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Energy Efficient Refrigerators Incentive Program Options for South Africa

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ABSTRACT

As energy-intensive mainstream products, residential refrigerators offer a significant opportunity to reduce electricity consumption through energy-efficiency improvements. This paper presents the results of a preliminary techno-economic analysis of refrigerator energy efficiency for South Africa. The analysis considers design options that can improve the efficiency of current refrigerator configurations. We then describe incentive program options for accelerating adoption of more-efficient refrigerators and associated energy savings. Based on the findings and on international experience with program designs, we briefly discuss possible program options to accelerate the market penetration of more efficient refrigerators. Finally, we point out that local data and stakeholder participation will be essential to refine and validate the analysis presented here and to develop a program that is best suited to the market conditions and barriers in South Africa.

1. INTRODUCTION

During the past two decades, the government of the Republic of South Africa has actively developed policies and regulatory measures to promote the efficient use of energy, driven primarily by economic need and secondarily by environmental concerns.

South Africa's government is currently developing the country's first mandatory minimum energy performance standards (MEPS) and labeling program. The South African Bureau of Standards has developed the South African National Standard (SANS) 941 to establish energy-efficiency measurement methods and labeling scales for different appliances. For refrigerators, the energy performance categories for the labeling program are adopted from the European Union (EU) Directive of 2010 [1].

The South African National Regulator for Compulsory Specification – in collaboration with the Bureau of Standards, the Department of Energy, and the Department of Trade and Industry – is developing a compulsory specification based on standards. VC 9008 will set required energy-efficiency levels for all new refrigerators. The MEPS is expected to be published in the government gazette in December 2013 after which it will be open for comment through March 2014.

Unlimited Energy conducted an impact assessment study in 2012 [2]. This study, funded by the Fund for Research into Industrial Development, Growth and Equity (FRIDGE), assesses current efficiency levels of local and imported appliances and considers the potential impact of a standards and labeling (S&L) program on consumers and local manufacturers. Based on a market assessment,[1] the FRIDGE study found that MEPS could achieve level B efficiency[2] for refrigerators.

South Africa has also set up a transparent, systematic mechanism to fund energy efficiency. An environmental levy in the electricity tariff is used to fund the implementation of energy efficiency demand-side management (EEDSM) programs by South Africa's public utility, Eskom. Energy efficiency is now included as a resource of choice in integrated planning for future energy resources. The current multi-year price determination (MYPD3) allows funding of 5,183 million (M) Rand (R) for EEDSM for a period of five years, 2013 to 2018. Other non-residential measures to support energy efficiency have been implemented or are being considered by the government [3,4].

2. MARKET ASSESSMENT

2.1 Market Penetration

Refrigerators are very common household appliances. About 85% of South African households have refrigerators (SAARF Living Standards Measure Surveys). As shown in Figure 1, refrigerator ownership increases rapidly as living standards improve and households gain access to electricity. Ownership is close to 100% for the top six brackets of the living standards measure (LSM)[3] and close to zero for about 6% of the population. Refrigerators are key appliances that meet a basic need to conserve food and one of the first assets,

[1] The FRIDGE project steering committee decided that it was most appropriate to conduct an impact assessment study with a specific focus on local manufacturing rather than an engineering analysis.

[2] Level B refers to the energy performance categories adopted from the EU Directive 2010 [1]

[3] The SAARF LSM divides the population into 10 LSM groups, based on various living standards criteria

after a television that a typical low-income household acquires. It is estimated that refrigerators account for about 15% of residential electricity use in South Africa and represent a large share of low-income households' energy bills.

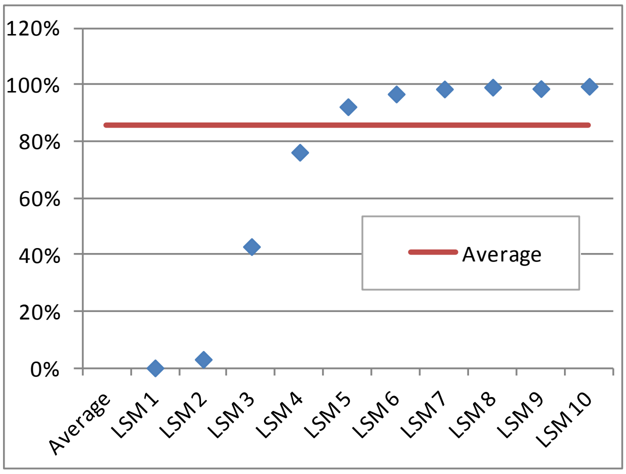

Figure 1. Refrigerator Ownership by Living Standards Measure (LSM)
Source: [5]

Market Product

The market for refrigerators and refrigerator-freezers can be broken down into the following product classes, based on the EU labeling program (EC, 2010):

- Refrigerators (EU Categories 1-6)
- Refrigerators that include a Freezer (EU Categories 7&10)

Based on two data sets of imported and locally manufactured refrigerator models sold in South Africa [2] we found that 91% of refrigerator models on the South African market are in the refrigerator/freezer category (EU categories 7&10). Table 1 shows the number of models in each category and the market shares by product category. We estimated domestic versus import market shares from sales data provided by [6] and found that the majority of refrigerators are produced locally. The current analysis focuses on refrigerator/freezers because they make up the majority of the market.

Table 1. Import VS. Local production for each product class

	Domestic	**Imported**	**Overall**
Refrigerator (1-6)	0%	9%	9%
Refrigerator/Freezer (EU category 7&10)	68%	23%	91%
Total Refrigerator/Freezers	68%	32%	100 %

3. ENERGY PERFORMANCE ANALYSIS

A multi-country international techno-economic analysis of refrigerators energy efficiency, commissioned by the United States Department of Energy (U.S. DOE) in support of the SEAD initiative, is currently being performed by the International Energy Studies group at Lawrence Berkeley National Laboratory (LBNL) in collaboration with Navigant Consulting Inc. [7]. For the current paper, our analysis of the potential costs and benefits of increasing refrigerator energy efficiency in South Africa was based on selected data adjusted to represent South Africa. Our analysis determines the cost vs. efficiency relationship of more efficient design options for the most common refrigerator unit sold in South Africa, which we refer to as the *base case*.

The design improvement options include:

- optimization of capillary tube characteristics
- optimization of thermostatic control, including use of electronic control
- optimization of evaporator characteristics
- optimization of condenser characteristics
- use of a higher-efficiency compressor
- increase in insulation thickness

The engineering analysis was adjusted to the local market taking into consideration:

- the predominant refrigerator product class
- the technical characteristics of the baseline appliance
- energy performance test procedures
- materials costs
- energy costs
- labor costs
- mark-ups for importers, transportation and distribution, retailers
- value added (sales) taxes

Table 2 shows the resulting design options and associated retail prices, and manufacturing costs. Of particular note is the fact that adding extra insulation such as options 3 and 4 are not expensive but can have a disproportionately large impact in energy terms since the base case assumed low insulation thickness. Also of note is the fact that these options reduce the storage volume available and hence have a modest impact on the service available.

Table 2. Energy-Efficiency Design Options

Option #	Change from previous option	**Annual Energy Consumption (kWh)**	**Retail Price (Rand)**	**Manufacturing Cost (Rand)**	**EEI***
Base case	Fresh-food cabinet insulation (22mm door, 25mm sides, niche and top, 50mm mullion, 35mm back), freezer cabinet insulation of 30mm, compressor = Zanussi GL80AA90, R134a	746.8	3,448	1,586	128
1	As base case with fresh-food evaporator height = 0.33m, condenser height increased to 1.5m, application of thermal paste to improve evaporator conductivity, and re-optimized thermostat/controls and capillary tube	547.1	3,631	1,678	94
2	As Option 1 with fresh-food evaporator height = 0.38m, freezer evaporator width = 0.45m , use of higher-efficiency compressor (Danfoss NLX15, R600a), and re-optimized control	409.9	4,205	1,944	70
3	As Option 2 with 10mm extra insulation in fridge, freezer back/niche, and fridge door, and 20mm extra in freezer; fridge evaporator to 0.48m; and re-optimized control	203.7	4,345	2,036	35
4	As Option 3 with extra 10mm insulation on freezer back and niche, fridge evaporator to 0.41, freezer evaporator = 0.42m, and re-optimized control	131.8	4,375	2,051	23
Design option with less certain impact					
5	Application of maximum vacuum-insulated panel coverage and reduction of evaporator cooling capacities to attain design temperatures	111.1	7,474	3,504	19

Source: [7]

* Energy Efficiency Index (EEI) are set out in the European Energy Labelling Directive [1] but essentially an EEI value of 100 is the efficiency of the average product on the EU market in 1993

Although refrigerators with energy consumption and costs equivalent to the base case presented in Table 2 are still currently available on the market, we considered the proposed MEPS as the “technical floor” for new sales, which is close to Option 2 in the program analysis.

4. PROGRAM ANALYSIS

Incentive programs are essential policy tools to move markets toward energy-efficient products. These programs complement mandatory standards by accelerating market penetration of energy-efficient products that exceed mandatory standards, thereby preparing the market for future increases in the stringency of mandatory standards. Incentive programs also influence consumer purchase decisions and, where a labeling program is also in place, incentive programs educate the public on the benefits of the higher-efficiency products in the labeling program. The existence of a consumer rebate is a signal in itself, underscoring the value of the labeling program. Incentive rebates are often linked to high-performance products (that are labeled as highly efficient).

Several factors make an incentive program for energy-efficient refrigerators an attractive option:

- Refrigerators represent a high percentage of total residential energy consumption in low-income households
- Higher-income households may have two or even three refrigerators
- Refrigerator energy performance has improved significantly during the past 15 years, creating significant room to capture energy savings by accelerating penetration of newer models

- Refrigerator lifetimes tend to be longer when a secondary market exists

5.1 International Experience

There are numerous international examples of programs targeting refrigerators although program designs vary among countries. Table 3 shows examples of refrigerator incentive programs from around the world:

Table 3. International Examples of Refrigerator Incentive Programs

	Administrator	Beneficiary	Form
Ghana [8]	Government	Utility customers	Rebate/ replacement
Mexico [9]	Government-owned utility	Utility customers	Rebate/ replacement
Brazil [10]	Investor-owned utilities (IOU)	Low-income utility customers	Rebate/ replacement
United States[4] [11]	Federal government and Utilities	Manufacturers and Consumers	Tax credit and Rebate/ replacement
China [12]	Government	Manufacturers and retailers	Rebate

The term "administrator" in Table 3 refers to the body that carries out the incentive program. The table shows examples in which the administrator is the government (Ghana, U.S., China), a government-owned utility (Mexico), or investor-owned utilities (Brazil, US). The term "Beneficiary" denotes the recipient of the incentive. Upstream programs use incentive funds to affect costs at the point where an appliance is produced; the Beneficiary for these programs is the manufacturer. Downstream programs aim incentives at the consumers who will buy the products. The form of incentive explains the mechanism by which the incentive is conveyed. For example, in a rebate/replacement scheme, consumers are offered rebates on efficient refrigerators often in exchange for surrendering their old, inefficient units. Under a tax credit design, a manufacturer could receive a tax credit (up to a specified maximum amount) for each unit produced that meets a defined minimum efficiency.

5.2 Cost-Benefit Analysis

The techno-economic analysis in the previous section estimates the incremental cost of producing and purchasing more efficient refrigerators based on an engineering analysis. This information can be used to assess program implementation costs and benefits and to screen energy efficiency programs. When the ratio of benefits to costs is greater than 1, the program is perceived as cost effective; the higher the number is, the more the benefits surpass the costs.

Costs and benefits can be calculated according to different stakeholder perspectives. In this section, we focus on two common tests used by U.S. utilities. Table 4 summarizes information about the program administrator cost (PAC) and total resource cost (TRC), which represent the perspective of the program administrator (often a utility) and all customers in the service territory as well as the program administrator, respectively. [13,14].

Table 4. Cost-Benefit Tests

Test	Benefits	Costs
TRC	Utility avoided supply costs	- Program administrator costs - Incremental cost
PAC	Utility avoided supply costs	- Program administrator costs - Incremental cost covered by incentive

TRC: As shown in Table 4, the TRC test compares the benefits of avoided supply costs from discounted savings to the costs of administering a program and upgrading refrigerators.

PAC: The PAC measures cost effectiveness from the program administrator's viewpoint. It accounts for benefits and cost in a manner similar to that used by the TRC but only account for the incremental share of costs covered by an incentive offered by the utility. Therefore TRC and PAC only differ when the amount of incentive does not cover the full incremental cost.

[a]
The next equation shows the Benefit-Cost ratio.

$$B/C\ Ratio = \frac{NPV\ \sum Avoided\ Supply\ Cost}{NPV\ \sum AC + IC}$$

Where AC represents the administrative cost and IC represents the incremental manufacturing cost in the case of an upstream program and the incremental purchasing cost in the case of a downstream program.

The next two sections show the results of the above tests for two scenarios:

Scenario 1: The first scenario considers an upstream program in which 100% of the incremental manufacturing cost is covered by an incentive to the manufacturer to produce refrigerators that are more efficient than the MEPS level B.

Scenario 2: The second scenario considers a downstream program in which the incentive is given to the consumer to reduce the retail price of refrigerators that are more efficient than the MEPS.

Table 5 lists the assumptions in this analysis of incentive programs. Discount rate is assumed to be equal to the before tax Weighted Average Cost of Capital (WACC)

[4] Two types of refrigerator program exist in the U.S.: a manufacturer tax incentive administrated by the federal government and rebate and replacement programs administrated by Utilities or State third party agency.

calculated by Eskom in accordance with the approved MYPD methodology [15]. The avoided generation cost is the 2012 estimate calculated by NERSA [16]. Administrative cost includes 10% of the incentive cost for administrating the program and 8% for M&V. These estimates correspond to the maximum allowance permitted by NERSA [16].

Table 5. Incentive Analysis Assumptions

Assumptions	
Discount rate	7.65%
Avoided generation cost - rand/kWh	0.7146
Administrative cost	18% of total incentive cost
Baseline	B (hypothetical new standard)
Refrigerator lifetime	10 years

Scenario 1 Results: UPSTREAM PROGRAM

In this scenario, **Error! Reference source not found.** shows the results of the TRC and PAC cost-effectiveness tests, using the assumptions in
Table 5 and an incentive that covers 100% of the incremental cost of more-efficient refrigerators. The results are shown according to Options 3 to 5 in

Table 2. Energy-Efficiency Design Options

, which correspond to efficiency ratings A+ A++, and A+++.

The TRC and PAC test results overlap. They are superior to 1 for A+ and A++ models. The benefit-cost ratio is highest in the case of A++. Conversely, incremental costs for an A+++ model are too high at this point in time.

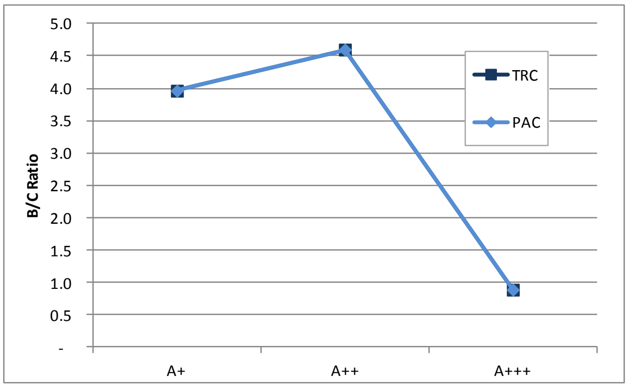

Figure 2. Upstream Scenario 1 Results

Scenario 2 Results: DOWNSTREAM PROGRAM

In a downstream program, the level of incentive (or rebate) offered by the utility varies. Figures 3 and 4 show the results of the TRC and PAC tests for different level of rebate offered (x axis). The rebate level does not affect the TRC test result because that test takes into account the overall incremental cost, representative of the service territory incremental cost. The rebate level does not differentiate whether the participant or the program administrator pays for this incremental cost. On the other hand, the PAC is affected by the level of rebate that the program administrator offers. As the rebate gets closer to 100%, the results decrease.

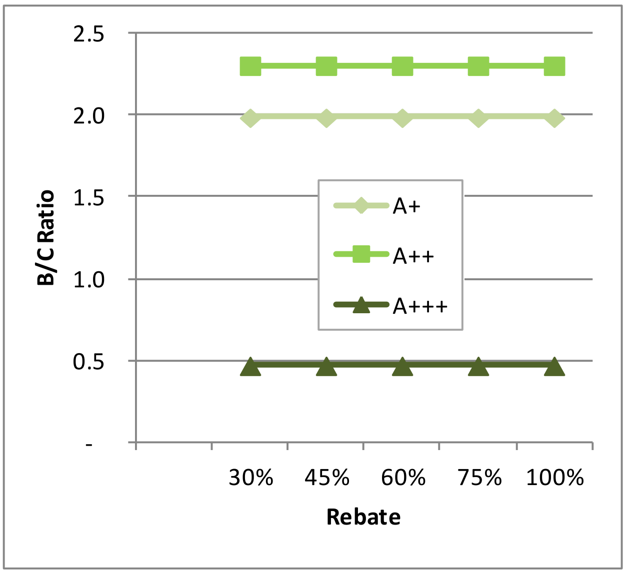

Figure 3. TRC Test

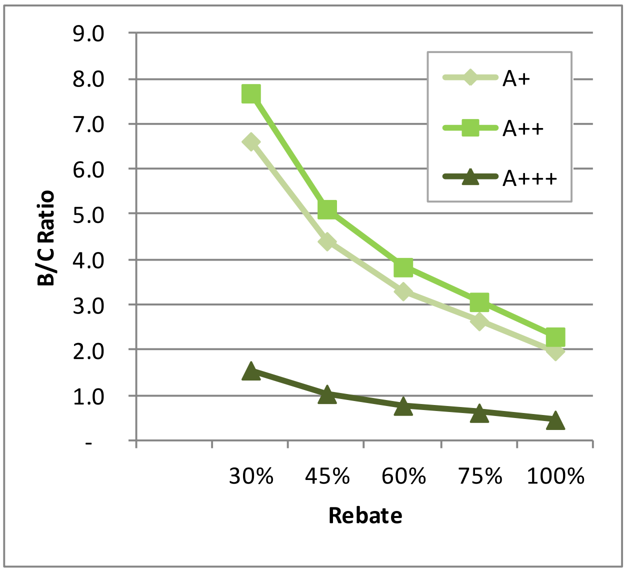

Figure 4. PAC Test.

Overall, the TRC and PAC tests are superior to 1 for A+ and A++ refrigerators, and the PAC test is superior to 1 for A+++ refrigerator for rebates covering only 30% of the incremental cost.

Other tests could complement this analysis, notably the participant cost test (PCT) and the societal cost test (SCT). However, the cost of electricity to consumers, which is a key element in the PCT, was not available to us for this analysis. This is because, in South Africa, a significant share of electricity is distributed by municipalities, which then recover some of their municipal services cost through a surcharge on the cost of electricity. An average consumer electricity tariff would be required to add the participant perspective to this analysis. Similarly, more research would be needed to calculate the SCT and account for all quantifiable benefits attributable to a program, such as avoided pollutant emissions, and other non-energy benefits, such as avoided blackouts etc. Our analysis does not take into account additional benefits of increased refrigerator efficiency beyond energy savings; these additional benefits include reduction in carbon dioxide emissions from electricity production and reduction in chlorofluorocarbons as a result of recycling old refrigerators.

These programs will also experience free ridership (i.e., participation by consumers who will buy efficient equipment regardless of the incentive will benefit from the incentive as well) and spillover, i.e. increasing adoption of energy-efficient products from program non-participants due to increased knowledge about the benefit of energy efficiency. Neither of these phenomena is accounted for in this analysis.

Moreover, additional benefits may be accounted for if avoided capacity costs for transmission and distribution, avoided emissions control costs for future generators and increased system reliability are considered. NERSA rules include transmission and distribution capacity as components of EEDSM avoided costs. We did not attempt to estimate these costs in the case of South Africa (as well as several other categories of system cost avoidance) but relied instead on the avoided cost of energy supply alone, as calculated by NERSA for 2012 [16]. Capacity savings also may be limited by the assumed deferral period for the avoided supply investments. Lastly, several other categories of avoided costs may be warranted, depending on market structures and future government actions. If renewable energy requirements were anticipated in the future, the avoidance of the increased costs of procuring those resources might be appropriate for consideration.

Finally, we would like to point that program administration costs typically are fixed and do not necessarily relate to the incentive cost. Therefore, the linear relation assumed between program administration cost and incentive cost is likely to overestimate administrative costs as incentives rise.. However, absent a history of administrative costs in South Africa, our method gives a first order of estimation.

5.3 Market Barriers

There are many different incentive program design options, and there is no perfect program design. A critical factor in successful program design and implementation is a thorough understanding of the market and effective identification of the most important local factors hindering the penetration of energy-efficient technologies [17]. In some case, a combination of upstream and downstream programs can be necessary to achieved market transformation [12].

6. DISCUSSION

This analysis is based on international data and assumptions. For development of an efficient refrigerator program in South Africa, the results of this study should be refined using data that reflect better the local conditions in South Africa, in particular as follows:

- *Engineering analysis*: In this study, manufacturing costs for refrigerator energy-efficiency improvements are based on an engineering analysis that used international data to model South African production conditions. The resulting estimates need to be validated with input and review from South African manufacturers. Similarly, retail costs for refrigerators with different energy-efficiency ratings need to be validated based on a price survey of refrigerators available on the South African market.
- *Market survey*: The South African market should be surveyed to determine not only the specific

types of refrigerators sold on the local market but also the types of refrigerators that constitute the stock currently in use. This information would allow for a more precise estimate of current energy consumption by refrigerators in South Africa as well as of the potential energy savings from an efficient refrigerator program. A market survey would also inform the refrigerator program design by providing information on the consumers' purchasing habits, the types of refrigerators available in stores, the extent of the secondary market, etc.

- *Use of field vs. rated energy consumption data*: Our analysis used rated energy consumption for refrigerators. It is important to consider actual consumption in the field and the influence of factors like outdoor temperature, and power supply quality. The analysis also assumes all refrigerators are always connected but this is not always the case in developing countries.
- *Additional factors to consider:* Other considerations include the "rebound" effect, i.e., the possibility that reductions in energy costs may encourage customers to use more energy and therefore lower the impact of the energy savings achieved; net savings, i.e., exclude savings from program participants that would have undertaken the energy-efficiency activities in the absence of the program (free riders) and include savings from nonparticipant programs that resulted from the influence of the program (spillovers).

All of the above parameters influence the ultimate savings that can be achieved through a refrigerator efficiency program and that must be considered during the program design phase in order to maximize the energy savings and social benefits that are associated with increasing the refrigerator efficiency. In addition, this analysis considers only two types of programs (upstream and downstream). Additional designs exist, including replacement programs that affect the energy efficiency of the refrigerator stock.

Moreover, how an incentive is directed, and to whom, and what program design will be most advantageous depends on program goals, market barriers that may constrain uptake of efficient models, and the local market structure. The best program design for South Africa may emerge from collaboration of local stakeholders and perhaps take into account factors unique to to South Africa and its different geographic and economic segments.

Thus, the assumptions in this study should be refined to include local data as part of designing an efficient refrigerator program in South Africa. Moreover, local stakeholders should participate, to contribute both to the methodology and assumptions made in the analysis of a program design for South Africa and to the development of the program itself. Meaningful stakeholder participation helps ensure not only an analysis that accurately reflects local conditions but also acceptance and success of the resulting program design.

7. CONCLUSION

Well-designed incentive programs address market barriers and complement mandatory standards. Incentive programs push market penetration of more-efficient equipment, and appliance standards cement these market improvements by eliminating the least-efficient models from the market. In countries with slow-moving S&L programs or weak standards, incentive programs can help jumpstart negotiations to achieve higher efficiencies or can reveal real limitations to efficiency improvement. Incentive programs can make ambitious standards politically palatable and acceptable to local manufacturers and the public.

The current study gives a first-order estimate of the cost effectiveness of a refrigerator program based on the data and assumptions developed for a multi-county international study. A follow-up analysis to the current study is needed to obtain additional data from South Africa and input from local stakeholders regarding energy and cost assumptions as well as program design options that address the market barriers to energy efficiency that are specific to the South Africa. Once a tentative program design is devised based on local data and stakeholder input, a small-scale pilot program could be implemented to test the opportunities and barriers that will face a regional or national program.

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Presenter:
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