ESSEX, S. & de GROOT, J. (accepted 2019) Understanding energy transitions: the changing versions of the modern infrastructure ideal and the 'energy underclass' in South Africa, 1860-2019, *Energy Policy*,

Understanding energy transitions: the changing versions of the modern infrastructure ideal and the 'energy underclass' in South Africa, 1860-2019

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Abstract

There is increasing recognition that the prospects of a post-networked city challenges the myth of the modernist ideal of a networked city and offers a more realistic proposition for energy transitions in the global south. This paper examines the energy transitions involved in the development of South Africa's versions of the modern infrastructural ideal for electricity provision since the nineteenth century. Four phases of South Africa's energy transition are identified, consisting of colonial, apartheid, post-apartheid and low-carbon phases. The paper argues that the agendas influencing the generation, distribution and consumption of electricity in South Africa are multiple and potentially conflicting, which are emblematic of the limitations of the modern infrastructure ideal, particularly in relation to the formation of an 'energy underclass'. Recognition and consideration of the potential uneven and differentiated spatial effects of energy transitions will continue to be integral to the planning and management of any transformations towards a post-networked city.

Highlights:

- Insights into how technological and urban models function within specific places
- Agendas influencing electricity in South Africa are multiple and conflicting
- Energy transitions create new uneven spatial effects within society.

Key words: energy transition; South Africa; apartheid; post-apartheid; renewable energy.

Acknowledgements: The authors would like to thank Professor Mark Brayshay, Dr Charlotte Lemanski, Dr Jon Phillips, Dr Lucy Baker and Dr Federico Caprotti for their constructive comments on a previous draft of this paper.

Funding: This work was supported by the Economic and Social Research Council / National Research Foundation Newton Fund *Urban Transformations in South Africa* scheme (ES/N014138/1 ‘Urban Transformation in South Africa through co-designing energy services provision pathways’ project, which is a collaborative project between the University of Cape Town, Sustainable Energy Africa, King’s College London, and the Universities of Exeter, Manchester, Sussex and Plymouth).

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1. Introduction

Human development is closely interlinked with energy and the relationships between people and energy have taken several forms over the centuries moving from traditional energy sources to modern fuels, and from fossil-fuel driven energy systems towards less polluting ones (Grubb, *et al.,* 2008). Ever since the first transition from traditional energy sources to modern energy sources, electricity has taken a central role in energy transitions. In the global north, standardised, centralised, homogeneous and near universal electricity networks were established to distribute energy, usually delivered by a monopolistic (and often state-led public utility) provider as a 'public good' in a period of industrial growth. These networks have become known as the modern infrastructure ideal (Furlong, 2014) and represent the modernist ideal of a networked city (Monstadt and Schramm, 2017, p.106; Lawhon, *et al.*, 2013).

Many countries in the global south have aspired and made progress towards this same modern infrastructural ideal in their efforts to supply the millions of urban citizens who lack access to affordable and reliable energy services. However, this conventional networked model has proved to be ill-suited to meeting the energy demands of cities in the global south. Rapid urban and population growth, often onto private land at the edge of cities, has highlighted the technical, financial and legal limits of an energy system based on a networked grid. The capacity of public utility institutions to extend the network is constrained by the skills of its workforce, regulatory legislation, institutional structures and inertia, as well as by issues of economic viability, where infrastructural investment requires at least some cost-recovery from its potential users. The outcomes from such a networked energy distribution system is often characterised by an unequal, unreliable and rationed service (Jaglin, 2014), with place-based creativity and pragmatism providing adaptation, appropriation, hybridisation and refusal of the ideal to meet the real energy needs and preferences of local residents (Monstadt and Schramm, 2017, p.121).

The emergence of post-networked or off-network cities, characterised by heterogeneous and informal infrastructural provision, such as small-scale embedded renewable energy generation, offer an alternative delivery model and a ‘pragmatic turn’ to improve access to essential services for the growing populations of cities in the global south (Jaglin, 2015). While alternative models of energy generation and distribution have been associated with meeting the basic living needs of the urban poor, there is an equally significant demand from the rise of the middle classes in the global south, who wish to secure a reliable energy supply from new technologies to meet their social aspirations and status. The emergence of a post-/heterogeneous networked city not only challenges the myth of the modernist ideal of a homogeneous networked city, but potentially offers a more realistic proposition for energy transitions in the global south. As noted by Jaglin (2015, p.189), the challenge is “… not so much to do with employing these technologies as with embedding them in appropriate and durable socio-technical systems”.

The local and international conditions within which these transitions are taking place are changing, especially given the urgency to tackle climate change and the emergence of alternatives to fossil fuels. While current energy systems have become unsustainable on social, economic and environmental criteria (Grubler, 2012), contemporary energy transitions have become intertwined with numerous competing agendas, which can create trade-offs between growth, equity and sustainability (Patel, 2006). The ability of emerging energy systems to generate sufficient power at a competitive price for economic growth while, at the same time, distribute it in an equitable and affordable way and develop clean energy sources to mitigate against climate change present considerable challenges, especially for countries in the global south.

These challenges are encapsulated in Cock's (2004) conceptual framework of environmental justice, which emphasises the relative importance of the 'red', 'brown' and 'green' agendas. First, the brown agenda refers to the role of energy in establishing the basics of quality of life, including livelihoods, public health, sanitation, well-being and poverty alleviation strategies (Freund, 2001; Khan, 2014). Second, the red agenda concerns itself with matters of social justice and equality of opportunity within the population and so focuses on the access and affordability of energy supply to all groups within society (Cock, 2004). Third, the green agenda of ecologically sustainable development focuses on ecosystem protection, mitigation of further degradation of natural resources, inter-generational equity and environmental justice from energy generation and distribution (Bolnick *et al.*, 2006). In the context of energy provision, these agendas translate into access to affordable energy services for the brown agenda, access that is just and equitable for the red agenda and the use of clean, environmentally benign energy for the green agenda. The achievement of all three agendas at the same time is challenging, especially given the potentially competing nature of some of the goals. For example, the production of cheap power for economic growth and/or universal access for all groups in society does not necessarily mean that the distribution will be affordable or clean. Environmentally benign energy might increase the prospect of limits on generation and/or higher costs, which might then limit access and/or affordability and constrain economic growth. Indeed, these relationships between these agendas might be made more complex in the countries of the global south, where historical legacies and influences have created ingrained cultural norms related, for example, to colonial rule, or the response to colonial rule. Some agendas might be privileged over others, with concomitant effects on the extent and character of the energy provision and groups that might be identified as the 'energy underclass'.

This paper examines the energy transitions involved in the development of South Africa's versions of the modern infrastructural ideal for electricity provision since the nineteenth century, with particular emphasis of the balance of the brown, red and green agendas within policy discourses. By adopting a historical perspective on energy transitions, it is possible to identify patterns, dynamics and drivers of past shifts which have relevance to contemporary policy formulation (Grubler, 2012, p.8). As the leading African economy, South Africa is seen as a 'front-runner' and model for the prospect of 'rolling out' the latest version of the modern infrastructural ideal for the rest of the continent. As a result of its apartheid legacies, access to power supplies is inequitable and deep-rooted, which is replicated in different guises in many other African countries. In post-apartheid South Africa, the country has adopted a pro-poor policy towards energy access and affordability, which has produced many benefits for its population, although much of this capacity is based on polluting fossil fuels. The country has signed up to obligations related to international climate change agreements, which has begun to develop its capacity in clean renewable energy. Despite these progressive developments, inequitable access to modern energy sources remains and the prospect of more decentralised renewable energy as part of the post-networked city has the potential to undermine the country's pro-poor principles. In order to clarify the form of future energy transitions, there is a need for a much better understanding of the ways in which energy systems were shaped in the past so that the origins and underlying causes of apparent contemporary obstacles and impediments can be identified. This paper contributes to the literature on energy transitions in that the analysis will help to better understand the emergence of South Africa's energy transitions in the past in becoming pro-poor, ecologically sustainable and equitably distributed. The discussion partly addresses Monstadt and Schramm's (2017, p.122) call for planning research and practice to address how technological and urban models function within specific places and infrastructural domains. In addition, by understanding the changing energy underclass, the needs of this large group of energy users might be better addressed.

Four broad, but distinct, chronological phases of energy provision in South Africa are presented and analysed, which form the basis and structure of the discussion: the limited spatial extent of the supply infrastructure in the colonial period (1860-1948); the highly segregated supply of the Apartheid period (1948-1994); the more equitable and pro-poor emphasis of the post-Apartheid era (1994-2011); and the so far unknown effects of a sustainable energy transition (2011-) (Table 1). Using Cock's (2004) conceptual framework of environmental justice, the relative importance of the 'red', 'brown' and 'green' agendas in each of these phases of the energy transition is analysed in relation to the inherent potential conflicts between the agendas and the effect on the extent of the 'energy underclass'. The paper argues that recognition of the potential uneven and differentiated urban spatial effects of a sustainable energy transition will continue to be integral to the planning and management of such transformations in South African cities. These have wider implications for energy in the African continent.

2. Phase I: The emergence of South Africa's electricity network in colonial South Africa (1860-1948)

The emergence of an electricity network in South Africa from the late nineteenth century was heavily influenced by two dominant political factors: the minerals-energy complex (MEC) and the apartheid regime. The MEC is a 'core set of industrial sectors which exhibit very strong linkages between each other and relatively weak linkages with other sectors' (Fine and Rustomjee, 1996, p. 91). The MEC in South Africa is dominated by minerals and mining companies (together with its associated institutions) and lies at the core of the South African economy. It is not merely a 'core set of industries and institutions but also a system of accumulation' (Fine and Rustomjee, 1996, p. 10). The need for cheap electricity, based on low-grade domestic coal reserves mined in Mpumalanga, Limpopo, Kwazulu-Natal and the Free State, was a driving principle for the foundation of the South African economy at this time.

At the end of the nineteenth century, private electricity generation companies, usually associated with the growth of diamond and gold mining across the country, established mining towns equipped with local electricity grids (Gentle, 2009). Some of these operators, such as the Victoria Falls and Transvaal Power Company, were substantial and powerful industrial players and formed the basis of the emerging MEC (Jaglin and Dubresson, 2016, p.10). Urban municipalities also began to generate their own electricity to light public spaces as part of their public duties, which subsequently stimulated demand for electrical supply in retail businesses and then residential properties within (or in close proximity to) town and city centres. However, after the formation of the Union of South Africa in 1910, the creation of an integrated system of electricity generation and transmission regulated by government to supply cheap power for mining, manufacturing and the railways became a priority (Gentle, 2009, p.56), and was arguably a fundamental and symbolic component of the country's 'nation building' by consolidating Afrikaner politico-economic power over British interests (Jaglin and Dubresson, 2016, p. 11).

By the 1920s, the Afrikaner government seized control of the electricity sector to promote its political and economic vision. The production of a stable, plentiful and cheap supply of electricity was required to facilitate state capitalism by the expansion of the MEC and the development of manufacturing (Jaglin and Dubresson, 2016, p.9-11). The mining sector, in particular, required cheap power to offset the increasing costs of exploiting more inaccessible and lower quality deposits. The same principle applied to the creation of cheap labour for the mining sector in the form of the compound labour system, which later became intrinsically associated with racial segregation and apartheid in the interests of wealth creation for the white population (Gentle, 2009, p.53). Thus, the nationalisation of electricity and urban segregation became essential features of the state's development strategy, which were to define the 'energy underclass' in the apartheid period.

The generation of electricity was nationalised in the Electricity Act No. 42 of 1922. The Electricity Supply Commission (Escom, or in Afrikaans, Elektrisiteitsvoorsieningskommissie, Evhom) was formed on 6 March, 1923, which subordinated supplies to one Electricity Control Board and compelled all electricity users to obtain their supplies through this Board (Christie, 1984). The creation of Escom signified the formation of the South African national grid. According to Jaglin and Dubresson (2016, p.14), through the creation of Escom and the national grid, the government had acquired "…an instrument of control essential to the fulfilment of a political regime that has been described by some as racial Keynesian capitalism …, by others as racial Fordism". Escom's capability to produce cheap electricity from coal was facilitated by a level of autonomy that protected it from shifts in the ruling party, and by an unerring faith and legitimacy based in the technical and professional competence of its engineers. Escom could therefore implement the network with minimal political intervention, which enabled the task to be an exercise based on its technical competence rather than on political negotiation. Jaglin and Dubresson (2016, p.16) use the term 'controlled technopolitics' to describe "the deliberate use of knowledge and technical choices to promote a socio-political vision aligned with that of government". While municipalities continued to generate some electricity, it was controlled centrally by Escom tied to the political regime of apartheid. Despite changing political, socio-economic and environmental agendas indicated in the following phases, the reputation of Escom based on its technical prowess remained strong until the 2000s.

The energy underclass during this first phase consisted of the majority of the population, as electricity was only provided in a few pockets across the country. The MEC shaped an energy system to service mining and industrial activities, and most South African households were unelectrified. The energy underclass, therefore, consisted of the majority of South Africa's population as only mining towns and a few privileged households benefited from electricity. During this period, the green, brown and red agendas had no relevance to energy planning and decision-making.

3. Phase II - Electricity under Apartheid, 1948-1994

With the election of the National Party in 1948, the apartheid regime was introduced, which created segregation, spatial inequality, exclusion and marginalisation in order to create cheap pools of labour to facilitate industrial growth (Beall, *et al.*, 2000). There were two pieces of legislation that defined the Grand Apartheid period (1950-1994). First, the Population Registration Act of 1950 formalised a racial classification of four groups (whites, coloureds, Asians and Natives) and the introduction of identity cards. Second, the Group Areas Act of 1950 defined the racial composition of every residential area and required forced removals for anyone who did not comply (Field, 2001). During the apartheid era, neighbourhoods were designated with specific 'Black, Indian and Coloured' designations (Turok, 2014; Crankshaw *et al.*, 2000; Lemanski, 2009). These areas were located at the urban periphery in so called 'townships' or, for rural areas, 'homelands'. Furthermore, these settlements were poorly or not serviced by the municipalities. Due to the exclusionary apartheid policies, less than a third of self-built housing and informal settlements in townships had electricity connections (Beall *et al.*, 2000; Louw *et al*., 2008; Lloyd *et al*., 2004). As a result, most South Africans were forced to rely on polluting and inefficient fuels to meet their energy needs.

Apartheid's political regime created a rather distorted version of the modern infrastructural ideal, whereby 'universal' electricity was supplied to white areas only. A very large, racially determined, energy underclass, which consisted of the majority of the non-white population, did not have access to modern energy. Electricity itself had become "…an instrument of discrimination, employed in the complex task of managing the relations between the government and human groups ordered into 'races' and assigned unequal statuses and rights" (Jaglin and Dubresson, 2016, p.17). As a consequence, these circumstances were the antithesis of the brown or red agendas. Similarly, the green agenda did not emerge until the end of the Apartheid era, when concern about the environmental impacts of energy systems began to be raised (Van Horen *et al.*, 1993). The legacy of this politicised system of service provision is that, despite the end of apartheid, it continues to influence the way in which urban spaces and energy infrastructure are shaped today.

4. Phase III: Electricity in the Post-apartheid era, 1994-2011

With the end of Apartheid in 1994, the African National Congress's (ANC) Reconstruction and Development Programme focused on rebuilding the country's economy, while bridging the gap between the rich and the poor (Mohlakoana, 2014). Electricity was central to this vision, because it was perceived as a convenient, modern fuel able to reduce indoor air pollution and related negative health impacts (from open fires and paraffin) as well as fire risks. Moreover, electricity supply was seen as key to the creation of business opportunities and creating a better life for its citizens. The heavy focus on South Africa’s post-apartheid government on equality and redress resulted in the pursuing of a very strong brown and red agenda in its energy policy and planning, with the green agenda remaining largely absent.

The advent of a constitutional democracy in South Africa at the end of apartheid brought a shift in the responsibilities of municipalities. Municipalities became an independent tier of government with autonomous powers, subject to constitutional constraint, which was now seen as having an important social inclusion and development role for communities. In particular, municipalities became responsible for the distribution or reticulation of electricity to the majority of their populations in a sustainable manner (Mosdell, 2016). To illustrate, Eskom generates 96 per cent of the country’s electricity and continued to distribute about 60 per cent, mainly to rural areas (including the former Homelands) and some parts of cities. The remaining 40 per cent of electricity is distributed by the municipalities. Municipalities purchase their electricity from Eskom, but reap significant profits from on-selling. The distribution of electricity plays an important role in maintaining the viability of municipalities and their public services, especially pro-poor energy schemes.

After 1994, the modern infrastructural ideal was extended to all population groups through an ambitious electrification programme by Eskom, working with municipalities and the Department of Energy. A target to connect 2.5m households by 2000 was set and achieved (Mohlakoana, 2014, p.29). Between 1991 and 2005, about 4.9 million households were provided with an electricity supply, with 3.2 million connected by Eskom and 1.7 million connected by local government (Greenberg, 2009, p.89). In 1996, 58.2 per cent of households in South Africa had access to electricity for lighting. By 2011, this figure had risen to 85 per cent, which was considered internationally as a remarkable achievement (Table 2).

A key factor for Eskom in extending the electricity supply to all households, and so move towards a modern infrastructural ideal for all, was the introduction of pre-payment meters. While metering has been linked to the perpetuation of inequalities based on the ability to pay and for introducing strains on households to limit consumption and expenditure on electricity (Makonese *et al.,* 2012), the technology did provide the means by which Eskom and municipalities could recover the costs of universal access to electricity in areas where the billing of households without addresses was virtually impossible (McDonald, 2009; van Heusden, 2009). The introduction of pre-payment meters by Eskom has also allowed households, especially in townships and rural areas, to manage their energy consumption and bills more effectively. Under the New Household Electrification Strategy (2013), universal provision is now set to be achieved by 2030, although with population growth and the continued expansion of informal settlements, this target is a moving one.

The increase in the use of electricity within the population after 1994 was substantial (Table 2). In terms of energy for lighting, electricity use rose from 57.6 per cent in 1996 to 69.7 per cent in 2001 and 84.7 per cent in 2011. Electricity use for heating increased from 44.5 per cent in 1996 to 58.8 per cent in 2011, while electricity for cooking grew from 47.1 per cent in 1996 to 73.9 per cent in 2011. Although natural gas use also increased marginally, all other energy forms declined absolutely and proportionally despite substantial increases in population numbers from inward migration. Nevertheless, there remain 3.4 million households without electricity. In the urban context, the populations in this situation are mostly those in informal settlements as their informal status inhibits them from electrification. National policy and planning guidelines for the electrification of unproclaimed areas stipulate that informal dwellings located on private, unstable land, within zones prohibited for development (such as flood plains and road or rail reserves) cannot be electrified. These households have either illegal connections or remain unelectrified. Huber (2015, p. 4) warns that “electricity networks not only reflect the uneven geographies of cities but actively reproduce them”.

More significantly, there are many low-income households with connections whose supply was either interrupted or not affordable. As a consequence of people’s inability to access or afford electricity, people remain reliant on other, often ‘dirty’ fuels for some of their energy needs, usually for heating and/or cooking applications. Thus, the energy underclass is no longer defined as those without electricity connections, but now has expanded to include those who cannot afford to use this energy source. The energy expenditure burden for a poor household can be as much as 18 per cent of their household income (Winkler *et al.*, 2011), compared to the 10 per cent norm set by the National Department of Energy (Kohler *et al.*, 2009).

While connections to the electricity network have been impressive, the ability of Eskom[1] to generate sufficient energy to meet these growing demands has been undermined by the government's indecision over whether to privatise fully the sector (Jaglin and Dubresson, 2016, p.36-37). The post-apartheid political regime heralded a desire to extend market principles to former agencies, commissions or public enterprises and so change the state's role in the nation's system of accumulation and the MEC (Jaglin and Dubresson, 2016, p.21-22). So as to create appropriate conditions for privatisation/ neoliberalisation, the government introduced a moratorium on investment by Eskom in new generating capacity over the period 2001-2004. The attempt to restructure the electricity distribution sector with the creation of six state-owned regional electricity distributors (REDs) failed in 2006 because the reform had not given sufficient to the impact on the revenue streams of the municipalities (Jaglin, 2013; Swilling, 2014; Palmer, *et al.*, 2017). The consequence of the moratorium was that, combined with an inadequate reserve margin during unscheduled maintenance operations, electricity generation by Eskom failed to keep pace with demand, which led to two outcomes.

First, in circumstances were demand exceeds supply, the electricity grid can become unbalanced and trigger a complete black-out across the country that can take days to resolve. In order to mitigate against these occurrences, the practice of load-shedding was adopted by Eskom in 2008, whereby defined areas experience outages of power for a specified period in order to maintain the stability of the

[1] Escom had become Eskom following the Electricity Act and Eskom Act of 1987. The main change introduced by this legislation was that, while remaining a commission, it was made responsible for its profits and losses. As a result, new investment was more carefully considered and its number of employees was reduced. Eskom itself became a public company (Eskom Holdings Limited) under the Eskom Conversion Act of 2001 (Baker, 2016) and had to comply with South African commercial law. It became a commercial state-owned enterprise (SOE).

system. However, the practice of load-shedding over the period 2008-2015 caused substantial reputational damage to Eskom. The shortages of supply have only been eased by a reduction in demand related to a decline in economic output and the effect of energy conservation measures.

The second outcome of delayed investment in generation capacity was that, in order to finance new coal and nuclear power stations, significant price increases were experienced by customers. In Cape Town, for example, the price increases for electricity since 2006-07 have been in the range of 4.9 to 34.6 per cent., while the consumer price index has been in the range of 4.6 to 6.6 per cent (Table 3). As a result, it has been the low-income groups who have experienced the greatest rise in spending on electricity as a proportion of household income. These price increases have been absorbed more easily within high-income groups. While physical access to electricity might have improved, there are other factors, particularly ability to pay and affordability, that are now having a far more important influence on evaluations of the success of the electrification programme and definitions of the 'energy underclass'.

Alongside the electrification programme, the post-Apartheid regime introduced a range of energy-related pro-poor policies, where the disadvantaged are identified intentionally and offered access to a basic or minimum level of free service. Both the municipalities and Eskom have a role to operate these schemes, although Eskom appeared less willing to implement this support. The centrepiece of creating universal access to modern energy services is the Free Basic Electricity Tariff of 50 KWh per month (if using less than 450 KWh per month) introduced in 2000

(Mohlakoana, 2014). The scheme is partly funded by the Local Government Equitable Share Grant from the National Treasury and, in cases of shortfalls, partly by surpluses generated by the municipalities' sale of electricity (including for Eskom service areas within urban centres, who refuse to provide these pro-poor subsidies). In 2007, this support was extended to subsidise alternative energy services to households not connected to the national electricity grid through the Free Basic Alternative Energy in Rural Areas scheme, although not all municipalities have been able to implement the policy. The electricity consumption by the poor is also subsidised through an 'Inclining Block Tariff System' (IBTS), introduced in 2010, whereby charges increase with consumption. This system enables users with higher consumption rates to be charged at a higher rate and so facilitates cross-subsidisation of the low-income groups charged at the lower rates. The higher charges for high consumption are also intended to promote energy conservation.

These initiatives are, however, only a partial remedy in the task of resolving energy poverty. Many 'indigent' households, although eligible for FBE, have limited benefit from the policy as, in many cases, the 50 kWh per month subsidies do not benefit the poorest households (Franks and Prasad, 2014; Wolpe and Reddy, 2010). Free electricity up to 50 KWh per month provides only a small part of the energy needs of households and is often associated with a limited supply capacity (Bekker *et al.*, 2008, p.3132). While the scheme is promoted as being sufficient for basic lighting, television, radio, ironing and cooking needs, in reality, it is only enough to run household lighting (Ruiters, 2009, p.252). Ruiters (2009, p.260) argues that the FBE is pegged at a level that is too low and frugal to uplift the poor. It pressurises the poor to economise and, in doing so, acts to complicate everyday life. The ability to pay ultimately restricts the use of electricity and causes the sustained use of ‘dirty’ and hazardous fuels.

The high occurrence of informality also constrains many households from accessing FBE. Although some informal settlements have access to electricity, many do not, as municipalities are reluctant to sanction infrastructure on land which is not zoned for settlement within the city’s long-term spatial planning framework. Where electricity has been provided, an increase in the erection of illegal shacks in the backyards of formal houses in informal settlements has had implications for the distribution of FBE. Owners sell electricity to their tenants on an illegal basis and, consequently, many South Africans also lose their entitlement to 50 KWh of free electricity per month because their household’s meter is used by more than one household. Some meter owners sell their electricity to other users at a higher rate as a private money-making venture, which can lead to a trebling of the cost of electricity for the purchasers (often ‘back-yard shack’ dwellers). Less common, but also reported, is that some households lose their formal subsidy through meter tampering and theft. Each meter can be connected to three additional users via the extra sockets on the box, which can then have the effect of taking the consumption for that meter above the minimum level and, in some cases, into the higher tariffs designed for the high consumption customers. Calculations by Franks (2014) illustrated that four households using 150 kWh per month would pay R212 per household on a shared meter, rather than R78 if each had been charged on a separate meter. The scheme can also be accessed by high income consumers with low energy consumption.

The IBTS has similar recognised limitations. Indeed, only 30 per cent of municipalities have adopted this system and many municipalities have not been convinced of the benefits to the poor (PDG, 2013). Where multiple poor households were using a single meter, which is often the case in townships, the combined consumption moved the charges into the more expensive tariffs. Very small differences in the bills charged by municipalities applying the IBTS and those that were not were demonstrated (Table 4). Such marginal benefits had been achieved at substantial cost and effort, together with considerable confusion to customers (PDG, 2013).

While significant progress has been achieved towards universal access to electricity supplies in urban South Africa during the post-apartheid period, the number of connections fails to convey a complete picture of the situation. Arguably, the ‘energy underclass’ is now composed of two groups. First, those who do not have physical access to the electricity network, which comprise 15 per cent of the population or 3.5 million households in 2011, predominantly located in rural and informal areas. Second, there are households who have access to the network, but do not utilise the energy source because of cost or some other reason or set of circumstances. This second group might be more accurately described as the ‘energy vulnerable’, who experience socially and materially inadequate levels of domestic energy services because of a combination of socio-technical factors, such as income, prices, energy efficiency, the structural fabric of the building, tenure and legal constraints, and variations in infrastructure (Bouzarovski and Petrova, 2015). Such measures are not reflected in official energy data sources and highlights the need for more qualitative research into the experiential dimensions of energy use in urban South Africa to provide firmer evidence for potential policy reform.

5. Phase IV: Climate Change and renewable energy, 2011-present

The emergence of the green agenda has the potential to introduce new processes and implications for the delivery of the brown and red agendas noted in the previous section, and so, once again, redefine the energy underclass. It could be also argued that some of the legacies of apartheid and the failure to resolve inequalities will make the achievement of green objectives much harder. As the 'lion's share' of the country's electricity is generated from cheap and dirty coal, its carbon emissions are high. South Africa is the 12th highest emitter of greenhouse gases in the world (SEA, 2015) and has been a signatory to international agreements to reduce emissions, such as the Kyoto Protocol (2002) and the targets set by the Copenhagen Climate Change Conference (2009). Carbon dioxide emissions are to be reduced by 34 per cent by 2020 and by 43 per cent by 2025. South Africa's Integrated Resource Plan (Department of Energy, 2011) set to increase the national electricity generation capacity from 41,000 MW to 89,532 MW by 2030, and which incorporated 23,559 MW of grid-connected renewable energy (comprised 9,200 MW wind, 8,400 MW photovoltaics and 1,200 MW solar power) (Lombard and Ferreira, 2015; Baker, 2016). The South African government's support of renewable energy was, ironically, partly triggered by the load-shedding experienced since 2008, as well as external pressure about climate change from the international community.

While the mix of renewable energy was projected to increase in this plan, so too was the new generation from coal-fired power stations, indicating that a genuine energy transition is far from becoming a reality. The legitimising discourse based on the crisis of supply had been used simultaneously for the introduction of renewable energy as well as new coal-fired and nuclear power stations to meet existing demand (Baker, 2016). As Lombard and Ferreira (2015) suggest, despite the transformative potential of the IRP, it leaves Eskom's business model unchallenged and might merely perpetuate high-carbon lock-in. The analysis of the Climate Action Tracker rates South Africa's progress towards achieving carbon emissions reductions as 'insufficient'. The rating further indicates that South Africa's commitment is not consistent with a 'fair' approach to holding warming below 2°C, let alone with the Paris Agreement's more stringent 1.5°C limit (Climate Action Tracker, 2017). Nevertheless, the generation of energy from coal and nuclear power stations is needed to meet the immediate demand requirements to fulfil the brown and red agendas. It also illustrates the capacity constraints of renewable energy under the green agenda to service the demands of the brown and red agendas.

There are two types of renewable energy generation in South Africa, which have the potential to create a post-networked electricity supply. First, there are the large-scale wind farms and solar arrays, which feed directly into the grid. In August, 2011, the South African government introduced the Renewable Energy Independent Producers Procurement Programme (RE IPPP), where independent power producers were invited to tender for licences to sell electricity to the Eskom grid under a 20-year purchase agreement. The bids were evaluated on the basis of price (70 per cent) and economic development potential (namely job creation, participation of disadvantaged populations, local environmental protection, rural development, community ownership and skills development: 30 per cent). By the end of the fourth bid window in 2016, a total of 6,326 MW of procured renewable energy capacity had been created (Mushwana, *et al.*, 2016, p.20).

In addition to the amount of renewable energy generated from such projects, the scheme's assessment of economic development potential as part of the bids are likely to produce positive effects in terms of employment opportunities and community ownership for those hosting the development locally (Tait, *et al.*, 2013; Baker and Wlokas, 2015). The high quality regulatory framework and tough qualification criteria of this scheme has been praised internationally, although it proved complex and expensive for investors/developers, with high compliance costs (Baker and Wlokas, 2015, p.24). Most striking about the scheme is its community benefit requirements, which stipulates quantitative targets for socio-economic development, as well as a community shareholding threshold in new enterprises. This component of the scheme has resulted in the availability of around 11.5 billion Rand for community development[2] (Wlokas, 2014). As communities eligible for support under this scheme are those within a 50 km radius of a project, geographically, these legacies will be clustered in areas of wind, solar, hydro or biomass capacity, which are usually located at some distance from urban centres. The current pattern of urbanisation does not match the geography of large-scale renewable energy resources. Communities in areas rich in renewable resources might be eligible for funding from multiple renewable energy projects, which can create problems of ensuring that the available development spend is in proportion to the scale of the community (Tait, *et al.*, 2013, p.20). When the outcomes of the

[2] The value of 11.5 billion Rand was equivalent to approximately US$1.5 billion (based on exchange rates on 25 August, 2011, exchangerates.org.uk).

scheme become clearer over time, the fair distribution of the community benefits from such projects (ie the red agenda) are important issues to be investigated alongside the impacts on the green and brown agendas.

The second type of renewable energy generation are small scale embedded generation schemes, where the electricity generated is used solely on site (Baker and Phillips, 2018). It is this second type that has the potential to resolve, accentuate or create new inequalities in a post-networked city. Renewable energy offers a form of decentralised generation, which, at least theoretically, is well suited to the sprawling and informal nature of much of the urbanisation in South Africa. International donor funded schemes for the generation of renewable energy in informal areas have had small-scale impact. Renewable energy technologies have the potential to generate electrical power for the remaining 3.4 m households, mainly in informal settlements, which are not on the grid. There are, nevertheless, considerable limitations to this prospect. Building structures in informal settlements, which are often no more than shacks, do not necessarily have the space or are capable of bearing the weight of a solar panel of sufficient size to generate a worthwhile amount of electricity. Solar Home Systems, for example, consist of a compact solar panel which can be installed on the roof, but is only sufficient to power a light, television and heater for a few hours per day. Larger panels can also be mounted on poles, but these are also then subject to the risk of theft and wind damage.

Ultimately, however, the introduction of such systems, and the realisation of associated benefits, depends on the ability of households to pay for the technology and its installation and maintenance. While middle to high income groups and businesses might have the resources to afford such an investment to improve their access to power, low income and poor groups do not necessarily have the same options. The perpetuation of an ‘energy underclass’ appears to be a real likelihood from the sustainable energy transition (Bickerstaff, *et al.*, 2013, p.5).

There are also other potential implications for the poor of small-scale embedded generation related to the electricity distribution model operating in South Africa. As the municipalities’ pro-poor policies are partly funded by the profits made from the distribution of electricity, the adoption of small-scale embedded renewable energy generation by high-consumption consumers would undermine this funding model. Two significant effects might be created. First, the loss of revenue from reduced sales of electricity to high-consumption users would affect the ability of municipalities to cross-subsidise the tariffs of the existing poor consumers. Ultimately, these pressures might lead to a reduction in minimum service levels. The ability of local government to contribute to the brown and red agendas would be affected detrimentally, even if the green agenda is progressed. This ‘hidden funding gap’ is likely to affect the ability of municipalities to continue current practices without considerable restructuring of the organisations and/or redefinition of service levels. Second, it would question the financial sustainability of further extending the electrification programme for those populations still not connected to the grid, including the growing number of new in-migrant households forming in informal settlements. Both effects would undermine the welfare goal to reduce inequalities in society.

6. Discussion

The aim of this paper was to examine the development of South Africa's versions of the modern infrastructural ideal and energy transition for electricity provision since 1860, together with the changing balance of the brown, red and green agendas and the associated effects on the 'energy underclass' in urban South Africa. The results presented above show that the agendas are in conflict in certain configurations and that the composition and definition of the energy underclass has changed with each transition.

In the first phase of electrification, during the emergence of the electricity system that fed the MEC, all but a few of the population comprised the energy underclass. Energy was predominantly supplied in cities and towns with mining operations and industry. No green, brown or red agendas were pursued at this time. Under apartheid, the second phase of electrification identified in this paper, a rather distorted version of the modern infrastructural ideal formed, whereby 'universal' electricity was supplied to white areas only and the energy underclass of non-whites were defined by a disconnection from the centralised network influenced by systems from the global north. The apartheid period was characterised by the provision of electricity to the white population only, with the energy underclass clearly defined as the non-white population. As with the first phase of electrification, none of the agendas applied during this period.

The post-apartheid era, which constituted the third phase of electrification, has positioned universal access to electricity as a central element of the creation of a more equitable and democratic society, encompassing the brown and red agendas.

This policy goal has been implemented through two main mechanisms: first, by the roll-out of an extensive distribution grid by the national electricity generator, Eskom, with municipalities; and second, by the implementation of pro-poor policies by a 'developmental' local government to ensure that electrical energy is affordable to the population. The extent to which these initiatives have been successful is debateable and many studies have shown that there is a considerable energy underclass that cannot access or afford to use electricity for their cooking, lighting and heating needs. Instead, they rely on multiple sources of energy, including 'dirty' fuels which are harmful to human health (Musango, 2014; Knox *et al*., 2017). In these circumstances, the energy underclass is defined by their inability to pay for energy use and remains predominantly black in composition, especially as the cost of electricity rises to fund new generation capacity.

Phase four is being dominated by the emergence of the green agenda to national policy in the form of a low carbon transition and, through new technologies, the prospect of a post-networked electricity supply. Since 2008, this agenda has introduced new dynamics and implications for universal electricity distribution and the affordability of those services. Most notably, the emergence of the green agenda has affected the ability to deliver the goals of the red and brown agendas. The generation of renewable energy has the potential to reduce the ability of municipalities to cross-subsidise the tariffs of the existing poor consumers as well as fund capital expenditure to extend the grid. Furthermore, while decentralised forms of renewable energy have the potential to reach populations that are presently not serviced by the electricity grid, the technology might also diminish the ability of municipalities to cross-subsidise their pro-poor policies because of the loss of high-consumption consumers to embedded generation (SEA, 2014; Carter, 2015). Low income and poor groups do not have the resources to benefit from this new technology. In these circumstances, the energy underclass is likely to be redefined once more, but in ways that are not possible to specify with any precision at this point in time. The emergence of a new pathway based, however loosely, on renewable energy and more decentralised forms of generation and distribution of the post-networked city is not, therefore, an ideologically or spatially neutral project.

7. Conclusion and policy implications

While the transferability of urban models and the limitations of anticipating future energy demands and uses should be recognised (Shove and Walker, 2014), this discussion has raised a number of policy implications, which have relevance to both the South African context and the wider international community. First, the need for a more integrative approach to energy policy in South Africa has been demonstrated. What is clear from this essentially historical review is that the agendas influencing the generation, distribution and consumption of electricity in South Africa are multiple and deeply conflicted. While there is scope for some positive synergies between the agendas, the achievement of the green energy targets are unlikely because of the legacy of profound energy inequality that has not been addressed to a sufficient extent. It is perhaps necessary to have advanced considerably further with the brown and red agendas before anything meaningful can done about the green agenda. A focus on the interconnections between the brown, red and green agendas might lead to a more integrated approach, where the agendas are better aligned and would enhance the delivery of electricity services to the benefit of all citizens in South Africa, whilst mitigating the effects of climate change.

As each new agenda has been emerged over time, no fundamental reorganisation of the system has taken place, which has allowed established vested interests to hinder progressive change. The apparent lack of political will to reform Eskom has been cited as a real challenge to energy transitions (McDaid, 2009). A more integrative approach to both the management of energy systems and the formulation of policy across multiple levels of governance, including at municipal and national levels as well as between public and private entities, appears to be needed. In particular, integration between the green and brown agendas is at present severely lacking. For example, although the FBE policy has a clear potential to provide a bridge between pro-poor energy provision and decarbonisation of the energy supply (for example, by supplying decentralised energy systems to indigent households), the two remain largely separate in official energy governance spheres. A fundamental component of achieving this integration therefore lies in the establishment of appropriate governance structures in the energy sector.

Second, it is clear that the modern infrastructure ideal of the networked city has shaped energy systems in the global north may not be the most appropriate way to achieve access to clean, affordable and equitable access to modern energy in the global south. Local and international conditions shape national and sub-national energy and development policies as well as the configuration of local and national electricity systems, which then influence the delivery of the brown, green and red agendas in a particular locality. The recognition that a centralised energy grid may not be appropriate to local circumstances has significant policy implications for South Africa and countries that are facing similar energy access and poverty issues within their transition to low-carbon societies. The importance of understanding the local context is therefore fundamental to the effective transferability of the models of a centralised grid (which might be suited to urban areas), a mini-grid (for remote areas with relatively high population density), decentralised generation (for stand-alone systems in remote areas or informal areas), and/or any combination thereof.

Other African nations often look to South Africa, as the region's most advanced economy and energy system, for guidance on energy-related issues. However, the high costs of grid-electrification create a situation where the majority of Africans remain without adequate access to energy, and both energy access targets and climate change commitments remain unfulfilled. South Africa's REIPPP model, which is hailed as an international model of renewable energy procurement, is often copied uncritically by other countries, but might replicate some of South Africa's problems in other geographical areas. Furthermore, by understanding the electrification of South Africa, other nations may be able to 'leap-frog' any issues experienced. For example, other African countries could implement and adapt those policies that are likely to be transferable to the new policy context, whilst mitigating for the known side effects of interventions in local circumstances.

Third, international energy policy must recognise that, whatever the causes and local variations, the potential uneven and differentiated urban spatial effects of a sustainable energy transition will be integral to the planning and management of such transformations. It is clear that measures of energy poverty defined by connection (or not) to the electricity network are no longer adequate in defining the 'energy underclass'. A range of circumstances and factors affecting a household's ability to secure adequate energy services are now recognised in terms of energy poverty and ‘energy vulnerability’ (Bouzarovski and Petrova, 2015), which are not always captured in official data sources. There is a need for research into the energy vulnerability of the urban poor and the experiential dimensions of energy use to better frame policy interventions.

Fourth, the potential threat to the budgets of the municipalities’ pro-poor energy initiatives from small-scale embedded generation from renewable energy requires an alternative funding model so that brown, red and green agendas can advance. One proposal is for the introduction of standing charges for households with a SSEG to cover the cost of maintenance of connections to compensate for the reduced income from the lower consumption of energy. Another option might be to fully fund pro-poor energy policies by the national exchequer rather than as a system partly dependent on surpluses from the sale of electricity by municipalities in each local area.

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Table 1. Inter-relationships between the political, technological and institutional dynamics of electricity generation and distribution in South Africa, 1950-2019

Period	Political	Technological	Institutional
1860-1948	Emergence of national industrial strategy based on MEC dependent upon cheap electricity and labour.	Generation of electricity from cheap coal and hydro sources. Limited distribution capacity	**Private companies** generated power for mining operations. **Municipalities** generated own power for public spaces in town and city centres, which later extended to businesses and residential areas. Creation of **Eskom** in 1926 to pool and distribute low cost electricity.
1948-1994	Apartheid era: overt forms of racial segregation and exclusion created highly segregated urban forms (well-serviced white areas were geographically separated from poorly serviced black townships).	Plentiful supply of electricity from cheap coal (and later nuclear power).	**Eskom**: effective in generating cheap and plentiful electricity as a central feature of the industrialisation of the country within the 'Minerals-Energy Complex'. **Local government**: Many urban municipalities generated and distributed their own electricity to white areas only. Bantustans/homelands for black populations and elected councils for black townships (after 1982) had limited 'parastatal' electricity providers.
1994-2011	Post-apartheid: pro-poor policies to reduce inequalities in society.	Plentiful supply of electricity from cheap coal and nuclear power until 2007. Then shortages in the generation capacity requiring load-shedding.	**Eskom**: Retained distribution of electricity to rural areas and some parts of cities, and merged with Homeland electricity parastatals. Failed government attempts to privatise the sector resulted in a lack of investment in generation capacity, 1998-2004, creating the load-shedding crisis, 2008-2015. **Local government**: Municipalities given a 'developmental' role in the new Constitution, including the distribution or reticulation of electricity

			in urban areas with cross-subsidisation of poor populations, especially in townships. Municipalities in urban areas were able to build on their existing functions and competencies from the apartheid era, while townships, rural and homeland areas had to build from a low or non-existent base.
2011-	Climate change agenda and renewable energy. Government pledges to reduce carbon emissions by 34 per cent by 2020 and 42 per cent by 2025 (Copenhagen Climate Change Conference, 2009).	Shortages in generation capacity encouraged investment in two new coal-burning power stations and nuclear power as well as renewable energy, especially wind and solar.	**Eskom**: After 2004, the ban on Eskom investing in new generation capacity was lifted, but then suffered from a lack of expertise and mismanagement of the development of that new capacity, 2010-. The rising cost of new investment required increases in the cost of electricity to consumers. In the Integrated Resource Plan of 2010, the Government encouraged independent power producers for the generation of renewable energy. **Local government**: Some municipalities formulate climate change strategies as an additional duty alongside its pro-poor obligations. The effect of small-scale embedded renewable energy as a form of decentralised generation is recognised as a potential threat to the financial viability of pro-poor subsidised energy provision.

Table 2. Use of energy Services for households in South Africa, 1996-2011

Energy/fuel for Lighting

Census Year	1996	%	2001	%	2011	%
Electricity	5220825	57.63	7815270	69.74	12242401	84.72
Gas	35512	0.39	27065	0.24	34347	0.24
Paraffin	1144014	12.63	759817	6.78	426205	2.95
Candles	2583031	28.51	2545532	22.72	1649082	11.41
Solar	0	0.00	24175	0.22	51505	0.36
Other	800	0.01	33845	0.30	0	0.00
None	0	0.00	0	0.00	46621	0.32
Unspecified	75389	0.83	0	0.00	0	0.00
Total	9059571	100	11205705	100.00	14450161	100.00

Energy/fuel for Heating

Census Year	1996	%	2001	%	2011	%
Electricity	4030850	44.49	5493021	49.02	8503109	58.84
Gas	107689	1.19	124982	1.12	357062	2.47
Paraffin	1294964	14.29	1641458	14.65	1230223	8.51
Wood	2417724	26.69	2758861	24.62	2203384	15.25
Coal	735632	8.12	734455	6.55	293949	2.03
Animal dung	84447	0.93	83058	0.74	48251	0.33
Solar	0	0.00	23509	0.21	38370	0.27
Other	5828	0.06	346361	3.09	2442	0.02
None	0	0.00	0	0.00	1773372	12.27
Unspecified	382438	4.22	0	0.00	0	0.00
Total	9059571	100.00	11205705	100.00	14450161	100.00

Energy/fuel for Cooking

Census Year	1996	%	2001	%	2011	%
Electricity	4265306	47.08	5761354	51.41	10675094	73.88
Gas	286657	3.16	284295	2.54	507616	3.51
Paraffin	1943862	21.46	2394919	21.37	1227337	8.49
Wood	2073219	22.88	2292674	20.46	1807606	12.51
Coal	320830	3.54	310059	2.77	104171	0.72
Animal dung	106068	1.17	110969	0.99	45349	0.31
Solar	0	0.00	24225	0.22	22255	0.15
Other	987	0.01	27210	0.24	29344	0.20
None	0	0.00	0	0.00	31390	0.22
Unspecified	62641	0.69	0	0.00	0	0.00
Total	9059571	100.00	11205705	100.00	14450161	100.00

SOURCE: StatsSA SuperWeb2

Table 3. Average percentage increases in City of Cape Town and Eskom electricity prices relative to increases in consumer price index (as published in Eskom tariff history document)

Year	City	Eskom	CPI
2006-07	4.9	5.1	4.6
2007-08	5.6	5.9	5.2
2008-09	34.6	27.5	6.6
2009-10	33.4	31.3	6.16
2010-11	24.6	24.8	5.4
2011-12	19.9	25.8	4.5
2012-13	11.0	16.0	5.7
2013-14	7.9	8.0	6.0

SOURCE: City of Cape Town (2015, p.85).

Table 4. Effect of IBTS on household charges

Households	Effect of IBTS on charges
Low income households (R1600 income per month using 200KWh per month)	R2 lower
Middle income households (R12800 income per month using 500KWh per month)	R90 lower
High income households (R51200 income per month using 1000 KWh per month)	R5 higher

SOURCE: PDG (2013)