Estimating greenhouse gas emissions associated with achieving universal access to electricity for all households in South Africa

Louise Tait

Harald Winkler
Energy Research Centre, University of Cape Town

Abstract
Climate change, energy security and achieving universal electricity access for all households are all pressing issues that South Africa must address. These objectives need not be trade-offs, however, and achieving electricity access for the poor does not justify the building of large coal-fired power stations or threaten South Africa's climate change objectives. This paper estimates the electricity demand from the residential sector to 2020 resulting from universal access, and finds that electricity for low-income households would constitute only a small addition to total electricity demand and would represent only a minor portion of output from the coal-fired power station, Medupi. Furthermore, emissions from the additional electricity consumed by newly connected households would have a negligible impact on South Africa's emissions profile.

Keywords: South Africa, emissions, climate change, universal access, electrification, household

1. Introduction

Although South Africa has a gross domestic product (GDP) in line with those of many middle-income countries, there remains wide-scale poverty and inequality, a legacy of the previous apartheid administration. One of the major challenges facing the present government is extending service delivery to the previously un-served majority of the population (ANC, 1994). Since 1994, the ANC Government has embarked on ambitious national programmes tackling issues such as housing, water and electrification. Despite impressive successes in the electrification programme, there remains a sizeable backlog of unconnected households.

Alongside these developmental objectives South Africa has acknowledged the threat of climate change and pledged to adopt appropriate mitigation measures to reduce its emissions (RSA, 2010). The argument is sometimes advanced (Davidson et al., 2010) that achieving universal access to electricity requires more coal-fired power stations to be built, with a 4 500 MW station adding approximately 30 Mt of carbon dioxide (CO_2) per year for fifty to sixty years. By estimating the emissions associated with the electricity consumption of previously unconnected households, this paper investigates whether there are real trade-offs between extending access to electricity to the poor and climate change mitigation in South Africa.

2. Context

2.1 Climate change

South Africa has a highly energy-intensive economy by international comparison, with a total primary energy supply per GDP output of 0.27 tonnes of oil equivalent per thousand US$ (2000) in 2009 (International Energy Agency, 2011). The bulk of South Africa's electrical energy is, however, used by industry rather than the residential sector and the country has a very low per-capita consumption of electricity (IEA, 2011). The high amount of energy used per unit of economic output (which defines energy intensity) is ascribed to an abundance of coal deposits enabling historically cheap electricity prices and a competitive advantage in energy-intensive industries.

South Africa's emissions profile on the supply side is driven predominantly by coal-based fuel combustion, using low-grade coal with its higher associated greenhouse gas (GHG) emissions) (Kessides *et al.*, 2007). On the demand side, energy emissions from fuel combustion in 2000 were driven primarily by industry (83%) and transport (13%), followed by the residential sector (2%), agriculture (1%) and commerce/services (1%) (DEA, 2009).

In 2009 at the fifteenth meeting of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen, South Africa committed to reduce its emissions by 34% by 2020 and by 42% by 2025 below business as usual (RSA, 2010). The commitments were qualified by the statement that 'in accordance with Article 4.7 of the Convention, the extent to which this action will be implemented depends on the provision of financial resources, the transfer of technology and capacity building support by developed countries' (RSA, 2010). The implication of this emissions reduction target is that South Africa must fundamentally change its current emissions-intensive growth path. A climate-friendly development path may, however, come into conflict with other economic and social considerations – for example, a historical reliance on cheap electricity prices (Fine & Rustomjee, 1996), or increasing access to affordable energy services in accordance with established energy policy (DME, 1998).

Bazilian et al., (2011) critically assess the intentions behind building the Medupi coal-fired power station and its consequences for South Africa's climate change objectives. Referring to the pressures that a large proportion of the population without access to electricity will have on prioritising climate change in new-build options, they suggest that 'it is quite possible that the immediate needs of the poor in gaining access to electricity services will be put ahead of the impacts of climate change on future generations' (Bazilian *et al.*, 2011).

2.2 Universal access to electricity

Universal access to clean and modern energy services is seen as critical to achieving human and social development in the developing world. Indeed, energy is seen to underpin the achievement of the Millennium Development Goals (UNDP, 2005). There are numerous positive socio-economic impacts associated with providing households with access to clean and safe energy services, including health, education, and gender equality, as well as providing the basis for increased economic activities (Prasad, 2006).

About one-third of the population in South Africa had access to electricity in 1990, and this proportion has risen to about two-thirds since the implementation of the electrification programme (Borchers *et al.,* 2001; Gaunt, 2005; SAIRR, 2010). Poor households typically have very low consumption levels (Prasad, 2006) and the question of whether the additional emissions associated with providing electricity access would significantly jeopardise climate change objectives does not appear to be sufficiently justified. For example, the emissions associated with extending the poverty tariff, the so-called Free Basic Electricity (FBE) subsidy, to poor households have been estimated to add an additional 0.15 Mt CO_2 per year, accounting for only 0.04% of total emissions (Sparks & Mwakasonda, 2006).

Since 1994 when it officially commenced, the electrification programme has existed in various guises. Since 2005 it has been housed in the DoE as the Integrated National Electrification Programme (INEP) and funded by National Treasury. There is also an off-grid electrification programme (undertaken by service providers) aimed at supplying solar power in areas where grid electricity is not financially or technically feasible. To date, this programme remains very small in relation to the grid electrification programme and has had many challenges in its implementation, including affordability and acceptance by poor households (Winkler et al., 2011).

The first phases of the grid electrification programme saw impressive results, made possible by excess capacity and available funding (Bekker et al., 2008b) with 2.5 million households connected from 1994 to 1999) (Prasad, 2006). In more recent years, however, the programme has slowed, with annual connection rates dwindling, primarily because of funding and bulk infrastructure constraints (DoE, 2011). The DoE estimates that the current backlog in 2011 is approximately 3 388 156 households (DoE, 2011).

A universal access target to be achieved by 2012 was first announced in 2004 by President Mbeki (Bekker et al., 2008a). This has been revised, however, and pushed back several times due to challenges with funding and lack of infrastructural capacity. Most recently, the DoE has announced a target of 92% of all households by 2014 (DoE, 2011), with no indication of when the 100% target would be reached.

A key issue with understanding the extent of the backlog is the lack of clarity surrounding the definition of universal access used by the DoE. It is unclear as to whether the targets refer to 100% of existing households when the policy was made or of future households at the date set for achievement of the target (Bekker *et al.*, 2008a). In policy documents (e.g. Free Basic Electricity policy) and presentations (e.g. by DoE on the INEP to Parliament in March 2011) the programme appears to refer to the current number of households, not taking the growth rate into consideration. Bekker *et al.*, concur that the INEP does not appear to consider future households. In the following analysis therefore, we assume that electrification is limited to 100% of existing households, but we also show the implications if new households are considered.

3. Method and assumptions

This study estimates residential electricity consumption and associated emissions for a baseline year 2006 and with projections made to 2020 using a spreadsheet model. The base year was chosen as the most recent year for which reliable data could be found to estimate the baseline residential electricity consumption. This section attempts to describe the key inputs into the calculations and the assumptions and data sources underpinning them.

3.1 Estimating the number of households with electricity in 2006

The first step in the process was to attempt to estimate the number of households with electricity in 2006. Table 1 shows the diversity of estimates of the backlog, with the number of unelectrified households in 2006 reported in the literature ranging from approximately 2.5–3.5 million households. This variance may be attributable to the different methods used by different sources (Bekker *et al.*, 2008). Bekker *et al.* (2008a) suggest that the General Household Surveys undertaken by Statistics South Africa (Statssa) may overestimate electricity access because of sampling issues. For the purposes of this analysis, we use the DoE's INEP estimate of 3.4 million households, which is a middle of the range estimate and is used by DoE for electrification planning purposes.

This study does not take the off-grid electrification programme into consideration. The number of households in the off-grid programme at this stage represents a minor proportion of total electrified households. As at 2011, there were a total of 10 500 'planned installations' (DoE, 2011), which represents approximately 0.1% of all electrified households. Addressing the limited data availability for off-grid households – while important in its own right – would require significant effort and would not make a material difference to our purpose of estimating electricity consumption and GHG emissions.

Consumption of electricity is positively correlated with income (Louw et al., 2008), meaning that as households move up the income spectrum their electricity consumption generally increases. While there is no deterministic move up an 'energy ladder' (Mehlwana & Qase, 1999), the broad relationship is a reasonable approximation for these purposes. To accurately estimate total residential electricity consumption on this basis, it is therefore necessary to disaggregate households by income level.

The estimated total number of households for 2006 was sourced from the General Household Survey 2006 (Statssa, 2007a). The DoE's backlog estimate of 3.4 million (DoE, 2007) was used to apportion these into electrified and unelectrified categories. The disaggregation of households by

Table 1: Various estimates of electrification backlog for 2006

Source[1]	*Estimate of backlog*	*Year of estimate*	*Backlog as a % of all households in 2006**
SAIRR (2010)	3 497 670	2006/07	27%
DME (2007)	3 416 533	2006	26.3%
Statssa (2007a)	2 568 456	2006	19.8%

** Total households taken to be the total from the GHS, 2006 of 12 972 000 households*

Table 2: Estimated electrified and un-electrified households by income category, 2006
Source: Numbers calculated based on Statssa (2007a; 2007b); DME (2007)

Annual household income	*All households*	*Electrified households*	*Unelectrified households*
No income	1 193 237	768 694	424 543
R1-R4 800	728 579	454 605	273 973
R4 801-R9 600	1 307 478	821 829	485 649
R9 601-R19 200	2 765 106	1 858 100	907 006
R19 201-R38 400	2 786 005	2 026 649	759 356
R38 401-R76 800	1 669 980	1 365 571	304 408
R76 801-R153 600	1 112 044	978 876	133 168
R153 601-R307 200	776 363	706 310	70 053
R307 201-R614 400	414 446	378 520	35 926
R614 401-R1 228 800	137 464	125 517	11 947
R1 228 801-R2 457 600	47 394	41 359	6 035
R2 457 601 or more	33 906	29 436	4 470
Total	12 972 000	9 555 467	3 416 533

income category was obtained from the Community Survey (CS) 2007 (Statssa, 2007b). It was assumed that there was no significant movement in income groups between the two years 2006 and 2007, and that the profile of households from the CS 2007 was representative of households in 2006. Table 2 shows a breakdown of electrified and un-electrified households in 2006 by income category:

Income categories were further classified into low, middle and high-income groups for ease of reference, following the grouping by Senatla (2010). This study grouped the bottom two, middle four and top five income categories. We use that combination, with results reported in Table 4.

3.2 Electricity consumption in 2006

The National Energy Regulator of South Africa (NERSA) published an Electricity Supply Statistics report for 2006 which breaks down total electricity supplied during the year by sector, as shown in Table 3. The residential or 'domestic' sector consumed 39 TWh or 19% of total electricity supplied in 2006.

Table 3: Electricity supplied by sector, 2006
Source: NERSA (2006)

Sector	*Electricity supplied (TWh)*	*Percentage supplied to each sector*
Domestic	39.08	19.1%
Agriculture	5.84	2.8%
Mining	32.69	15.9%
Manufacturing	85.63	41.8%
Commercial	28.78	14.0%
Transport	3.28	1.6%
General	9.76	4.8%
All sectors	205.04	100%

NERSA's supply statistics do not, however, disaggregate this data further and so this study made use of data from the NRS034 Domestic Load Research Database (Markus Dekenah Consulting). This database is funded by Eskom and is based on a series of surveys recording household electricity consumption by different income groups. Consumption data was available over a 15-year period, with year 1 being the first year the household was electrified. It is therefore possible to observe how consumption changes over time since electrification and take growth in consumption into account in the consumption estimates. Since it is not apparent in the electrification statistics how long households have been electrified, we take an average consumption value over the 15-year period for existing electrified households.

The Domestic Load Research Database income categories were matched to those from the CS 2007. Average consumption for each income group was multiplied by the number of households in each income grouping to estimate total electricity consumption. This resulted in a total estimated consumption by all households of 39.62 TWh in 2006, which is broadly in line with the value recorded by NERSA for total electricity supplied to the residential sector in 2006: 39.08 TWh.

Multiple fuel use is a ubiquitous feature of low- and many middle-income households and the practice continues even after electrification (White *et al.,* 1998; Winkler *et al.,* 2011; Louw *et al.,* 2008). It is important to consider multiple fuel use in a study on household emissions and the extent to which increased electricity consumption may displace emissions from other fuel sources. However, there are significant challenges with recording multiple fuel use among households, and data collected at a national level in South Africa is inadequate. It is difficult to aggregate data from samples as households in different locations may have very different usage profiles (Senatla, 2010). Calculating the displacement of other emissions from electrification was therefore not considered feasible at this stage. The consumption rates assumed in this study are reported in section 4, which discusses the results.

3.3 Future electricity connection rates

Figure 1 shows the declining number of annual electricity connections since 1994/95. This is attributable to the shift in the programme over time from an original urban focus (associated with cheaper and easier connections) to a now predominantly rural focus as the urban backlog has been addressed. Rural households typically have higher average connection costs, due to dispersed settlement patterns, and greater infrastructure requirements (Bekker *et al.,* 2008b). However, Bekker *et al.* (2008a) suggest the observed decline could also be overstated due to be under-reporting of new connections. Recent connection rates have not kept pace annually with new household formation, with the result that the backlog has been growing rather than decreasing (Bekker *et al.,* 2008a).

To reach a revised target of connecting 92% of existing households by the end of 2014 would require an additional 630 000 connections per year starting from 2011. This is based on the DoE's 2011 estimate of 3 388 156 unconnected households (DoE, 2011). However, there are only 199 561 planned connections for 2010/11 (DoE, 2011). The target therefore, appears unrealistic, given that the programme has never achieved such high connection rates and, furthermore, now faces significant financial and infrastructural constraints.

The study therefore, looked at what a universal access target (for existing households) by 2020 might look like. This would require an annual con-

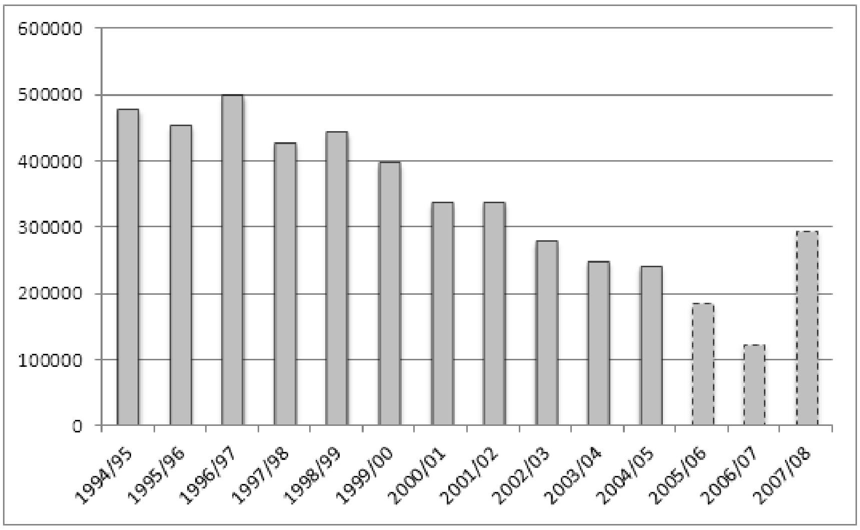

Figure 1: Annual new electrical connections

Sources: 1994 /95–2007/08: SAIRR (2010); 2008/09 and 2009/10: DME Annual Reports: 2010/11: DoE (2011)

nection rate of approximately 274 000 new households per year – a lower figure than connections from 1994–2004, but higher than recent annual rates. It might. Therefore, be called an ambitious-but-realistic rate of future electrification. The connection rate is based on connecting the current number of households as at 2006 and does not take future household growth into consideration; in a scenario including new household formation, approximately 618 000 new connections would be required each year. This figure is based on projected household growth rates obtained from the Bureau of Market Research (BMR, 2007) which says that the number of households in South Africa is likely to grow from approximately 12.9 million in 2006 to nearly 17 million in 2020. It suggests that the rate of household growth will be greater than population growth because of a trend of decreasing average household size.

3.4 Emissions from electricity consumption

To estimate the emissions associated with residential consumption of electricity, this study used an Eskom specific emissions factor of 1.03 $kgCO_2/kWh$ on energy sold (Eskom, 2011). Eskom also reports an emissions factor on energy generated of 0.98 $kgCO_2/kWh$. This emissions factor for electricity sold was applied to the estimated residential electricity consumption (calculated above), giving estimated emissions of approximately 41 Mt CO_2 in 2006. Note that in this analysis, emissions associated with electricity (which occur upstream) are attributed to the end-user, and should not be simply compared to other studies in which those emissions are counted under 'electricity supply' or a similar category.

4. Results and discussion

This section presents the results of the calculations estimating consumption and emissions for households in South Africa.

4.1 Electrified households and electricity consumption in 2006

Typical electrical consumption in poor rural households tends to be very low and to remain low for an extended period even after electrification (Prasad, 2006). Subsequent to the initial implementation of the National Electrification Pro-gramme during the 1990s, households were found to typically consume between 100 and 150 kWh per month, much lower than the initial expectations of 350 kWh (Borchers *et al.,* 2001).

Table 4 presents estimates for the number of electrified and un-electrified households and their electricity consumption for the year 2006. The majority of the backlog (in absolute terms) is amongst households in the middle-income group (which includes over 60% of total households in South Africa). In terms of the percentage of each income group that remains unelectrified, the low-income group has the greatest proportionate backlog, with 37% of households remaining to be electrified, compared to 25% of middle-income households and 9% of high-income households. The relatively high number of high-income households that are still unconnected is interesting, and some portion of this could be attributable to sampling errors in Statssa's Community Survey 2007[2].

Table 5 shows that households were estimated to have consumed 39.62 TWh of electricity during 2006, based on calculations using data from the Domestic Load Research Database. This figure was verified against NERSA's Electricity Supply Statistics

Table 4: Number of electrified and un-electrified households, 2006
Source: Statssa (2007a; 2007b), DME (2007), own calculations

Households type	*All households*	*No of electrified households*	*No of unelectrified households*	*Electrified as % of all households in that income category*	*Unelectrified as % of all households in thatincome category*
Low income					
	3 229 293	2 045 129	1 184 165	63%	37%
Middle income					
	8 333 134	6 229 196	2 103 939	75%	25%
High income					
	1 409,572	1 281 142	128 430	91%	9%
All households	12 972,000	9 555,467	3 416 533*	74%	26%

** This value based on estimates from INEP Masterplan (DME, 2007)*

Table 5: Residential electricity consumption, 2006
Source: Based on Marcus Dekenah (2011); NERSA (2006)

Household type	*Total estimated electricity consumption (TWh)*	*Contribution to total residential electricity consumption*	*Contribution to total electricity consumption (all sectors)**
Low income	0.95	2.4%	0.5%
Middle income	25.02	63.1%	12.2%
High income	13.65	34.4%	6.7%
All households	39.62	100%	19.3%

** Calculated using NERSA (2006)*

(NERSA, 2006), which reported that the residential sector consumed 39.08 TWh during 2006. Total electricity supplied to all sectors reported by NERSA during 2006 was approximately 205 TWh.

Middle-income households consume the greatest portion of residential electricity, approximately 63% as shown in Table 5. This is attributable to the fact that the majority of electrified households (almost 65%) fall within this income bracket. It is also evident that the poor constitute a very small proportion of residential electricity consumption and at a national level they account for only half a percent of total electricity consumption. This equates to just less than 1 TWh of electricity consumed by 3.2 million households in 2006.

Low consumption levels can be attributable in large part to lack of affordability in poor households (Winkler *et al.,* 2011). The proportion of the household budget that is spent on energy is referred to as the household energy burden (Prasad, 2006). While the question of how high a burden constitutes a fuel-poor household is debatable, a figure of 10% is widely used (Winkler *et al.,* 2011), including by the DoE (DoE, 2009). A survey undertaken by the DoE of both electrified and un-electrified households in LSM[3] groups 1–3 found that households typically spend between 10% and 25% of their household income on energy (DoE, 2009). This suggests poverty and affordability issues dampen demand for electricity in poor households.

4.2 Future electricity consumption

This study bases future projections of electricity consumption on historical consumption, assuming that existing trends continue into the future. In reality there are a number of factors that may influence how households consume electricity. The first is changes in income. This study assumes no movement in income groups over the time period of the study, but it is possible that if economic growth and poverty alleviation efforts continue there will be some upward movement of households in terms of income level. As income is a significant factor influencing consumption, particularly in dampening demand among low-income households, if income levels rise this might increase electricity demanded above estimates made here.

A second factor that could influence future electricity consumption is energy efficiency. The implementation of policy documents such as Energy Efficiency Strategy (DME, 2005) and Climate Change Green Paper (DEA, 2010) may see a decline in per household electricity consumption through initiatives such as efficient technologies (solar water heaters, efficient lighting, and efficient appliances), thermal insulation or the expansion of the solar off-grid programme.

Figure 2 shows the estimated growth in electricity consumption to 2020 from connecting 100% of existing households to the grid. Total electricity consumption would grow from approximately 40 TWh in 2006 to an estimated 52 TWh in 2020. The portion of this total in 2020 attributable to newly connected households (since 2006) in all income categories is approximately 12.8 TWh. The portion attributable to low-income households is 1.36 TWh, just 3% of the total residential consumption in 2020.

In a scenario where future household growth and growth in household electricity consumption is taken into account to 2020, consumption would rise to 65 TWh in 2020, with newly connected households contributing an additional 25 TWh in 2020.

Eskom produced estimates of future electricity demand to inform the IRP 2010, which assumes that electricity demand will increase from its base year assumption of 260 TWh in 2010 to 356 TWh in 2020 (DoE, 2011). In other words, electricity demand is projected to increase 37% over the twenty-year period. The most significant portion of this demand derives from the minerals-energy complex, with demand in the industrial sector[4] forecast to grow by almost 60% over the time period and demand in the mining sector to increase by 30%. Together the mining and industrial sectors account for almost 50% of total forecast demand in 2020 (Eskom, 2010). In contrast, demand in the residential sector is estimated here to increase by approximately 32% over the same time, accounting for 15% of the IRP 2010's estimated demand in 2020. Of this, low-income households would account for only 0.4% of total demand in 2020, or 1.36 TWh of the total 356 TWh. Newly connected low-income households will account for 0.1% (0.4 TWh) of total estimated demand. The contribution of electricity demanded from all newly connected households to total estimated demand in 2020 is 3.6% or 12.8 TWh.

Medupi is estimated to add an additional 4 332MW to the system. Of the total annual energy sold by Medupi, low-income households will consume approximately 4% in 2020. Newly connected low-income households will consume 1.3% of the energy sold. The majority of Medupi's output will therefore not contribute towards achieving universal access targets for the poor but will be used to support an energy-intensive industrial sector.

4.3 Residential emissions from electricity

The residential sector emitted approximately 41 Mt CO_2 from electricity in 2006. This is shown broken down by household income group in Figure 3. The majority of emissions emanate from middle-income households (26 Mt CO_2) since this classification has the greatest absolute number of households. However, Figure 4 shows that on a per household basis, high-income households generate by far the greatest amount of emissions, 10 tonnes CO_2 per year compared to 3 and 0.3 tonnes for middle and low-income households respectively.[5]

Total household emissions are projected to grow from 41 Mt CO_2 in 2006 to 54 Mt CO_2 in 2020 if 100% of existing households are electrified by 2020, a growth of approximately 32%, as shown in Table 6. The greatest emissions growth rate is observed in the low-income households group despite the absolute value of their emissions remaining significantly below those of middle- and upper-income households.

Figure 5 shows graphically the additional emissions from newly connected households (since 2006) only. This again shows the bulk of emissions growth stemming from middle-income households. By 2020, newly connected households will be adding an additional 13 Mt CO_2eq to the atmosphere. Of these emissions, high-income households account for 4 Mt CO_2eq, middle income ones for 8.5 Mt CO_2eq and low income households just under half a Mt CO_2eq in 2020.

Using the Long Term Mitigation Scenarios 'Growth Without Constraints' scenario as a business-as-usual (BAU) scenario to 2020, newly connected low-income households would contribute only 0.06% to total emissions in 2020. If South Africa were to meet its Copenhagen targets by 2020, the increased emissions due to additional

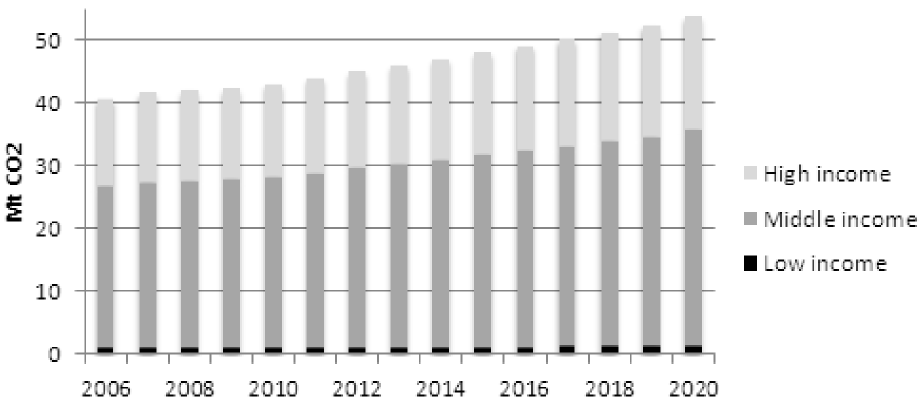

Figure 2: Projections of household electricity consumption by income group, 2006–2020

Table 6: Total emissions from all households to 2020 (Mt CO_2)

	2006	*2010*	*2015*	*2020*	*% growth 2006 – 2020*
Low income	1.0	1.04	1.2	1.4	43
Middle income	25.4	26.9	30.2	33.9	34
High income	13.9	14.6	16.2	17.8	29
All households	40.2	42.6	47.6	53.2	32

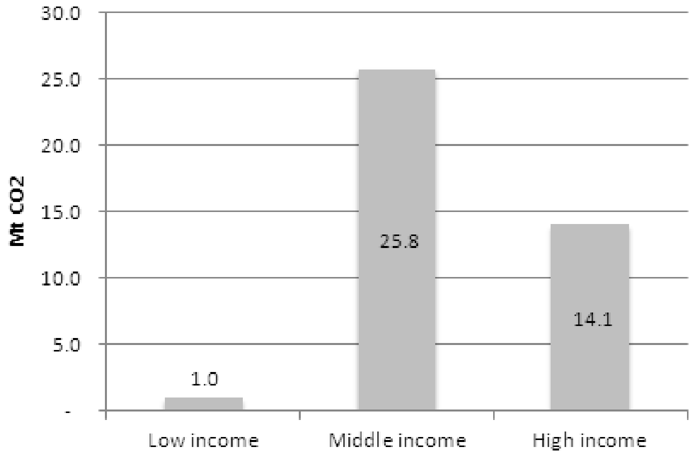

Figure 3: GHG emissions from all households, attributing electricity sector emissions to residential sector, 2006

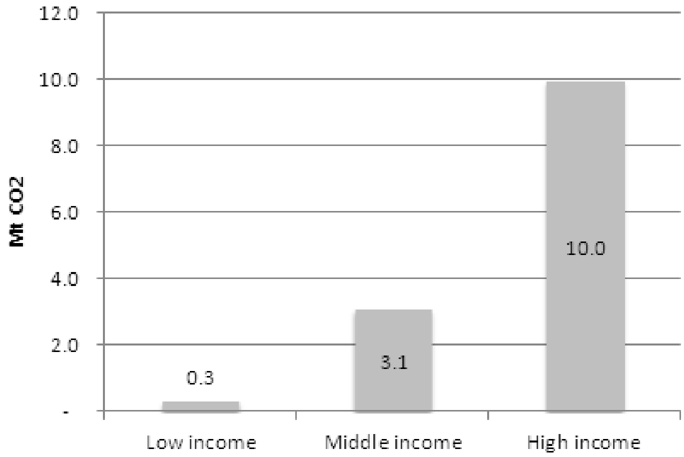

Figure 4: Typical GHG emissions per household, attributing electricity sector emissions to residential sector, 2006

consumption by newly electrified households would be 0.09% in 2020. The electricity supplied to all low-income households would contribute 0.2% to total targeted emissions under a BAU scenario and 0.3% if the Copenhagen targets are met. Electricity emissions for the whole residential sector would account for 7% of total emissions under a BAU scenario and 12% if the Copenhagen targets are met.

In a scenario where household growth is taken into account to 2020, total emissions would grow to approximately 67 Mt CO_2 in 2020 or an increase of 64% from 2006. Low-income households would contribute 0.2% to total emissions under a BAU scenario and 0.4% if the Copenhagen targets are met.

5. Conclusion

This study has demonstrated that providing 3.4 million households with access to a basic need would represent only a minor addition to South Africa's electricity demand and emissions profile. Residential electricity consumption is a relatively small share of total demand for electricity, accounting for approximately 15% of forecast demand in 2020. The share of poor households in this total is minor, accounting for only 0.4% of total electricity demand.

Electrification of low-income households will only increase electricity consumption by 0.11% in 2020, which indicates that this is not a credible basis to motivate building new coal-fired power sta-

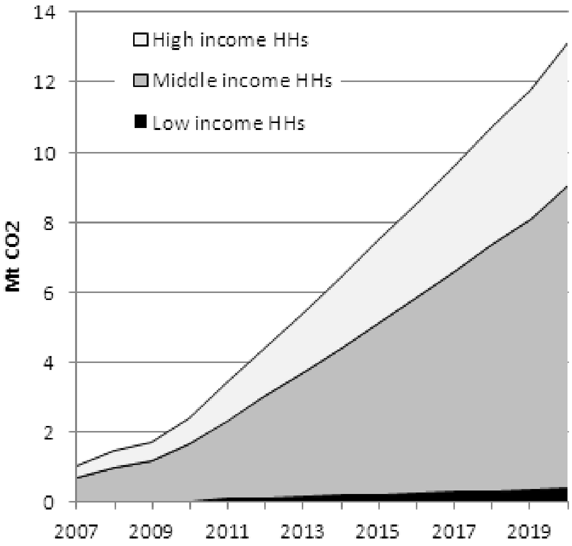

Figure 5: Additional GHG emissions attributed to electricity use, from newly connected households

tions. The projected demand from all poor households in 2020 is expected to account for just 4% of the total electricity from the Medupi power station. The emissions associated with increasing access to electricity for poor households would contribute only 0.09% to total emissions in 2020.

Whether emissions should be attributed to end-users or to producers of electricity is a normative question. However, it appears that the goal of achieving universal access for the poor is not a compelling reason to build another coal-fired power station nor would it significantly jeopardise South Africa's climate change commitments. Most of the growth in generating capacity is currently being planned to meet the demands of energy-intensive industry. Whilst South Africa still has significant challenges with regards to reducing its emissions intensity there are huge opportunities provided by energy efficiency and diversifying the fuel mix away from low-grade coal. Meeting developmental goals of providing millions with a basic need need not be detrimental to South Africa's climate change response nor serve as a justification for another large-scale coal-fired power station.

Notes

1. These documents are available online at the following locations: The South African Institute for Race Relations Survey of Living Conditions and Communications at www.sairr.org.za/services/publications/south-africa-survey/south-africa-survey-online-2010-2011; The Department of Minerals and Energy's INEP Masterplan, 2007 at www.ameu.co.za/library/industry-documents/neac/; and the General Household Survey at www.statssa.gov.za.
2. Statistics South Africa released a revised version of the Community Survey 2007 in which they highlighted areas of concerns relating to some of the data and issued a health warning regarding the sampling frame (Statssa, 2007b).
3. The Living Standards Measure (LSM) developed by the South African Advertising Research Foundation (South AfricaARF) categorises the population according to an index of household variables such as ownership of assets, access to services and geographical location (www.saarf.co.za/LSM/lsms.htm).
4. The industrial sector, as defined in the report prepared by Eskom's System Operations and Planning (2010) for the IRP 2010, includes activities in iron and steel, aluminium, ferro-chrome, ferro-manganese, man-made fibres, petrol, fuel oils etc, and other sectors.
5. If an emission factor of 0.98 is used, which Eskom cites for electricity generated, then total residential emissions from electricity would be 39 Mt CO_2 in 2006. Emissions attributable to demand from low income households would be 0.9 Mt CO_2, middle-income households 24.5 Mt CO_2 and high-income households 13.4 Mt CO_2. Total emissions would grow to 51 Mt CO_2 by 2020 if 100% of existing households are electrified.

References

Bazilian, M., Hobbs, B., Blyth, W., MacGill, I. & Howells, M., (2011). Interactions between energy security and climate change: A focus on developing countries, *Energy Policy*, 39: 3750–3756.

Bekker, M., Gaunt, C., Eberhard, A. and Marquard, A., (2008a). Uncertainties within South Africa's goal of universal access to electricity by 2012, *Journal of Energy in Southern Africa*, 19(2): 4-13.

Bekker, M., Gaunt, C., Eberhard, A. & Marquard, A., (2008b). South Africa's rapid electrification programme: Policy, institutional, planning, financing and technical innovations, *Energy Policy*, 36: 3115–3127.

Borchers, M, Qase, N, Gaunt, T, Mavhungu, J, Winkler, H, Afrane-Okese, Y & Thom, C (2001). National electrification programme evaluation: Summary report. Cape Town, Energy & Development Research Centre, University of Cape Town.

Bureau of Market Research. (2007). *Population and household projections for South Africa by province and population group, 2001 – 2021*. University of South Africa (UNISA).

Davidson, O., Hirst, N. & Moomaw, W. (2010). Recommendations to the World Bank Group on lending to South Africa for Eskom investment support project that includes a large coal burning power station at Medupi. Report by Expert Panel.

Department of Environmental Affairs (DEA) (2009). *Greenhouse gas inventory 2000: National inventory report*. Compilation under the United Nations

Framework Convention on Climate Change. May 2009, prepared Pretoria.

DEA (2010). *National climate change response green paper*; prepared Pretoria.

DEA (2011). Defining South Africa's desired greenhouse gas mitigation outcomes. Presentation to Parliamentary Portfolio Committee for Water and Environmental Affairs, 29 March 2011, Cape Town. Available at www.pmg.co.za.

Department of Minerals and Energy (DME) (2007). *Integrated National Electrification Programme (INEP) plan to achieve universal access to electricity by 2012, Masterplan/Business plan*. Pretoria.

DoE (2009). *Electrification statistics.* Pretoria.

DoE (2011). Integrated national electrification programme INEP. Presentation to Parliamentary Select Committee on Economic Development, 8 March 2011, Cape Town. Available at www.pmg.co.za.

DoE (2011). Integrated resource plan for electricity, 2010-2030. Revision 2, final report, 25 March, prepared Pretoria. Available at www.energy.gov.za.

Department of Minerals and Energy DME (1998). *White paper on energy policy for South Africa*, prepared Pretoria, DME. Available at ww.dme.gov.za/pdfs/energy/planning/wp_energy_policy_1998.pdf.

DME (2003). *Electricity basic services support tariff free basic electricity policy*; prepared Pretoria. Available at www.energy.gov.za/files/policies/Free%20Basic%20Electricity%20Policy%202003.pdf.

Eskom Holdings Ltd. (2011). *Integrated Report* 2010. http://financialresults.co.za/2010/eskom_ar2010/corp_tables_enviro.htm.

Fine, B & Rustomjee, Z. (1996). *The political economy of South Africa: from minerals-energy complex to industrialization*. London, C. Hurst.

Gaunt, T. (2005). Meeting electrification's social objectives in South Africa, and implications for developing countries. *Energy Policy,* 33: 1309–1317.

Heltberg, R. (2004). Fuel switching: evidence from eight developing countries, *Energy Economics*, 26: 869–887.

International Energy Agency (IEA). (201)1. *Key world energy statistics*, Paris.

Kessides, I., *et al.* (2007). *Current and forthcoming issues in the South African electricity sector*, World Bank policy research working paper 4197. The World Bank Group.

Letete, T., Guma, M. & Marqard, A. (2008). Information on climate change in South Africa: Greenhouse gas emissions and mitigation options, carbon accounting for South Africa. Energy Research Centre, University of Cape Town.

Louw, K., Conradie, B., Howells, M & Dekenah, M. (2008). Determinants of electricity demand for newly electrified low-income African households, *Energy Policy*, 36: 2814–2820.

Madubansi, M and Shackleton, C.M. (2006). Changing energy profiles and consumption patterns following electrification in five rural villages, South Africa, *Energy Policy*, 34: 4081–4092.

Marcus Dekenah Consulting. (2011). NRS034 Domestic load research database. Available online at: www.mdekenah.co.za/research_downloads.asp?cid=16. Consulted February 2012.

Mehlwana, A M & Qase, N. (1999). The contours of domesticity, energy consumption and poverty: The social determinants of energy use in low-income urban households in Cape Town's townships (1995-1997). Cape Town, Energy & Development Research Centre, University of Cape Town.

National Energy Regulator of South Africa (NERSA) (2006). *Electricity supply statistics for South Africa*. Pretoria.

Prasad, G. (2006). Social issues. In: H. Winkler, ed. *Energy policies for sustainable development in South Africa: Options for the future.* Cape Town, Energy Research Centre: 61–76.

The Presidency of South Africa (2009). *Medium term strategic framework 2009–2014*. Pretoria.

Republic of South Africa (RSA) (2010). Letter dated 29 January, for the South African national focal point, prepared Pretoria, Department of Environmental Affairs. Available at http://unfccc.int/files/meetings/application/pdf/southafricacphaccord_app2.pdf;

Senatla, M. (2010). Determining the impacts of selected energy policies on Gauteng's residential energy consumption and the associated emissions, using LEAP as a tool for analysis. M Sc thesis. Energy Research Centre, University of Cape Town.

Sparks, D. & Mwakasonda, S. (2006). Energy and the environment, in O. Davidson, H. Winkler, A. Kenny, G. Prasad, D. Sparks, M. Howells, T. Alfstad, S. Mwakasonda, B. Cowan and E. Visagie (Eds). *Energy policies for sustainable development in South Africa: Options for the future.* Cape Town, Energy Research Centre.

South African Institute for Race Relations (SAIRR). (2010). *Survey of living conditions and communications 2009/10*.

Statistics South Africa (Statssa) (2007a). *General household survey 2006*, Statistical release P0318.

Statssa. (2007b). *Community survey* (*2007 (Revised Version)*, Statistical release P0301.

United Nations Development Programme (UNDP) (2005). *Energising the Millennium Development Goals – A guide to energy's role in reducing poverty*. Technical report, United Nations Development Programme.

White, C., Crankshaw, O., Mafokoane, T. & Meintjies, H. (1998). Social determinants of energy use in low-income metropolitan households in Soweto. Report No. EO9423. Department of Minerals and Energy, Pretoria.

Winkler, H., Hughes, A., Marquard, A., Haw, M. & Merven, B. (In press 2011) South Africa's greenhouse gas emissions under business-as-usual: The technical basis of 'growth without constraints' in the long-term mitigation scenarios. *Energy Policy*.

Winkler, H., Simoes, A., Lebre la Rovere, E., Alam, M., Rahman, A., & Mwakasonda, S. (2011). Access and affordability of electricity in developing countries, *World Development*, 39 (6): 1037–1050.

Received 22 February 2012; revised 12 September 2012