



CSIR-INSTITUTE OF INDUSTRIAL RESEARCH

Measurement and Evaluation of Refrigerator Energy Consumption and Efficiencies in Ghana

Final Report

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January, 2008

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1. BACKGROUND

In February 2006, the CSIR-Institute of Industrial Research submitted technical and financial proposal on the *Ghana Refrigerator Efficiency Initiative* for the consideration of the Energy Commission for funding. The proposal was submitted by the Institute on behalf of the Ghana Refrigeration Efficiency Collaborative (GREC), which comprises the CSIR-Institute of Industrial Research, Energy Foundation, National Air-Conditioning and Refrigeration Workshops Owners Association (NARWOE), Kwame Nkrumah University of Science and Technology (Department of Mechanical Engineering), all in Ghana, and the Lawrence Berkeley National Laboratory, California, USA.

The objective of the project is to promote efficiency standards of refrigerators in households in Ghana, and thereby contribute towards poverty reduction. There are three key expected benefits from this project: (1) Environmental benefits of reduced carbon emissions and CFC leakage, (2) Economic benefits of decreasing the cost of modern energy services supply to rural households, and (3) The poverty reduction benefits of decreasing the electricity bill of poor households with refrigerators and refrigerator-freezers.

The outputs of this initiative will include: (1) A database of refrigerator efficiency measurements; (2) The formulation of efficiency measurement protocols; (3) A draft manual for refrigerator rehabilitators on how to increase refrigerator efficiency; (4) A refrigerator energy use monitoring and evaluation curriculum that can be applied to science classes in Ghana; and (5) A draft policy document on regulation and legislation that can assist the enhancement of refrigerator efficiency over the long term in rural, urban and peri-urban households in Ghana.

In response to the proposal, the Energy Commission offered to support aspects of the initiative that involved the measurement and evaluation of the refrigerator energy consumption and efficiencies in the country. In May 2006, a contract was signed between the Energy Commission and the CSIR-IIR for the execution of the project.

The survey commenced on 25th July 2006 and was completed on 15th December, 2006. A Progress Report was submitted to the Energy Commission in December 2006. This document presents the Draft Final Report on the project.

2. PROJECT METHODOLOGY

The key activities taken under the project on measurement and evaluation of the refrigerator energy consumption and efficiencies were:

- i) questionnaire development, pre-testing and modification;
- ii) selection of survey locations;
- iii) training of survey enumerators;
- iv) national survey on refrigerator energy consumption in households; and
- v) data coding, entry and analysis.

2.1 Sampling Framework

The selection of the survey areas of the study was based on a multi-staged sampling technique, and it covered households in urban communities, peri-urban communities and rural communities. The urban communities selected for the survey were Accra, Kumasi, Cape Coast, Tamale, Ho, and Bolgatanga. The peri-urban communities were selected from areas near to these urban communities. The selected rural communities were also within 50 kilometres from the urban communities. Table 2.1, Figure 2.1 and Figure 2.2 present the distribution of households covered by the surveys in the various communities.

Table 2.1: Number of Households covered by National Survey on Refrigerator Energy Consumption

Name of Town /Village	Urban				Peri-urban No. of Households	Rural No. of Households
	Low Income	Middle Income	High Income	Total		
Accra	50	30	20	100	60	40
Kumasi	50	30	20	100	60	40
Cape Coast	40	25	15	80	50	30
Ho	35	20	15	70	45	25
Tamale	40	25	15	80	50	30
Bolgatanga	35	20	15	70	45	25
Sub-total no. of households	250	150	100	500	310	190
Total no. of households						1000

2.2 Training of Survey Enumerators

The survey enumerators were carefully selected from undergraduates in the departments of engineering in the universities and polytechnics, as well as some students who had completed senior secondary school. The enumerators underwent orientation sessions to introduce them to the objectives of the project and were provided with special electricity meters procured for the project. They were trained in the administration of the questionnaires in the households, and the measurement of the energy consumption of the household refrigerators and refrigerator-freezers with the special meters. The meters were imported from Germany, and had to be fitted with mounting boards by the consultants to facilitate their use in the project.

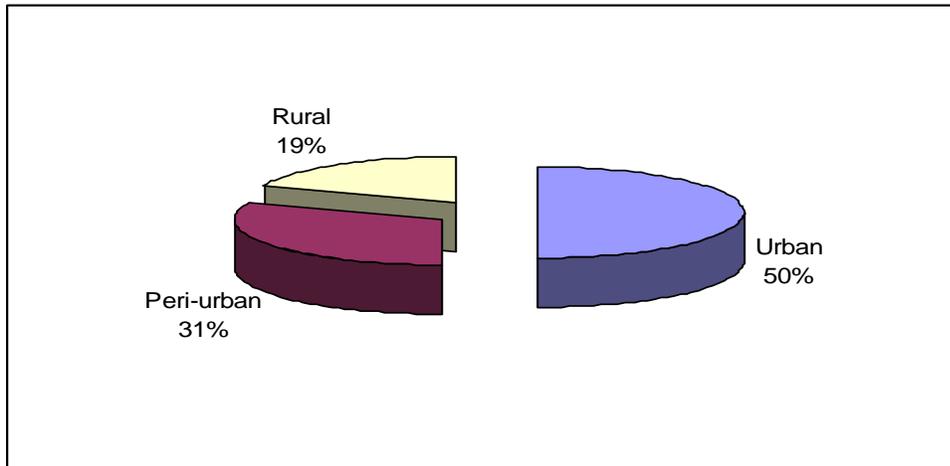


Figure 2.1: Distribution of Households covered by the Survey

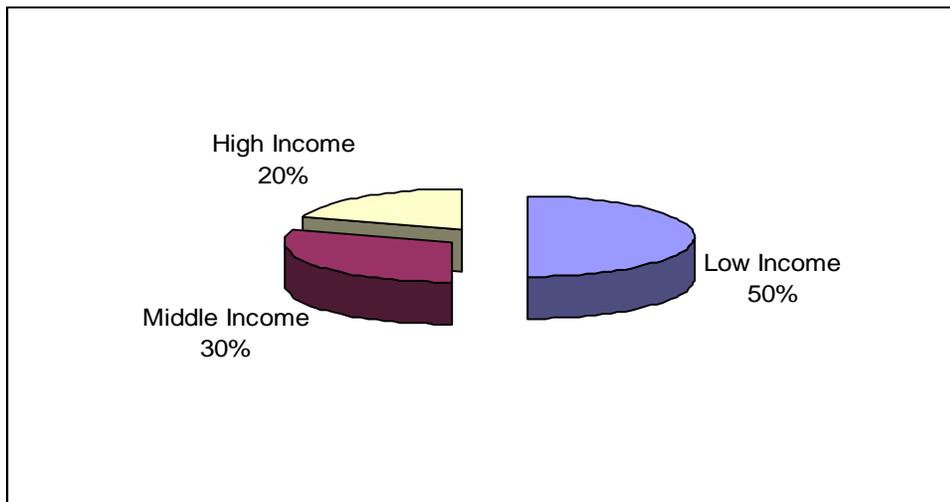


Figure 2.2: Distribution of Households covered in Urban Areas

2.3 Administration of Questionnaire and Energy Consumption Measurement

During the survey, the special electricity meters were fitted to refrigerators and refrigerator-freezers in a household for 15-24 hours to monitor the electricity consumption. A questionnaire was then administered by the trained enumerators through direct interview of the head of the household or the spouse. A copy of the questionnaire is presented in the Appendix. The data gathered in the households by the enumerators included:

- i) electrical power consumed by the refrigerator in 15-24hrs;
- ii) refrigerator brand name / model / manufacturer;
- iii) temperature in refrigerator's food and freezer compartments;
- iv) ambient temperature near refrigerator; and
- v) size of refrigerator.

2.4 Data Analysis and Presentation

Microsoft Excel software was used for the multivariate analysis of the data collected in the survey, as well as for the presentation of the electricity consumption levels and patterns of the refrigerators and refrigerator-freezers in the households of the various communities.

2.5 Internal Quality Assurance of Study

The following steps were taken to assure excellent quality survey data, data analysis and final report:

- i) pre-testing of questionnaire in one of the possible survey locations to identify gaps and difficulties in information gathering, convenience and speed of questionnaire administration, and ease of data processing and interpretation; modification of questionnaire to address these gaps and difficulties;
- ii) comprehensive training of survey enumerators by the Project Leader on:
 - a) general questionnaire administration techniques;
 - b) basic communication skills;
 - c) random sampling of survey respondents

- iii) close monitoring of survey enumerators by the Project Leader during the survey (by joining them in the field in carefully selected segments of the survey) to check on the selection of respondents, strategy of communicating with respondents, and recording of the response of respondents;
- iv) periodic working sessions between the Project Leader and survey enumerators to review field data, discuss difficulties and constraints in the survey, and to develop and implement remedial measures;
- v) collaboration between the Project Leader and the officers of the Energy Commission throughout the project to ensure that the concerns and expectations of the Commission are coherently reflected in the output of the project.

3. RESULTS OF SURVEY

3.1 Energy Consumption of the Household Refrigerators and Refrigerator-Freezers

The annual energy consumption of the household refrigerators and refrigerator-freezers of different external volumes in the various types of communities is presented in Table 3.1 and Figures 3.1-3.5. Survey data of six households were found to be unsatisfactory and had to be rejected. Also shown in Table 3.1 are ambient temperatures, and the temperatures in the food and freezer sections of the refrigerators. The annual energy consumption of the household refrigerators and refrigerator-freezers was $1,250 \pm 1,200$ kWh/m³ depending on the external volume of the appliance. The external volume of the refrigerators and refrigerator-freezers was 0.45 ± 0.14 m³. The temperature in the food and freezer sections of the refrigerators and refrigerator-freezers was $10 \pm 5^\circ\text{C}$ and $6 \pm 7^\circ\text{C}$, respectively.

The annual energy consumption of the refrigerator and refrigerator-freezers generally increased with the external volume of the appliance. Figures 3.1-3.5 show that the energy consumption of the refrigerator and refrigerator-freezers per unit external volume decreased with increasing external volume of the appliance. The figures also indicate that there were no marked differences in the rate of decrease of the energy consumption of the refrigerator and refrigerator-freezers per unit external volume in the various types of communities – low, middle and high urban, peri-urban and rural households.

Table 3.1: Summary of National Survey Results

Area	Community Type	Average Temperature, °C				External Volume, m ³	Energy Use, ' 000 kWh/year	Deviation				
		No.	Outside	Food Section	Freezer Section			Outside Temp °C	Food Section, Temp °C	Freezer Section, Temp °C	External Volume, m ³	Energy Use, kWh/day
Accra	Low Income	30	26.6	13.4	-3.0	0.49	1.37	1.3	3.3	4.1	0.14	1.62
Accra	Middle Income	50	28.4	14.9	2.2	0.48	1.23	1.1	4.5	5.5	0.15	1.29
Accra	High Income	20	28.0	8.7	-3.8	0.60	1.17	0.6	1.9	4.2	0.28	1.16
Kasoa	Peri-Urban	60	28.0	13.9	-3.9	0.52	1.43	1.7	3.3	5.4	0.16	1.72
Akporman & Boiman	Rural	40	28.1	12.8	-5.0	0.45	1.13	1.4	3.9	3.9	0.14	1.31
Kumasi	Low Income	50	26.2	8.6	-4.5	0.36	0.94	2.2	5.4	9.0	0.12	0.92
Kumasi	Middle Income	28	27.4	4.9	-10.3	0.49	1.36	2.3	6.0	7.0	0.13	1.19
Kumasi	High Income	22	28.2	8.5	-9.6	0.46	1.21	2.0	6.6	7.6	0.12	0.85
Kotei	Peri-Urban	60	27.1	5.7	-7.5	0.43	1.13	2.5	5.2	4.9	0.19	1.18
Pakoso	Rural	40	26.3	8.9	-6.5	0.44	1.11	1.7	5.2	6.9	0.20	1.27
Cape Coast	Low Income	40	27.2	9.2	-7.9	0.44	1.27	2.3	5.0	5.3	0.14	0.92
Cape Coast	Middle Income	25	25.8	8.5	-14.9	0.44	1.02	1.6	5.9	5.1	0.12	1.22
Cape Coast	High Income	15	25.4	7.8	-11.2	0.45	1.27	1.3	2.8	6.5	0.12	1.38
Moree	Peri-Urban	50	26.6	9.1	-7.6	0.37	1.19	1.8	5.0	6.3	0.12	0.98
Kissi	Rural	29	26.3	7.6	-11.5	0.43	1.22	1.8	5.5	6.0	0.16	1.32
Ho	Low Income	33	31.3	5.9	-9.4	0.41	1.02	2.8	8.6	7.5	0.11	1.13
Ho	Middle Income	20	31.1	5.3	-8.5	0.35	1.04	2.8	7.9	7.3	0.11	0.94
Ho	High Income	15	34.3	12.3	-2.7	0.37	1.02565	4.5	6.0	8.2	0.17	0.85
Ahoe Town	Peri-Urban	45	30.6	11.0	-2.7	0.47	1.28	2.1	6.0	9.1	0.17	1.48
Ho-Dome	Rural	25	32.1	7.8	-5.9	0.49	1.20	2.3	6.3	10.0	0.18	1.31
Tamale	Low Income	40	30.6	13.0	-9.1	0.42	1.17	3.7	5.6	6.5	0.11	0.89
Tamale	Middle Income	24	27.8	10.2	-5.1	0.43	1.06	2.1	3.9	7.6	0.14	0.96
Tamale	High Income	15	28.4	14.4	-8.3	0.50	1.19	1.8	5.6	6.0	0.11	1.38
Sakasaka	Peri-Urban	50	29.7	7.7	-7.6	0.48	1.14	3.3	6.5	5.6	0.11	1.27
Wurushe	Rural	30	28.9	11.1	-7.3	0.44	3.41	1.6	3.1	4.8	0.13	1.02
Bolgatanga	Low Income	21	29.6	5.3	-5.7	0.40	1.05	2.0	8.3	9.8	0.08	0.97
Bolgatanga	Middle Income	20	32.7	19.3	13.0	0.44	1.25	1.8	8.8	10.5	0.11	1.41
Bolgatanga	High Income	20	26.5	9.9	-4.4	0.46	1.13	1.5	5.7	5.9	0.11	1.08
Zaare	Peri-Urban	37	30.6	7.7	-4.5	0.46	1.22	2.1	7.5	12.1	0.16	1.02
Daweo	Rural	40	32.7	14.7	-3.1	0.43	1.25	2.1	6.2	9.5	0.13	1.50
Total		994										
Average			28.6	10.0	-5.8	0.45	1.25	2.08	5.41	6.81	0.14	1.20

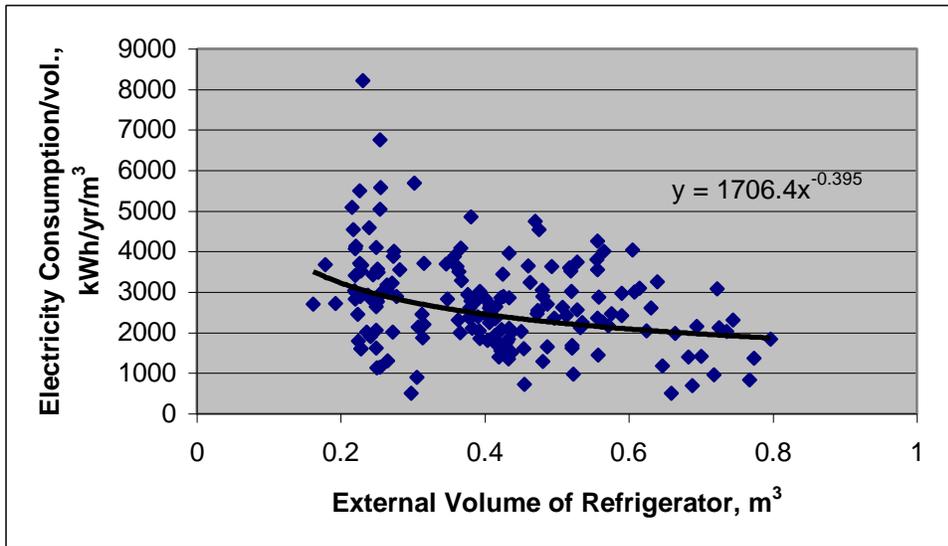


Figure 3.1: Energy Consumption of Refrigerators and Refrigerator-Freezers - Low Income Urban Households

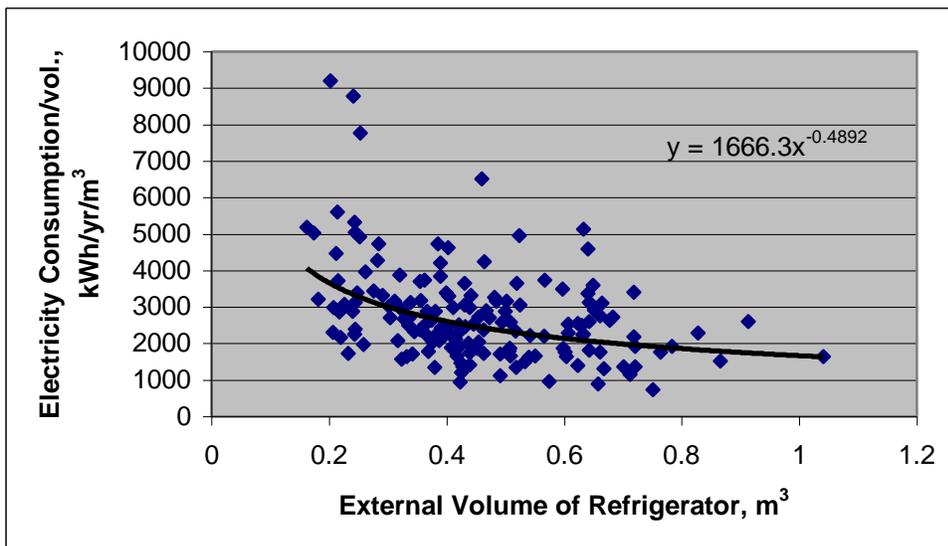


Figure 3.2: Energy Consumption of Refrigerators and Refrigerator-Freezers - Middle Income Urban Households

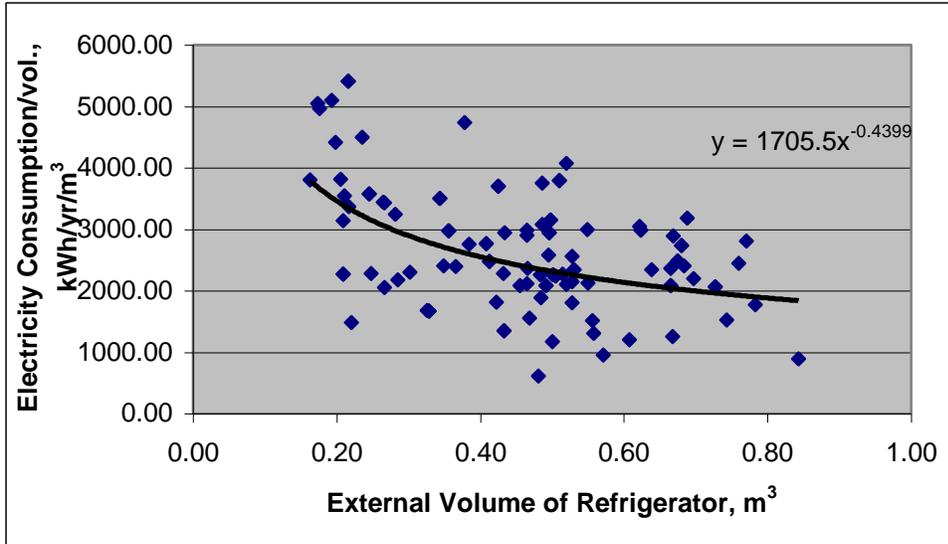


Figure 3.3: Energy Consumption of Refrigerator and Refrigerator-Freezers - High Income Urban Households

3.2 Challenges and Problems

It has not been possible to complete the project in accordance with the timelines in the project contract due to the following unforeseen factors:

- i) The commencement of the project was delayed for several weeks due to the unexpected late arrival of the special electricity meters that were imported from Germany;
- ii) Additional adaptation had to be done by the consultants on the meters by fitting mounting boards to facilitate their use in the field, and this further delayed the commencement of the project;
- iii) Periodic power outages, particularly in the urban and peri-urban communities, slowed down the data collection on the household refrigerators and refrigerator-freezers, since measurement of electricity consumption had to be repeated several times.

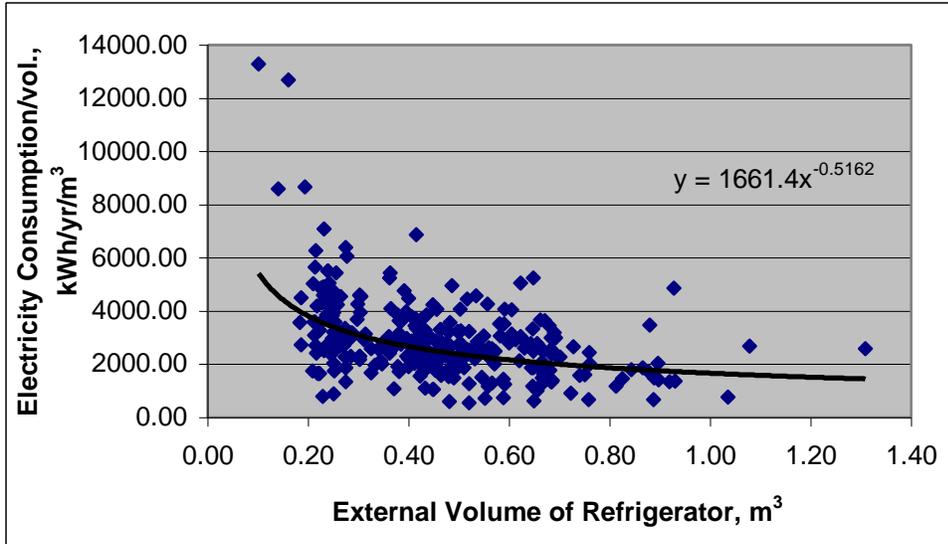


Figure 3.4: Energy Consumption of Refrigerators and Refrigerator-Freezers – Peri-Urban Households

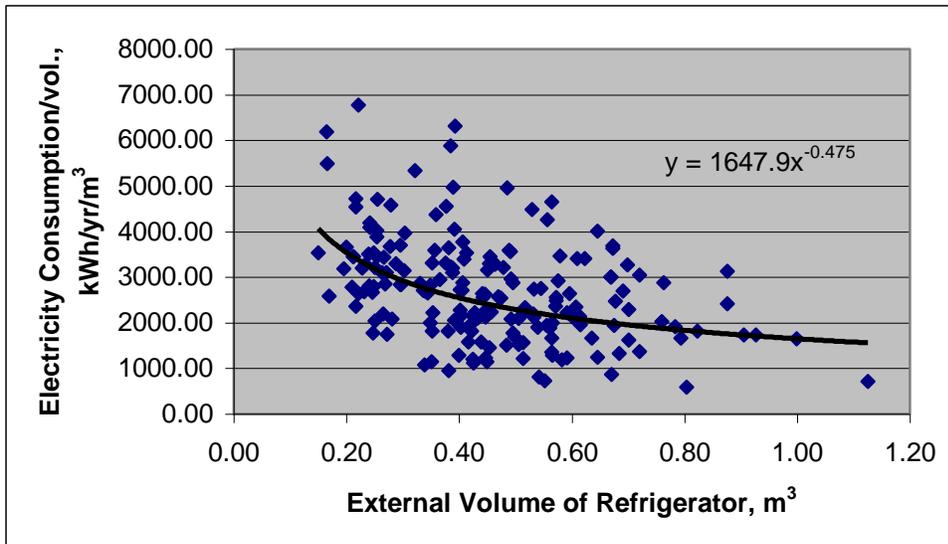
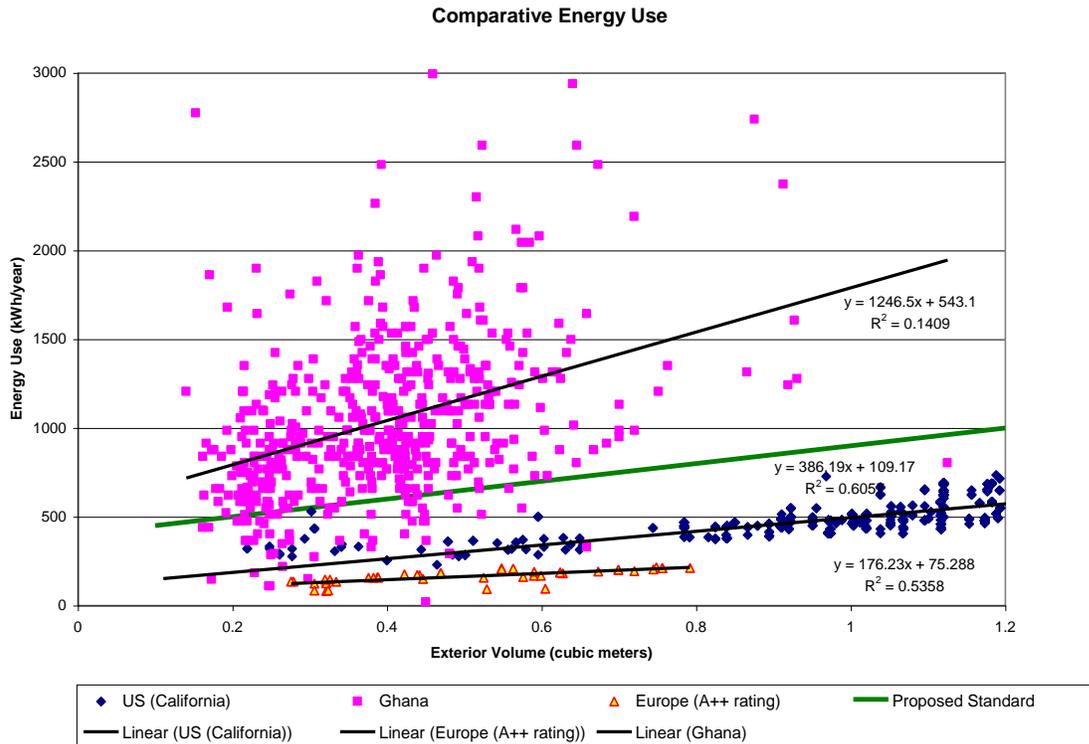


Figure 3.5: Energy Consumption of Refrigerators and Refrigerator-Freezers – Rural Households

Energy Consumption of Refrigerators in Ghana, compared with USA and Europe

The energy consumption of refrigerators in Ghana is generally more than three times the standards for the various sizes of refrigerators in the USA and Europe, as indicated in Figure 3.6.



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Energy Consumption of Refrigerators in Ghana

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Figure 3.6: Energy Consumption of Refrigerators in Ghana, compared with USA and Europe

4. PROPOSED ENERGY EFFICIENCY STANDARDS REGULATIONS FOR REFRIGERATORS AND REFRIGERATOR-FREEZERS

The annual energy consumption of the household refrigerators and refrigerator-freezers of different external volumes in the various types of communities is presented graphically in Figure 4.1. The energy consumption of the refrigerators and refrigerator-freezers is generally represented by the equations:

$$y = 1332.5x + 515.3 \quad \text{for refrigerators} \quad \text{(i)}$$

$$y = 1417.6x + 706.4 \quad \text{for refrigerator-freezers} \quad \text{(ii)}$$

where

y is the annual energy consumption of the refrigerators and refrigerator-freezers in kWh/year; and

x is the external volume of the refrigerators and refrigerator-freezers in m³

In consideration of the analyzed survey data of the annual energy consumption of the household refrigerators and refrigerator-freezers of different external volumes in the various types of communities, and the opportunities observed for energy savings, the proposed standards are to be represented by the equations, and presented in Figure 4.1:

$$y = 500x + 400 \quad \text{for refrigerators} \quad \text{(iii)}$$

$$y = 650x + 500 \quad \text{for refrigerator-freezers} \quad \text{(iv)}$$

where

y is the annual energy consumption of the refrigerators and refrigerator-freezers in kWh/year; and

x is the external volume of the refrigerators and refrigerator-freezers in m³

Accordingly, it is proposed a *one-star to five-star* energy efficiency rating for refrigerators and refrigerator-freezers in Ghana in which the ascending number of stars represents a higher energy efficiency ratio (ECR). The proposed rating based on the annual energy consumption is as presented in Table 4.1. The Proposed Energy

Efficiency Standards Regulations for Refrigerators and Refrigerator-Freezers is presented in Appendix 2.

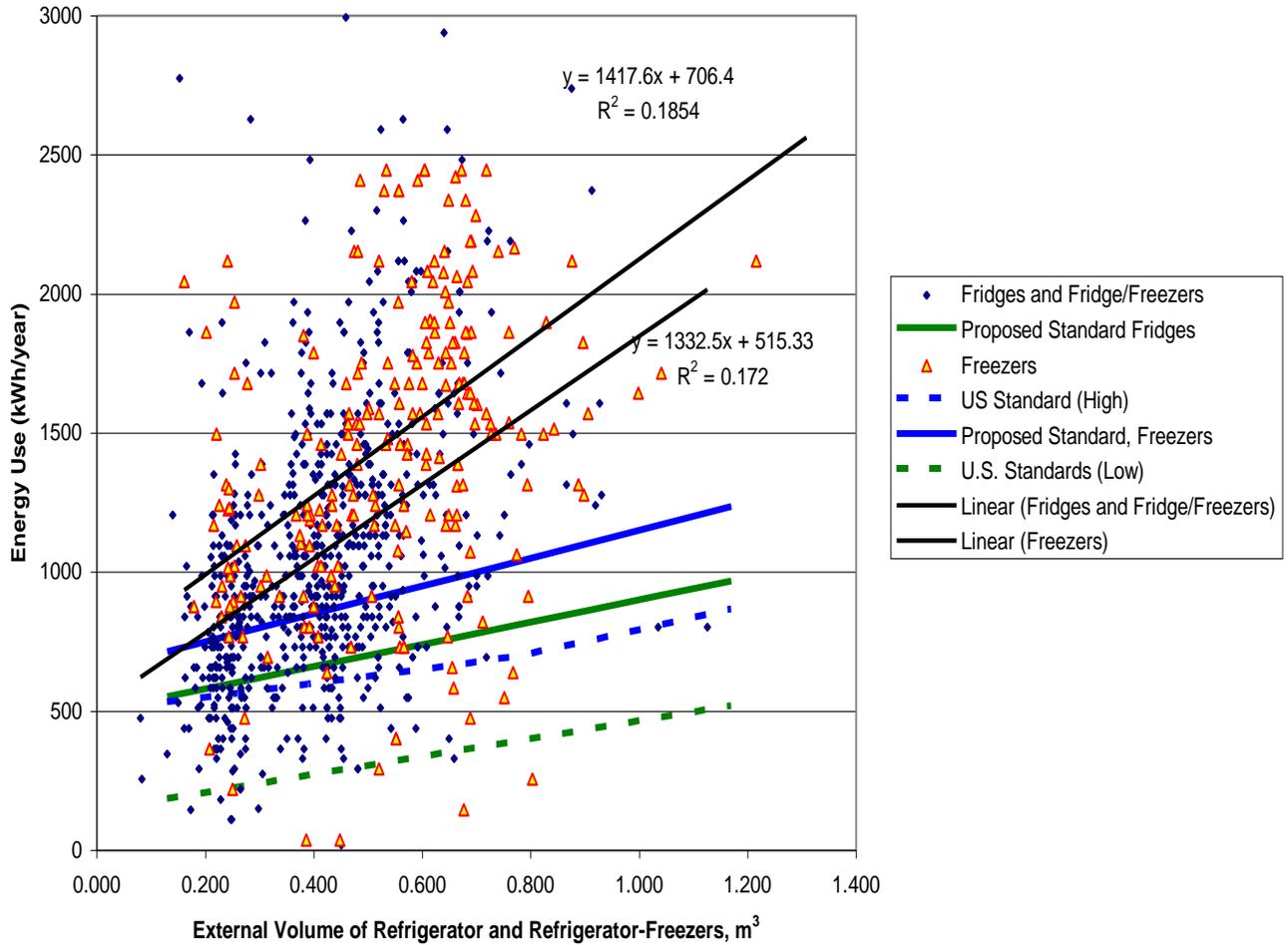


Figure 4.1: Current Energy Consumption of Refrigerator / Refrigerator-Freezers and Proposed Standards

Table 4.1: Proposed Rating for Refrigerators and Refrigerator-Freezers in Ghana

Appliance	Annual Energy Consumption, kWh/year				
	***** 5-Star	**** 4-Star	*** 3-Star	** 2-Star	* 1-Star
Refrigerators and Refrigerator/Freezers	<250	250 – 300	300 – 350	350-400	400 – 500
Freezers	<300	300-350	350-400	400 – 500	500 – 650

5. ESTIMATED ECONOMIC IMPACTS OF PROPOSED ENERGY EFFICIENCY STANDARDS AND LABELLING (REFRIGERATORS AND REFRIGERATOR-FREEZERS) REGULATIONS, 2007

The economic impacts of the enforcement of the energy efficiency standards for refrigerators and refrigerator-freezers in Ghana are summarized as:

- (i) Environmental benefits of reduced carbon emissions;
- (ii) Economic benefits of decreasing the cost of modern energy services supply;
- (iii) Poverty reduction benefits of decreasing the electricity bill of poor households with refrigerators and refrigerator-freezers.

5.1 Methodology of Impact Analysis

The estimation of these economic benefits has been conducted using the CLASP Policy Analysis Modeling Spreadsheet (PAMS) tool and the results from the household survey, and this methodology is explained in Appendix 3. The long-term forecast of refrigerator sales in Ghana that is used in the impact analysis is presented in Figure 5.1.

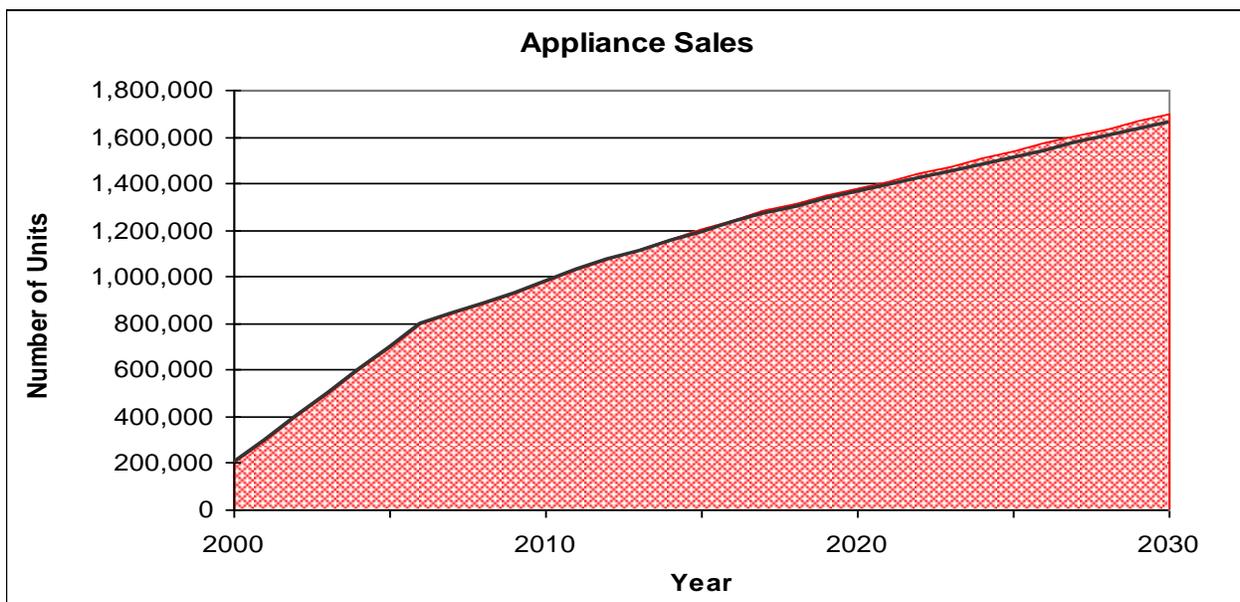


Figure 5.1: Appliance Sales Forecast used in Efficiency Standards Impact Analysis

With respect to the cost of more efficient refrigerators, available data indicates that there is no correlation in the marketplace between energy use and purchase price for refrigerators in Ghana, as indicated in Figure 5.2.



Figure 5.2: Price vs. Efficiency Curve used for Benefit/Cost Analysis*
**The cost factor is the price of the average standard-compliant refrigerator divided by the average price of the baseline refrigerator. The efficiency factor is the ratio of the standard-compliant efficiency divided by the baseline efficiency.*

Even though there is no correlation between cost and efficiency in the market there still is likely to be an increase the average price of refrigerators as efficiency of the refrigerators in the marketplace increases. As a standard is implemented, there is a market transformation process that will eliminate or rehabilitate the less efficient refrigerators leaving refrigerators that are compliant with program efficiency targets. For the cost-benefit analysis, as the average energy use of refrigerators decrease by a factor of three, it is assumed that the price of a refrigerator will increase from an average price of US\$150 to US\$400. The shape of the curve reflects the fact that very small increases in efficiency result in hardly any increase in price, but as efficiency is increased further, the price of the appliance starts increasing steadily.

5.2 Benefit/Cost Forecast Results

Figure 5.3 shows the estimated future benefits of a refrigerator market transformation program in Ghana beginning in 2010 in units of dollars/person/year. The bars in the graph represent the operating cost savings, and the line represents the net benefits when the increased cost of refrigerators is considered. The calculation assumes a mandatory standard that moves the market to refrigerators that consume an average of 600 kWh/year of electricity starting in the year 2010. The benefits from a potential program increase linearly starting in 2010 as the old stock of inefficiency refrigerators is replaced by more efficient models. Over the long term the benefits are potentially very high, nearly US\$100 per household on average. This is because with estimated appliance sales numbers of nearly a million refrigerators per year, this implies a large number of refrigerators in use over the long term with almost two refrigerators in use in the country for every three people by 2030 (both residential and small commercial use). If this estimate is too high, then the costs and benefits of the standard will be proportionally smaller.

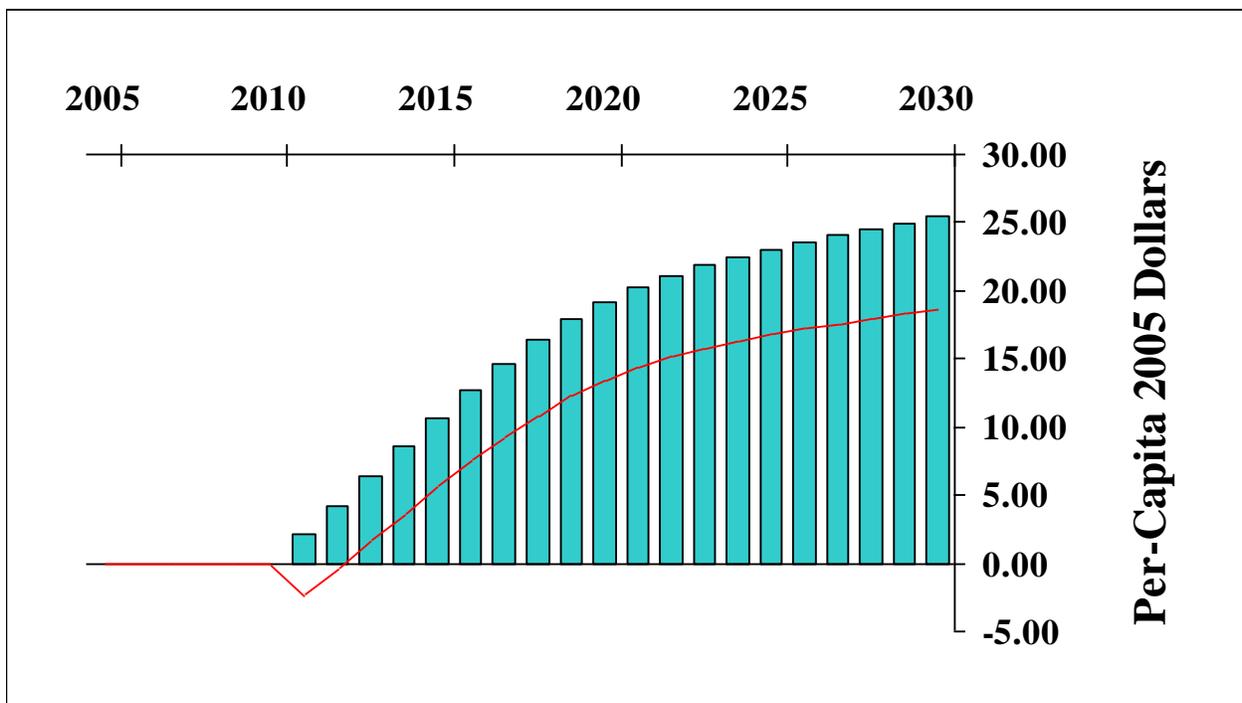


Figure 5.3: Estimated Annual per-Capita Benefits of a Refrigerator Efficiency Market Transformation Program in Ghana

From the consumer perspective, the average annual savings per refrigerator is approximately US\$35/year. Given the PAMS default real consumer discount rate of 11.6%, this provides a life-cycle operating cost savings of US\$185/refrigerator which, combined with a very rough estimate of an average price increase of US\$75 for the more efficient refrigerators, results in a net life-cycle cost benefit of about US\$110 per refrigerator.

5.2.1 Net Present Value of Economic Benefits

Using a real national discount rate of 10% to reflect the relatively higher cost of capital in Ghana, the present value of the benefits from a refrigerator market transformation program from 2010 to 2030 is US\$856 million. In comparison, the cumulative net benefit of refrigerator standards for the U.S. economy from 1987 to 2050 is estimated at US\$40 billion. Thus, especially in terms of relative national economic impact, a refrigerator efficiency market transformation program in Ghana may provide much more important economic benefits than similar programs in developed countries.

5.2.2 Carbon Emissions Reductions

Figure 5.4 illustrates the estimated carbon emissions reductions from a refrigerator efficiency market transformation program in Ghana.

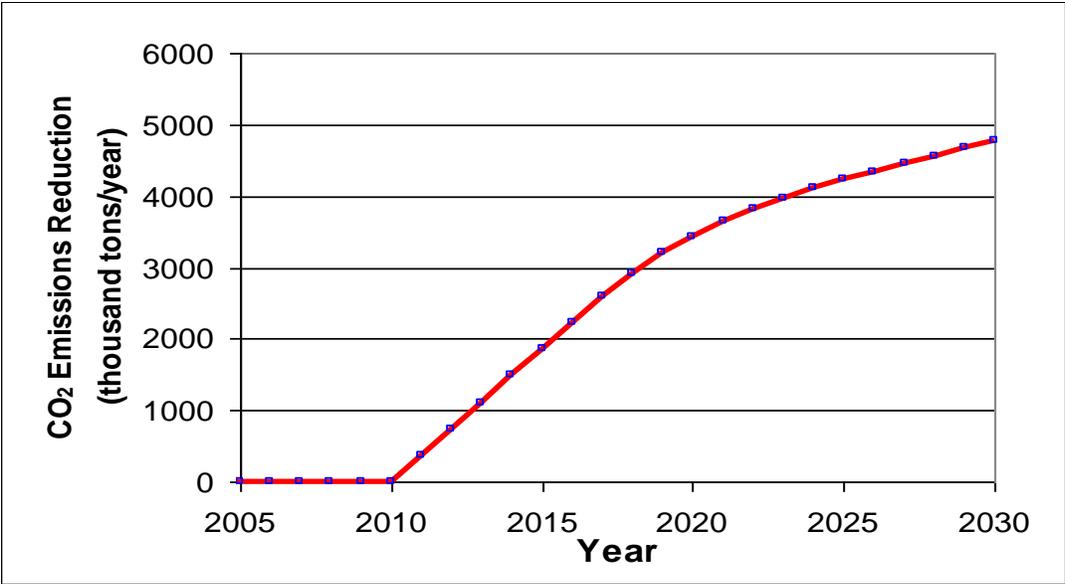


Figure 5.4: Estimated Annual Carbon Emissions Reductions from a Refrigerator Efficiency Market Transformation Program in Ghana

The estimated cumulative emissions reductions are nearly 20 million tonnes up to 2020, and nearly 63 million tonnes through 2030. The annual emissions reductions increase linearly from 2010 from zero to more than four million tonnes/year in 2025. Because the model of the refrigerator sales dynamics used in the impact analysis is based on more than a million refrigerator sales per year over the long term and because 100% enforcement of the standard is assumed, this emissions estimate is likely to be high. With respect to estimating potential revenues from verified carbon dioxide emissions reductions, financial planners should use a forecast emissions reduction volume of about half of this forecast or less to provide a margin for uncertainties in the forecast.

In some sense, the economic cost of these emissions reductions is negative. That is, there is likely a net benefit from the implementation of the market transformation program that produces the emissions reduction. But the programmatic investments and research needed to implement the market transformation program that will bring about this emissions reduction does have a net cost, which can be justified by attaching a forecasted value to the emissions reduction and estimating the present value of annual emissions reduction. In the case of carbon emissions reduction value of US\$5/tonne and a discount rate of 10%, the present value of these emissions reductions is more than US\$60 million, though perhaps a more conservative forecast of US\$30 million would be a more reasonable estimate of the probably future value. .

6. CONCLUSIONS AND RECOMMENDATIONS

The enactment and enforcement of the energy efficiency standards for refrigerators and refrigerator-freezers in Ghana would result in considerable economic and environmental benefits, and should be pursued seriously by the Energy Commission and the Ministry of Energy.

The standards proposed in this report are ones where new refrigerator and freezers from Europe and the U.S. should be automatically compliant with the proposed Ghanaian standards. But currently more than half of existing refrigerators, which are largely old, used refrigerators, would not be compliant. The proposed standards would save a net present value for Ghana of potentially as much as US\$856 million. While this is likely to be an over-estimate, even half this savings represents approximately US\$20 of benefit on average for every man, woman, and child in Ghana or about US\$100 per household. In relative economic terms, the standard could generate an economic savings relative to personal income that is higher than perhaps any other appliance efficiency program in the world.

6.1 Recommended Follow-up Activities

This study involved the measurement and monitoring of refrigerator energy, and represents one out of six major activities to promote the use of efficient refrigerators and refrigerator-freezers in Ghana, as presented in Table 6.1. To facilitate the compliance of the proposed Energy Efficiency Standards Regulations on Refrigerators and Refrigerator-Freezers, the following remaining follow-up activities need to be pursued, under the sponsorship of the Energy Commission:

- i) Experimenting with refrigerator rehabilitation and redesign;
- ii) Developing curriculum and educational programmes;
- iii) Institutional and human resource capacity building;
- iv) Pilot scheme on 100 households supplied with efficient refrigerators and refrigerator-freezers.

Table 6.1: Summary of Activities and Budget to Promote the Use of Efficient Refrigerators and refrigerator-freezers in Ghana

Activity	Personnel	Man-months	Monthly Cost, US\$	Cost, US\$	Total Amount, US\$
1. Measurement & monitoring of refrigeration energy use	1 Energy Efficiency Specialist	5	850	4,250	22,250
	50 S.S School students	4	150	18,000	
2. Experimenting with refrigerator rehabilitation and redesign	1 Electrical Engineer	5	850	4,250	23,800
	1 Research Scientist	5	850	4,250	
	3 Engineering Technicians	6	850	15,300	
3. Developing curriculum and educational programs	1 Energy Efficiency Specialist	5	850	4,250	7,650
	1 Electrical Engineer	4	850	3,400	
4. Designing programs and policies	1 Energy Efficiency Specialist	4	850	3,400	6,800
	1 Research Scientist	4	850	3,400	
5. Institutional / human resources training / capacity building	1 Electrical Engineer	5	850	4,250	11,050
	1 Research Scientist	4	850	3,400	
	1 Energy Efficiency Specialist	4	850	3,400	
6. Pilot scheme on 100 households supplied with efficient refrigerators					15,000
7. Overhead, administration, contingency					5,000
TOTAL					91,550

6.1.1 Experimenting with Refrigerator Rehabilitation and Redesign

Because of the very large used and rehabilitated refrigerator market in Ghana, methods for increasing the efficiency of refrigerators and refrigerator-freezers in local workshops need to be examined. Some of these might include changing out compressors and condensers to more efficient models, increasing insulation, and adjusting the charge of the coolant. To the extent that the added cost of efficiency can be invested in a local industry of refrigerator efficiency rehabilitation, an initiative to promote and increase refrigerator efficiency in the used and rehabilitated refrigerator market can contribute to the stimulation of the national economy and create added revenues and employment for refrigerator rehabilitators and distributors.

The specific activities that may be included in the refrigerator design work may include refrigerator efficiency rehabilitation design contests, university research in refrigerator rehabilitation and design, capacity building and training in refrigerator efficiency evaluation and design for repairers and shop owners, and development of a refrigerator efficiency rehabilitation/repair manual.

6.1.2 Developing Curriculum and Educational Programmes

Another follow-up activity will be enhancing education and awareness around refrigerator energy use and efficiency, and collecting data and information at the grassroots level. A key element of this work will be developing curriculum regarding energy efficiency and energy use at the senior secondary school level, as part of senior secondary school science education in a way that motivates both students and teachers. Initial efforts have been made to demonstrate the use of simple electricity meters as an educational tool that can be used for educational home energy audits that can teach students the connection between science, physics, energy and concrete economic savings in the household.

In addition to senior secondary school curriculum development and student measurement and research activities, another key element of efficiency program education will be public education. This can be done through the use of the mass media to sensitize both consumers and retailers of refrigerators and refrigerator-freezers about energy use and efficiency. The public education campaign will involve:

- i) Dissemination of brochures and radio interviews;
- ii) Awareness workshops for policy makers; and
- iii) Establishment of Household Energy Conservation Clubs in educational institutions.

6.1.2.1 Dissemination of Brochures and Radio Interviews

The brochure will provide households with graphical easy-to-follow information on the opportunities to improve refrigerator efficiency and save money on their electricity cost. The brochures will be distributed free of charge to households across the country,

through a collaborative effort with shops and other commercial retail outlets. The entire brochure will also be published in the national papers for wider coverage.

Radio interviews will also be conducted on local radio FM and national radio stations on the brochure to reach households in urban, peri-urban and rural communities. The interviews will be conducted in the various local languages, highlighting the educational information in the brochure. Questions on energy efficiency, posed by listeners through phone calls will also be answered. The radio interviews will also cover a review of the energy sector, touching on issues related to energy sources, energy demand, supply and end-use efficiency.

6.1.2.2 Awareness Workshops for Decision Makers

Awareness workshops will be conducted for decision makers (e.g. members of Parliamentary Select Committee on Energy, top officials of Ministry of Energy and Energy Commission) on refrigerator energy efficiency. The aim of the workshops is to equip the decision makers with the knowledge that will enable them make informed decisions in support towards programs and investments that are aimed at improving refrigerator and refrigerator-freezer energy efficiency in the Ghana.

6.1.2.3 Household Energy Conservation Clubs in Educational Institutions

Household Energy Conservation Clubs (HECCs) will be launched in secondary schools which will organize fora to sensitize students on the opportunities to improve refrigerator and refrigerator-freezer efficiency, so that they could impart the knowledge to their parents and others.

6.1.3 Training and Capacity Building

Training and capacity building will occur primarily through the concrete experience and learning undertaking by the institutions participating in this collaborative effort. Technical volunteers from Lawrence Berkeley National Laboratory, University of California, Berkeley, USA, who have been actively involved in this effort, will assist these institutions.

6.1.4 Pilot Scheme on Households Supplied with Efficient Refrigerators

A pilot scheme will be implemented where selected 100 households in the project areas will have their old inefficient refrigerators and refrigerator-freezers exchanged for rehabilitated efficient ones. The aim of this scheme is to demonstrate the impact of switching to efficient and refrigerator-freezers on electricity bills to households, policy makers and other stakeholders, The difference in cost of the inefficient refrigerator and the rehabilitated efficient one is estimated at US\$100, which should be borne by the project.

APPENDIX 1: QUESTIONNAIRE FOR NATIONAL SURVEY ON REFRIGERATOR ENERGY CONSUMPTION

- 1.0 Name of Refrigerator/Freezer
- 2.0 Model
- 3.0 Type.
- 4.0 Serial Number.
- 5.0 Manufacturer.
- 6.0 Operating Voltage..
- 7.0 General Description
 a) Double Door b) Single Door c) Front Open
 d) Top Open
- 8.0 Length of Refrigerator/Freezer .. (L)
- 9.0 Width of Refrigerator/Freezer . . (B)
- 10.0 Height Refrigerator/Freezer. (H)
- 11.0 Average Temperature in food section. (t_{fd})
- 12.0 Average Temperature in freezer section (t_{fz})
- 13.0 Average Temperature outside (t_0)
- 14.0 Main voltage as monitored by Energy Monitor (V_m)
- 15.0 Average Power consume by refrigerator/freezer (P_{AV}).
- 16.0 Cost per annum of Energy consumed (₨)
 (For 24hr period)

APPENDIX 2: DRAFT ENERGY EFFICIENCY STANDARDS AND LABELLING (REFRIGERATORS AND REFRIGERATOR-FREEZERS) REGULATIONS, 2007

In exercise of the powers conferred on the Minister responsible for Energy by section 56 of the Energy Commission Act, 1997 (Act 541) these Regulations are made this Xnd day of XXX 2007.

Application of Regulation

1. (1) These Regulations apply to refrigerators, refrigerator-freezers and freezers manufactured in Ghana, imported for use in Ghana, sold or offered for sale in Ghana.

(2) Exempted from regulation are those refrigerators and refrigerators-freezers sold by individual persons where the seller has had the refrigerator or refrigerator freezer in continuous operation for at least one year in their personal residence, and where such individuals have sold less than two refrigerators or refrigerator freezers in the previous year.

Requirement to comply with Regulation

2. (1) A person who manufactures, imports, sells or offers for sale refrigerators or refrigerator freezers for use in Ghana shall ensure that,

- (a) the refrigerators and refrigerator-freezers comply with the relevant performance and energy efficiency standard specification for refrigerators and refrigerator-freezers stipulated by Ghana Standards Board;
- (b) the refrigerators and refrigerator-freezers comply with the minimum performance and labeling requirements prescribed in these regulations.

(2) A person who manufactures imports, sells or offers for sale in Ghana refrigerators or refrigerator-freezers in contravention of regulation 2(1)(a); commits an offence and is liable on summary conviction to a fine not exceeding two hundred and fifty penalty units or imprisonment for a term not exceeding twelve months or both.

Minimum performance requirements

3. (1) A refrigerators, refrigerator-freezers and freezers manufactured, imported, sold or offered for sale in Ghana shall--in accordance with the applicable performance and energy use efficiency standard test procedures for refrigerators and refrigerator-freezers stipulated by Ghana Standards Board--have;

- (a) an ability to maintain a temperature of less than 10 degrees Celcius in the fresh food compartment and a temperature of less than -5 degrees Celcius in the freezer compartment.
- (b) a maximum energy consumption of 500 kilowatt-hours per year plus 400 kilowatt hours per year times the exterior cubic volume of the appliance for refrigerators and refrigerator-freezers and a minimum energy efficiency of 650 kilowatt-hours per year plus 500 kilowatt hours per year times the exterior volume of the appliance in cubic meters for freezers.

Information on package and labeling requirements for refrigerators and refrigerator-freezers

4. (1) A person shall not store, offer for sale, sell, distribute, import or otherwise dispose of a refrigerators or refrigerator-freezers unless the refrigerators or refrigerator-freezers bears a label that indicates the minimum performance.

(2) The Label on a refrigerator or refrigerator-freezer shall be in the form provided in Scheduled II and shall

(a) where the label is not printed on the packaging but placed or attached to the packaging, be in full colour, and

(b) where the label is printed on the packaging and in “black on white” be in colours that preserve the legibility of the label.

(3) The label shall be in the English language and shall be pasted conspicuously on the packaging of the refrigerator or refrigerator-freezer.

(4) A label on a refrigerator-freezer shall also provide the following information:

(a) the manufacturer’s name or trade mark;

(b) the manufacturer’s model identifier;

(c) the energy star rating of the model, determined in accordance with the applicable Ghana Standards Board test procedures for refrigerator and refrigerator-freezer energy efficiency and energy use and Schedule I;

(d) the food compartment and freezer compartment volumes determined in accordance with the applicable Ghana Standards Board test procedures for refrigerator and refrigerator-freezer energy efficiency and energy use;

(e) the Energy Consumption Rating (ECR) in units of kilowatt hours per year that the appliance is determined to use in accordance with the applicable Ghana Standards Board test procedures for refrigerator and refrigerator-freezer energy efficiency and energy use;

(f) the type of refrigerant; and

(g) a one-star to five-star energy efficiency rating in which the ascending number of stars represents a higher energy efficiency ratio determined in accordance with the table in Schedule I where ECR is determined in accordance with the applicable Ghana Standards Board test procedures for refrigerator and refrigerator-freezer energy efficiency and energy use. *(recommended schedule I, Change the constant of the ECR equation, <250 kWh/year five-star, 250 – 300, four-star, 300 – 350 three-star, 350-400 two-star, 400 – 500 one-star for fridges and fridge/freezers. For freezers <300 five-star, 300-350 four star, 350-400 three-star, 400 – 500 two-star, 500 – 650 one-star.)*

(5) The label shall be printed in colour on a water proof material and pasted conspicuously on the appliance.

(6) The background of a label pasted on an appliance shall be gold and all stars on the label shall be black and the text shall be in black, whilst the box enclosing the label shall be in green or red.

(7) A person who contravenes any of the requirements on labeling in this regulation commits an offence and is liable on summary conviction to a fine not exceeding two hundred and fifty penalty units, or a term of imprisonment not exceeding twelve months or to both.

Offences in relation to removal of label

5. (1) A person shall not remove the label on a refrigerator or refrigerator before the retail purchase of the item.

(2) If the refrigerator or refrigerator-freezer is offered for sale after a retail purchase, and if the seller is not exempt under regulation 1. (2) above, then the refrigerator or refrigerator-freezer shall be re-labeled consistent with this regulation before being offered for resale.

(3) A person who contravenes sub-regulation (1) or (2) commits an offence and is liable on summary conviction to a fine not exceeding two hundred and fifty penalty units or a term of imprisonment not exceeding twelve months or to both.

Powers of an inspector

6. (1) An inspector appointed under section 52 of the Act may at any reasonable time

(a) enter any premises or place where the inspector has reason to believe that refrigerators or refrigerator-freezers are being manufactured, imported, offered for sale or otherwise being disposed of; and

(b) examine or if necessary test refrigerators or refrigerator-freezers,

(i) displayed for sale;

(ii) at the point of import; or

(iii) at a warehouse

to ascertain whether the items comply with the provisions of these Regulations.

(2) An inspector may without prejudice to regulation 10 seize any refrigerators or refrigerator-freezers which contravene any provision of these Regulations or which are improperly labeled or labeled in such a way as to be deceptive, misleading or false.

(3) An inspector or a Customs Officer shall refuse to release to the importer a refrigerator or refrigerator-freezer imported for use in Ghana which is not labeled in the manner provided for under these Regulations.

(4) Where an inspector or Customs Officer refuses to release a refrigerator or refrigerator-freezer to the importer under sub-regulation (3), the inspector or Customs Officer shall within forty-eight hours of detention of these goods give notice to the importer to properly label the goods, and the notice shall state that within twenty-eight days after the date of the notice the goods must be relabeled in the required manner or be re-exported out of the country.

(5) Where an importer is required under sub-regulation (4) to re-label the imported goods the re-labeling of the imported goods shall be done under the supervision of an officer authorized for the purpose by the Energy Commission and the Ghana Standards Board.

(6) Where an importer fails to re-label goods as required under sub-regulation (4), an inspector shall after the expiration of the period specified, seize the goods.

(7) An inspector who assists a person to contravene these Regulations commits an offence and is liable on summary conviction to a fine not exceeding five hundred penalty units or imprisonment for a term not exceeding twenty four months and shall be liable to dismissal.

Petition against detention or seizure

7. (1) Any person whose refrigerator or refrigerator-freezer is detained or seized under regulation 7 may within seven days after the detention or seizure petition the Commission for the release of the seized or detained item.

(2) The Commission shall within seven days of receiving the petition either confirm the seizure or order the seized items to be released to the petitioner.

Forfeiture of and fines for refrigerators and refrigerator-freezers

8. (1) Subject to regulation 8, a refrigerator or refrigerator-freezer found in the country and which does not conform to these Regulations is liable for seizure, forfeiture or fine.

(2) The Commission shall in consultation with the Minister and the Ghana Standards Board shall set the appropriate level for fines and dispose of any forfeited refrigerators or refrigerator-freezers in a manner that the Commission may determine.

(3) The Commission shall setting the fine per appliance for attempted sale or import of a non-compliant refrigerator, refrigerator-freezer or freezer to no less than the average net operating cost per appliance for the Ghanaian consumer of allowing the use of an inefficient refrigerator, refrigerator-freezer or freezer compared to a compliant refrigerator, refrigerator-freezer or freezer. The method for determining this cost shall be determined by the Commission.

(4) Revenue raised from non-compliance appliance fines shall be allocated for efficient appliance regulation and program education implementation and enforcement activities in a manner determined by the Commission.

Offences and penalties

9. A person who obstructs or interferes with an inspector in the performance of the inspector's functions commits an offence and is liable on summary conviction to a fine not exceeding two hundred and fifty penalty units or imprisonment for a term not exceeding twelve months or both.

Offence by corporate bodies

10. (1) Where any offence under these Regulations is committed by a body corporate or by a member of a partnership or other firm, every member, director, or officer concerned with the management of the firm shall also be guilty of the offence and is liable on summary conviction to a fine not exceeding twelve months or to both unless that member, director or officer provides that:

(a) the member, director or officer exercised due diligence to secure compliance with the provisions of these Regulations; and

(b) the offence was committed without that member, director or officer's knowledge, consent or connivance.

Civil actions; jurisdiction

11. (1) Except as otherwise provided in subsection (ii) of this section, any person may commence a civil action against—

(a) any manufacturer or private labeler who is alleged to be in violation of any provision of this part or any rule under this part;

- (b) any government agency which has a responsibility under this regulation where there is an alleged failure of such agency to perform any act or duty under this part which is not discretionary; or
- (c) the Commission in any case in which there is an alleged failure of the Commission to comply with a nondiscretionary duty to implement this Regulation.

The XX courts shall have jurisdiction, without regard to the amount in controversy or the citizenship of the parties, to enforce such provision or rule, or order such government agency to perform such act or duty, as the case may be. The courts shall advance on the docket, and expedite the disposition of, all causes filed therein pursuant to paragraph (1) (c) of this subsection.

(2) Limitation. No action may be commenced—

(a) under subsection (1)(a) of this section—

- (i) prior to 60 days after the date on which the plaintiff has given notice of the violation
 - (A) to the Commission
 - (B) to the Minister responsible for Energy, and
 - (C) to any alleged violator of such provision or rule, or
- (ii) if the Commission has commenced and is diligently prosecuting a civil action to require compliance with such provision or rule, but, in any such action, any person may intervene as a matter of right.

(b) under subsection (1)(b) of this section prior to 60 days after the date on which the plaintiff has given notice of such action to the Minister and Commission.

Notice under this subsection shall be given in such manner as the Commission shall prescribe by rule.

(3) Right to intervene. In such action under this section, the Minister or the Commission (or both), if not a party, may intervene as a matter of right.

(4) Award of costs of litigation. The court, in issuing any final order in any action brought pursuant to subsection (1) of this section, may award costs of litigation (including reasonable attorney and expert witness fees) to any party, whenever the court determines such award is appropriate.

(5) Preservation of other relief. Nothing in this section shall restrict any right which any person (or class of persons) may have under any statute or common law to seek enforcement of this part or any rule thereunder, or to seek any other relief (including relief against the Minister or the Commission).

(6) Compliance in good faith. For purposes of this section, if a manufacturer or private labeler complied in good faith with a rule under this part, then he shall not be deemed to have violated any provision of this part by reason of the alleged invalidity of such rule.

Interpretation

- 12.** In these Regulations unless the context otherwise requires,
“Act” means the Energy Commission Act, 1997 (Act 541);
“refrigerator or refrigerator-freezer” means YYY;
“Commission” means Energy Commission;

“energy efficiency rating” (EER) means ratio of the food cooling service time to the effective power input for a set of rating conditions specified by the Ghana Standards Board;

“GS” means Ghana Standards;

“label” means a label relating to a refrigerator or refrigerator-freezer which contains information on its consumption of energy (whether or not it also contains other information);

“Minister” means Minister responsible for Energy;

Commencement

13. These Regulations shall come into force on Xth YYY, 2007 except regulation 2 which shall come into force on Xth YYY, 2009.

APPENDIX 3: ESTIMATED ECONOMIC IMPACTS OF PROPOSED ENERGY EFFICIENCY STANDARDS AND LABELLING (REFRIGERATORS AND REFRIGERATOR-FREEZERS) REGULATIONS, 2007

This appendix provides an estimate of the potential economic benefits and impacts from the proposed energy efficiency standard based on rough estimates derived from the CLASP Policy Analysis Modeling Spreadsheet tool and the results from the 1000 household survey.

The PAMS Efficiency Policy Impact Model

The Collaborative Labeling and Appliance Standards Program (CLASP) was founded in order "to facilitate the design, implementation, and enforcement of energy efficiency standards and labels for appliances, equipment, and lighting products in developing and transitional countries throughout the world." As part of its mission, CLASP has developed the Policy Analysis Modeling Spreadsheet (PAMS) in order to provide an easy-to-use software tool to help local policymakers assess the benefit of standards and labeling programs, and to identify the most attractive targets for appliances and efficiency levels. PAMS is available via the CLASP website at <http://www.clasponline.org>.

The objective for PAMS in calculating policy cost/benefits is to provide a fairly comprehensive accounting of the costs and benefits for several different appliances in a single spreadsheet. Further, the tool is constructed in such a way that a wide variety of country scenarios can be accommodated through user selection of macro-level forecast data. The over-all cost benefit accounting model can be described in terms of several component models that provide important inputs for the final aggregate cost/benefit calculation.

The efficiency policy analysis model calculates the costs and benefits of efficiency standards from two distinct but related perspectives:

- The Consumer Perspective: examines costs and benefits from the perspective of the individual household or enterprise. The calculation from the consumer perspective is called the Life-Cycle Cost (LCC) calculation.
- The National Perspective: projects the total national costs and benefits including both financial benefits, and energy savings and environmental benefits. The national perspective calculations are called the National Energy Savings (NES) and the Net Present Value (NPV) calculations.

Model Inputs and Assumptions

In order to provide a first-order estimate of the impact of standards in a wide variety of countries, PAMS relies on proxy engineering data from countries where technologies are well understood and where economic and population data are publicly available. A more accurate estimate of policy impacts can be produced by the spreadsheet in cases where local experts have detailed local data on hand.

- Engineering Data – In the event that detailed engineering calculations have been made for typical products in the country, these can be entered in terms of the fractional efficiency improvement and corresponding equipment cost increase, for up to six design technologies.
- Shipments – Although appliance sales forecasts are difficult to obtain at a global level, often these can be estimated by local experts. Common sources of shipments forecasts are manufacturer industry associations or, in the case of import-dominated markets, by data provided by customs or other government agencies. A full shipments forecast can be entered, thus bypassing the econometric ownership-driven model.
- Appliance Data – Even if no detailed engineering data is available for the country being modeled, prevalent prices in the market can be taken into account. In this case, the engineering and cost factors are scaled by the prevalent baseline retail equipment price.
- Energy Sector Data – Accuracy of estimates can be greatly improved if certain parameters concerning the generation and sale of energy are known. These include: Current prices for electricity paid by residential consumers (according to

prevailing tariff structures); Site to Source Conversion Factor (according to fuel mix); Transmission and Distribution Losses and; Carbon Emissions Factors. In the current version of the spreadsheet, default assumptions are made about generation mix. These are highly variable from country to country, however. Therefore, this is an area for which user inputs can greatly increase the accuracy of assessments.

- Economic Data – The econometric model forecasts future economic growth through 2030 using the trend over the period of 1975-2000 in order to minimize fluctuations over recent years. This may be significantly different than the most accurate forecasts (provided by national financial ministries or international sources).

Estimation of Model Inputs

The key inputs to the Policy Analysis Modeling Spreadsheet include the cost vs. efficiency curve and estimate of the change in unit energy consumption as a function of efficiency standard level. The vast majority of refrigerator appliance efficiency testing occurs outside of Ghana using test procedures that have a much lower ambient temperature than what is found in typical Ghanaian households. Thus if Ghana accepts test standard results from other countries, it will likely have to make adjustments to the energy use estimates so that they match Ghanaian conditions.

In our application of the PAMS model we used the average energy consumption measured in our Accra sample of 1000 homes of 1164 kWh/year as the baseline energy use, and assumed that standards programs could reduce average energy use to approximately 600 kWh/year. Furthermore we used a sample distribution of monthly household electricity consumption collected by the Energy Foundation to estimate how many households fall into which rate category, and on this based calculated a weighted average marginal price of electricity as US\$0.065/kWh.

Data available from appliance shipments or sales is highly inconsistent. Shipments estimates available from market intelligence data purchased from Gobi International

(Gobi International, 2004) indicate shipments of approximately 60,000 units per year. Yet a much more recent (and perhaps comprehensive) data from a recent Energy Commission survey of refrigerator and freezer vendors. This report indicates that “CEPS GCNET in Tema provided information ... for total imports in 2006 was 852,000 units at an estimated value of US\$68 million.” The report also indicated that “On the other hand the survey revealed the quantity of refrigerators and freezers sold by vendors in 2006 as 1,660,112.”

In order to make a reasonable and conservative forecast of refrigerator sales, we consider the following information: Total households in Ghana are about 22 million/5 = 4.4 million households. Given the claims 852,000 units imported in 2006 and a total of about 1.6 million sold. We know from a household energy consumption survey in 2003 that the number of refrigerators per occupant of electrified households ranged from 0.213 to 0.252 refrigerators/capita. If we estimate that approximately 1/2 of households have access to electricity this implies the number of refrigerators in households in 2003 ranging from about 2.3 to 2.8 million. Total sales of 1.6 million per year would imply a turnover time of less than two years for refrigerator stock. Thus the 1.6 million/year sales number is probably not a sustained annual sales figure. There are at least four possible explanations: (1) Incorrect data, (2) Rapid increase in refrigerator ownership, (3) Ownership of refrigerators in non-residential buildings, (4) Rapid breakage of refrigerators due to intermittent power supply (which started in August 2006). These sales figure discrepancies that it is a combination of all four reasons.

It may be concluded therefore that the 2006 numbers are unusually high due to both economic growth and breakage from the intermittent power supply. Given the balance of the numbers, we suspect that with non-residential establishments included, there are perhaps 4 million fridges in use now or the near future. And that a reasonable turn-over time for this stock would be about 8 years. So total imports (new and used) can perhaps be of the order of 500,000 to 1 million per year.