PV is now contributing to a wave of energy sector transitions around the world.

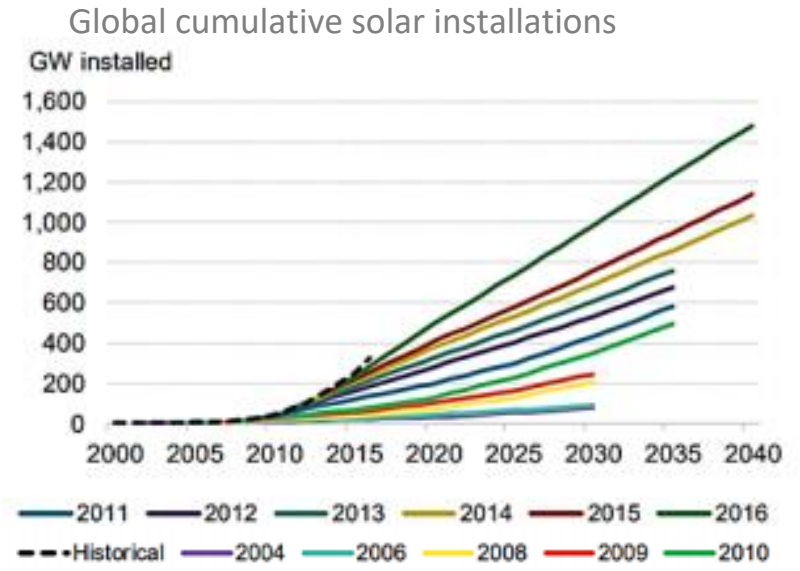

Figure 4 Expected IEA global solar installations Vs historical. Source: ERC (2017).

2.2 Solar PV in Africa

In Africa, renewable expansion has followed similar trends to those observed globally, albeit at a smaller scale (Pillot et al., 2019). Renewable energies are argued to be particularly important in climate action in Africa (IEA, 2017; Schwerhoff and Sy, 2017; Pillot et al., 2019). Although the primary concern of industrialised countries lies in addressing climate impacts in current production, many African nations see renewables as a means to fuel development and increase access (Karekezi, 2002). Increased energy access can enable development (Peters and Sievert, 2016; Holstenkamp, 2019) and is thought crucial to achieving the SDGs (Szabóa et al., 2013).

Renewables present several opportunities for African countries. Capital requirements are often less than for conventional energy, in part due to the modularity and scalability of renewables, which allows for phased government investments (Hafner et al., 2018). Renewables may circumvent the need for traditional and increasingly obsolete large-scale grid infrastructure and enable technological 'leapfrogging' in countries with limited physical infrastructure (Szabóa et al., 2013). Finally, rapid deployment may solve recurring power crises faced by many of the centralised power systems in the region (Hafner et al., 2018).

Figure 5 charts the growth of installed PV capacity in Africa using IRENA data. South Africa has emerged to play a key role in the sector and now contributes over 40% of the continent's total installed PV capacity.

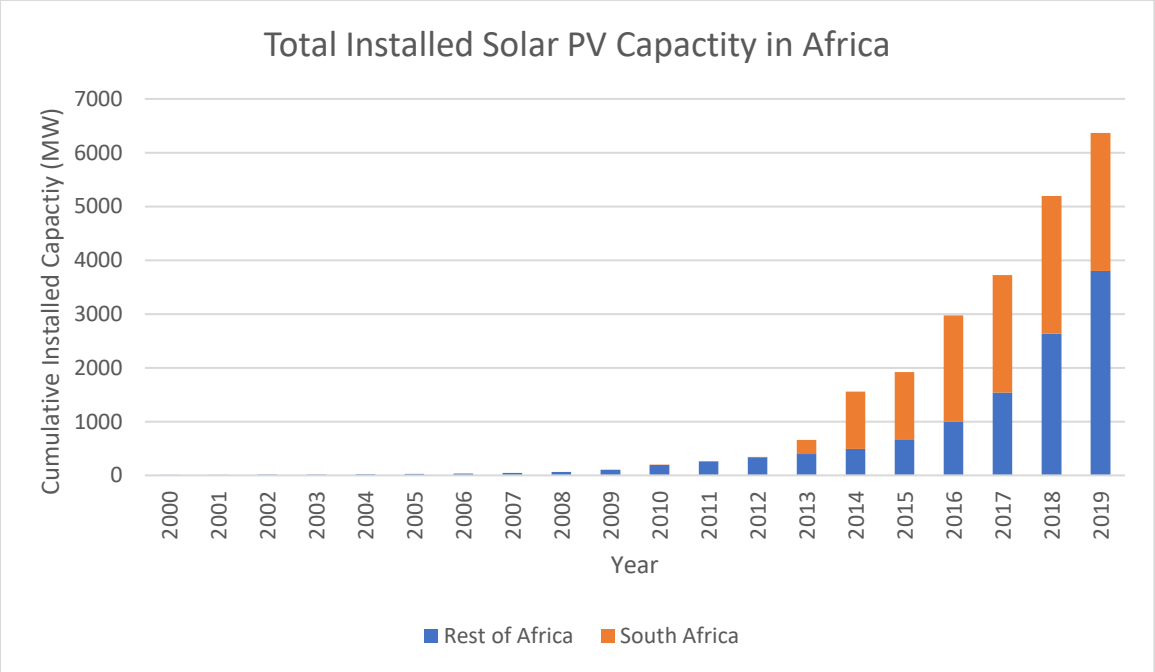

Figure 5 Total installed Solar PV capacity in Africa. Source: IRENA (2020a).

As the world's 14th largest GHG emitter, South Africa's support for renewables has been driven, in part, by international pressure to act (SEA, 2015), and targets established since ratification of the Paris Accord. South Africa has high levels of solar irradiation across much of its landmass (Figure 6). When combined with wind resources, PV has potential to accurately match the country's energy demand profile (ERC, 2017).

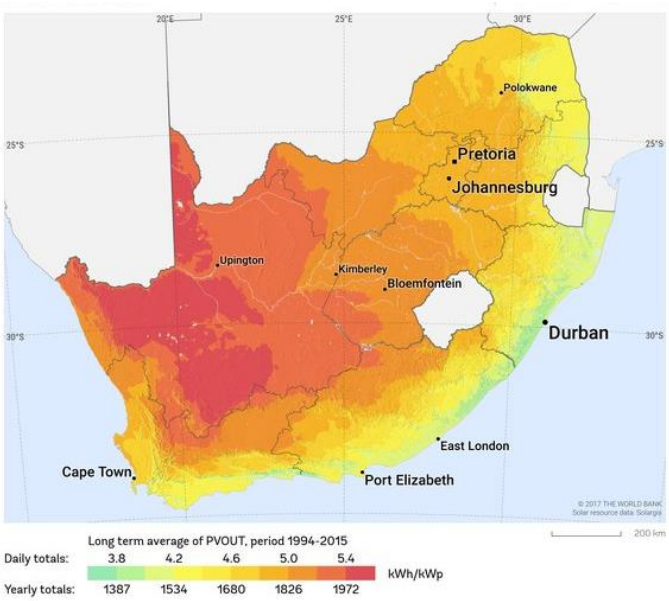

Figure 6 PV power potential for South Africa. Source: SolarGIS (2020).

South African PV growth has caused prices to fall dramatically. In 2015, the price of new build utility-scale PV reached R0.62/kWh, well below that of new-build coal (R1.03/kWh) and nuclear (R1.09/kWh) (DoE, 2016; ERC, 2017). Falling costs have influenced a range of application scales. SSEG has become increasingly prevalent in South Africa, although the actual extent, growth rates and implications of this sector remain unclear.

Falling PV cost has created the possibility of a rapid transition to renewable energy. South Africa's energy transition is likely to be influential in the region due to its geopolitical significance as unofficial economic leader and its influence within the Southern African Power Pool (SAPP) (Krupa and Burch, 2011). However, persistent inequality in electricity access and widespread poverty is impeding sustainable development. Ensuring the transition to a low-carbon energy system does not deepen poverty, marginalisation and inequality is a key area for research (Krupa and Burch, 2011).

2.3 Socio-technical transitions

There is now widespread acceptance that transforming socio-technical systems such as energy is critical to addressing climate change and bringing human activity within planetary boundaries (Meadowcroft, 2009). Socio-technical transition theory has become influential in attempting to comprehend the co-evolution of societies and their technical systems (Murphy, 2015:1). Socio-technical systems comprise a network of actors, institutions, knowledge, and infrastructure, all interconnected and interdependent (Geels, 2004; Markard et al., 2012).

Systems are embedded within multi-scalar dynamics, and their situated context shapes their development (Chlebna and Mattes, 2020). Socio-technical transitions occur when developments trigger deep structural changes to the system involving complex reconfigurations of infrastructure, policy, technology, knowledge, and social practice (Geels, 2011:24; Markard et al., 2012). Numerous authors have highlighted that transitions are long processes from one dynamic equilibrium to another (Meadowcroft, 2009), commonly in pursuit of sustainable ends (Baker et al., 2014).

Originally stemming from institutional theory and evolutionary economics there is now extensive literature on socio-technical transitions (Baker et al., 2014). While this encompasses a range of different emphasis, the most relevant for this study is the multi-level perspective (MLP) (Geels, 2002; 2011).

The MLP integrates historical macro-perceptions with actor-based micro-economic and institutional understandings (Grubler, 2012). Comprising three inter-linked dimensions; landscapes, regimes, and niches, the MLP suggests that socio-technical transitions occur through interactions between these levels. In attempting to understand how broader global processes influence political and technological change, the MLP has been argued useful in evaluating the case of South Africa (Baker et al., 2014).

Landscapes are the broad context of opportunities or constraints in which the regime operates (Hodson and Marvin, 2010). They are the exogenous developments or shocks that can pressure regimes (e.g. climate change) (Sovacool, 2016).

Regimes refer to the prevailing forms of technologically-determined behaviour shaped by the 'cognitive routines' of system stakeholders (Geels and Schot, 2007:400). Regimes are socio-technical because technologies and their functions co-evolve with social interests. Technological development is fashioned by a network of actors: engineers, technologists, social groups, end-users, policymakers, businesses, NGOs and scientists (Hodson and Marvin, 2010). Actors interact through norms, rules, regulations, and policy priorities, which together stabilise the regime and its trajectories (Geels and Schot, 2007; Hodson and Marvin, 2010). For these reasons, socio-technical transitions take time, as new technologies struggle against the incumbent system, to which regulations, practices, maintenance networks are aligned (Geels, 2002). Regimes are therefore conceptualised as 'dynamically stable' and relatively predictable (Geels and Schot, 2007).

Niches are the micro level where innovations are developed, often protected, subsidised, or promoted by governments (Solomon and Krishna, 2011). Within niches 'small networks' of dedicated actors participate in 'radical' innovations and learning from new technologies, ideas, and practices, which diverge from the regimes (Geels and Schot, 2007:400; Geels, 2011:27).

The MLP focuses on how to counter path dependence, inertia, and lock-in in socio-technical transition and how niche innovations may or may not be incorporated into a regime (Bridge et al., 2013). For example, a landscape can pressure a regime creating opportunities for niche innovation. In investigating past transitions, Geels (2005) argues that transitions occur when developments at all three levels reinforce each other. Figure 7 highlights the factors influencing such transition pathways.

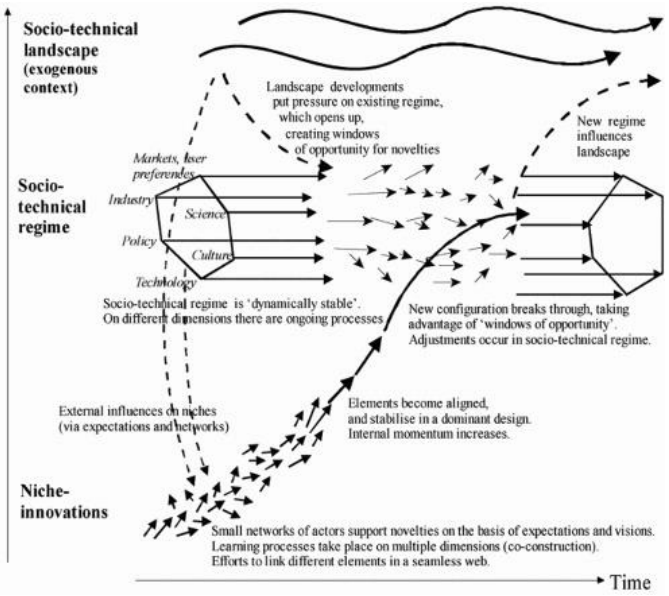

Figure 7 Typology of Socio-technical transition pathways. Source: Geels and Schot (2007).

Within energy systems, Bridge et al. (2013) argue the landscape describes the interconnected activities and socio-technical relations associated with the conversion, distribution, and consumption of energy. Drawing on historical transitions, Fouquet (2016) highlights how innovations or novel energy sources that became dominant started as a niche product. Marginal consumers were willing to pay a premium for additional or superior characteristics of the niche innovation. Over time technology improvements and economies of scale increase competitiveness with the incumbent regime (Fouquet, 2016). Fouquet (2010) highlights that once price parity is reached; adoption of new technologies will likely be rapid. In this way niche innovations can trigger major system transition (Verbong and Geels, 2007).

In South Africa, SSEG remains a niche innovation that is challenging the socio-technical regime. The current national regime, discussed in chapter 4, comprises a highly centralised and increasingly outdated network of predominantly coal-fired power stations.

Geels and Schot (2007) identify four potential transition pathways within the MLP. Technological substitution results from landscape pressures occurring when niche innovations are suitably developed. Transformation results from landscape pressures when niche innovations are inadequate: this stimulates regime actors to adjust the regime (Geels and Schot, 2007). Reconfiguration is the result of symbiotic niche innovation incorporated into the regime and causes further adjustments when landscape pressures are applied. De-alignment and re-alignment result from landscape pressures destabilising the regime when niche innovations are un-developed: the regime is recreated around a new niche innovation (Sovacool, 2016).

Previous transition research has focused disproportionately on OECD and European countries (Baker et al., 2014), largely because historical transition studies have concentrated on temporal change (Geels, 2005; Fouquet, 2010; 2016). Transitions are 'more developed' in industrialised economies and sustainability-orientated policies are more embedded (Marquard et al., 2012; Truffer et al., 2015). Despite limited attention in transition research, Truffer et al. (2015) highlight a rapid proliferation of sustainability-orientated initiatives in the Global South. In contrast to the Global North, the Global South must increase electricity access, whilst simultaneously decarbonising current production and creating new capacity to service rising demand. Economies in the Global

South may chart alternative and potentially rapid transition pathways, benefiting from new and existing technologies developed in niches in industrialised countries.

Fouquet (2016) argues that stimulating transitions in developing countries will necessitate distinct approaches to those adopted in the Global North. Accordingly, Murphy (2015) calls for case studies focused on different contexts to those found in the 'core'. Transition studies within these contexts should focus not only on the environmental aspects of transition, but on the ways in which new technologies, policies and practices may instigate inclusive economic growth, protect vulnerable communities, and foster development (Murphy, 2015). This research responds to this call.

2.4 Energy Transition

García-García et al. (2020:2) define energy transition as a "process of shift that affects the generation, distribution, storage and use of energy and causes rearrangements in policies, economies and societies". Energy transitions are complex co-evolutional processes of change in elements of the socio-technical system or regime (Geels and Schot, 2010; Sovacool and Geels, 2016; García-García et al., 2020). García-García et al. (2020) simplify this, arguing that the crux of current transition is not the shift in energy mix, but the pursuit of sustainability.

Transition to a low-carbon energy system will require shifts in infrastructure, governance, regulation, tariff structures and behaviour, and will re-configure the geographies of producing, consuming, and storing energy (Grubler, 2012; Bridge et al., 2013; Sovacool, 2016). Climate change, resource depletion and energy insecurity are re-shaping existing patterns and scales of distribution, consumption, and supply of energy (Haas et al., 2008). Yet there is no one clear route to transition, and no one clear model of low-carbon society post-transition.

In the Global South, energy transitions have different drivers and outcomes than the Global North. Investigating the role of SSEG in South Africa's energy transition can help understand the social, economic, and developmental implications of disruptive technologies and energy transition in the Global South (Caprotti et al., 2020).

Energy transition research has often focused on historical transitions (Smil, 2010; Grubler, 2012; Essex and De Groot, 2019). Understanding past transitions and their processes, drivers and characteristics can help inform present and future policy creation (Fouquet, 2016).

Researchers have extensively argued that energy transitions take time (Fouquet, 2010; Smil, 2010; Grubler, 2012). Arguments for slow transitions include, inter alia: market size (larger systems take longer to change), technological interrelatedness (more complex systems take longer to change) and infrastructure needs (more infrastructure intense systems take longer to change) (Grubler, 2012). Uptake and speed of uptake depend on a range of contextual features (Grubler, 2012).

Capital pre-invested in infrastructure, training, business interests and political associations, and the complexities associated with their change result in path dependencies, 'lock-in' or 'inertia' which resists change (Unruh, 2000; Sovacool, 2016). For Lund (2006) this is due to relatively long infrastructure investment cycles. Incumbent actors can subvert energy transitions by co-opting and preventing transition pathways to maintain regime interests (Stirling, 2014).

Given the urgent need for climate action the slow nature of energy transitions is troubling. However, the relevance of historical insights on future transitions is questionable, and mounting evidence of rapid transitions provide reason for optimism (Fouquet, 2016; Sovacool, 2016).

The drivers of future energy transitions are likely to be fundamentally different from those past (Sovacool, 2016). As climate change continues, the comparative advantage of renewable energy increases.

The concept of societal energy transition is a recent development (Solomon and Krishna, 2011). While past transitions were 'involuntary': a result of sporadic and uncoordinated decisions made at a range of scales, García-García et al. (2020) highlight that the present transition represents a deliberate, complex policy-led process with time goals. Therefore, future transitions may be considerably different to those of the past, with increased awareness of their necessity, the range of alternatives available, and the social, environmental, and economic implications.

Analysing the drivers of SSEG regulation and uptake in South Africa can help elucidate the extent to which transition may occur rapidly and outline the implications and characteristics of such a transition. Furthermore, in investigating what drives regulation, the barriers to rapid adoption of innovations can be identified. This can provide important insights into energy transitions in non-OECD countries.

2.5 Increasing decentralisation

In traditional centralised energy production models, a limited number of electricity generators feed power via a central grid to consumers. Decision-making is centralised (Nordholm, 2020). Governance of this system involves limited actors; policy decisions are made by government, with collaboration from a system operator often in consultation with industry (Brisbois, 2020). Responsibility and accountability are recognised and defined (Brisbois, 2020). Decentralised transitions involve the movement from a focused grid system to a more diverse one with more stakeholders.

Renewable energy technologies have enabled increased uptake of distributed electricity production and increased the prevalence of electricity 'prosumers' (Goldthau, 2014; Sioshansi, 2014). In the Global North, the focus of much transition research, decentralisation is considered prerequisite to energy transition.

For Bridge et al. (2013) this results from a focus on 'liberalisation' in transition discussions. Structural reform, including diversification of energy sources, distribution models and ownership as well as increased competition and localisation are key results of the move towards 'liberalisation' (Hermanus, 2017). Increasing decentralisation is partially the result of renewables increasing the technological and financial feasibility of electricity production at a range of scales (Riahi, 2015), and partly the result of transition theorists emphasising the benefits of end-use decentralised innovations (Grubler, 2012).

With renewable energy generation strategies focused on flow resources[5], dispersion of generation assets helps counter intermittency, seasonal variation, and low power density[6] (Bridge et al., 2013). While dispersal of generation assets does not preclude them being networked nationally, it influences infrastructure and grid use. Increasing distributed generation increases the number of actors engaged in the energy sector and complicates the roles of establishments responsible for ensuring access to clean, secure, and affordable energy (Brisbois, 2020). Brisbois (2020) argues that increased decentralised assets can increase competition for grid space. Grid architectures must therefore be adapted to allow for distributed generation. Local coordination over grid supply and

[5] E.g wind or solar.
[6] Compared to fossil-fuels.

demand is argued necessary to address technical challenges posed by increased distributed generation (Brisbois, 2020).

With dispersed assets, accountability becomes less clear. For Brisbois (2020), as increasingly distributed systems form, there is often a lack of appropriate institutions to deal with these new challenges. As existing methods of accountability were developed alongside centralised systems, there is need for new governance structures to ensure reliability, accessibility, and affordability of the electricity system (Brisbois, 2020).

As local energy decisions are increasingly delegated and decentralised, local actors have begun to take a central role in decentralised transitions (Bulkeley et al., 2012). In the Global North, shifts are under way within energy governance to account for decentralised and multi-level sites of energy production unaccounted for in established procedures (Briosbois, 2020). Transforming electricity governance to maintain accountability is key to ensuring multi-level electricity systems can meet societal needs (Jaglin, 2014; Brisbois, 2020). Concurrently, there is growing acceptance that implementing effective policies to encourage sustainable energy transition will require enhanced local governance and multi-level systems that account for this (Bridge et al., 2013; Jaglin, 2014; Caprotti et al., 2020).

Despite benefits of increasing decentralisation, its implementation presents key challenges, and its implications are likely to be significant. Although regulation can attempt to impede distributed generation, redefinition, and adjustment of government roles at a range of scales will be required. Regulation must therefore guide the shift to increasingly distributed and decentralised energy generation. The unique nature of South Africa's energy context will contribute to the implications of distributed generation. In Cape Town, SSEG and regulatory attempts will not just have social, developmental, or economic implications, but issues with technical and governance facets. Ensuring regulation enables a just and sustainable energy transition presents a difficult challenge to governments at all scales.

2.6 Governing transitions

With the need for transition accepted, societies have aimed to accelerate transitions and discuss the most effective ways to enact change (Bellos, 2018). How to promote and govern such a transition is the subject of much debate in social-science and policymaking arenas (Markard et al., 2012). Public policy attempts to mitigate climate change whilst managing the consequences for human and natural systems (García-García et al., 2020). To drive a sustainable transition, Grubler (2012:1) argues for persistence and continuity within policy to ensure consistent and congruent policy signals. The management of transitions describes the conscious attempts to guide such transitions along a desired trajectory (Meadowcroft, 2009). As decision-making occurs across many actors, influencing such actions is a challenge (Tait and Euston-Brown, 2017). Accordingly, there is a need for interactions at a range of scales.

Discussions over the orientation and acceleration of transitions have been particularly acute within the MLP with the notion of 'transition management' (Meadowcroft, 2009). Meadowcroft (2009) argues that policy agendas are dominated by short-term goals, resulting from short election cycles, and technologists often focus on incremental improvements to dominant system designs. Transition management attempts to coordinate processes at different system levels to align and support each other. By analysing interactions within the system and using insights to influence subsystems, practitioners can drive coherence at each level, moving the entire system in the desired direction (Bellos, 2018).

There is much contention within the literature on the extent to which guiding transition is possible. Meadowcroft (2009) outlines three issues arising in attempting to guide transitions: difficulties specifying transition goals, difficulties disrupting 'lock-in', and difficult decisions confronting decision makers.

Jaglin (2014) criticises these approaches arguing they 'depoliticise' energy issues and adopt a 'managerialist' view of energy system governance. For Jaglin (2014), the compatibility of national or local agendas, the development of a 'shared vision', and preferred pathways to sustainable energy systems do not arise from a lack of technical coherence and will not be resolved by better-informed policy. Fundamental tensions exist between different government levels that are often overlooked. Agendas and priorities will differ and influence the ability to pursue transitions and their direction. Geels (2014) extrapolates on this, arguing that transition management approaches frame transitions as 'techno-economic management challenges', resulting in the presentation of a singular preferred pathway.

While there is growing evidence that transitions can extenuate existing disparities (Solomon and Krishna, 2011; Bartiaux et al., 2016), governance of energy systems can mitigate these issues. Energy governance, "the actions and decisions taken regarding a particular resource" (Brisbois, 2020:1) can determine the trajectory of transition, how it is enabled, and who is involved (Nordholm, 2020). To achieve sustainable development, governance should attempt to orientate transition pathways to achieve desirable social and environmental outcomes (Meadowcroft, 2009). Transition management approaches have often neglected the social, economic and development implications of transition. Understanding the implications of a transition and responses to it, can ensure future transitions are just and sustainable.

2.7 Scale in energy governance

Within transitions research, there has been a lack of focus on the spatial scale at which transitions occur (Caprotti et al., 2020; Chlebna and Mattes, 2020; Hodson and Marvin, 2010). Transition theorists have often adopted a national level focus based on assumptions that energy systems should be governed at that scale. In response, Bridge et al. (2013:231) call for increased spatial focus in transition research arguing that energy transitions are spatially constituted processes. Discussion of low-carbon transition should therefore be attentive to the diverse social, economic, and political settings within which they occur (Baker et al., 2014). Transitions are embedded in locally specific contexts, that are fundamentally place-dependent (Chlebna and Mattes, 2020). Accordingly, research has increased its focus on local and regional scales (Truffer et al., 2015).

In response to increasingly distributed generation, local government engagement with energy policy is growing. Cities are taking increasing responsibility for infrastructure management and playing a role in shaping energy transitions (Hodson and Marvin, 2010). Yet, responses and agendas of cities may be dramatically different from those of national government. Hodson and Marvin (2010) highlight the agency of cities in influencing and defining national transition pathways and call for further research into cities in the Global South.

Previous literature has often failed to explore the political economy underpinning transitions (Baker et al., 2014) and fully consider the impacts of policy proposals for low-carbon transition on currently uneven social and economic development (Bridge et al., 2013). Yet, for Bridge et al. (2013), the diffusion of innovations is culturally contingent. Attention to spatial scale therefore allows greater focus on the context within which transitions occur.

Recently, researchers have started to acknowledge the importance of cities and urban infrastructure networks as key sites of energy consumption, policy design and intervention on climate change (Bulkeley et al., 2012; Patel, 2014; Tait and Euston-Brown, 2017). For Truffer et al. (2015), national-scale policy is unable to understand the role of sub-national actors and processes in shaping the development of socio-technical systems. However, cities may be constrained by national policy and the division of responsibility between levels of government (Harker et al., 2016; Tait and Euston-Brown, 2017). As energy systems are situated in a local context and are increasingly recognised as central to climate change response, it will be beneficial to understand how energy transitions take place at the city scale.

2.8 Analysing policy in the transition to a sustainable energy system

Considering global challenges, future energy transition must be both environmentally sustainable and just (García-García et al., 2020). A just transition to a low-carbon economy is defined as a:

"long-term technological and socio-economic process of structural shift, that affects the generation, distribution, storage and use of energy, and causes rearrangements at micro, meso and macro levels, while also ensuring that the desired socioeconomic functions can be accomplished through decarbonised and renewable means of energy production and consumption, safeguarding social justice, equity and welfare" (García-García et al., 2020:5).

However, mitigative climate action whilst enabling inclusive economic growth is a challenge. As Essex and De Groot (2019) highlight, ensuring the equitable distribution of sufficient electricity supply from low-carbon sources at a cost-competitive price is a significant task. This challenge is particularly complex in the Global South where the impact of climate change will be most pronounced, social injustices are most profound and the need for economic growth is most pressing. Krupa and Burch (2011) question how renewables can be implemented whilst attending to all three pillars of sustainable development (environmental sustainability, economic efficiency, and social justice).

Practically, attempts to direct a just transition to a low-carbon economy require policy implementation. At the city scale, Patel (2014) highlights how policy may be influenced by various agendas such as attempts to address climate change. Policy positions shift over time in response to ideas and agendas developing at a range of scales and with contexts (Patel, 2014). This draws on Kingdon's (1995) work on agenda setting within public policy research, which attempts to understand why policies and their outcomes change. For Kingdon (1995), policymakers are often unaware of the origins of policy, or why certain policies emerge over others. Instead, policy evolution is partially a process of chance, which results in rapid change and variability in the policymaking process (John, 2003).

Kingdon (1995) highlights how policy agendas compete for influence over a policy. Once a certain agenda gains traction it can rapidly influence policy outcomes (Baumgartner and Jones, 1993). Such agendas will often develop rapidly in response to external processes (John, 2003). John (2003) criticises the assumption that such agendas and policies evolve gradually, demonstrating that introduction can be rapid. Policy diffusion has potential to 'punctuate equilibrium': shifting the system rapidly from one stable point to another (Baumgartner and Jones, 1993:17). Agendas are influenced by a wide range of stakeholders in the policy process. Institutions act to shape agendas, determining which issues are addressed, which agendas prevail in discussion, and the speed of action (John, 2003). Influencing policy agendas can cause rapid changes in policy and interactions between policy streams can trigger deviations from existing policy trajectories (John, 2003). John

(2003) highlights how different agendas can co-exist and co-evolve but remain in competition with one another. Policy response to outside pressures creates a process of 'darwinian' policy selection.

While the process of energy transition remains contested, local agendas hold potential to influence the direction of transitions at the local level. Evaluating the impact of policy on local government agendas can help to highlight the rationale behind policy and its implications for the direction of energy transition. The drivers and impacts of SSEG policy in Cape Town have been analysed using an agendas framework, as outlined in the next section.

2.9 An agendas framework

Energy justice research provides a foundation for encouraging energy policy to "provide all individuals, across all areas, with safe, affordable and sustainable energy" (McCauley et al., 2013:108). Accordingly, for Sovacool et al. (2016:12) a just energy system is a "global energy system that fairly disseminates both the benefits and costs of energy services".

This study employs a red, brown, and green agendas framework to investigate the influence of SSEG policy in Cape Town on the transition to a just energy system. Du Plessis (2015) highlights how literature on environmental governance commonly references environmental issues in terms of 'brown' and 'green' agendas and their interactions. The green agenda concerns itself with environmental conservation, mitigating impacts of environmental change and resource degradation and promoting intergenerational equity (Cock, 2004). The brown agenda is the impact of energy on livelihoods, health, wellbeing, and poverty alleviation (Freund, 2001). This framework was established for application in South Africa making it useful in understanding contextual nuances.

Initially, development of the green and brown agendas reflected the environment vs development discourse that proliferated throughout the 1990s. To address growing awareness that climate responses must recognise their social implications, Cock (2004) adds a 'red' agenda to complete her framework on environmental justice. This emphasises the importance of social justice alongside environmental conservation and poverty alleviation within environmental policy-making. The red agenda represents social justice, anti-poverty and equality and relates to electricity accessibility (Cock, 2004; Death, 2014). Cock's (2004) energy justice agenda framework reflects the three pillars of sustainable development. Achieving a just transition to a low-carbon energy system will necessitate policy attending equally to each of the three agendas.

2.9.1 The green agenda

Research on climate change and promoting sustainable development has commonly focused on issues of global warming, resource depletion and environmental destruction. These issues comprise the 'green' agenda, which focuses on ecosystem protection and mitigation of resource degradation (Bolnick et al., 2006; Du Plessis, 2015). Its primary concern is with the delayed and dispersed environmental impacts of human activity and it attempts to ensure inter-generational equity, environmental justice, and the protection of environmental rights (Du Plessis, 2015). Bolnick et al. (2006) highlight that international environmental concerns maintain a strong green focus. Thus, ensuring the generation and distribution of low-carbon energy is the aim of the green agenda.

Under apartheid, the green agenda held a strong conservation focus in South Africa. The legacy of this is still visible in structures and approaches around sustainability policy (Davidson et al., 2016). More recently, the green agenda has been promoted by environmental departments within better resourced metropoles, as increasing pressures to address climate change has resulted in expanding mandates (Davidson et al., 2016).

2.9.2 The brown agenda

Following the 1992 Rio Earth Summit, environmental issues around development have become increasingly significant (Patel, 1996) and the scope has expanded to incorporate human environmental issues. Issues such as health, waste management, and air quality have come to the forefront of environmental discourse (Freund, 2001). These issues have become known as the 'brown' agenda (World Bank, 1993).

Access to affordable energy is central to improving health, sanitation, wellbeing, and poverty alleviation (Freund, 2001). The brown agenda is concerned with addressing the challenges of poverty, unemployment, disease and reducing the vulnerability of the most marginalised in society (Du Plessis, 2015). Fulfilling human requirements such as food, housing, infrastructure and addressing the immediate impacts of current environmental issues is the concern of the brown agenda. For Du Plessis (2015) these issues cannot be isolated from the environment. In terms of energy policy, the brown agenda refers to the affordability of services (Essex and De Groot, 2019). The focus on reducing threats to human wellbeing has led some to argue that pursuit of the brown agenda is most pressing in Africa (Bolnick et al., 2006).

2.9.3 The red agenda

The red agenda refers to social justice and equity of opportunity and access to energy supply (Cock, 2004). In terms of energy provision, the red agenda concerns ensuring just and equitable access (Essex and De Groot, 2019).

For Fuller and McCauley (2016), embedding justice and equity within energy systems has two key facets. Firstly, in production and consumption; and secondly, in distribution and procedure of energy. Distributional justice refers to the intra-generational distribution of positive and negative energy policy impacts. In production, distributional justice relates to the politics of production and location of energy infrastructures, whilst in consumption, it represents energy accessibility (Fuller and McCauley, 2016). Procedural justice reflects suitable engagement and participation in policy development. Recognition justice is the appropriate identification of adversely impacted stakeholders (García-García et al., 2020). These justice elements are contained within the red agenda.

In South Africa, the red agenda became significant following Apartheid and is central to the constitution; "everyone has the right to an environment that is not harmful to their health or wellbeing" and "protected, for the benefit of present and future generations, through reasonable legislative and other measures" (RSA, 1996:9).

2.10 Conclusion

This Chapter has outlined the growth of SSEG and the need for transition to a just and sustainable energy system. It has justified the adoption of a city scale focus to investigate the role and implications of SSEG in an ongoing energy transition in the Global South. It has described the MLP adopted to investigate the drivers and perceived implications of SSEG regulation at the municipal regime level. Finally, it has outlined the agendas-based framework, focused on red, green, and brown agendas, which will be employed to assess the extent to which SSEG impacts a just and sustainable transition in Cape Town. The following chapter outlines the research design and methodology adopted in this research.

3. Research Design and Methodology

This chapter outlines and justifies the research design and methodology adopted, before detailing potential limitations and ethical considerations. The chosen method arose from consideration of the aims and objectives, given the findings of the literature review.

The case study method has been selected as it is argued to have an intrinsic ability to investigate complexity (Yin, 2014). Three data collection techniques of desktop contextual analysis, policy analysis and semi-structured interviews (SSIs) were implemented.

3.1 Methodological Approach

Past research on SSEG in Cape Town has maintained focus on quantitative evaluations of sector growth and revenue impacts (Janisch et al., 2012; Kotzen, 2014; Mayr et al., 2015). Despite this, the true scale of uptake and resulting implications are not well understood. SSEG is a relatively new phenomenon, rendering data on the extent and impacts of uptake elusive. Qualitative research is most beneficial in exploratory studies (Ward et al., 2018) when limited knowledge exists on a subject (Edin and Pirog, 2014). In the rapidly evolving space of SSEG across South Africa, descriptive and interpretive analysis can provide valuable contextualisation of a case. To date, there has been no qualitative assessment of recent SSEG policy interventions.

Due to its exploratory nature, the lack of previous qualitative studies, and in response to calls for increased qualitative policy research in the Global South, a qualitative approach was adopted to investigate the case of CoCT SSEG policy developments and implementation. Qualitative research enables enhanced focus on the human dimension of policy impacts, resulting in legitimacy and depth in research and exploration of contextual nuances (Sadovnik, 2007).

Policy-orientated qualitative approaches have been advocated in energy transition and energy justice research (Jenkins et al., 2017; García-García et al., 2020). Policy research has also demanded an increased role of qualitative approaches (Wagenaar, 2007). As policy-making is situated and contextualised, occurring within social, political, cultural, and economic influence, attention to the context of study is important.

For Wagenaar (2007) policies are texts, to be 'read' by various stakeholders. This study adopts an interpretive approach to policy analysis, attending to the meanings of policy, or "the values, beliefs and feelings they express, and on the processes by which those meanings are communicated to and 'read' by various audiences" (Yanow, 2000:14). Qualitative case study narratives can thereby provide greater detail for future policy interventions (Flyberrg, 2010).

3.2 Case Study Method

A case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context… in which multiple sources of evidence are used" (Yin, 1994:23). Case studies allow for detailed investigation and can obtain a more systematic and comprehensive understanding from qualitative research (Yin, 2004; Flyberrg, 2010). Findings from different sources can be triangulated to find intersections confirming similar outcomes (Yin, 2014). Within African milieus, Baxter and Jack (2008) argue for the use of case studies to highlight institutional, environmental and socio-economic complexities.

The CoCT was selected as a single case study for this research "to examine, in-depth a case within a real-life context" (Yin, 2004:5). The CoCT was selected as both an extreme and critical case as it is at the forefront of SSEG policy in South Africa, has importance in relation to the general phenomenon in South Africa, and may serve as a test bed for future SSEG policy development. The case study

creates knowledge on SSEG policy impacts in South Africa and identifies the causes of potential policy impacts rather than simply contributing to describing its symptoms (Flyberrg, 2010). The case study method enabled a detailed and comprehensive evaluation providing insights into the complexities of SSEG regulation impacts within the South African context. Analysing the impacts of recent regulation will prove useful for future policy initiatives in municipalities across South Africa.

3.3 Data Collection Methods

A range of methods were adopted to answer the research questions. A range of qualitative methods allows for a variety of differing perceptions that may otherwise go unnoticed (Morse, 2009). The data collection methodology comprised three key methods: a contextual analysis to develop the context for the study; a review of SSEG related policy in Cape Town; and semi-structured interviews with a range of SSEG stakeholders.

The contextual analysis and analysis of policy documents provided background information for interviews that could validate or contradict interview responses (Yanow, 2007). The triangulation of data collected from these three methods allowed for a more thorough understanding of the topic (Carter et al., 2014).

3.3.1 Contextual Analysis: South Africa's Energy Context

To provide context, and situate the CoCT regime, the South African energy landscape is presented in Chapter 4. Understanding the context is particularly important as the implications of SSEG and energy transitions are place and context dependent. The contextual analysis will demonstrate; how the South African energy context presents a series of landscape pressures on the CoCT regime, and how the implications of SSEG in Cape Town are affected by the country's unique history and resultant electricity provision structures.

3.3.2 Desktop Policy Study

A desktop study of current, publicly available, CoCT municipality and national policy was undertaken to help identify patterns, themes or biases (Leedy and Ormrod, 2001:155). Whilst this study focuses on the municipal level and South African governance is devolved to a large degree, municipal policies are influenced by policy shaped at higher organisational levels. Decisions at the national level may influence local government policy (Chlemba and Mattes, 2020).

The development of high-level narratives within the policy landscape were analysed. Taken as the "overall development of a line of argument" (Yanow, 2007:412), narrative policy analysis investigates how such narratives influence interactions between stakeholders (Van Eeten, 2007). Understanding how these narratives have been produced, reproduced, and altered over time provides insight into the impact of policy on the three framework agendas.

Nineteen policy documents and media releases were analysed (Table 1) which resulted in the identification of six key themes of technical compliance, financial sustainability, environmental impacts, safety, municipal reputation, and illegal connections. Shifts in these themes over time were identified and the legitimacy of these shifts triangulated in semi-structured interviews. This was in line with Yin's (2004) argument that policy and media sources are best use to corroborate and augment evidence from other sources. Findings are presented in Chapters 5 and 6.

Table of evaluated policy documents / media releases

Policy/Media Release	Agency	Year	Reference to SSEG
National Energy Act	DoE	2008	No
Integrated Resource Plan (IRP) 2010	DoE	2010	No
Electricity supply by law	CoCT	2010	No
Standard conditions for Small-Scale Embedded Generation	NERSA	2011	Yes
State of Energy: Cape Town	CoCT	2015	Yes
Integrated Energy Plan (IEP)	DoE	2016	No
Climate Change Policy	CoCT	2017	Yes
Municipal Integrated Development Plan (IDP)	CoCT	2017	Yes
Electricity Supply amendment By-law	CoCT	2017	No
Requirements for Small Scale Embedded Generation.	CoCT	2017	Yes
Guidelines for embedded generation	CoCT	2017	Yes
Registration procedure for small-scale embedded generators	NERSA	2018	Yes
Rules for registration of Small-Scale Embedded Generation	NERSA	2018	Yes
Rooftop PV: Guidelines for safe and legal PV installation in Cape Town.	CoCT	2018	Yes
Solar PV info Sheet; July 2018. SSEG tariff	CoCT	2018	Yes
Registration of Small-Scale Embedded Generation	CoCT	2018	Yes
Integrated Resource Plan (IRP) 2019	DoE	2019	Yes
Licensing Exemption and Registration Notice	DoE	2020	No
City of Cape Town Annual Report 2018/2019	CoCT	2020	Yes

Table 1 Table of evaluated policy documents/media releases

3.3.3 Semi-Structured Interviews

To understand further the reactions to policy and the perspectives of a range of SSEG stakeholders in Cape Town, ten in-depth, SSIs were conducted. SSIs are a key tool in conducting case study and policy-related qualitative research (Fontana and Frey, 2000; Owen, 2014). SSIs enabled insights into elements of the topic that may not have been considered previously, which had potential to provide the researcher with new ways of understanding the subject (Galletta, 2013). SSIs provide a "thorough examination of experiences, feelings and opinions" (Kitchin and Tate, 2000:13), and allow flexibility and responsiveness to individual comments (Carter et al., 2014). This flexibility was particularly important given the relative newness of the topic, which resulted in limited awareness of what answers to expect.

An interview guide was used to maintain some structure whilst allowing freedom to explore arguments raised by interviewees and encouraging a more conversational interview (Kitchin and Tate, 2000). Questions related to the research aims and objectives. Three types of question were used: key questions, follow-up questions and probes. These questions can be found in Annex 1. Key questions focused on the central elements of the research. Further questions were designed to encourage detail, depth, and richness (Rubin and Rubin, 1995).

3.3.3.1 Interviewee Selection

Ten SSEG stakeholders were identified and interviewed (Table 2), allowing for a broad range of opinions. Interviews took place between April and September 2020 and participants were selected based on their knowledge of SSEG in Cape Town using a purposeful sampling strategy. Interviews were not restricted to elite policy-related actors but were drawn from a range of actors influenced by SSEG policy. Yanow (2007) highlights the role in which 'non-elite' actors can shape policy response, most notably in the rejection of top-down policy implementation.

Interviews were conducted with relevant stakeholders from the CoCT, the National Energy Regulator of South Africa (NERSA), NGOs, SSEG Installers, homeowners, academics, and consultants. All interviewees elected to remain anonymous. Interviews were recorded and transcribed (with relevant permissions). Interview transcripts were then analysed.

Table of Research Participants

Participants Organisation	Organisation Name/Reference
City of Cape Town Municipality	CoCT
NGO	GreenCape
National Energy Regulator of South Africa	NERSA
Solar EPC Installer	EPC1
Solar EPC Installer	EPC2
Solar EPC Installer	EPC3
Solar EPC Installer	EPC4
Consultant	WWF
Homeowner with legal PV	HO1
Homeowner with Illegal PV	HO2

Table 2 Table of Research Participants

3.4 Data analysis and coding

The data analysis methodology involved the manual analysis of interview transcripts and policy documents using established qualitative techniques of data coding. Coding is defined as "a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based… data" (Saldana, 2021:362).

Descriptive coding was used to summarise the fundamental topic of a passage of data (Saldana:134). Descriptive coding was used as a preliminary data analysis tool, with each of the three agendas of the conceptual framework.

Thematic analysis was used to identify and categorise themes within the data (Braun and Clark, 2006; Owen, 2014). This involved familiarisation with the data set, generation of codes according to responses to each research question, the creation of initial themes, the refinement of themes through comparison to the data, the establishment of themes, and the creation of an analytic narrative (Braun and Clark, 2019).

Policy documents and interview transcripts were initially coded descriptively based on the three agendas of the conceptual framework, before being coded thematically. This allowed identification of themes within each of the three agendas and themes that influenced multiple agendas. Table 3 highlights how descriptive and thematic codes operate together. The researcher attempted to trace the development of agendas over time within the policy landscape.

Descriptive and Thematic themes identified in coding

Thematic			Descriptive
Regulatory Drivers			
	Technical		
		Grid Capacity	Brown
		Non-registration	Red/Brown
	Safety		Brown
	Financial		
		Municipal Revenue	Red/Brown
	Environmental		Green
	Reputation of alternative governance model		-
Regulatory Impacts			
	Registration Changes		Red
	Environmental Impact		Green
	Tariff responses		Red/Brown
	CoCT overheads		Red/Brown
Load-shedding			Red/Brown
Independent Power Producers (IPPs)			Red/Brown/Green
Enhanced performance characteristics			Red/Brown

Table 3 Descriptive and Thematic themes identified in coding.

3.5 Study Limitations

Several limitations arose during the research that had potential to influence the findings. Research was conducted throughout the COVID-19 pandemic. Social distancing measures and government-enforced lockdown prevented face-to-face interviews and access to university libraries. Accordingly, all interviews took place online.

Case study methodologies have been criticised for the inability to generalise findings to larger populations (Yin, 2014). The context-specific nature of a case study can limit the transferability of knowledge, yet the goal of case study research is to describe a specific case in detail and explain patterns existing within the case, rather than uncover general laws of human behaviour (Schofield, 2011). For Flyberrg (2010:10), "formal generalisation is overvalued as a form of scientific development". The aim of this research is not to provide transferable and generalisable knowledge, rather to understand further the unique situation of Cape Town. While the findings of this research may prove useful in understanding the issues with SSEG in Cape Town, the study does not attempt to present anything more than the unique context of Cape Town. The inability to generalise findings is therefore not taken as a limitation, but the richness of data on a single case may provide important learnings for policy development in the South African SSEG sector.

Qualitative research is often criticised for its more subjective nature, which may hold bias towards confirming the researcher's preconceptions (Yin, 2004). To mitigate this, the researcher remained open to having preconceptions disproved and approached each question with a genuine desire to find a legitimate answer. The researcher reflected on the potential impacts of bias throughout the study, and attempted to remain objective in the research's undertaking, analysis, and presentation. A range of data collection techniques was employed to offset the limitations of each.

3.6 Ethical Considerations and Approvals

Prior to undertaking the research, ethics clearance was obtained from the Faculty of Science (University of Cape Town) (Annex 2).

Participant engagement in the study was undertaken voluntarily. A consent form was given to all interviewees and written consent obtained prior to commencing interviews (Annex 3).

Participant were made aware of any risks and benefits of participation. All interviewees elected to remain anonymous. Interview transcripts were stored on a password-protected computer.

3.7 Conclusion

This chapter has justified the adoption of a qualitative mixed-methodology in response to calls for increased qualitative approaches to energy transitions research, particularly in the Global South. This approach arose from consideration of the research aims and objectives and context within which the research is situated. The situated nature of energy transitions and the resulting potential impacts of disruptive technologies make a qualitative case study beneficial in understanding the complexity of the case. Analysis of interview transcripts, media releases, and policy documentation was undertaken using an organic and reflective descriptive and thematic coding approach guided by the aims and objectives. The potential limitations of the research related mostly to influences beyond the research design and were not thought to be a hinderance.

4. Contextual analysis: energy in South Africa

Developments in SSEG policy and regulation in Cape Town are influenced by the unique history and context of South Africa. Drivers and impacts of SSEG, as well as the effectiveness of regulatory attempts are influenced by this context. Understanding the contextual landscape of South Africa, within which the CoCT is situated, clarifies the role and agency of the CoCT as a regime responding to SSEG. This chapter outlines the contextual features that serve as landscape pressures on the CoCT and influence the role of SSEG in transition.

4.1 South Africa's Energy Context

When Apartheid ended in 1994, South Africa's new democratically elected ANC government inherited a highly centralised energy system comprising a network of coal-fired power plants providing electricity to South Africa's white minority. Eskom, South Africa's state-owned monopolistic electricity utility owned and operated over 90% of all energy generation (now 95%), managed the country's transmission grid, and was responsible for over 50% of electricity distribution (Baker et al., 2014; OECD, 2015; DPE, 2020). Eskom controlled access to both energy sources and pricing. Planning, procurement, and management strategies were directed by top-down institutional agreements between Eskom and the Department of Minerals and Energy (DME), later the Department of Energy (DoE) and now re-merged into the Department of Mineral Resources and Energy (DMRE) (Hermanus, 2017).

National energy generation was almost solely dependent on low-cost coal-powered electricity (93% of Eskom generation) (Jaglin, 2014; McEwan, 2017). Under Apartheid, international sanctions made energy independence a necessity, triggering concentrated research on coal technologies as reserves were naturally abundant (Van Norden, 2015). Apartheid-era coal generation investments had been almost completely remunerated resulting in some of the world's lowest electricity prices (Krupa and Burch, 2011). South Africa's minerals-energy complex (MEC) (Fine and Rustomjee, 1996) has structured an economy around energy-intensive growth, mining, and mineral extraction, dependent on low-cost coal power (Baker et al., 2014).

Against this background, South Africa is among the most energy intensive economies and one of the highest GHG emitters compared with other developing economies (Jaglin, 2014). Since democratic transition, South Africa's economy has been growing rapidly. In Africa, South Africa has the second highest GDP (World Bank, 2020a) and highest electricity consumption/capita (IEA, 2020c). The country has become increasingly urbanised. In 2019, 66.9% of the population inhabited urban areas, projected to reach 71% by 2030 (Pelcher, 2020; PMG, 2020). Expanding electricity demand, an urbanising population, and supply-side issues with legacy systems designed to supply a minority population has presented a set of compound challenges for government.

As the new regime attempted to rejuvenate the economy and redress the socio-economic legacy of Apartheid, expanding electricity access and overcoming energy poverty became a key strategic objective (Edkins et al., 2010; Essex and De Groot, 2019). Electricity access became a constitutional right (Mayr et al., 2015). This has had profound impact on the implementation of red and brown agendas by municipalities. The subsequent Reconstruction and Development Programme (RDP) and National Electrification Programme (NEP) increased electricity access from 35% of households in 1990 to 84.7% in 2011 (World Bank, 2020b). Despite these remarkable results, many low-income households remain unable to afford services to which they have been connected (Baker and Phillips, 2019). 47% of South Africans are therefore considered 'energy poor' (SEA, 2015).

To combat persistent energy poverty, in 2004, the government implemented a Free Basic Electricity (FBE) Tariff of 50KWh/month[7] (Mohlakoana, 2014). This policy was underpinned, in part, by access to abundant cheap electricity resulting from over-capacity expansion during Apartheid (Edkins et al., 2010). An additional pro-poor subsidy, introduced in 2010, was an Inclining Block Tariff (IBT) system enabling subsidy of low-income electricity users through exponential price increases for greater consumption. IBT mechanisms are designed to enable increased local equity in accessing services (Jooste and Palmer, 2013). Wealthier households consuming more electricity pay more for each unit over a certain threshold.

Under the inherited system, municipal governments acted as local energy utilities buying electricity from Eskom and reselling it via local distribution grids. Municipalities used sales margins for infrastructure maintenance, cross-subsidising other services, and to finance electricity delivery for low-income households on FBE tariffs (Hermanus, 2017). Electricity mark-ups historically ranged from 20-150% (Baker and Phillips, 2019). This unique municipal function has enabled the inclusive urbanisation and rapid electrification that followed Apartheid (Swilling, 2014). Municipal electricity distribution has enabled progress in local red and brown agendas. With democracy, sections 156 (1-2) of South Africa's new constitution maintained municipal authority over electricity distribution as a municipal service delivery function. In 2019, Eskom sold 41.9% of energy generated to 184 of 278 municipalities that elected to exercise their right to distribute (Eskom, 2019). Municipalities without the capacity to perform electricity reticulation and delivery, relinquish service delivery to Eskom. The price and revenue contribution of electricity sales is unique to each municipality. Nationally, the overall contribution of electricity sales to municipal revenue is approximately 33% (Statsa, 2016; Filipova and Morris, 2018). In 2019, the CoCT raised 44.2% of its revenue from service charges[8] (CoCT, 2020b) and stated its intention to reduce its operational reliance on electricity sales (CoCT, 2020b:157).

After Apartheid, the ANC implemented broad restructuring of the local government system. The resulting multi-level governance structure was highly decentralised giving municipalities greater independence (Tait and Euston-Brown, 2017). Decentralised controls include budget management and execution, progressing individual development plans, construction of differentiated by-laws (provided they comply with national legislature) (Tait and Euston-Brown, 2017). Municipalities receive national fiscal support under revenue sharing agreements and can advance their own revenue through a range of sources including charges, fees, taxes, and financial market access (Tait and Euston-Brown, 2017). While larger metropolitan governments can raise as much as 70% of revenue from their own sources, smaller municipalities are often wholly dependent on national allocations (Tait and Euston-Brown, 2017). These landscape developments established the available tools with which the CoCT can respond to SSEG.

In early democratic South Africa this model proved relatively effective, as municipal governments received cheap electricity from Eskom. However, electricity generation remained a matter for national government and municipalities were not mandated to invest in local generation or benefit from energy investments within municipal boundaries (Hermanus, 2017). Consequently, municipalities are dependent on the decisions, governance regimes, infrastructure, and performance of Eskom. For Jaglin (2014) this has created a democratic deficit in the process of decision-making, regulation, and stakeholder inclusion within energy policymaking. Furthermore, the viability of South Africa's electricity system directly influences the financial sustainability of municipal

[7] If consumption <400kWh/moth.
[8] Both electricity and water.

governments (Hermanus, 2017). Threats to electricity sales undermine this financial sustainability and influence service delivery and grid management. Consequently, the ability of municipal governments to achieve red and brown developmental agendas requires sustained electricity revenue.

4.2 Attempted reform

Under Apartheid, government had attempted to privatise Eskom to counteract rising debt resulting from global sanctions and escalating military expenditure (Swilling, 2014). A key component of privatisation involved the removal of municipal responsibility over electricity distribution through the establishment of Regional Electricity Distributors (REDs) (Swilling, 2014). Post-Apartheid, Eskom continued to lobby for the removal of municipal control over electricity distribution, an idea that began to gain traction with the ANC government.

In 1998, government released an Energy White Paper (DME, 1998) encouraging increased competition, privatisation, and generation diversification, alongside establishing an emissions reduction pathway, shifting local government's role in distribution, and redistributing Eskom's assets into new, more effective structures. Six REDs were proposed in 2001 to take on the combined activities of Eskom and Municipalities and encourage improved performance, service quality and tariff rationalisation (Dubresson and Jaglin, 2017). Initially proposed as municipal entities, legal objections by Eskom forced reconsideration. New attempts to launch REDs as public entities failed in 2006 due to municipal resistance over revenue concerns (Swilling, 2014). The inclusion of electricity provision within the constitution as a local government responsibility prevented RED establishment (Swilling, 2014).

As part of privatisation plans the government placed a moratorium on new generational capacity investment by Eskom between 2001-2004 (McEwan, 2017; Essex and De Groot, 2019). Privatisation was shelved in 2004 and White Paper reforms have not been fully enacted. The National Energy Regulator Act was then passed in 2004, which established the National Energy Regulator of South Africa (NERSA) to regulate the energy sector. Electricity sector regulation is established in the 2006 Electricity Regulation Act (ERA) and involves the setting and approval of tariffs and pricing, setting of rules and guidelines for regulation, and licencing and registration (RSA, 2006). Although some privatisation, national energy planning and renewable generation has been introduced, Eskom remains mandated to generate, transmit, distribute, and sell electricity (DPE, 2020). Despite this, municipalities have maintained control of electricity distribution, a key revenue-raising tool in fulfilling their red and brown developmental mandates.

4.3 The electricity supply crisis

In 2008 South Africa declared a national emergency. The culmination of strong economic growth and mass electrification resulted in Eskom's generational capacity failing to meet demand (Essex and De Groot, 2019). Inadequate load planning and limited infrastructure investments resulting from the government-imposed moratorium on new generation and continued uncertainty around the potential course of Eskom's privatisation exacerbated the problem (McEwan, 2017).

To prevent unbalancing the electricity grid and resulting country wide black-outs, Eskom introduced load-shedding, a form of electricity rationing with controlled rolling power outages for set times in defined catchments (Krupa and Burch, 2011). Reduced demand allowed load-shedding to be lifted. It was reintroduced in 2014 and 2019, due to coal storage issues and widespread boiler failure resulting from poor-quality coal (Moore, 2019). Load-shedding has since become an accepted feature of South Africa's energy system.

To reduce demand, Eskom entered into expensive buy-back agreements with high-intensity industries. Companies were paid to reduce electricity consumption and limit production (Baker et al., 2014). Until recently, shortfalls in electricity supply have only been mitigated by reduced demand from energy conservation and declining economic output (Essex and De Groot, 2019).

Since 2005, when the moratorium on new capacity was lifted, Eskom has focused on building 17,000MW of new generation capacity (McEwan, 2017). However, low electricity prices combined with expensive buy-back agreements resulted underfunding and delays of capacity expansion and a backlog of maintenance (Mayr et al., 2015; Baker et al., 2015). Consequently, Eskom's generation capacity regularly operated at peak levels, resulting in the neglect of preventative maintenance. This has caused long-term grid functionality issues (Krupa and Burch, 2011).

To finance generation expansion and to negate funding issues, Eskom has raised prices significantly. Before the electricity supply crisis, average electricity prices were 25c/kWh (Baker et al., 2014). Between 2010-2013 NERSA approved price increases of 24.8%, 25.8% and 25.9% respectively (Jaglin, 2014). Between 2008-2016, Eskom's average electricity price increased by 200% (Baker and Burton, 2018; Baker and Phillips, 2019). For the 2021/2022 tariff year, Eskom tariff changes represent a 15.63% increase (Claasen, 2021). For Baker et al., (2014:792), "the era of cheap electricity… is over".

NERSA restricts the extent to which municipalities can transfer these price rises to consumers. Eskom increases have occurred at a higher rate than inflation resulting in degradation of municipal revenues (Janisch et al., 2013; Baker and Phillips, 2019). Despite this, electricity price increases for residential consumers in Cape Town since 2006 have been between 4.9-34.6% (Figure 8).

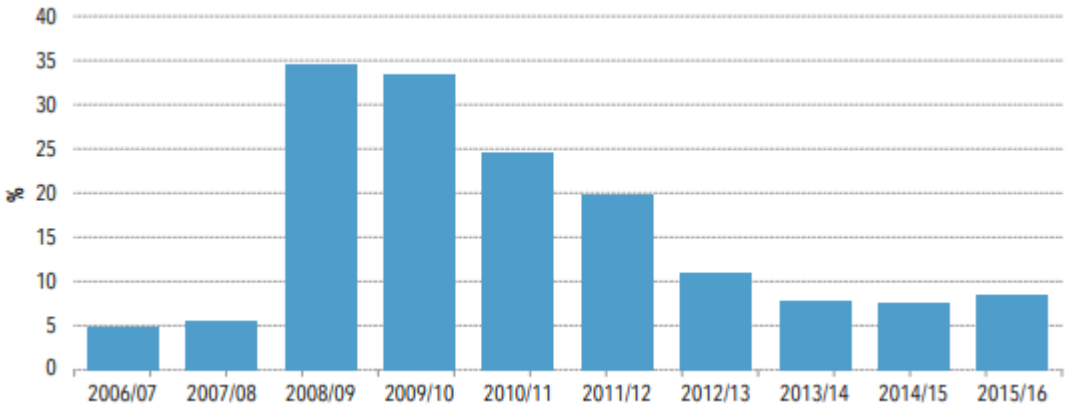

Figure 8 CoCT electricity tariff increases 2006-2016. Source: CoCT (2015).

Price increases, load-shedding, and allegations of 'mismanagement' and involvement in 'state capture' has caused severe reputational damage to Eskom (Jaglin, 2014; Renwick, 2018). Eskom's credit rating has since been downgraded to 'Junk' status and it has become widely criticised as an institution in financial, political, and technical crisis at the forefront of a national corruption and state capture scandal (Bhorat et al., 2017; Baker and Phillips, 2019).

The electricity supply crisis has accentuated the environmental and social implications of South Africa's current energy system. For Krupa and Burch (2011) it highlights the extent to which environmental sustainability, economic development, and social justice, the three pillars of sustainable development, are fragile and in contestation with each other in South Africa. In the

wake of such a crisis, the need for a just energy transition is more pertinent than ever. As will be discussed in chapter 5, these landscape pressures have influenced the uptake of SSEG and its role in transition.

4.4 Towards low-carbon transition

Since the 2008 National Energy Act (NEA), national government has remained committed to ensuring "that diverse energy resources are available, in sustainable quantities and at affordable prices, to the South African economy in support of economic growth and poverty alleviation" (RSA, 2008:3). The urgent need for additional capacity has triggered huge investments in coal and nuclear power and renewable energy has started to play an increasingly important role. South Africa has been making progress towards reducing its carbon emissions, partly in response to international pressures, and, as Essex and De Groot (2019) highlight, continued load-shedding at home.

In 2009, President Zuma vowed to reduce national GHG emissions by 24% by 2020 and 44% by 2025 (Baker et al., 2014). While these targets have been argued to be unachievable (Winkler, 2011), they highlight a gradual policy shift towards acceptance of renewable energy and endorsement of the green agenda (McEwan, 2017). This policy shift is founded in the 2003 White Paper on Renewable Energy (DME, 2004) and continued in the 2008 Energy Act (RSA, 2008), and the 2010 and 2019 Integrated Resource Plans (IRP) (DoE, 2013; 2019). The revised 2011 IRP aimed to double national generation capacity with 42% of expansion from renewable energy sources (DoE, 2013). Utility-scale wind and solar have become focal points of renewable energy discussions to harness South Africa's abundant natural assets (Edkins et al., 2010; McEwan, 2017).

In 2011, the government launched the Renewable Energy Independent Power Producers Procurement Programme (REI4P), a public-private partnership aiming to drive low-carbon transition (McEwan, 2017). The REI4P has facilitated investment in utility-scale renewable power by inviting independent power producers (IPPs) to tender for licenses to sell electricity to Eskom (Montmasson-Clair and Ryan, 2014). REI4P is currently on bid window 5, with projects from the first 4 phases currently under completion or functioning (RSA, 2020). PV prices fell 68% between rounds 1 and 3 (McEwan, 2017). REI4P has led to the direct procurement of 6422MW of renewable energy (DoE, 2019) and has been described as "one of the world's most successful and best-governed renewable energy procurement programmes" (Eberhard and Naude, 2017:3). It is hailed worldwide as a model for renewable energy procurement for its assessment of economic development impacts, employment opportunities and community ownership motivations (Montmasson-Clair and Ryan, 2014; Essex and De Groot, 2019). The REI4P has triggered more investment in independent power generation than realised across the entire African continent since 2000 (McEwan, 2017). It has led to renewable energy becoming the cheapest new-build generation option and created windows of opportunity for SSEG to infiltrate the market (Filipova and Morris, 2018). However, while utility-scale and off-grid solar may increase energy access, SSEG has potential to reduce energy security, increase electricity costs and hinder poverty alleviation. These challenges are outlined in Chapter 5.

Currently, Eskom maintains a dominant role in South Africa's energy system and the MEC continues to exert influence (McEwan, 2017). For Jaglin (2014), despite national climate commitments, national policy has remained sympathetic to further industrialisation and resource extraction. However, at the State of the Nation address in 2019, President Ramaphosa announced the decision to unbundle Eskom into three constituent parts: generation, transmission, and distribution (RSA, 2019). This may challenge the influence of Eskom in the sector. These landscape pressures have triggered a rapid proliferation of SSEG in South Africa and defined the responses available to, and impacts on, municipalities.

4.5 Conclusion

This Chapter has outlined South Africa's national energy context, the structures it adopts and recent landscape developments. These factors contribute to the growth and implications of SSEG in South Africa discussed in Chapter 5.

5. SSEG in South Africa

Within this context, SSEG has experienced rapid growth in recent years. Although municipalities hold a large degree of autonomy, they remain answerable to national government decisions. Using data from previous research, policy documentation and interviews, this Chapter reviews the growth and impacts of SSEG, recent national policy developments, and the impact of SSEG on municipalities.

5.1 The rise of SSEG Small-Scale Embedded PV Generation

In South Africa, SSEG refers to distributed generation with capacity below 1MW, as per the 2017 amendment to the 2006 ERA which enabled installation and connection of systems up to 1MW without the need for a ministerial generation licence from NERSA (DoE, 2017). While SSEG can refer to any small-scale renewables, it is mostly associated with PV systems. SSEG occurs at residential, commercial, and industrial locations where electricity is also consumed (Mkhwebane and Ntuli, 2019).

SSEG systems are typically connected to the grid which is used to supply energy when consumption exceeds production. There is a requirement for SSEG producers to be net consumers[9] but surplus electricity generated can be exported to the grid at a predetermined Feed-in Tariff (FIT) (Filipova and Morris, 2018). Generated electricity is embedded within the local distribution network.

Rising electricity prices, falling technology costs, growing awareness of the need for emission reductions, and the enduring electricity supply crisis render SSEG increasingly cost-effective to a range of South African end-users (Shumba et al., 2019), seeking alternatives, either to mitigate the impacts of load-shedding or guarantee certainty over electricity prices (Interview: CoCT). Continuing distrust of Eskom is also driving SSEG installations (Interview: IPC1). Technology cost reductions for PV have been dramatic and as grid price parity is reached, the number of SSEG adopters should rise considerably (Kotzen, 2014).

While these drivers act to increase the prevalence of SSEG in South Africa, historical uncertainties around registration requirements and legislation makes the extent of SSEG unclear. SSEG installations have occurred without regulation, and the estimated number of non-registered installations is high. Padarum et al. (2019) estimate the total capacity of SSEG installations at 285MW in December 2017. A recent study in Cape Town estimated that 50% of systems were unregistered (Kritzinger et al., 2020). Figure 9 depicts estimated yearly installed SSEG capacity. The green bar represents annual capacity increase.

[9] Annually must consume more electricity than export.

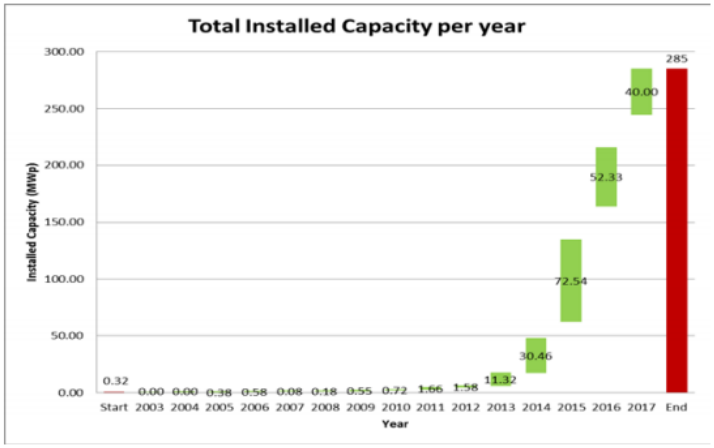

Figure 9 Total installed capacity per year (MW). Source: Pandarum et al. (2019).

Growing SSEG trends are observable in all consumer sectors, although industrial and commercial sectors represent approximately 70% of estimated capacity (Pandarum et al., 2019). These applications offer compatible relationships between demand and production profiles, enabling self-consumption of PV electricity, often favourable given the low FITs offered by municipalities (Pandarum et al., 2019). With continuing load-shedding, SSEG can ensure enhanced reliability of electricity supply, particularly when installed alongside storage technologies (Kotzen, 2014).

In South Africa, SSEG has potential to challenge the current centralised electricity sector structure and provide an opportunity for affordable, green alternatives (Baker and Phillips, 2019). Increasing SSEG can reduce technical losses through diminished transmission distances and enhanced 'generator-to-end-user' efficiency (SEA, 2014). This is particularly relevant in Cape Town where much grid electricity is sourced from Mpumalanga or REI4P projects in the Northern Cape.

As SSEG continues to propagate, stakeholders must prepare for a more diverse energy supply mix with increased technical complexities. While cheaper electricity and reduced technical losses are clear benefits for municipalities, concerns exist as to how SSEG will influence network operations and revenue structures (Shumba et al., 2019). The rise of the 'prosumer' has shifted power dynamics within the electricity system enabling consumers and municipalities to adopt generation roles (Filipova and Morris, 2018). This raises key questions over the mandate of municipalities, who are forced to develop processes to incorporate SSEG into their networks and prevent widespread illegal connection. This is a key argument for the municipal level scalar focus in investigating SSEG in South Africa. While SSEG may appear to support the transition to a sustainable energy system, its implementation is likely to have several implications on municipalities (Mayr et al., 2015).

5.2 The impact on municipalities

Left unregulated, the widespread SSEG adoption will predominantly impact municipalities due to their role in electricity distribution outlined in Chapter 4. Many authors (Janisch et al., 2012; Kotzen, 2014; Mayr et al., 2015) have highlighted that besides increasing overall consumer energy costs, the price structures between municipalities and Eskom are incompatible. Therefore, Essex and De Groot (2019:7) indicate that SSEG may either, "resolve, accentuate or create new inequalities in a post-networked city".

When opting to perform their mandated role as energy distributors, municipalities purchase electricity from Eskom on a Time of Use (ToU) tariff. Eskom's ToU tariff comprises a High Demand[10] (HD) and Low Demand (LD) season, with three periods in each season; Peak Time (PT), Standard Time (ST), and Off-Peak Time (OPT) (Kotzen, 2014). ToU tariffs are designed to encourage "efficient allocation", "reflect the cost of supplying electricity" and incentivise "more effective use" (Ramokgopa, n.d.:14). Price differences between HD and LD seasons are significant, whilst PT prices are also considerably higher. Accordingly, in 2014/2015 electricity purchased by municipalities during HD-PT was 700% more expensive than that purchased in LD-OPT.

Municipalities resell electricity at marked-up volumetric charges, including different rates for different user categories and IBTs for consumption over set volumes. This results in a large variation in electricity profit margin throughout the day and year. Accordingly, when sales at specific times of the day and year are influenced, this can disproportionately affect revenue.

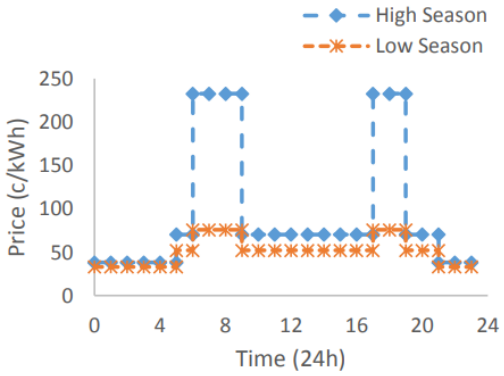

Figure 10 Breakdown of Eskom municipal tariffs per unit of energy for 2014/2015. Source: Kotzen (2014).

Figure 10 demonstrates the variation in Eskom's ToU Tariff prices for municipalities for 2014/2015. When price variability in in these tariffs are subtracted from Cape Town's fixed rate tariffs the diurnal variation in profit margins becomes apparent. Figure 11 highlights this profit variation over the course of a weekday. Sales made during HD-PT cause a revenue loss for the city.

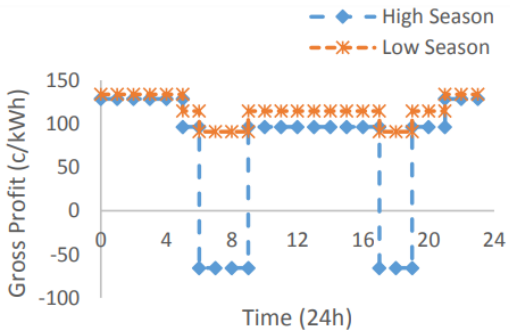

Figure 11 CoCT unit profit generated through electricity sales to residential customers for 2014/2015. Source: Kotzen (2014).

Comparing municipal profit variations over time of day to the generation profile for a solar panel in Cape Town (Figure 12) illuminates the potential for SSEG to undermine municipal revenues.

[10] HD is South African Winter.

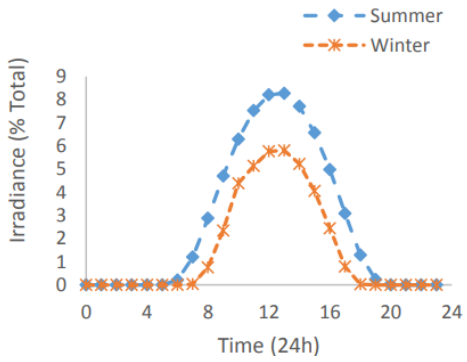

Figure 12 Generation profile of a PV panel in Cape Town during summer and winter. Source: Kotzen (2014).

Growth in SSEG reduces electricity demand in non-peak, midday hours where municipalities profit is highest, whilst retaining demand for grid electricity during peak hours, where municipal profit is lowest or negative. The result is a large impact on municipal profits (Kotzen, 2014). Figure 13 highlights the impact on CoCT profits.

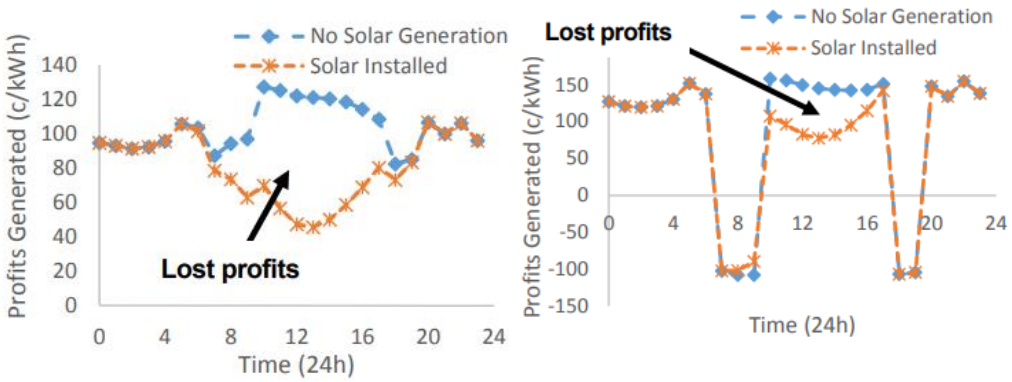

Figure 13 Low Demand/Summer (Left) and High Demand/Winter (Right) CoCT unit profits generated with and without PV SSEG. Source: Kotzen (2014).

SSEG impacts municipal revenues through reduced demand in peak profit times. As Jones (2012:16) clarifies, "PV generation takes place at times when it is relatively cheaper to purchase energy from Eskom, and consumption takes place when it is relatively more expensive to purchase electricity from Eskom".

These revenue impacts are compounded by effects on IBT mechanisms. While IBT and FBE form part of an essential suite of progressive economic policies and were key in the RDP, the result is the artificial inflation of electricity prices that incentivises high-consumption users to seek alternatives. As increasing numbers of high-consumption consumers implement SSEG systems, less revenue is available to subsidise low-income and FBE tariff users, or cross-subsidise other service delivery functions (Hermanus, 2017). While increased SSEG has green agenda benefits for municipalities it undermines their ability fulfil brown and red agendas.

To address shortfalls, municipalities may increase tariffs, thereby further incentivising high-consumption, high-profit users to install SSEG (Janisch et al., 2012). This can create a cycle of grid defection and rising tariffs, resulting in the municipalities' declining profit and capacity to cover fixed costs (Baker and Phillips, 2019). Such a spiral has become known as a 'utility death spiral' and can trigger utility collapse (Janisch et al., 2012; Costello and Hemphill, 2014; Mayr et al., 2015).

Increasing SSEG installations also increases the cost of maintaining a centralised grid, adding complexity to a distribution network that has previously functioned primarily as a one-way flow (Baker and Phillips, 2019). Grid maintenance and upgrades are required to accommodate local SSEG electricity (Camp et al., 2015). There are limits to how much self-generation the network is capable of absorbing. Accordingly, Baker and Phillips (2019) highlight that late installers may not even be able to connect to the grid.

Existing municipal residential tariff structures account for the fixed costs associated with grid management, maintenance, and operation within a single volumetric charge. This 'bundles' fixed network costs and volumetric energy costs together (Shumba et al., 2019). Figure 14 shows the average composition of municipal volumetric charges. Consequently, under traditional tariff structures, a 'free-rider' effect exists when SSEG customers purchase less energy. In this situation, "households with PV systems do not pay fully for their share of the system's fixed costs, shifting the burden to households without PV systems" (IEA, 2013:218). Furthermore, households without SSEG disproportionately cover increasing system costs resulting from SSEG. Commercial and industrial revenue impacts are less as customers already pay fixed network connection charges (Shubma et al., 2019).

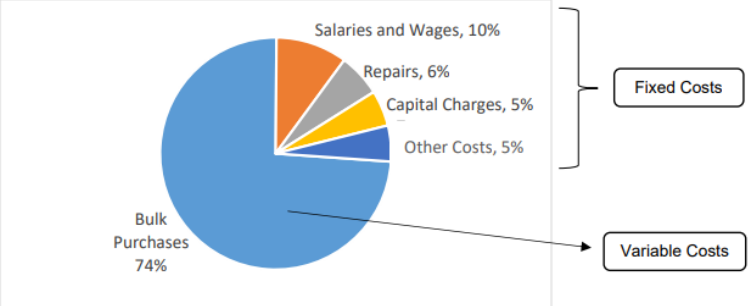

Figure 14 Average cost structure of municipal electricity distributors. Source: Shumba et al. (2019).

Both Eskom and municipalities are vulnerable to declining revenues from SSEG adoption. This has knock-on effects on the red and brown agendas which are funded by revenue from electricity sales. As the stability of a centralised energy system directly impacts the financial sustainability of municipalities, there is incentive for municipalities to attempt to maintain this system. For this reason, there has been some resistance to SSEG by South African municipalities (Korsten, 2015; Baker and Phillips, 2019). Until recently SSEG developments have occurred largely in the absence of regulatory frameworks and legislation. There is a clear requirement for the effective implementation of regulation to manage SSEG expansion and adapt municipal structures to accommodate its emerging role in the energy sector. This will allow for the realisation of SSEGs green benefits within municipal boundaries without undermining red and brown agendas.

5.3 A regulatory vacuum

In the absence of national legislation, in 2008, the CoCT and Nelson Mandela Bay municipality approached NERSA to raise the question of SSEG implementation and its impact on local electricity distribution (Hermanus, 2017). As neither municipalities nor Eskom were mandated to buy surplus energy from SSEG systems a regulatory gap was identified. In response, NERSA agreed to municipal pressures and allowed municipal engagement in local SSEG policy work, provided it conformed to the ERA and Municipal Finance Management Act (Hermanus, 2017).

Thereafter, certain municipalities began engaging with SSEG in earnest, driven in part, in response to energy insecurity challenges (see Chapter 4) and carbon reduction requirements, and in response to

SSEG growth and its potential impact on municipalities financial sustainability, grid safety and power quality (Interview: CoCT). In Cape Town, early SSEG engagement provided a potential opportunity for municipal revenue generation, which would aid service delivery financing for low-income households.

In 2011, NERSA released its '*standard conditions*' for SSEG, to address concerns over initial documents released by municipalities (NERSA, 2011). NERSA questioned "if it was the intention of those who drafted the ERA for this kind of generation to be licensed or registered by the energy regulator" (NERSA, 2011:3). NERSA acknowledged the need for record keeping and control at some level yet maintained that "this should be done at municipal level because the municipalities are the most impacted party" (NERSA, 2011:4). Accordingly, the standard conditions stated, "municipalities must register and maintain a database of all small scale (<100kW) embedded generation within their area" (NERSA, 2011). Authority to register and connect private SSEG systems below 0.1MW was passed to municipalities (NERSA, 2011). Systems between 0.1-1MW remained unregulated until 2015 when NERSA published draft small-scale regulations specifying national standards for municipalities to register SSEG up to 1MW (NERSA, 2015). The CoCT was at the forefront of calls for clarification from NERSA.

However, the standard conditions were presented as a set of 'guidelines' for municipalities and developed without municipal consultation: their legal status remains unconfirmed (Hermanus, 2017). Accordingly, different municipalities interpreted the document in different ways, with important consequences for the green, brown, and red agendas.

In February 2015, NERSA embarked on a stakeholder consultation process for the development of SSEG regulations up to 1MW. This consultation should have been completed in May 2015, but resulting licensing regulations were stalled by the DoE until amendments to the 2006 ERA had reflected the language used for privately-owned generation (Phillips and Baker, 2019). This happened in December 2016, after which the DoE published a '*draft licensing exemption and registration notice'* for public comment. The original draft notice removed requirements for SSEG below 1MW to obtain licensing from NERSA to connect to the distribution network. Generators between 0.1-1MW were initially expected to pay a R200 registration fee, while municipalities were expected to keep a register of all SSEG connections. In March 2020, the DoE published a new notice, removing the proposed registration fee and the requirement for SSEG below 1MW to obtain NERSA licensing[11] (DoE, 2020).

In the void created by the lack of a coherent national regulatory framework, South African local governments have developed their own regulations, by-laws and tariff structures for SSEG. National regulation has been driven primarily by municipalities rather than defined nationally. As Hermanus (2017:31) summarises, "municipalities have used small windows of opportunity to implement projects to determine local regulations, as well as influencing national regulations and policy, all while demonstrating an increasing potential of a workable alternative to Eskom's dominance". This marks a significant shift in the role of municipalities within the energy sector outlined in Chapter 4. In engaging with SSEG, municipalities have widened the scope of possible municipal engagement, formalised responses in localised policy, and influenced national energy policy and regulation (Hermanus, 2017). In this way, SSEG is forcing changes and transitions to the modus operandi of electricity distribution in South Africa at the municipal regime level. Furthermore, municipal responses to SSEG are driving the direction of national transition pathways.

[11] Municipalities must keep a register of all SSEG connections.

5.4 Challenges for municipalities

SSEG presents a complex challenge for municipalities. Municipalities must accommodate the unavoidable growth of SSEG whilst simultaneously ensuring safety and technical concerns are addressed, grid standards upheld, revenue impacts marginalised, and illegal connections discouraged. Municipalities must protect their ability to fulfil developmental mandates, balancing environmental action, with economic growth and addressing inequality.

Without regulation, SSEG will disproportionately benefit consumers with capital to invest, while municipalities will be forced to increase the cost of grid electricity to cover revenue shortfalls. This will further incentivise SSEG adoption and undermine service delivery and FBE subsidies, thereby threatening red and brown agendas. As a key mandate of municipal governments is alleviation of local poverty, and ensuring access to service delivery, the regulation of SSEG will be essential to prevent the exacerbation of existing inequalities.

SSEG requires a well-maintained grid, capable of distributed generation with metering capabilities to plan for and bill generated energy (Camp et al., 2015). There are a range of technical and safety concerns relating to SSEG installation and grid connection including: inverter testing; islanded operation and protection from maloperation; thermal tension on distribution network equipment as a result of increase loading during times of peak generation; variation in voltage from reverse power flow, and power quality issues (Pandarum et al., 2019). Technical requirements, previously drawn from international standards, have now been developed nationally (SEA, 2014). Whilst national standards resolve technical concerns, ensuring installer compliance remains crucial for municipalities.

Municipalities must achieve a difficult balance. On one hand, regulation must protect the safety and integrity of the grid and ensure consumers pay their share of fixed costs. On the other, compliance standards perceived as too demanding and tariff changes regarded as penalising can push aspirant installers 'under the radar' (SEA, 2014; Kotzen, 2014). Concurrently, municipalities must balance their green agenda commitments (increasing renewable capacity and reducing carbon emissions), with brown (increasing service delivery, and maintaining electricity revenues for cross-subsidisation) and red agendas (ensuring just access, safeguarding electricity revenues for IBT and FBE mechanisms).

Municipalities hold data on legally installed generation capacity from their application and commissioning process (Filipova and Morris, 2018). However, not all SSEG systems are registered and there is no national consequence for non-compliance. Instead, municipalities must address this through local regulation and by-laws. Legislation can prohibit installation and tariff structures can be modified to incorporate fixed connection fees or higher rates for 'prosumers'. Although adopted measures vary between municipalities, they tend to include an application and authorisation process, requirements for advanced meter systems measuring electricity fed into the grid, and migration to a SSEG tariff (Filipova and Morris, 2018; Kritzinger et al., 2019). Regulation has often lagged behind SSEG installations and the number of non-registered installations is estimated to be significant.

In Cape Town, analysis of aerial photos reveals more non-registered than registered installations (Filipova and Morris, 2018). In the Western Cape more widely, GreenCape estimates that only 7.8MWp of an estimated 27.5MWp has been approved (Filipova and Morris, 2018). A recent study found that 50% of Cape Town residential SSEG systems were not registered (Kritzinger et al., 2020). Encouraging registration is a key challenge for municipalities.

For end-users there are several advantages to non-registration. In Cape Town, SEA (2014) highlights that tariff changes increased the payback period of SSEG from 3 to 10 years. When illegally connected to unidirectional meters SSEG can run meters backwards effectively placing installers on a net-metering tariff unbeknownst to the municipality (Filipova and Morris, 2018).

In recent years municipalities have implemented SSEG tariffs to manage economic pressures, protect revenues and ensure cost recovery. Revenue protection allows for the continuation of cross-subsidisation of brown and red agendas. As of September 2020, 29 municipalities have implemented SSEG tariffs (ESI, 2020). Figure 15 shows the significant uptake of SSEG tariffs. Tariff restructuring is becoming a key tenet of municipal SSEG response. Municipalities can establish SSEG tariffs that set rates at which they buy and sell electricity from SSEG 'prosumers'. In Cape Town, the introduction of a fixed network connection fee has been proposed as a simple method of reducing revenue impact that complies with tariff structure designs (Mayr et al., 2015).

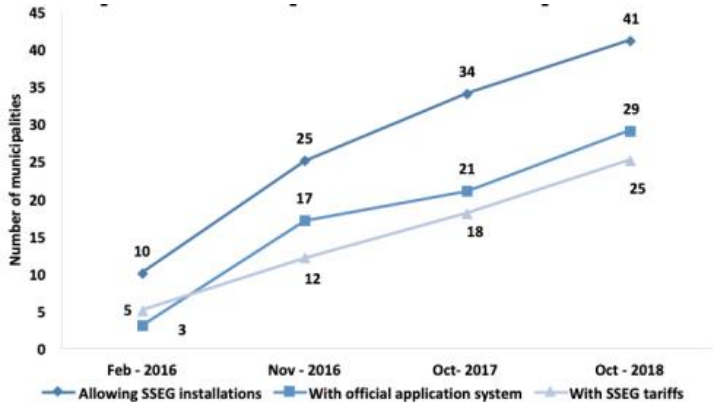

Figure 15 Trends in uptake of SSEG processes in municipalities. Source: SALGA (2018).

Municipalities implementing SSEG tariffs generally adopt a net-billing approach, commonly comprising a R/month connection fee with rates for each unit of electricity bought or sold (Shumba et al., 2019). 'Prosumers' are compensated for excess electricity fed into the grid at a FIT rate. For commercial and industrial consumers already paying fixed connection fees, SSEG tariffs often involve the simple addition of a FIT. FITs are often substantially lower than the cost of electricity for consumers (SEA, 2014). The CoCT uses the average rate at which they buy electricity from Eskom (LD-OPT) arguing that national legislation prevents them from purchasing electricity from independent sources above Eskom's bulk purchase price (SEA, 2014). Although tariff changes have been argued to retard SSEG installation rates and substantially influence payback periods (SEA, 2014; Kotzen, 2014), they are relatively straightforward to implement and comply with tariff structures designed nationally (Mayr et al., 2015). Tariff restructuring can help ensure 'prosumers' cover their fixed network maintenance cost, while also protecting municipal revenues and safeguarding the financing of pro-poor policy (Filipova and Morris, 2018). Tariff restructuring plays a key role in enabling the brown and red agendas.

There is a range of additional options available to municipalities to encourage legal installations worth investigation.

Complex compliance standards increase costs and frustrate SSEG installation thereby encouraging illegal installations. Municipal departments, often short-staffed, may struggle with installation applications, which can disproportionately impact municipal capacity (SEA, 2014). SEA (2014)

proffers that compliance inspection and sign-off could be performed more simply and cost-effectively by allowing completion by registered electricians and providing training.

Municipalities could adopt new financial models that remove the revenue-raising burden from electricity sales (SEA, 2014). For example, Kotzen (2014) outlines how residential ToU billing could reflect the cost price of electricity from Eskom and result in fairer electricity distribution. However, this is incompatible with revenue protection and the continuation of pro-poor red and brown policies and would require the deconstruction of the intensely engrained municipal revenue generation structure. Previous threats to this model, such as the formation of REDs discussed in Chapter 4, have faced stiff resistance. Increasing revenue generation from alternative sources would be a political battle and additional national funding is improbable (SEA, 2014).

Municipalities could offer more attractive SSEG tariffs. However, this would prevent cost recovery (SEA, 2014). Such a subsidy is not justifiable given economic pressures faced by municipalities to maintain basic service provision and ensure accessibility of electricity. The red and brown agendas entrenched in municipal mandates prevent municipalities from further promoting SSEG. Nationally, subsidisation may be possible, such as the 'single buyer' model discussed in early SSEG responses, yet this is now unlikely given the widespread adoption of SSEG (SEA, 2014).

While municipal regulation of SSEG attempts to ensure the safety and integrity of the grid and prevent the 'free-rider' effect by ensuring customers pay fairly for their network costs, many PV owners do not consider regulation to be fair (Kritzinger et al., 2019). Implementing SSEG regulation whist discouraging illegal connections is therefore vital to meeting municipal goals.

5.5 Conclusion

This Chapter has highlighted the growth and impact of SSEG on municipal revenues and responses available to municipal regimes in South Africa. Chapter 6 explores these challenges in Cape Town.

6. Cape Town Case Study

Considering the landscape pressures outlined in Chapter 4 and the impacts of SSEG at the municipal level outlined in Chapter 5, this chapter discusses the case of SSEG developments in the Cape Town regime and presents the findings from the analysis of relevant policy documents, technical papers, media releases and interviews conducted with SSEG stakeholders.

6.1 Policy Development

Following publication of NERSA's '*standard conditions'* (see Chapter 5), the CoCT has recognised its increasing agency in energy policy. In its 2015 '*state of energy'* report it states: "local governments are in a key position to steer this change and generate considerable impact through… implementation of more efficient and sustainable energy solutions" (CoCT, 2015:1). Since 2011, the CoCT has developed its own SSEG programme, "in the absence of national legislation" (CoCT, 2017a:77), with limited engagement with NERSA (NERSA: Interview).

NERSA's '*standard conditions*' requires municipalities to maintain a database of SSEG systems, reported to NERSA annually. For the CoCT, being released as guidelines, these standard conditions "are thus of uncertain regulatory status" (CoCT, 2015:88). Early CoCT engagement with SSEG involved the installation of SSEG on city buildings to "offset electricity consumption" (CoCT, 2015:13). For the CoCT these actions highlighted, "the city is leading by example and also gaining hands-on experience of the practicalities relating to SSEG" (CoCT, 2015:13). In September 2014, the CoCT finalised its application procedures and tariff structures to accommodate SSEG and registered its first customer (CoCT, 2015; CoCT, 2017b).

Yet the CoCT also recognised the challenges of SSEG discussed in Chapter 5,

"the current regulatory environment and management system include contradictions that have to be addressed… the obligation imposed on local governments to supply services in a sustainable manner, which entails both cost recovery/revenue-raising through the sale of… electricity, and renewable energy development... However, under the current system, energy efficiency and loss of sales through embedded renewable energy development mean that one priority is pitted against the other" (CoCT, 2015:32).

SSEG's revenue implications undermine the priorities outlined in the CoCT 2017 Integrated Development Plan (IDP), which states its objectives "to make Cape Town more inclusive, safe, sustainable, efficient and resilient" and maintain a "growing, sustainable and inclusive local economy" (CoCT: 2017a:3). Key amongst these priorities is economic inclusion, excellence in basic service delivery, mainstreaming basic service delivery to informal settlements, building integrated communities, and ensuring operational sustainability. Without regulation of SSEG, it is unclear how the CoCT can meet these red and brown commitments without impacting its operational sustainability.

Under existing legislation, the CoCT maintains that electricity generation 'not for own use' requires a generation licence from NERSA (CoCT, 2017c). The CoCT allows feeding surplus generation into the grid and drawing the same amount of energy back, provided the customer remains a net consumer: "the city will not require SSEGs smaller than 1MVA to obtain… a licence provided that, over any consecutive 12-month period, they do not feed more electricity onto the city's grid than they purchase" (CoCT, 2017c:11). Accordingly, the CoCT believes it is only mandated to buy electricity from SSEG installers provided they are net consumers (CoCT, 2017c:7,13)

Under the principles of resale of electricity within the 2010 Electricity Supply By-law, the CoCT outlines that the rate at which electricity is sold "shall not be less favourable… than those that would have been payable… had the purchaser been supplied directly with electricity from the service provider" (CoCT, 2010:20.4). The CoCT introduced SSEG tariffs in 2014, which included a /day service fee, two /kWh IBTs, and a FIT rate. For commercial customers existing service fees remained. In accordance with the Electricity Supply By-Law, the CoCT SSEG FIT matches the rate at which they purchase electricity from Eskom during LD-OPT.

In 2017, the CoCT released its '*requirements for SSEG*', which formalised much of the existing SSEG policy established by the CoCT since 2014. The requirements highlighted that SSEG systems must be registered with the CoCT: "the city will register and authorise grid connection of SSEGs up to 1MVA without evidence of a generation license" (CoCT, 2017d:9). As per Section 39 of the 2010 Electricity Supply By-Law, generation equipment may be connected with prior written consent from the Electricity Service Department Director (CoCT, 2010). The requirements outlined the distinctions between different types of SSEG and the registration requirements for each type. These distinctions are outlined in Figure 16. Subsequent regulation has caused these distinctions to have significant unintended consequences on the registration of SSEG systems and as a result the direction of transition, the green benefits of SSEG, the revenue implications for the CoCT, and its ability to fulfil its red and brown commitments.

SSEG Type	Requirements			
	Authorised by Director	Certified by ECSA-registered engineer/technologist	Certified by ECSA-registered technician	Certificate of compliance
Grid-tied Connected to electricity grid either directly or internally with reverse power flow blocking.				
	Yes	All	Residential only	Required
Hybrid Island after grid interruption and supply loads from the inverter using stored energy.				
	Yes	All	Residential only	Required
Off-grid Physically separated and electrically isolated from the grid. Export to the grid is impossible.				
	No	No	No	Required

Figure 16 Distinctions and requirements for types of SSEG. Source: CoCT (2017c:7,11,22).

Engineering Council of South Africa (ECSA) certifications are required until national standards have been completed and accredited SSEG installation and commission technicians/electricians exist. The full requirements for SSEG installations are outlined in Annex 4.

Customers wanting to participate in SSEG tariffs must install bi-directional AMI meters at their own cost[12] (CoCT, 2017c;2018c). Customers not wishing to be compensated for feeding back to the grid must install reverse power flow blocking to prevent flow back to the grid. Customers can then stay on existing tariffs and may require meter changes (detailed in Annex 5) to ensure "conventional credit and prepayment meters are never allowed to run backwards" (CoCT, 2017c:19). These tariff

[12] AMI meter cost is R9800-15300 (CoCT, 2017c).

changes have resulted in impacts to revenue and caused unintended consequences of subsequent regulation which has negatively impacted green, brown, and red agendas.

In 2017, the CoCT released the '*Electricity supply: amendment'*, which substituted subsection 1 of the 2010 by-law to state, "any person who contravenes any of the provisions of sections… 39 of this by-law shall be guilty of an offence" (CoCT, 2018a:18). The inclusion of section 39 within this clause gave the municipality authority to pursue and prosecute non-registered SSEG systems. This has criminalised the green agenda of SSEG installers.

Despite registration being legally required since 2010, non-compliance caused the CoCT to launch a registration awareness campaign. The CoCT published a notice stating, "as customers may be unaware of the requirement to register and obtain authorisation for their SSEG, the city is allowing a grace period for existing system to be registered and authorised" (CoCT 2018d:2). The CoCT urged customers to register SSEG system by 28th February 2019 (extended to 31st May 2019) or face disconnection of SSEG systems at a R6,425.90 disconnection fee.

Throughout these policy developments the CoCT has remained outwardly committed to encouraging SSEG as part of its green agenda commitments to addressing climate change and diversifying its energy mix (CoCT, 2017b; 2018b; 2018d). In its IDP the city highlights its ambitions to increase SSEG to 120MW by 2020 (CoCT, 2017a). The CoCT regards SSEG as "critical to improving Cape Town's energy security, reducing its carbon footprint and thereby building a more robust economy, creating local jobs and keeping money circulating in the local economy" (CoCT, 2017a:76). In its registration notice the city stated, "the CoCT supports SSEG… thank you for contributing to our goal of a greener and cleaner city by installing a PV system" (CoCT, 2018d:1).

6.2 Drivers of SSEG Regulation

Drawing on interview and policy data this section identifies the drivers of SSEG regulation. A diverse range of drivers for SSEG regulation were identified by interviewees. These were characterised as technical, safety related, financial and environmental. The financial drivers for SSEG regulation relate to the issues with municipal revenue structures identified in Chapter 5.

6.2.1 Technical

Technical compliance requirements were raised by all participants. One participant summarised these concerns, "there are technical limitations of how much intermittent energy [the grid] can contain… everyone is producing and discharging at the same time, for municipalities it is important to know how many systems exist to make sure the grid can actually handle this" (WWF).

The scale of SSEG niche growth increased this need for regulation. One solar EPC stated, "you need to regulate and monitor all of this additional electricity, when you've got the uptake that Cape Town's experiencing, you need to make sure you're maintaining the health of your grid" (EPC1).

Technical compliance is important to enable monitoring and ensure capacity is not exceeded, "there's… concerns around the capacity of the grid, which requires grid reinforcement to allow bidirectional metering" (CoCT). This supports CoCT policy which outlines the rationale for regulation, "the city needs to ensure… SSEG installations can be accommodated on the network and … capacity of the network has not been exceeded" (CoCT, 2017c:13).

Ensuring technical compliance is important for maintaining a functional grid capable of distribution of electricity to all users. Technical compliance also allows for green energy to be incorporated into the grid and diversifying the CoCT energy mix. Technical compliance is thus crucial for both a healthy and sustainable grid, and the continuation of brown, green, and red agendas.

6.2.2 Safety

Participants highlighted the necessity of registration to ensure grid safety. Unregistered SSEG systems could electrocute workers if electricity is fed into a grid that is believed to be off, "if they don't register… and maintenance needs to happen, but people have active energy exporting towards the grid, that is a major safety issue" (WWF).

The safety of the grid is also raised as a key driver of policy actions by the CoCT, "the safety stuff is critical… if you're allowing two-flow on the grid, for things like maintenance, people can get injured, really badly electrocuted" (CoCT). CoCT policy also raises safety as a driver of regulation, "the most pressing are the safety of the utility staff, the public and the user of the generator… There is therefore a strong need for such practice to be regulated for the general benefit and protection of citizens" (CoCT, 2017d:10).

6.2.3 Financial

SSEG revenue concerns were raised as a driver for regulation by the CoCT, WWF and GreenCape and one solar EPC. Revenue concerns driving regulation were not raised by other EPCs and households.

Concerns over the position of the CoCT as a developmental local government and the generation of revenue from electricity for the cross-subsidisation of other services were outlined by the CoCT official:

*"*you've got a system that is so dependent on cross-subsidisation, such inequality that you need expensive tariffs… the grid becomes a system for redistribution. That's how it's structured in terms of law and how it's structured in terms of policy. City officials… could see the implications [of SSEG]... on how they can fund other municipal services and how they can fund pro-poor tariffs and FBE…" (CoCT).

CoCT concern over threats to electricity provisions ability to cross-subsidise service provision for poor households is a key driver for SSEG regulation. The CoCT is mandated to facilitate equitable service provision and must maintain the financial viability of achieving red and brown agendas. Threats to municipal revenue threaten the extent to which energy transition can be just and inclusive. Revenue protection is therefore a driver of SSEG regulation to safeguard the cities operational sustainability and its red and brown commitments. One participant highlighted this distinction, "focus shouldn't be on municipalities trying to protect their revenue, it goes beyond that, the municipality is trying to protect their ability to provide a service, which is electricity, to achieve a common goal… having a sustainable electricity system, that is fair and financially viable" (WWF). Another participant highlighted that registration requirements would allow the CoCT to understanding better the possible revenue implications, enabling advanced planning and adaptation (Greencape).

The impact of SSEG on municipal revenue has been outlined in Chapter 5. One participant highlighted this impact: "higher electricity consumers pay a certain tariff at a certain level of usage, and that's the first one that gets reduced by SSEG, because it's based on amount of usage" (WWF).

SSEG revenue impacts were raised by the CoCT in interview but they are not widely acknowledged within official policy. The CoCT 2015 'state of energy' report is among the only CoCT documents to acknowledge this issue, estimating the likely impact of SSEG uptake on municipal revenue between 4-11% (CoCT, 2015). However, uptake has been more dramatic than expected and persistent non-compliance accentuates these revenue impacts. Higher than anticipated revenue impacts threaten the ability of the municipality to cross-subsidise its brown agenda commitments and continue to provide subsidised and FBE electricity to end-users as part of its red agenda. Rapid uptake,

persistent non-compliance, and revenue impacts has made tariff changes to cover fixed system costs difficult to enact without further incentivising noncompliance. The impacts of tariff changes are discussed in Section 6.3.

Several participants thought the CoCT did not want to acknowledge the potential revenue impacts of SSEG. One participant stated: "the municipality were initially more careful in trying to tell people, 'we are actually losing money and that's why you need to pay up'… it's sensitive… because people immediately associate government with corruption" (WWF). Another participant stated, "ultimately, it's a revenue thing. They'll probably want to disguise it with environmental and socio-economic stuff, but its revenue" (EPC1). Yet, the financial viability of the CoCT relates directly to its capacity to fulfil its mandate for environmental and socio-economic development as well as its brown and red agendas. The extent to which the CoCT is dependent on electricity is not well understood outside elite policy actors. Neither is the extent to which electricity policy is defined by pressures to maintain the red and brown developmental agendas. The CoCT official corroborated this, although felt that revenue implications had been publicised, "it's how municipalities are structured. I think the city has relayed that position in many different ways. Potentially people don't understand the extent to which this is a problem for the city" (CoCT). The CoCT response to SSEG is heavily influenced by the complexity of municipal finances and their dependence on electricity revenues.

6.2.4 Environmental

CoCT regulation has not been designed to prevent the addition of SSEG to the grid. This is emphasised by the CoCT's continued expressed support for SSEG, and its inclusion within the CoCT's energy diversification strategy. For the CoCT, support for SSEG is driven largely by its contribution to green agenda goals: "the city is very serious about climate change and mitigation and has made some very strong commitments" (CoCT). The environmental benefits of SSEG were widely acknowledged to drive CoCT support: "regulation is aligned with the city's broader renewable vision" (EPC4).

Given the wide range of regulatory drivers, policy has been designed to balance competing agendas. The CoCT official highlighted: "there's a… balance between stifling innovation with the tariff structure … so it might disincentivise uptake of private PV systems… you're balancing the capacity of the grid to cross-subsidise, balancing a … municipal revenue model that cross-subsidises other municipal commitments, and balancing commitments the city has made for mitigation, to stimulate renewable energy, and our C40 commitments".

6.3 Impacts of SSEG regulation

The perceived impacts of SSEG regulation were characterised into 5 key themes. These included: registration changes; technical impacts; environmental impacts; tariff responses, and impacts on municipal overheads.

6.3.1 Registration changes

Following changes to the Electricity Supply By-Law and increased municipal registration pressures, registrations have increased by 89% (EWWF, 2020). This was supported by interviewees who highlighted regulation changes have increased the number of legally connected systems.

For EPC1, fines for non-registration have dramatically encouraged registration: "there's been an increase in legal installations, a R6500 fine…that's a threat, they've scared the shit out of people with PV systems into registering them". However, despite fines being regarded as a tough approach by EPCs, several EPCs outlined that the move towards a better regulated industry was necessary and

that the CoCT were engaging with homeowners to encourage registration. EPC2 stated: “as soon as you start engaging … they immediately back off, they’re open to discussion”.

Figures for registration increases may seem high but they do not accurately reflect the number of registrations. A study by Kritzinger et al. (2020) found that 50% of Cape Town homeowners with SSEG had not registered their systems. EPC3 estimated that: “roughly 30% of solar installations are actually registered in Cape Town”. Another participant argued: “50% still doesn’t, so it’s obviously not working, rules only work when the majority complies, there’s a problem that people are not complying and think they are entitled to not comply” (WWF).

Low barriers to entry were highlighted as a key reason for continued non-registration: “there’s always going to be a number of illegal installations because barriers to entry… are really non-existent” (EPC3). EPC1 highlighted that: “with the drop in prices, this technology is increasingly available at an accessible price to smaller homeowners, a lot of people have started doing DIY installations, and those guys aren’t registering their systems”. One homeowner highlighted this position: “I found a kit online and installed PV… I haven’t registered it because I don’t want to be taxed on it” (HO2). Continued non-compliance and illegal connections threaten municipal revenues and municipal service provision as a result. This includes not only red and brown agendas but the ability for the grid to accommodate growing green energy capacity. Despite growth in registrations resulting from CoCT regulation, persistent illegal connections still threaten a just energy transition.

6.3.2 Technical impacts

The requirement for ECSA approved sign-off for registration was raised by participants as a challenge for installations. ECSA sign-offs added cost to projects and EPCs felt there was limited forewarning of these requirements. For GreenCape, sign-off was an “expensive element to a project”. EPC3 stated: “if we knew it upfront, it would make our life easier and save us money, it’s a huge cost if you don’t have an engineer and you have to outsource”. EPC2 stated: “it’s a lot of extra cost that gets pushed onto the client for an application”. EPC1 reiterated this: “sometimes it’s like R2,500 just for a signature”. While “some sign-off mechanism is important to ensure systems are designed and installed safely and reliably”, the CoCT is looking for ways to work around it (GreenCape).

Changes to the CoCT approved inverter list concurrently with attempts to encourage registration was raised as a key issue by all EPCs. For EPC1: “when the by-law came in, a whole bunch of inverters that were previously approved were taken off the list, which meant that existing installations which had been compliant, but didn’t have to be registered up until that point, were now not compliant… you had very well-meaning homeowners facing massive bills because either they’re getting fined by the city or having to replace inverters at significant cost… 5 years into an installation you have to fork out 15-25,000 rand for a new inverter” (EPC1).

Inverter list changes have rendered many past installations non-compliant. As pressure to register increases from the CoCT, EPCs have been forced to return to clients and redesign systems. EPCs highlighted that in many instances to get around this, SSEG installations were redesigned as ‘off-grid’ systems. EPC4 stated: “so what we do, and this has helped us to sidestep a lot of the regulations where our inverters have been removed from the list… is that we registered as an ‘off-grid’ system. You design the right distribution board and you’ve got less hassle. Although the home is still connected to the grid”. Approved inverter list changes are in line with changes to NRS standards and CoCT attempts to align regulation with these.

The need for the installation of AMI meters to participate in SSEG tariffs was also found to be a challenge. Several EPCs highlighted long wait times on quotes from the CoCT of meter costs. While

the cost of meters was also thought to prevent consumers from opting to feedback power. EPC2 stated: “the client has got to pay for an AMI meter, R10,800 and they feed in on a whole different tariff”.

Finally, one participant highlighted that SSEG investments were disproportionately taking place in certain neighbourhoods, resulting in increased maintenance and network upgrading in high-income areas rather than in areas where network connections are limited or unreliable: “it’s high-income electricity consumers who invest… solar panels become clustered in certain neighbourhoods along certain transformers, your focus is directed to those areas more than the areas where people cannot afford the system” (WWF). As a result, high-income areas are receiving unequal municipal capacity in upgrading and maintaining their local network while lowering their collective contribution to municipal revenues to cover these costs. This results in increasing inequalities in physical network infrastructure as well as increased inequalities in electricity cost as maintenance costs are disproportionately subsidised by homeowners without PV.

6.3.3 Environmental impacts

In environmental terms, SSEG regulation was widely thought to hinder potential green agenda benefits. All solar EPCs and homeowners felt that increasing SSEG would have a greater environmental benefit. EPC1 stated: “it’s not ideally positioned to drive the uptake in renewables”. EPC3 stated: “it’s hampering the environmental benefit because they’re limiting the installation of solar systems”.

However, while the environmental impact was thought to be less effective due to regulations, EPCs recognised that regulation was important in ensuring the stability and safety of the grid which would allow green energy to form part of CoCT’s climate change response. The loss of environmental benefits from regulation were thought necessary to allow for the maintenance and integration of renewable energy onto the grid. EPC1 highlighted this: “it feeds into the overall vision of creating a working, stable and safe renewable energy network”. EPC4 also outlined these challenges: “steps need to be taken to mitigate against climate change threats, the city has to regulate SSEG to ensure its environmental benefits can be shared”.

6.3.4 Tariff responses

EPCs highlighted that SSEG installations targeted consumption over the 600kWh IBT threshold. This maximises electricity cost savings for consumers but also increases revenue implications. Revenue impacts have triggered tariff changes by the CoCT. In response, EPC4 stated: “it’s very expensive to feed electricity back onto the grid, and you have to pay a monthly fee for that privilege”. SSEG tariffs, intended to reflect fixed network costs and additional costs associated with incorporating bi-directional flow on the grid have encouraged SSEG installers to adopt systems that allow continuation of existing tariffs. EPC3 commented: “I think most of the time the guys install batteries, and rather use that electricity… the payback is much better than feeding back”. Installing batteries allows SSEG installers to use more self-generated electricity and stay on original tariffs. Prior to 2019, this resulted in significant cost savings for consumers, as home-user tariffs had no fixed service charges. By adopting SSEG and remaining on existing tariffs, registered systems participate in the ‘free-rider’ effect discussed in Chapter 5. This loophole meant CoCT SSEG tariffs did little to ameliorate SSEG revenue impacts, resulting in threats to its operational sustainability and ability to fulfil brown and red developmental agendas. In 2019, the CoCT introduced a fixed service charge and lower /kWh rates on it’s home-user tariff (CoCT, 2019). This was likely due to SSEG installers continuing to opt out of SSEG tariffs and to mitigate the continued revenue impacts from this non-participation. These changes may have several consequences. They increase electricity costs to

those who use the least electricity above the home-user tariff threshold[13]. Lower prices /kWh may reduce impetus to conserve electricity. In this case, reduced energy conservation may increase electricity demand and influence green agendas.

One participant outlined the challenges around tariff structuring: "I think people just don't understand electricity tariffs, and why the municipality charges certain tariffs, its not the government trying to bully the electricity consumers. Municipalities have a mandate to provide electricity in the interest of all consumers or all citizens living within their jurisdictional borders. If you have a solar panel and you register it, you are transferred onto a tariff that's less beneficial than staying on your current tariff, especially if you have an old mechanical meter installed" (WWF). Payback times for systems have changed because of tariff changes (HO1).

Tariff changes were designed to allow the CoCT to cover fixed costs and maintain red and brown agendas. Prior to 2019, tariff structures increased cost for SSEG installers which encouraged continued non-registration. Registration requirements allowed customers to stay on existing tariffs thereby maintaining revenue impacts. Consequently, SSEG installers have increasingly opted out of SSEG tariffs, resulting in less PV energy fed into grid, and fewer shared green benefits from SSEG.

6.3.5 Municipal overheads

Another key issue raised by EPCs was municipal workload required for regulatory changes. For EPC2 this related to the authorisation of systems, "the city are spreading themselves thin in terms of engineering capacity… this whole private sector is putting out applications and that's making a bottleneck at the city because they've still got to go to site". For EPC3, this issue was with application and registration processes, "the backlog of 65% is huge, the only way to fix that is to have an easier line in and line out, we can't wait a year for an application".

Several interviewees regarded regulatory changes as an acceptance of the role of SSEG in energy transition. EPC2 stated: "they're definitely trying to do a transition, but they're trying to manage it, it's all happening so quickly". For GreenCape: "it represents an important shift by the city, they have acknowledged that SSEG is going to be an important part of the municipal landscape moving forward, and they need to understand how it is going to impact the municipality and how they need to adapt".

While the CoCT has accepted SSEG as part of an emerging energy transition, increased regulation has impacted its own workload capacity available to manage transition. Administration of applications and registration processes and increased grid maintenance (see 6.3.2) increase costs and workload. Limited resources are disproportionately spent on SSEG installers, who, having installed SSEG, are paying lower shares of these costs. This influences red and brown municipal agendas.

6.4 The impact of load-shedding

Load-shedding was cited by all EPCs as driving uptake of batteries in SSEG systems. EPC3 stated: "it's mostly due to Eskom instability, the guys opt for storage systems more often, when you have storage there's no need to export, 90% of our business is battery based". EPC1 and EPC4 also stated they had seen increased battery installations, and both stated that all recent residential projects came with battery requests. EPC2 corroborated this: "whereas typically clients would ask for a PV inverter and some panels. Now you're getting a PV inverter, battery inverter or a hybrid that does both and you're installing batteries. It's heavily influenced by load-shedding".

[13] Property value >R1million

In commercial and industrial applications load-shedding has also driven uptake of hybrid solutions to an extent. However, all EPCs interviewed thought this was less pervasive than in the residential sector. One interviewee stated "there's definitely been increased uptake… a factory has certain start-up and shutdown times, there's a lot of indirect costs… so the business case has improved a lot, which has resulted in increased uptake of hybrid solutions… The decreasing cost of lithium-ion batteries has also increased the uptake" (GreenCape). Load-shedding is a key driver for SSEG uptake with battery technologies.

6.5 Independent Power Producers

Another theme that emerged from interviews was IPPs. The CoCT is actively seeking to allow IPPs to generate electricity for purchase by the city. In 2017, the CoCT approached the High Court seeking to allow the procurement of renewable energy through IPPs. Since then, President Ramaphosa has announced that municipalities in good financial standing will be allowed to procure energy from IPPs (RSA, 2020).

For the CoCT, IPPs have several potential benefits. One official outlined these: "more security of supply, more autonomy… to provide more stability to businesses and residents, around climate mitigation interests, to have more control over pricing, and there's that kind of interest… to showcase the city as a different governance model in some ways". Grid stability was raised consistently as a key benefit of IPPs by all EPCs interviewed. IPPs were thought to allow for electricity procurement closer to the cost of generation (GreenCape).

While these developments refer to larger scale generation than SSEG they have several potential implications on SSEG policy. Security of supply may stabilise electricity prices and begin to address the persistence of load-shedding. These measures may reduce the uptake of hybrid SSEG. Proportionately fewer hybrid SSEG allows the green benefits of SSEG to be shared across the CoCT distribution network. Furthermore, IPPs would enable the CoCT to purchase electricity at different and potentially lower rates than those offered by Eskom. This could result in lower electricity prices and increased margins for subsidisation, generating more revenue for brown and red agendas. It could also enable the CoCT to lower SSEG FIT rates in line with current justifications.

7. Discussion

The findings have demonstrated the complexity associated with the impacts of SSEG and regulation attempts at the municipal level within South Africa's energy landscape. It has further shown that at the regime level, SSEG poses a complex challenge for municipalities who must balance a range of competing agendas to ensure a just transition to a low-carbon energy system. CoCT interventions have developed rapidly in response to these challenges. This chapter discusses the findings of this research in relation to the research questions and conceptual framing. It draws on the MLP and the agendas framework to assess the implications of SSEG on a sustainable energy transition at the municipal level.

7.1 SSEG in Cape Town's energy transition and the Multi-Level Perspective

In South Africa, SSEG presents a complex challenge for local governments. Municipalities must sustain the capability of the grid to continue providing electricity as a service, whilst maintaining the financial viability of electricity provision to continue with cross-subsidisation and expansion of service delivery. Unregulated, SSEG threatens these ambitions and, importantly the brown and red agendas of the city. Alternatively, too much regulation threatens the green benefits of SSEG and can cause widespread non-compliance, adversely impacting revenues and the viability of brown and red agendas.

In Cape Town, increasingly decentralised governance and generation assets are forming part of an ongoing transition towards a greener energy system. In recent years CoCT agency over energy issues has been increasing. While for Hermanus (2017:31), "municipalities have used small windows of opportunity to implement projects to determine local regulations, as well as influencing national regulations and policy", the findings of this research present a slightly different picture. Rather than using windows of opportunity to control local energy policy-making, the CoCT has been forced into action on SSEG by a lack of engagement from NERSA and the handing down of regulatory responsibility to the municipal level (discussed in Chapter 5). While decentralised energy governance has benefits for the CoCT, the lack of national assistance with policy creation and the uncertainty associated with NERSA's standard conditions may prove to be an issue in other, less affluent, South African municipalities. Nonetheless, the direction of national transition is being shaped by actions at the municipal regime level (Hodson and Marvin, 2010). The CoCT regime is defining a locally distinct transition influencing that occurring nationally, not only though the regulation of SSEG but also in the pursuit of IPPs.

The findings outlined a diverse range of drivers for SSEG regulation in Cape Town. Regulatory attempts derive predominantly from the need to understand the scale of uptake, ensure the safety and reliability of the grid, and prevent disruption to the financial sustainability of the CoCT and its associated ability to continue cross-subsidisation of FBE and other service delivery. Several of these drivers are pragmatic and are not influenced by municipal agendas. The environmental benefits of SSEG are a key reason for its acceptance in policy at the local level. The research has highlighted a disjuncture between the drivers and rationale of SSEG regulation, their presentation in policy and their perception by stakeholders. SSEGs revenue implications are not widely acknowledged outside elite policy actors. This has contributed to the ongoing discrepancy between municipal and individual objectives and resulted in the persistence of illegal and un-registered connections. Addressing this disjuncture through more open communication and engagement by the city may be necessary to dissuade continued non-compliance and ameliorate the resulting revenue impacts.

A range of impacts of SSEG regulation were also identified. Some of these were short-term technical issues resulting from rapid changes to legislation and the incorporation of national standards. Here,

national legislation, developed slowly in response to SSEG, is providing landscape pressures influencing transition at the municipal regime level. Initial registration requirements created pressure on SSEG 'prosumers' that inadvertently dissuaded engagement with SSEG tariffs. This arose from a combination of high AMI meter costs, higher SSEG tariffs, changes to approved inverter lists to comply with national standards, and CoCT distinctions between types of SSEG. To navigate this, SSEG 'prosumers' can install reverse power blocking (especially when generation can be stored or used), or register systems as 'off-grid'. These options enabled 'prosumers' to remain on current tariffs, resulting in lower consumption and the lack of connection fees. Resulting revenue impacts are dramatic, as grid consumption is diminished and occurs at times of minimal/negative municipal revenue, and network connection fees are avoided. This has severely impacted the capacity of the CoCT to fulfil its red and brown developmental mandate as reduced revenue prevents cross-subsidisation. In 2017, of an estimated 6MW of approved residential PV capacity, 5MW was connected without paying a service charge (IRENA, 2018). These challenges have been addressed by the restructuring of home-user tariffs which reduce the incentive for non-participation in SSEG tariffs (see Chapter 6). Moving forwards, regulation has increased clarity around approved inverter and registration requirements, and tariff modifications have reduced incentives for non-participation. Although technical issues must be resolved by existing customers, in the future these issues are unlikely to continue and SSEG installations are more inclined to opt to feed-in to the grid.

CoCT regime actors have adjusted the regime to accommodate the growing pervasiveness of SSEG through a process of transformation (Geels and Schot, 2007). While SSEG was initially a niche protected by the CoCT it has now become more mainstream. By becoming more mainstream the impact of SSEG on current municipal revenues, although reduced, remains, and continues to threaten equitable service provision and a just transition. One participant summarised these concerns: "SSEGs affecting the ability of the municipality to sustain that model… the municipality is adapting and is looking at ways to accommodate PV systems. The municipality ultimately wants to reach… sustainable energy transition where there's diversified energy solutions all working together harmoniously with the grid" (GreenCape). SSEG is currently unable fulfil the regime agendas that depend on electricity provision. Until it can, or until the regime has adapted its financial dependence on electricity revenue, SSEG will remain a niche technology.

Recent regulation by the CoCT outlines its acknowledgement of the inevitability of transition to increasingly dispersed SSEG that is underway. Moving forward, increasing registrations of SSEG must remain a priority for the CoCT, while the allowance of IPPs will enable increased renewable generation, addressing supply volatility and price instability in the longer-term. In the meantime, SSEG can be expected to remain a key component of the CoCT's energy transition to mitigate against load-shedding and reduce impacts from tariff rises. Changes to the home-user tariff will likely alleviate continuing revenue impacts from non-registration and non-participation in SSEG tariffs, allowing the green benefits of SSEG to be shared with the CoCT grid and safeguarding the continuation of red and brown agendas through increased cost recovery.

While regulation has attempted to manage the growth of SSEG this could be regarded as a form of inertia from the existing regime. The unique nature of South Africa's energy system presents landscape pressures on municipal regimes (see Chapter 4). As electricity sales act as a form of redistribution, threats to electricity revenue jeopardise electricity access for a large proportion of the population. Achieving just energy transition in South Africa and addressing the current 'lock-in' would therefore seem to necessitate either; an overhaul of electricity governance to remove the energy reticulation role from municipal governments, or the continuation of a subsidisation-based redistributive energy system. Municipalities have staunchly defended their mandate to distribute

electricity, as evidenced by the failed implementation of REDs (see Chapter 4). Restructuring does not seem feasible or viable given the limited time available to address climate change. However, pressures on the continuation of the current electricity regime threaten red and brown agendas at the city scale. The impact of decentralised technologies on these agendas should not be underestimated. Achieving sustainable energy transition in the CoCT will therefore likely require the continuation of electricity cross-subsidisation.

Using Cape Town as a case study, the research highlights the importance of context when evaluating transitions in the Global South. While in the Global North, increasing decentralised and distributed energy generation is often portrayed as having inherently beneficial characteristics for the transition to a sustainable and just energy system, in the Global South it has potential to disrupt systems of redistribution and dissuade sustainable development.

7.2 The electricity supply crisis impacts transition

South Africa's enduring electricity supply crisis is a key landscape pressure that has created impetus for the rapid uptake of SSEG systems combined with battery installations. The pressure of load-shedding has created new niches for SSEG technologies to thrive in, which has influenced Cape Town's transition. With declining costs, battery technologies have becoming increasingly prevalent in SSEG applications to mitigate the impacts of load-shedding, especially within residential applications. SSEG has adapted to fill this new niche, and, because of load-shedding, now provides superior characteristics to a minority of consumers willing to pay premiums (Fouquet, 2016). As discussed in Chapter 2, mass and rapid uptake is more likely when niche innovations hold such superior characteristics. In offering significant comparative advantages, SSEG deployed alongside battery technology has been growing rapidly.

While past studies have estimated the impacts of increased battery storage will not be realised until 2025 with little or no prior uptake (Mayr et al., 2015), participants highlighted that battery installations have become increasingly prevalent. All four of the solar EPC companies interviewed offered distinct 'load-shedding' packages, and all highlighted that the percentage of installations with storage had increased. The prevalence of battery storage is likely already significant.

Furthermore, installing battery storage to mitigate load-shedding allows for increased use of electricity generated and thus removes the incentive for 'prosumers' to opt for SSEG tariffs. When consumers opt to store and utilise their own electricity and stay on a traditional tariff, revenue implications are significant, and the 'free-rider' effect remains. This observation is particularly acute considering the acknowledgement from all EPCs that installations specifically target consumption over the 600kWh IBT threshold.

Accordingly, addressing the security of electricity supply is a key challenge for the CoCT to remove load-shedding as a driver of SSEG uptake. Here, the municipalities agency on influencing transition has been historically limited by South Africa's multi-level energy governance structures outlined in Chapter 4. While in the short-term, SSEG may continue to serve as a valuable niche tool by which to mitigate the negative impacts of load-shedding, long-term it's revenue impacts may be dramatic. When the CoCT is able to procure electricity from IPPs on its own terms and stabilise its supply, load-shedding may be removed as a driver. Until then, load-shedding will continue to impact municipal agendas.

7.3 Green agenda

The green agenda refers to environmental protection, mitigation of resource degradation, promotion of inter-generational equity and environmental justice in energy generation and

distribution (Du Plessis, 2015). The CoCT has been responding to increasing climate change pressures through policy action. As the first African city to publish a climate change strategy, the CoCT is committed to municipal action on climate change. This green agenda was repeatedly cited in policy as a key reason for CoCT engagement with SSEG to improve energy security, diversify its energy mix, reduce its carbon footprint, and create local jobs (CoCT, 2017a:76). These environmental benefits of SSEG were found to encourage municipal acceptance and subsequent transformation to accommodate it within the municipal network.

For solar EPCs, regulation was argued to limit the green benefits of SSEG and served only to tamper regulation rather than drive it. However, CoCT claims that SSEG represents a successful green agenda technology are becoming increasingly tentative as growing numbers of individuals opt to either install reverse power blocking or off-grid systems. In consequence, the green benefits of SSEG are increasingly unshared with the CoCT grid. Furthermore, it was argued that SSEG may even increase fossil-fuel use, as intermittency issues cause variability between peak and off-peak times, expanding reliance on rapid response micro fossil-fuel generation.

However, recent changes to CoCT home-user tariffs to incorporate fixed charges have made opting out of SSEG tariffs less attractive and may rectify issues associated with non-participation. Higher connection fees and lower price/kWh may dissuade consumers from energy saving and contribute to increased consumption and a rising carbon footprint. There is now increased certainty in regulation around SSEG which will encourage future uptake to remain grid-tied. Moreover, the introduction of IPPs will introduce more renewable generation into the grid, instilling stability and security long-term and enabling SSEG to continue contributing to the CoCT's green agenda.

7.4 Brown agenda

The brown agenda refers to the impacts of energy on quality of life, livelihoods, development, and poverty alleviation (Freund, 2001). The findings of this research highlight the impact of SSEG on municipal revenue structures. These impacts threaten the ability of municipalities to fulfil their developmental mandates, increasing service provision for residents without access to electricity and continuing to provide electricity on FBE tariffs. Increasing SSEG uptake can therefore decrease the affordability of electricity. Grid safety and stability were found to be crucial in driving regulation of SSEG in both policy and interviews. Grid stability is essential for continued grid expansion and maintenance, key to expanding electricity access in the CoCT.

Until recently, the introduction of SSEG tariffs had unintentionally encouraged non-registration or non-participation. Changes in home-user tariff structures have attempted to mitigate this and protect the financial sustainability of the municipality and accordingly its ability to expand access and maintain FBE tariffs. However, SSEG still poses a threat to municipal revenues as increased embedded generation influences the ability of the grid to cross-subsidise. While the CoCT has taken proactive measures to address this threat, continued load-shedding and spiralling electricity prices are landscape pressures that may continue to drive SSEG uptake if not addressed.

7.5 Red agenda

The red agenda refers to social justice and equity in energy access (Cock, 2004). The CoCT's red agenda of increasing equity of electricity provision has been significant in driving regulation of SSEG to mitigate revenue impacts. Ensuring continuity of IBT mechanisms and FBE is critical to improving and maintaining equity of service provision for all residents. The findings indicated that the red agenda was a central tenet to increasing registration and adapting tariffs to mitigate revenue losses.

However, the findings highlighted this agenda is less publicised as a rationale for regulation despite its importance as a driver. Consequently, amongst homeowners and EPCs the full impact of SSEG on reducing equity in service provision was poorly understood. Ensuring the viability and longevity of municipal structures to provide for all residents had only been considered by one of the EPCs interviewed. This poor understanding resulted in homeowners feeling victimised by SSEG tariffs. This has contributed to continued non-compliance and non-registration and the resulting revenue implications.

While regulation has been designed to balance each of these three agendas, the CoCT has had to expand grid capacity disproportionately in certain neighbourhoods to accommodate growing SSEG installations. As a result, development of local network capacity has focused excessively on high-income neighbourhoods at the expense of neighbourhoods where the network may be constrained. Combined with the shift to more cost reflective tariffs, which have been implemented through SSEG tariffs first, this results in the effective subsidisation of improved grid infrastructure in high-income areas at the expense of non-SSEG electricity consumers. This may result in deepening spatial inequalities within municipal boundaries and contributes to reducing equity in service provision.

7.6 Policy recommendations and suggestions for future research

This section outlines policy recommendations and suggestions for future research arising from these findings.

To encourage PV adopters with battery installations to engage with SSEG tariffs, a ToU export tariff is proposed for SSEG users. Municipalities could purchase electricity from 'prosumers' at a higher rate during peak times, when purchasing electricity from Eskom is most expensive. A ToU export tariff would encourage SSEG installers to connect to the grid and optimise their revenue while also improving profit margins on electricity resold by the municipality at peak times.

Interviewees felt that CoCT communication could be improved. This would help highlight the challenges posed by SSEG, provide more forewarning of regulatory shifts, and go some way to addressing continued non-registration.

Changes in home-user tariff structures to include network connection fees and a lower rate/kWh may have several consequences beyond SSEG adoption (see Chapter 6). The implications of these changes on Cape Town's energy transition are beyond the scope of this research and are a subject for potential further research.

Finally, the ability for municipalities to procure renewable energy through IPPs marks a significant moment in South Africa's energy history. IPPs may go a considerable way to addressing the revenue issues associated with SSEG, stabilising electricity supply and price and enabling the sustainable continuation of pro-poor policies. While IPPs may help increase equity of service provision within municipal boundaries they may accentuate inequalities between municipalities. The imminent introduction of IPPs in the South Africa context and their resultant implications requires further research.

8. Conclusion

The aim of this research was to explore the implications of SSEG on Cape Town's energy transition and assess the drivers and impacts of regulatory responses. The study aimed to utilise a multi-level perspective at the municipal regime scale to explore the role of SSEG in a just and sustainable energy transition and assess the implications of SSEG on each of the red, green, and brown agendas.

The research was guided by the following question:

What are the implications of SSEG and municipal policy on a sustainable and just energy transition in Cape Town?

To develop this question, five sub-questions were identified at the outset of this thesis.

The CoCT has responded to growth of SSEG within its municipal borders through increasing regulation. A diverse range of drivers for regulation were identified at the municipal level. The protection of municipal revenues to ensure grid maintenance, capacity, and the cross-subsidisation of FBE and other municipal services are key drivers for regulation. Tariff structures adopted by Eskom and the municipality are incompatible. SSEG installations negatively impact on municipal revenues, reducing consumption at times of peak profit for the municipality and increasing consumption at times of highest cost. Increased maintenance costs to accommodate SSEG and free-rider effects due to volumetric charges accentuate these revenue impacts and threaten the financial sustainability of municipalities and the viability of their red and brown agendas.

Technical and safety concerns are also driving regulation. Ensuring capacity on the grid and registration of systems is vital to maintaining a functioning grid that can distribute electricity to all its users. Environmental commitments served to hamper regulation and encouraged the CoCT to accept the role of SSEG in its energy transition. The CoCT views SSEG as a key component of a low-carbon transition, yet ensuring this green energy is incorporated in a just and safe manner that protects the ability of the grid to cross-subsidise red and brown agendas remains a key challenge. There was found to be a discrepancy between the stated drivers of regulation in CoCT public documentation and actual and perceived drivers. This has caused consumers to feel increasingly victimised by the CoCT, resulting in continued non-compliance.

In response, the CoCT has implemented regulation changes to require registration, introduced fines for non-compliance, effected tariff changes for SSEG users, and aligned technical specifications with national standards. The combination of these developments has caused increasing numbers of customers to either register systems as 'off-grid' or install reverse power flow blocking and remain on existing tariffs. In both circumstances the impact on municipal revenue remains and threatens the ability of electricity services to cross-subsidise other service delivery.

The city has responded rapidly to address these issues through changes to the home-user tariff. Regulation has increased registration pressures on 'prosumers', which can help the CoCT to further understand the extent of SSEG within its boundaries. However, distrust of municipal actions by 'prosumers' and continued non-registration must be addressed by clear and honest communication. This has been a key criticism of the city thus far.

National landscape developments have made load-shedding a recognised feature of South Africa's energy system. This has driven uptake of battery-based SSEG systems, which have complicated regulatory developments in Cape Town. While the price of battery storage is falling, past research focusing on revenue impacts thought it cost-prohibitive to potential installers, and did not foresee any scale of uptake until 2025. However, battery storage has become increasingly attractive to

installers as a direct response to load-shedding. In the regime of Cape Town, regulatory developments have resulted in niches for battery-based SSEG systems to avoid engagement with SSEG tariffs, either through registration as 'off-grid' or installation of reverse power flow blocking. These changes have little consumer impact with battery-based systems and circumvent tariff and registration requirements, resulting in continued revenue reductions for the CoCT.

Load-shedding has increased the comparative advantage of battery-based SSEG systems. If security of energy supply is not addressed, the uptake of these systems is likely to continue rapidly, resulting in severe revenue implications and less equitable distribution of green energy. The impact of battery technology in this sector has been underestimated and under researched.

The implications of SSEG in South Africa are shaped by the unique role of municipalities in energy distribution and the facilitation of local development and poverty alleviation. Landscape pressures from historic uncertainty around Eskom privatisation and the lack of infrastructure investment has caused dramatic electricity price increases in South Africa. These have contributed to driving the uptake of SSEG which, as a result of the centrality of electricity to municipal revenue-raising, has adversely impacted municipal revenue. Consequently, municipalities are increasingly under financial pressure because of SSEG and this influences their capacity to fulfil developmental mandates and continue red and brown agendas. In electricity terms, municipal capacity is disproportionately consumed by SSEG processes at the expense of non-SSEG consumers. More widely, revenue implications of SSEG threaten the viability of cross-subsidisation of service delivery.

The findings of this research demonstrate that the scalability of PV has necessitated shifts in the scale at which policy concerning energy generation is formulated and decisions are made. This coincides with arguments more broadly for increasing decentralisation of energy governance. The CoCT has come to play an increasing role in energy generation, in line with SSEG policy development and pursuit of IPPs. The MLP has highlighted the growth in CoCT engagement and its influence over national policy and transition. Notwithstanding, national landscape pressures are influencing the local CoCT transition. The CoCT remains mandated to facilitate local poverty alleviation and development, the financing of which remains largely dependent on electricity revenues. Without transformation to current processes, SSEG will continue to undermine the red and brown agendas of South African municipalities.

Overall, existing governance structures in South Africa seem well catered to deal with the challenges of SSEG, although transformation of processes takes time and there are vast discrepancies between different municipalities. The CoCT has enacted rapid transformation of its regime to form a new equilibrium in which the financial impacts of SSEG are minimised and technical and safety concerns addressed. This has allowed the city to safeguard its ability to fulfil its developmental mandates and protect its red and brown agendas.

For other municipalities with SSEG processes not yet in place, the number of non-registered installations is likely to be high due to the increased maturity of the PV market. Cape Town's experiences in encouraging registration and regulation of SSEG will provide learnings for many South African municipalities. While Cape Town has been at the forefront of SSEG regulation, the greater the delay in implementing registration processes the more entrenched illegal SSEG installations will become. Encouraging registration in such circumstances will prove a substantial challenge.

Importantly, while regulation marks an acceptance by the city of SSEG as part of a transition towards a sustainable energy system, the technology holds several potential impacts which may prevent such a transition from occurring in a just manner. Accordingly, decentralised technologies are not

inherently just, and the social implications of such technologies are dependent on the socio-economic context within which they are situated. In South Africa, transition to a sustainable and inclusive energy system will therefore require a degree of centrality to allow for equitable distribution and cross-subsidisation.

This research has identified that the role of SSEG in transition to a sustainable energy system is contested because of the unique role of energy in supporting pro-poor policy in South Africa. As McEwan (2017) argues, the transition to renewable energy is a spatially constituted and political process, that influences and is influenced by spatial interactions with policy. Understanding how spatial interactions are influencing policy agendas remains an important topic as the true scale and impact of SSEG becomes more apparent.

The decision to allow municipalities to procure and generate electricity through IPPs marks a significant turning point in South Africa's energy future. Attention must be paid to the impact this may have on discrepancies of service provision and inequalities between South African municipalities. Likewise, for SSEG regulations, interviews highlighted that differences in operational capacity and finances may render certain municipalities unable to implement and enforce SSEG regulation and prevent revenue implications. Unfortunately, this is more likely in municipalities that are already resource constrained.

Navigating the regulation of SSEG in Cape Town must continue to ensure the ability of the municipality to meet its mandate of provision of accessible and affordable energy for all. Current regulation structures seem to have resolved many of the safety, technical, and financial challenges of SSEG, yet the impact of SSEG on the ability of the municipality to maintain its mandates remains in question. Currently, the environmental benefits of SSEG in Cape Town come at the cost of reducing energy equity, accessibility, and poverty alleviation.

Decentralisation of energy generation will be a key element of energy transition and can enable socio-economic development. However, it can hamper inclusive transition and exacerbate existing energy injustices. To achieve the dual imperative of a low-carbon energy system with equitable, universal access, future transitions must contribute to addressing systemic poverty and inequality.

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Annex

Annex 1. Interview guide

Are you aware of CoCT regulation of SSEG?

Are you aware of the need for registration?

How do you understand this changes to the by-law?

Do you think the by-law has been effective? Please explain why?

What do you think the rationale behind the by-law was?

What do you think the effects/impacts will be?

- Has it promoted safer connections?
- Has in promoted increased legal connections?
- Has it hampered the SSEG market?
- Is there an increase in storage?

Have regulation changes affected your organisation?

How have different actors responded to regulation?

Do you think the by-law has influenced revenue stability of the City?

Does the by-law resolve or accentuate inequalities?

Does the by-law influence climate change objectives and environmental protection?

Does the by-law influence development in the city?

Does the by-law influence social justice and equity of service provision?

Where do you think the by-law originates from?

What is the future role of SEG in Cape Town?

Do you think NERSA guidelines attempted to allow municipalities more control over regulation?

Why do you think the CoCT first engaged with SSEG?

Are the city trying to block transition?

Will the right to IPPs influence SSEG?

What differences are there between sectors?

How do tariffs influence SSEG uptake?

Annex 2. Research ethics approval

UNIVERSITY OF CAPE TOWN
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18 March 2020

Mr Dominic William Oliver
Department of Environmental and Geographical Science

Small Scale Embedded Generation (SSEG) in Cape Town: A case study on the impact of Cape Town's SSEG by-law.

Dear Mr Dominic William Oliver

I am pleased to inform you that the Faculty of Science Research Ethics Committee has approved the above-named application for research ethics clearance, subject to the conditions listed below.

- Implement the measures described in your application to ensure that the process of your research is ethically sound; and
- Uphold ethical principles throughout all stages of the research, responding appropriately to unanticipated issues: please contact me if you need advice on ethical issues that arise.

Your approval code is: **FSREC 012 - 2020**

I wish you success in your research.

Yours sincerely

Dr Shari Daya
Chair: Faculty of Science Research Ethics Committee

Cc: Dr Jiska de Groot (Supervisor)

Annex 3. Consent form

Informed Voluntary Consent to Participate in Research Study

Small Scale Embedded Generation (SSEG) in Cape Town: A case study on the impact of Cape Town's SSEG by-law.

Invitation to participate, and benefits: You are invited to participate in a research study conducted with stakeholders in the Cape Town's solar industry. The study aim is to assess the impact of the City of Cape Town's SSEG by-law that came into effect in early 2019. I believe that your experience would be a valuable source of information, and hope that by participating you may gain useful knowledge.

Procedures: During this study, you will be asked to answer several questions.

Recording: We may record audio as part of the study. These will be used for the creation of transcripts in order to analyse repeated themes and include some direct statements within the research. If you object to this, please indicate below.

Risks: There are no potentially harmful risks related to your participation in this study.

Feedback: You will receive feedback about the results of this research in the form of an electronic copy of this thesis.

Disclaimer/Withdrawal: Your participation is completely voluntary; you may refuse to participate, and you may withdraw at any time without having to state a reason and without any prejudice or penalty against you. Should you choose to withdraw, the researcher commits not to use any of the information you have provided without your signed consent. Note that the researcher may also withdraw you from the study at any time.

Confidentiality: All information collected in this study will be kept private in that you will not be identified by name or by affiliation to an institution. Confidentiality and anonymity will be maintained as pseudonyms will be used.

What signing this form means: By signing this consent form, you agree to participate in this research study. The aim, procedures to be used, as well as the potential risks and benefits of your participation have been explained verbally to you in detail, using this form. Refusal to participate in or withdrawal from this study at any time will have no effect on you in any way. You are free to contact me, to ask questions or request further information, at any time during this research.

I agree to participate in this research (tick one box) ☐ Yes ☐ No _____ (Initials)
I would like my participation kept anonymous ☐ Yes ☐ No _____ (Initials)
I agree to be audio-recorded ☐ Yes ☐ No _____ (Initials)
I would like to be emailed a copy of the final thesis ☐ Yes ☐ No _____ (Initials)
I agree to the use of properly anonymized audio recordings/videos for the purpose of transcripts ☐ Yes ☐ No _____ (Initials)

_____	_____	_____
Name of Participant	Signature of Participant	Date
_____	_____	_____
Name of Researcher	Signature of Researcher	Date

Annex 4. SSEG requirements in the CoCT

ECSA certifications are required until SANS 10142-Parts 1,3 and 4 are completed, and accredited EG installation and commissioning technicians/electricians exist. SSEG installations must complete the "*General Application form for New or Modified Connection*", must conform to NRS 097-2 standards, must include inverters approved by the CoCT, and must include a full specification and wiring diagram (CoCT, 2010; CoCT, 2017c). Off-grid installations are not required to apply for authorisation but must complete a "*declaration of Off-grid Embedded Generation Form*", a certificate of compliance certifying physical separation from the grid, and a schematic diagram (CoCT, 2017c:15).

Annex 5. Credit meter changes for customers opting out of SSEG tariffs.

Customers with prepayment meters may “keep their existing meter and remain on the relevant electricity consumption tariff” (CoCT, 2017C:19). Customers with credit meters must replace meters with either a prepayment meter (capacity<100A) and remain on their existing tariff, or an AMI meter (capacity>100A) and be placed on a Small Power Users (SPU) tariff. This is designed to prevent meters from running backwards, “conventional credit and prepayment meters are never allowed to run backwards” (CoCT, 2017c:19).