Beyond Free Electricity: The Costs of Electric Cooking in Poor Households and a Market-friendly Alternative

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Abstract

The South African government is introducing a poverty-reduction policy that will supply households with a monthly 50kWh "Free Basic Electricity (FBE)" subsidy. We show that FBE distorts the energy choices of poor households by encouraging them to cook with electricity, whereas alternatives such as liquefied petroleum gas (LPG) can deliver a similar cooking service at a much lower cost to society. An alternative energy scheme, such as providing households with clean energy credits equivalent in value to the FBE's cost, could deliver additional energy services worth at least 6% of total household welfare (and probably much more) at no additional public cost; those benefits are so large that they would cover the entire cost of LPG fuel needed to implement the scheme. The analysis is extremely sensitive to the coincidence of electric cooking with peak power demand on the South African grid and to assumptions regarding how South Africa will meet its looming shortfall in peak power capacity. One danger of FBE is that actual peak coincidence and the costs of supplying peak power could be much less favorable than we assume, and such uncertainties expose the South African power system to potentially very high costs of service.

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Introduction

For a decade, the South African government has steadfastly supported energy policies that advance the welfare of the poor. These have included the world's most effective policy for electrifying low-income areas in urban and rural regions alike (Gaunt 2004). The government has set universal electrification as a national goal (Mlambo-Ngcuka 2002, 2003; Mbeki 2004; Mlambo-Ngcuka 2004), and the design of energy strategies that contribute to reducing poverty are a topic of perennial importance in South African political discourse. In contrast with the rest of Africa, South African electrification levels are high (about 70%) and roughly half of the nation's very poor (those with incomes in the bottom two quintiles) are electrified (Winkler et. al. 2005).

In this tradition, the government has introduced a "Free Basic Electricity (FBE)" scheme that will offer 50 kilowatt hours per month for free to most households that have access to electricity. The South African government has set the 50 kwh monthly figure so that it covers the electricity necessary for basic lighting, a small black-and-white television, a small radio, basic ironing and boiling of water using an electric kettle (DME 2005a; DME 2005b). During a trial phase in 2002-2003, FBE was implemented in low-income households that have prepaid meter systems by reducing the output of each system to 10 amps and crediting the meter with 50 kWh per month. Currently, the FBE is official government policy; implementation is proceeding through partnerships between local governments and suppliers. In crafting FBE the government has considered alternative energy subsidy strategies, although the current policy is limited to electricity (Crompton 2005; DME, 2005b).

The offer of 50 kWh for free is likely to have a substantial effect on the energy choices of poor households. Detailed surveys of energy budgets in extremely poor electrified households—such as impoverished shacks in townships—show that when the household must purchase its electricity that monthly usage varies but is typically about 20 kWh. Electricity is more expensive than traditional alternatives such as coal or firewood for cooking and heating (Williams et al. 1996); the rational household that pays for electricity (even at the very low tariffs that prevail in South Africa) consumes power sparingly. Typically, purchased electricity is used for television, lighting, electric irons, and a few other applications for which fuel substitutes are inferior or absent. For the most energy-hungry applications, such as cooking and heating, traditional fuels continue to dominate (Afrane-Okese 1998). Free electricity may change this.

In a trial run in 2002-2003, government offered 50 kWh of free electricity to households for a one year period. The response, documented in detail through Eskom's Load Research Programme, was a rapid rise in monthly consumption to about 35 kwh per month on average (Dekenah 2004). Consumption would likely have risen even further (up to the 50 kwh free limit) if the trial had been run longer and if households were confident that free electricity would become permanent, which would justify the purchase of electricity-consuming appliances such as cookers. Indeed, when free electricity was offered in Khayelitsha township, a survey by the University of Cape Town revealed that households are responding as expected. In ever-larger numbers, households are purchasing and using electric cookers, and there is some evidence that households are also using electricity for bulk heating of water (Cowan & Mohlankoana 2004).

There is little doubt that free electricity has improved the livelihoods of poor households. FBE is reducing household expenditures on energy and thus freeing income for other purposes; it has expanded the use of a clean fuel at the expense of mainly dirty alternatives. Our question is whether it is possible to do better at the same cost to government and the utilities that are supplying free power. We answer in the affirmative and offer an alternative strategy that could deliver larger—possibly much larger—benefits for the poorest households while also lightening the strain on the South Africa's power grid.

Methodology

We focus on the most striking and possibly costly shift to free electricity—the use of electricity for cooking, which we estimate will account for 17 kwh of the 50 kwh in free electricity. Electric cooking can be extremely costly because most cooking in low-income South African homes takes place during the afternoon when the electric power system is already stretched to its peak and the marginal cost of new service is at its highest. We assume, on the basis of surveys, that the hot plates introduced in response to FBE will operate 45 minutes per day (Cowan 2004). We also assume that there is a 70% chance that this takes place during peak periods—the so-called "peak coincidence factor." On average the plates run at 50% of their rated full power level. When cooking food by boiling water, for example, the hot plate is run at its maximum to heat the water and then reduced to sustain the boil.[1] We compare electricity with liquid petroleum gas (LPG), which is one of several rivals that can provide clean and flexible cooking services.

A full costing of providing electric services requires the daunting task of estimating the structure of the load curve and the costs of supply in South Africa over the period of time when free electricity and cooking appliances would diffuse fully into service—roughly twenty years. With that baseline calculation on hand we could then calculate the marginal effects of additional

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[1] A 1.5 kW electric cooker operating 30 days per month, 45 minutes per day at half its maximum load consumes 17 kwh of power. We assume that the rest of the 50 kwh is deployed by households to other services. Some of those services (e.g., the boiling of hot water in kettles) will also coincide with the afternoon peak in power consumption and thus impose power costs similar to those analyzed in this paper; for simplicity, however, we focus solely on the 17 kwh used for cooking.

loads on the system from cooking under FBE. Such a calculation, while theoretically attractive, is replete with uncertainties and complexities. Thus here we offer something much simpler—an estimate of what we call the "floor cost." That is, we calculate the additional costs that are certain to be imposed on the system due to electric cooking under the FBE. Wherever uncertainties and ambiguities arise we choose the most conservative values; thus, in practice, the real cost of supplying electric service is likely to be higher than our calculation—probably much higher—and in a sensitivity analysis we explore the range of uncertainty. Yet even this most conservative calculation shows that electricity is an exceedingly costly way to provide flexible and clean energy services to the very poor.

Throughout our analysis we rely on the same assumptions deployed in the National Electricity Regulator's most recent National Integrated Resource Plan (NER 2004). The models used in that work were based on the work of ESKOM's expansion planning team and have long served as the basis for integrated resource planning in South Africa; the models analyze not only the system requirements for delivering power but also for maintaining the 15% "reserve margin" that is required to assure stability of the power grid if a power plant or line are unexpectedly taken out of service.

To calculate the floor cost we examine both the running cost of supplying actual electrical power *and* the cost of the minimum additional capacity needed to preserve the grid system's reserve margin. We address both in turn.

At the margin, there are three options for supplying power in South Africa (table 1). Two of these—baseload coal plants and pumped storage—are already in widespread use in South Africa and expansions are planned for both.[2] In addition to these two power supplies, South Africa is building a third type of generator—open-cycle gas turbines (OCGT), which burn costly petroleum or natural gas fuels.

	Coal fired	**Pumped storage**	**Open cycle gas turbine (OCGT)**
	R/kWh	*R/kWh*	*R/kWh*
Operating & Maintenance (excluding fuel)	0.02	0.05	0.14
Fuel costs	0.04	0.06	0.81
Losses (T&D)	0.01	0.01	0.08
Total	**0.07**	**0.11**	**1.03**

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[2] In our base case analysis we assume that large, low-cost coal-fired power plants are "on the margin" 80% of the time; pumped storage facilities supply marginal power the remaining 20% of the time. The weighted cost for marginal power is 0.09 R/kWh (or US$ 0.015 per kwh, at USD 1 = R6, the June 2005 exchange rate). South Africa already has several pumped storage facilities used for peak service, and it is building a large new one (the Braamhoek scheme). According to available ESKOM statistics, historically, pumped storage plants have run at an annual load factor of 20% (ESKOM 1997). The load factor during peak periods is much higher since pumped storage rarely is used to generate electricity during off-peak periods.

Table 1: Operating costs for peak power generation. The O&M and fuel costs for pumped storage include those for the storage facilities themselves plus the baseload (mainly coal-fired) power used to pump the water uphill. The imputed cost for line losses are based on the assumption of current prevailing losses for service in low-income areas, which include line losses from transmission and high voltage distribution (9%), other low voltage losses (including theft) are ignored because it is difficult to estimate the effect of free basic electricity on theft levels. Source: NER (2004).

As a general rule, pumped storage schemes are costly to build and require long lead times, but have low operating costs in supplying peak power. Most conventional coal-fired plants are also marked by high capital costs and thus run as baseload units. By contrast, the third option—OCGT—is relatively inexpensive to build but extremely expensive to operate. (These turbines are derived from jet engine technology; in South Africa the units will burn refined oil products, which are particularly costly when oil prices are high.)

Mindful of these characteristics, historically the South African power system has deployed coal-fired power plants and pumped storage in a system that is optimized by the national utility. Most coal plants (along with the nation's sole nuclear plant) operate continuously; during non-peak periods extra electricity from these plants is used to pump water uphill in pumped storage facilities. (In effect, the load curve is flattened by raising power consumption during the "trough," off-peak period.) Peak service is provided by the ramping up coal plants and supplementing that power with pumped storage. [3]

We assume that this approach to power dispatch will continue to provide the actual power needed for peak periods. Today, marginal power is supplied, on average, with coal (80% of the time, on average) and pumped storage (20%). For our base case analysis we assume those proportions remain the same. (In reality, more expensive pumped storage will provide a greater share of electricity during peak periods, and in the sensitivity analysis we vary the proportions.) Weighting the costs for coal and pumped storage in table 1 by these dispatch fractions leads to 0.09 R/kwh in actual power costs. Again, these assumptions are conservative since they do not address the likelihood that the installed base of coal and pumped storage facilities will, at times, be insufficient to meet full peak load; during those times, smaller OCGT's that provide the reserve margin will also be called upon to generate power, at much higher marginal cost (1.19 R/kwh, per table 1).

In addition to the cost of actual power supplied, we also include the lowest possible cost of preserving the reserve margin as electricity demand grows. After a long period when power generating capacity is in surplus, South Africa has now entered a period of scarcity. Already, reserve capacity during peak periods in the winter is fully utilized (NER 2004). Thus any new demand added to the system, including the new demand from cooking as a result of FBE, requires investment in new reserve capacity. Consistent with the government's own planning assumptions, we assume that the least costly option for building reserve capacity is OCGT, and

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[3] In summer, peak periods are 7am to 10am and 6pm to 8pm; in the winter, when demand is higher, the peak periods are longer and the afternoon peak is highest.

every kilowatt of OCGT capacity incurs a once-off cost of R5949. (This is the per kilowatt cost of an OCGT plant inflated by the need for a fifteen percent reserve margin as well as losses associated with transmitting and distributing it to the customers concerned[4].) Again, our simplifying assumptions are consistent with the "floor cost" approach taken in this paper. For example, we make no provision for actually operating the OCGT capacity—it is held only as reserve and never used. (We vary this assumption in our sensitivity analysis.)

Among the many other conservative simplifications that we have made for our "floor cost" calculation is the assumption that the amplitude of the South African load curve will not change appreciably. In fact, the amplitude of the South African load curve is already rising, and thus the system is already forced to plan for peak load at the margin. Mindful of this shift to a "peakier" load curve, it may be difficult to sustain the assumption that 80% of power dispatched on the margin comes from coal—let alone peak demand. In our sensitivity analysis we explore the ramifications of this and other assumptions.

Suppose that electricity were not free. What alternative sources of heat energy might households select for cooking? We focus on LPG because it offers service that is comparable to electricity: quick heating with essentially zero indoor air pollution (Williams 1994)[5].

Already many low income households select LPG for cooking where it is available. From those markets—which are served mainly by private enterprise—we derive estimates of the actual costs for LPG services and compare them with actual market costs for electric equipment.[6] We find that, compared with electric stoves, LPG systems (stove, valve and tank) can be about 50 R more costly. Most components of the LPG system have a physical lifetime of 10 years (compared with 5 for electric stoves); the LPG valve lasts only about 3 years. The retail price to fill a six-kilogram LPG cylinder is 36 Rand (Tatham 2004). We use these values for the analysis, although we expect that some additional cost reductions will arise through experience and scale if the LPG market were to expand. We focus on a twenty year period, and we assume

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[4] In the extreme this assumes that OCGTs are infinitely scalable; in reality, of course, these units have minimum effective sizes (about [400] MW) and require construction of the whole unit to obtain the increment of capacity needed to assure that the reserve margin is maintained. Given that FBE targets millions of households, implying potentially significant increases in capacity requirements, this simplifying assumption is reasonable. It should also be noted that by not including the cost of low voltage distribution we are, again, underestimating the actual full cost of supply.

[5] We do not consider kerosene as an option due to health effects associated with the way in which kerosene is commonly used. Several thousand die annually in South Africa due to poisoning and burns; moreover, when LPG is compared with the already popular kerosene wick stoves the kerosene is about 20% more costly for the same quantity of useful cooking heat.

[6] We obtain data from the Afrox-Wild Orchard pilot project (Tatham 2004), with the cost of an LPG system, R156 and the equivalent single plate electric hotplate is taken as per local supermarket costs of about R110.

that a 1.3 kW LPG stove[7] provides approximately the equivalent cooking capacity as a 1.5 kW electric stove.

Results, Sensitivity and Analysis

Table 2 summarizes the calculations. The difference between cooking by electricity and LPG (R2413) is that it is 252 R/yr cheaper for households using LPG instead of electric hotplates. To put that figure in perspective, that amount is about 6% of the annual income for the poorest 10% of households in the country (estimated from UCT 2002). In energy terms, it is equal to the total cost of the LPG stoves as well as giving every household 3.2 free kilograms of LPG per month, which is more than the very basic cooking requirements considered in this experiment. 3.2 kilograms of LPG provides an equivalent amount of cooking service to 43 kwh of electricity. This suggests that for the equivalent subsidy, twice as much service could be provided using LPG rather than electricity.

Stove type

	NPV Stove costs (2005R)	**NPV Fuel and running costs** (2005R)	**NPV Electric capacity costs** (2005R)	**NPV Total** (2005R)	**Annualized Cost** (2005R)
Electric	R225	R117	R3123	R3465	R376
LPG	R216	R893	None	R1109	R118
Difference				R2413	R252

Table 2: The cost of cooking with electricity and LPG over 20 years. Stove costs for LPG are per main text; for electric stoves they are R110 (at prevailing supermarket costs for a 1.5 kW electric stove). The power requirement for the electric stove is the product of the stove rating (1.5 kW) and the 50% load factor, which equals 0.75 kW. In addition to that power requirement there is also a peak capacity requirement at the 70% peak coincidence factor (i.e., 0.525kW). Values are in present value (10% discount rate) for a 20 year calculation. The operating costs for LPG include a wick that costs R6 and is replaced every three years.

We are mindful that these calculations are very sensitive to several assumptions. Thus we perform four types of sensitivity analysis.

First, we examine the sensitivity of the peak coincident factor, shown in table 3. If the peak coincident factor rises to 100% then the floor cost rises by more than half. The cost increases as the new load becomes coincident with the system's peak requirements because preserving the reserve margin during peak periods is especially costly.

Peak co-incidence factor	**Annualized saving** (2005R)

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[7] We assume that the LPG stove is run at a higher power rating – or "load factor" than the slightly larger-capacity electric hot-plate. The power rating of the electric hotplate was assumed to be 50%, for the LPG stove it is 58%.

100%	395
90%	347
80%	299
70%	252
60%	204
50%	162

Table 3: Annualized of moving to LPG from electrical cooking as a function of peak coincidence factor. Grey shows our base case.

Second, we examine the assumptions concerning the technologies that will be used to supply peak power at the margin (table 4). Our base case employs the very conservative assumption that peak power would be dispatched in the same ratio as power is supplied on the margin throughout the year (80% coal, 20% pumped storage). Moreover, as South Africa has already committed to build new pumped storage capacity, we have assumed that actual power generated by OCGT plant(s) is 0% of the total marginal power consumed by these hot plates. OCGT is used *only* to preserve the peak reserve margin. These dispatch assumptions are questionable since the South African power system is already shifting to a peakier load curve, and thus this new pumped storage capacity could be fully utilized in the near future. The ability to site new pumped storage facilities is in doubt, and South Africa may need to rely more heavily on OCGT for providing peak service power in addition to reserve margin. We examine this in table 4 by varying the assumptions about the blend of generators that dispatch power on the margin according to four scenarios:

- Scenario A: the base run (80% coal, 20% pumped storage)
- Scenario B: 70/20/10 (70% coal, 20% pumped storage, 10% OCGT)
- Scenario C: 60/20/20 (60% coal, 20% pumped storage, 20% OCGT)
- Scenario D: 50/20/30 (50% coal, 20% pumped storage, 30% OCGT)

The final scenario is an extreme (though not improbable) outcome in which the peak coincident factor is moderate (70%) and OCGT is increasingly relied upon to serve actual peak power needs in addition to reserve margin.

Power Dispatch Scenario (coal/pumped storage/OCGT)	**Annualized saving** (2005R)
Scenario A (80/20/0)	252
Scenario B (70/20/10)	273
Scenario C (60/20/20)	294
Scenario D (50/20/30)	316

Table 4: Annualized of moving to LPG from electrical cooking as a function of marginal power generation mix. Grey shows our base case.

Third, we examine the sensitivity to the prices of appliances, shown in table 5. Our base case used the least costly LPG appliances currently on the market; here we examine the impact of more expensive cylinder and stove combinations, such as those from LPG companies "CADAC" (R375) and "Easygas" (R175). While there is large variation in appliance costs (more than 100%), the effect on annual cost savings from using LPG instead of electricity for cooking is small.

LPG Appliance system costs (2005R and % increase over base)	**Annualized saving** (2005R)
375 (140%)	219
175 (12%)	249
156	252

Table 5: Annualized of moving to LPG from electrical cooking as a function of the cost of the LPG cylinder-stove combination. Grey shows our base case.

Fourth, and finally, we examine the cost of LPG, which varies in part because it is tied to the price of oil (which varies) and because distribution networks could vary in their cost if LPG services were to expand in scope and volume. We assume a delivered cost of 9 and 11R/kg, a 50% and 83% increase over the case study costs used for this calculation. Even at high LPG costs the savings from using LPG are significant (R180); at the highest LPG system cost (R375) and the highest LPG cost there is still a net saving from LPG cooking of R141 per year.

LPG costs in 2005 (R/kg and % increase over base case)	**Annualized saving** (2005R)
11 (83%)	173
9 (50%)	205
6	252

Table 6: Annualized of moving to LPG from electrical cooking as a function of LPG cost. Grey shows our base case.

Implementation

These calculations illustrate the potential for substantial savings. They also suggest urgency for reform since the expectations and investments of households are solidifying around the promise of free electricity. Once those promises are cemented in place it may be politically difficult to change course.

We focus on two options. For both, we assume that government will keep the social cost of pro-poor energy policy fixed. Our aim is to illustrate how deployment of the same level of public resources could yield much larger benefits for poor households.

The first option reflects what many governments in other countries have done. Namely, government could simply extend the policy of free (or cheap) energy services to a wider array of fuels, so as to re-level to playing field. It could cut prices on LPG, for example, so as to encourage its use. But such policies have two severe—and, in our view, fatal—problems. First, it is politically very difficult to contain costs through a policy that multiplies price distortions in an already distorted market. Government will find it very difficult to roll back the 50 kWh of free electricity already on offer; instead, it will probably find the need to add new cut price services on top of the existing subsidies. Second, managing behavior and technological choices through distorted markets is extremely difficult and prone to failure. For example, although LPG appears to be superior for cooking, should government also offer subsidies for solar hot water heaters that, like LPG, are more cost effective than electricity for supplying the service of water heating in some settings? How will government anticipate the rise of new technologies—will it offer to subsidize all newcomers, and will innovators of new technologies believe that such a promise is credible? (Already LPG is at a disadvantage relative to kerosene (or "paraffin") as the latter enjoys special tax treatment.) With time, such an approach to pro-poor energy policy is likely to become both expensive and highly market distorting. Such an option is economically unattractive, but we include it because it is what many governments, in practice, actually implement—namely, they tailor policies for particular favored fuels and technologies.

A second option is to make use of the market. We envision a simple but profoundly important change to the free electricity policy: to offer an energy credit of economic value *equivalent* to the cost of providing 50 kWh electricity per month. Allow households to choose the clean energy source that best meets their needs, rather than specifying (through an electricity-only subsidy) that the choice must be electric[8]. The best way to implement such an approach will probably vary by region and type of household. For households that use pre-paid codes on their electric meters, the subsidy can be delivered by household, allowing the user to choose a mix of energy options adding up to a total consistent with the subsidy. Such a system could be administered by means of distributing to consumers, vouchers or an "energy card" akin to a bank card. Approved vendors—whether LPG sellers or installers of solar hot water heaters—could debit the cost of their services directly from the cards or use the vouchers as a cash equivalent[9]. This option, which we suggest here but merits more detailed analysis for its implementation,

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[8] It should be noted, that by applying limits to the current drawn, that peak demands (which drive up the costs) can be constrained. Such was the approach of the pilot study cited, however this has not been carried through to FBE policy. In effect, such constraints limit the overall cost of supplying electricity to the household by forcing consumption away from peak periods.

[9] Presently FBE (electricity only) is implemented as follows (DME 2005b): For pre-paid meters a household will be provided with a non-interchangeable voucher or token loaded with free basic units per month. When the free units have been used up, the consumer will need to buy additional units at the prevailing approved rates. For credit-metered customers, the total units consumed will be reduced by the amount of free basic units. For credit-meter customers, it is not easy to see when the free units are exceeded.

offers the opportunity to rectify a distortion that is already arising in electric services, with negative consequences for innovation and fairness in the provision of electric services: rural homes served by solar power have limited electricity supply. The approach proposed here, which would make free basic energy fungible for non-grid electric services as well as non-electric services, would level the playing field.

For households that have traditional meters (rather than pre-paid cards), implementation may prove more difficult. Such households presently receive FBE directly on their electric bills; for non-electric services to have easy access to the same subsidy it may be necessary to create a scheme that would allow households to transfer some (or all) of their subsidy from the electric distributors to non-electric vendors. Such an approach may be cumbersome and could allow incumbent electric distributors to frustrate the policy by raising barriers and complications; those problems, however, are not appreciably different from those that arise with many types of regulation of electric distributors worldwide and can be overcome with relative ease and the focused attention of local policy makers. One strategy might be to begin implementation of our proposed scheme with users that have card-operated meters as a demonstration case. Those users are, disproportionately, the least wealthy households that are, indeed, the targets for the pro-poor FBE.

Conclusion

We offer these calculations and thoughts on FBE reform in the spirit of directing a powerful locomotive before it travels too far down a track that could prove costly and much less effective than plausible alternatives. Throughout, we have estimated the cost of FBE, comparing it with LPG, by focusing solely on the service of cooking. By our estimates, cooking will account for 17 kwh of the free electricity provided by FBE; to the extent that the energy services that use of the balance of the free 50 kwh have similar properties (e.g., high peak coincidence), the costs of FBE will multiply. Moreover, our calculation is based on a series of highly conservative assumptions that lead to what we have termed the "floor cost" for electric cooking—the actual costs will be higher, perhaps much higher as we have demonstrated in our sensitivity analysis.

The importance of careful policy design is important at this early stage because as households gain confidence that FBE is a permanent policy they will optimize their investment in electric appliances (including stoves) to make fullest use of the free power. Moreover, the 50 kWh figure is not set in stone; already there are agitations to raise the number. Additional loads would require additional supply during peak periods and would exacerbate the shift to a peakier load curve, which in turn will increasingly require dispatch of OCGT.

We accept the importance of pro-poor energy policies and propose reforms that could be surprisingly simple to implement yet profoundly important in multiplying the benefits to the poorest households from the offer of free energy. We also suggest that this reform will make it politically easier for government to contain the cost of these programs through the value of the credits it awards. A focus on performance will encourage innovators to devise a wider array of pro-poor energy services than would occur through an electricity-only approach. Indeed, this approach may alleviate pending power shortages on the national grid due to current peak reserve limits and help serve at least two urgent national imperatives.

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Appendix A: Calculating the “floor cost” of generating electricity

We define the “floor cost” of electricity generation as the calculated cost to supply electricity which is lower than the actual cost to produce electricity. The calculations presented are valid for the situation where the shape of the new demand curve is either “peaky[10]” or “flat” and are useful for when new demand will create a shortage of electricity supply capacity (such as in the case of South Africa at the time of writing)[11].

The cost of generating electricity will be a function of the cost increases of any new capacity required, as well as the marginal cost of fuel, operations and maintenance of the plant used to generate the required electricity required. These costs are then be escalated by the transmission and distribution costs required to transmit the electricity to its intended consumers. This note focuses on the cost of generating the increased electricity demand.

The calculation rests on two simplifying assumptions:

1. It is assumed that the marginal capacity required will at least be equal to the portion of the new demand occurs during peak time plus the required reserve margin. The cost of this capacity is at least equal to the cost of the plant available with the lowest capital cost. In South Africa’s case that is OCGT peaking plant.
2. And, the marginal cost of electricity “production” is at least the marginal cost of supply were the demand profile of the new demand “flat”. It is assumed that peaking plant are run on the margin at least in proportion to load factor of the most run peaking plant. In the case of South Africa, that is that pumped storage plant which is run at a load factor of 20% and coal fired baseload plant for the rest.

For any new demand in electricity consumption we can therefore compute the floor price P_F as follows:

$$P_F = \frac{\sum (CI_t + P_t)(1+r)^{-t}}{\sum \frac{E(1+r)^{-t}}{(1-D_L)}}$$

Where

P_F = Floor cost[12] of meeting increases in electricity demand [R/kWhr]

CI_t = Capital investment cost required in time period t [R]

P_t = Marginal running cost to meet an increase in time period t [R]

r = Discount rate [fraction]

D_L = Distribution losses to the customer [fraction]

CI = Marginal capacity investment due to increased demand [R]

<u>Where CI:</u>

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[10] That is more electricity is demanded during peak than off-peak times.

[11] This method could be used to estimate a “below minimum” cost for meeting new electricity demand” as well estimating minimum cost differences of supplying new demand with differing peak coincidence factors. Such as would be needed evaluating the minimum benefits of demand side management (DSM) activities.

[12] Or, equivalently, the “*below-minimum marginal cost*” of meeting increases in electricity demand.

$CI = ND*(1+V_M) * PCF * CC_{OCGT}$
ND = Marginal increase in demand [kW]
V_M = Reserve margin requirements as a fraction of peak demand [fraction]
PCF = (Peak coincidence factor) giving the proportion of new demand during peak time [fraction]
CC_{OCGT} = Per unit of capacity capital cost of new OCGT plant [R/kW].

Where P:
$P = [P_{ps} * LF_{ps} + P_{PF}*(1-LF_{ps})]*E$
P_{PS} = The running cost of a pumped storage plant per kWhr [R/kWhr]
P_{PF} = The running cost of a coal fired power plant per kWhr [R/kWhr]
LF_{PS} = The annual percentage load factor of the most run peaking plant [fraction]
E = The marginal increase in energy demand [kWhr]