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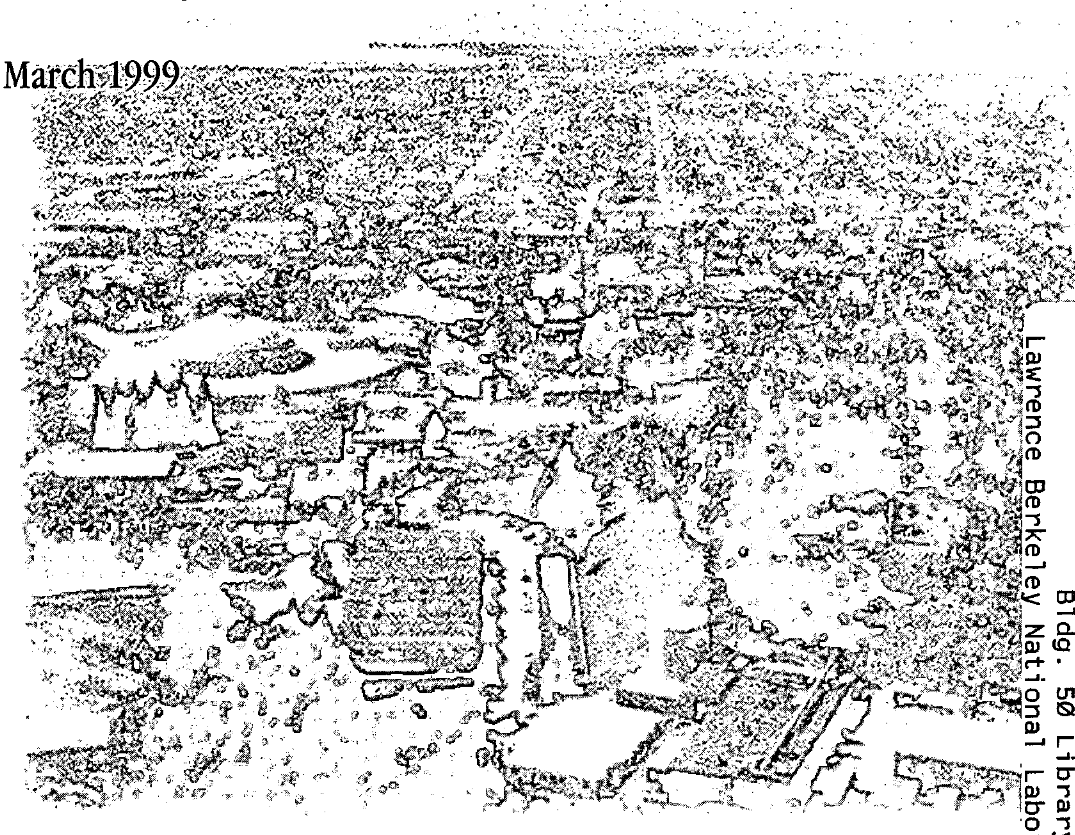

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ABSTRACT

The Government of Ghana, through the Ministry of Mines and Energy is committed to improving the national energy infrastructure and market in Ghana. This report presents the results of a survey and analysis of household energy use and appliance ownership in Ghana. This work, with the collaboration and support of the Government of Ghana, Lawrence Berkeley National Laboratory, USAID, the Alliance to Save Energy, and the Energy Foundation of Ghana, is expected to support legislation requiring minimum energy performance standards for home appliances. Refrigerators, room air conditioners, and lighting, which together account for the bulk of residential energy use, are the initial targets for regulation. The time is now for Ghana to act and take a leadership role in promoting energy efficiency in the region. With so many reforms taking place in the energy sector, appliance energy performance standards can only enhance the ability of the Ghanaian economy to move ahead in the next decades.

Preliminary findings indicate that implementing a European-type minimum energy performance standard for refrigerators could result in savings up to **¢107 billion by 2010 (US$50 million)** for consumers, and reduce **carbon emissions** over the same period by **230,000 tonnes**. A 10% savings in energy consumption for room air conditioners could save residential consumers nearly **¢18 billion (US$8 million)** and reduce **carbon emissions** by **38,000 tonnes**. For lighting, saving 10% of the residential load through policy and regulation would translate into **¢13.8 billion (US$6 million)** in consumer savings and that is only counting urban customers. The carbon reductions would amount to **24,000 tonnes**. More study is recommended.

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1. Overview

The Government of Ghana, through the **Ministry of Mines and Energy,** is committed to improving the national energy infrastructure and market in Ghana. Part of that commitment includes the development of codes and standards for domestic appliances as a cost effective means to: 1) protect consumers from unnecessarily high electricity bills due to inefficient appliances; and 2) mitigate the need for additional, higher-priced new electricity generation stations. Energy efficient appliances would also be an inexpensive but essential element in Ghana's climate change mitigation program.

Now is a critical moment in Ghana's history. If the government and the private sector do not act decisively, a great opportunity to promote the future energy efficiency of the Ghanaian economy will be lost. First and foremost, Ghana must ensure an adequate energy supply to meet growing residential, commercial, and industrial demands. To this end, major energy sector reforms have been completed or are underway.

These laws, policies and new regulatory institutions are important precursors on the road to reaching the Nation's energy goals and economic freedom, but by themselves are insufficient.[1] Now is the time, before home appliance saturations reach high levels across the country, to insure that Ghanaian consumers are able to purchase appliances that are both affordable *and* energy efficient.

For example, in the U.S., capital markets function extremely efficiently. An adequate energy supply is not in question. A competitive industry with good demand feedback from consumers provides an ostensibly optimal amount of appliances. Yet some analysts observe that there is a so-called **energy efficiency gap** between the amount of investment that consumers and firms put into the energy efficiency of home appliances and what would make economic sense from both the individual and societal points of view.

Consumers do not gain any utility, or benefit, directly from the energy that an appliance consumes. Rather their motivation for purchasing the appliance is for the energy services that it supplies, as in food storage or room temperature control. Energy efficient technology exists that could deliver these energy services at a lower cost,[2] but consumers often do not take advantage and the market does not end up supplying this technology. That is, the amount of efficiency supplied is not consistent with consumers maximizing net present value.

In the absence of standards, the diffusion rate of the efficient technology remains lower than would be expected given the potential economic savings. By contrast, the diffusion rate of inefficient products is higher then would be expected or desired. Thus the Ghana appliance market is ripe for dumping. Consumers, interested only in first costs, look to cheap, imported used appliances that create unnecessary demands on the power grid,

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[1] An Energy Roadmap for Ghana: From Crisis to the Fuel for 'Economic Freedom', US Gov. Interagency Team, final report, Aug. 1, 1998, p. 12

[2] By this we mean lower operating expenses and lower life cycle costs, even in the presence of some increase in purchase price.

without giving any better service. It is this efficiency gap, analysts argue, which suggests the opportunity for intervening government regulation.

Effective implementation of appliance standards requires careful market analysis and long term coordination of stakeholders and consumer interests. The Ministry has indicated that **refrigerator/freezers, room A/C**, and **lighting systems**, which collectively account for the bulk of residential demand for electricity, are the targets for initial regulations. This report serves to focus this policy objective by applying past experience with the development of standards in other countries to the situation in Ghana. For example, the law in Ghana says that the Energy Commission will develop performance standards but it does not say what these standards will be or how they will be developed.[3] **Section 1** of this report discusses the general state of the economy as it applies to the market for home appliances; **Section 2** examines the resources, stakeholders and institutions that are important to this process.

Berkeley Lab, responding to a request from the Government of Ghana, has developed a general approach to appliance standards in Ghana. Six major steps are identified: 1) market assessment - a) market survey and b) assessment of potential impact of standards; 2) development of legal authority; 3) market conditioning and capacity building; 4) the setting of standards; 5) maintaining and enforcing standards; and finally 6) monitoring the impact of standards. An initial market survey and impact assessment is complete, and the results are presented in **Sections 3** and **4**. Step 2, *legal authority*, has long since been established and the responsibility for codes and standards rests with the **Ghana Standards Board (GSB).** Step 3 is a process already underway. This report is intended to build on this process and suggest specific steps for the future. **Section 5** lays out the primary recommendations and findings of this study.

1.1 Energy sector

As a developing economy, Ghana's domestic and industrial demand for electricity has long been relatively low, although increasing. When the Akosombo project was first completed, the peak demand from Ghana was 100 MW, less than 20% of the installed capacity.[4] For decades, Ghana's development has been fueled by abundant inexpensive hydropower.

In 1998, falling water levels at Akosombo Dam, brought on by drought in the North, led to severe shortages in supply. The crisis reached its peak in February, with rolling blackouts and severe restrictions on energy consumption. Government estimates projected total electricity generation at 5,600 GWh for the year, 30% below the expected demand of 8,100 GWh.

Recently, the power plant at Takoradi just brought an additional 130 MW on line, bringing the total installed capacity of the public electricity sector to approximately 1,400 MW. The bulk of this capacity is attributable to two hydro-projects on the Volta with the balance coming from Takoradi (330 MW) and Tema (30MW). It is clear that Ghana will

[3] Energy Roadmap, p 12
[4] Energy Roadmap, p. 6

have to expand and diversify installed capacity, no matter what can be achieved through conservation and efficiency, but expansion is costly and takes time. In the meantime, any energy resources that can be saved through efficiency or conservation can be used for other purposes.

1.2 Demographics

Residential electricity demand, although a small percentage of total consumption, has been the fastest rising use. This can be accounted for by the increase in grid connections, rising per capita income, penetration of appliances in higher income households and no apparent incentives for more efficient utilization. The Electricity Corporation of Ghana (ECG), Ghana's main distribution utility, has attempted to deal with the residential load problem through the imposition of quotas and a surcharge. This is fraught with problems and has been seen as unfair given the ECG's meter reading practices.[5]

Furthermore, as more and more communities are connected to the grid, they will naturally demand more electrical appliances, particularly lighting and refrigeration. The Minister of Mines and Energy estimated that this year alone 1850 additional communities would have access to electricity.[6]

Based on data collected in this survey, the average household in Ghana contains more than 7 people. With a current population of over 18 million, this means that there are approximately 2.6 million households in the country with the potential to own electrical appliances. At present, most appliance ownership is concentrated in urban areas, which account for only 37% of the population. Thus residential energy use is far below what it could be.

By 2010, assuming an annual growth rate of 2.7%, Ghana's population will surge to almost 25 million. All other factors constant, that would mean over 3.5 million households. In the cities alone, where saturations of lighting and refrigerators are near 100%, that would mean 347,000 more units not counting replacements. If, as could be expected, continued prosperity leads to more and smaller households, than the number of potential consumers of major appliances increases even more. At the very least, the prospect of all of these potential consumers buying inefficient appliances and thereby unnecessarily burdening the national energy grid and squandering limited resources should provide some justification for standards.

1.3 The case for standards

Proponents of standards argue that an energy efficiency gap exists and economic efficiency is enhanced by government intervention. Consumers, they argue, are under-investing in energy efficiency technology that has the potential to deliver the same energy end-use services at a lower long run cost. Cost-benefit analysis projects that in the US minimum energy performance standards already in place will result in a range of net benefits to consumers of at least $33 billion by 2010. Annual savings in 1998 are estimated to average about $30 per household. Of course, the savings for Ghana would

[5] Energy Roadmap, p. 15
[6] "Foundation set up to promote energy sector," Ghanaian Times, Feb 25, 1998, p. 1

be significantly lower due to the size of the market and relatively low price of electricity. (Section 4 provides some estimates of the magnitude of savings)

More widespread recognition of the extent to which energy performance standards improve economic efficiency would enhance both the future of the Ghanaian standards program and the prospects for similar policies in the other developing economies of the world.

These economies face significant problems concerning cash flow and the supply of hard currency. Energy efficiency can reduce the need for large capital investments like new power generation plants, and energy performance standards do this particularly effectively. Individuals recoup any initial incremental expenses through lower life cycle costs associated with more energy efficient products.

In the following general discussion of energy performance standards, a clear distinction must be made between energy efficiency and economic efficiency. An empirical argument for performance standards will follow in later sections.

Energy efficiency is used here to mean the level of services provided per unit of energy consumption. For example, the energy efficiency of a refrigerator is expressed as liter-days per kilowatt-hour; higher energy efficiency means that a liter of refrigerator space can be kept cool for a day using less electricity (kWh). The maximum technically feasible level of energy efficiency is usually higher than what is economically efficient, due to increasing marginal costs associated with reducing energy consumption.

Economic efficiency is somewhat more complex. In *Classical Economic* discourse, efficiency is defined by the concept of *Pareto Optimality*. In brief, a market is at a Pareto Optimal point when all markets have cleared (supply = demand), no party can be made better off without making another worse off, and price equals the marginal cost. The central goal of any economic actor is to maximize her utility. Cost minimization, as in the energy efficiency discussed above, is one of the necessary conditions for economically efficient allocation of resources.[7] In a perfectly competitive model, the one preferred by neo-classical analysts, accurate prices are all that is necessary to coordinate all maximizing actors and lead to a point of optimality. This condition is based on several assumptions about the market including: perfect information; strictly rational behavior; and zero transaction costs. The logical conclusion is that whatever the market yields is an efficient outcome, or at the very least a "second best" outcome in the presence of some acknowledged market imperfections.

However, a more policy-relevant approach to economic efficiency is grounded in the empirical observation of the functioning of the real market. In Ghana's case, as in many developing economies, severe market barriers exist which mitigate the assumptions of classical economics. Chief among them are consumer information and pricing problems. These problems persist even in mature market economies but are more acute in developing markets.

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[7] Varian, H. *Microeconomic Analysis*, Norton, NY, 1984.

A fundamental precept is that government should intervene to correct market failures that otherwise will function to the disadvantage of society (or individuals, or both) whenever the cost of intervention is less than the resulting reduction in transaction costs. The question, then, is not *whether* a government should impose regulations and controls on the market, but *which* and *how many* regulations should be imposed. The real problem is not in identifying deviations from perfection or optimality: it is in identifying the best organizational package from among the real alternative ways to coordinate economic agents in specific situations.[8]

Investment in energy efficiency is typically viewed as involving a trade-off between higher initial unit prices and lower operating expenses for incremental increases in energy performance. Faced with a choice, consumers consistently make investments in energy consuming products with heavy focus on the purchase price and little attention to subsequent energy expenses over the operating life of the product. Ghanaian consumers in particular are faced with lack of capital and cash flow problems. In effect they undervalue the savings associated with efficiency. Consumers typically make decisions based more on first costs, even though the total expected bill savings could easily justify higher initial costs for efficient products. Performing a life-cycle cost analysis to explicitly analyze the tradeoff is very *information intensive*, requiring information that is hard to come by and will be underproduced due to its public good nature, even though it would lead to more economically efficient decisions. Consumers often lack necessary

Magnetic Lamp Ballasts: An Energy Efficiency Success Story

In the market for efficient magnetic ballasts for fluorescent lights, Koomey, Sanstad and Shown calculated consumers' implicit Internal Rates of Return (IRRs) for investment in efficiency gains, based on technical analysis of potential cost savings from efficiency. They found that individual decisions implied an IRR far in access of what "a rational investor should demand from such an investment," in some cases as high as 270%. The Vice President of Advanced Transformer Company lamented the fact that it "has been so difficult to sell such a bargain," referring to sales of his company's efficient ballasts. The slow diffusion of the technology was directly attributable to market failures arising from transaction costs of gathering information, many of which are obviated by performance standards. From 1980 to 1988, sales of efficient magnetic ballasts for fluorescent lamps rose from about 12% of the total industry sales to about 1/3 of the market nationally. All of the increase in sales during this period can be attributed to standards imposed in various states.

With an efficient ballast, consumers get the same level of lighting, but they get it at lower operating costs, from a product that is in all other respects a perfect substitute for inefficient ballasts. Thus no hidden costs are relevant. And efficient ballasts were widely available and a proven technology, so a time lag associated with the diffusion of new technology could not be responsible for the failure to adopt this beneficial technology. "The standards were particularly efficacious because they were directly targeted at the consumers' transaction/search costs that impeded the adoption of the efficient ballasts. The standards eliminated those transaction costs, and did not disrupt the market in any measurable way."

Summarized and excerpted from: JG Koomey, AH Sanstad, and LJ Shown, "Magnetic Fluorescent Ballasts: Market Data, Market Imperfections, and Policy Success." LBL-37702, Dec. 1995, PP 4-20 information like the current and future price of energy, or the efficiency range of alternative appliances available on the market.

Even in the face of adequate information, individuals and even firms face cognitive challenges to achieving outcomes that are consistent with optimized rational choice. Human beings have a limited capacity to take in information and process it to the most logical conclusion. Labels can help, but consumers are often unable to effectively calculate the risks of certain behavior or predict the full benefits of the savings from energy efficiency. Individuals (and firms) may intend to make rational decisions, but they are constrained by a lack of attention, resources, or simple analytic ability. Thus energy efficiency, in the form of efficient appliances, will be underconsumed.

There is no one "best solution" to market failures and each specific market sector will need to have a tailored policy. Harvard economist Michael Porter argues that standards will be effective from an economic efficiency standpoint for appliances ("nonconvenience goods") in general.[9] Of the many regulatory options available to policy makers, energy performance standards offer a way to condition the market without curtailing profit maximizing, behavior that can drive a competitive market to the *optimal* point of allocation.[10] When obtaining information is prohibitively expensive for individuals, standards are a way to simply avoid many of the transaction costs present in the market and proceed directly to a relatively efficient exchange.[11] Appliance performance standards are part of the long term solution to Ghana's capacity shortages since minimum energy performance standards for home appliances are one way of preventing the "dumping" of inferior goods (both new and used) on the Ghana market.

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[8] Friedman, L., "*Microeconomic Policy Analysis*" 1984 p. 425.
[9] Porter, ME. Interbrand Choice, Strategy, and Bilateral Market Power. Harvard University Press, 1976, pp. 235-239.
[10] Breyer, Stephen. Regulation and its Reform. Harvard University Press, 1982.
[11] Porter, 1976, p. 236.

2. Resources, stakeholders and institutions

2.1 Background

LBNL is providing technical assistance with financial support from the USAID Global Office in Washington for the development of efficiency codes and standards for basic household appliances namely, lighting, refrigerators, room air conditioners and deep freezers. These funds are also expected to leverage other resources, identify and involve stakeholders, and strengthen institutions necessary for the development and maintenance of standards. The process of setting standards is intended to be part of a more comprehensive energy efficiency program, including targeted R&D, manufacturer incentives, consumer product labeling, and utility demand-side management (DSM) programs.

2.2 Resources

Above all else, proponents of standards in Ghana must take advantage of the extraordinary level of activity and change in the energy sector. Heightened awareness and concern for Ghana's energy use must be considered a "resource" that can be used to good advantage. Specifically, the USAID support can be seen as leveraging funding available to the Electricity Demand Management Project, which includes the setting of standards. Funds may be available from the World Bank to develop testing facilities in support of standards. One project begets the other. The confluence of efforts will achieve more at once than piecemeal over time.

2.3 Stakeholders

Stakeholders, both private and public sector actors, are crucial to the regulatory process. In the US, the appliance standards program benefited greatly from their participation in various rulemakings. As a US Government sponsored interagency team noted in a report to Vice President John Attah Mills, "[Stakeholders'] views are important because the process of planning and rate setting tries to anticipate the stakeholders' needs and reactions. It is also important because these stakeholders represent a valuable source of information and assistance and potentially investment that can help the Government as it moves the energy sector forward."[12]

The subjects of these regulations -appliance manufacturers and importers- need not be enemies of the process. Whirlpool recently objected to what is perceived as too *lenient* a refrigerator standard, reflecting their view that performance standards would give them a competitive advantage (short lived in the highly competitive appliance market) as a result of their high levels of R&D.[13] Other manufacturers have supported standards as a way to justify efficiency investments that will make their products more competitive. For example, the largest room air conditioner manufacturer in the US recently argued that strong US standards would help them to better compete in the Asian market.[14]

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[12] Energy Roadmap, p. 20
[13] Quintanilla, Carl. "*Whirlpool is Cool to New Refrigerator Standards*", Wall Street Journal, April 23, 1997.
[14] Giordano, Sal, 1994, March 28 letter to Robert Holding, Fedders Corp., Peacack, NJ cited in Nadel, Steven, *"The Future of Standards"*, Energy and Buildings Vol. 26 (1997) p. 124

As Michael Porter suggests:

> Ultimately, nations succeed in particular industries because their home environment is the most forward-looking, dynamic, and challenging. Strict government regulations can promote competitive advantage by stimulating and upgrading domestic demand. Stringent standards for product performance, product safety, and environmental impact pressure companies to improve quality, upgrade technology, and provide features that respond to consumer and social demands. Easing standards, however tempting, is counterproductive.[15]

Without the standard, some component producers find it very difficult to market their efficient products. Standards may be helping the industry to compete. Overall, we find little evidence of harm from well-planned energy performance standards to the appliance industry, but recommend further research.

One important stakeholder in this process that must not be left out is the consumer, represented in this case by the Energy Foundation. Energy bill savings and a cleaner environment are just as important as overall energy savings.

2.4 Institutions

It has already been pointed out that the Ghana Standards Board is a key player and that any progress on standards is predicated on their ability to enact and enforce the regulations. A strong PURC and Energy Commission also have a role to play, as will the Ministry of Mines and Energy. But the most critical element will be the institutional capacity of the government of Ghana and its representatives to carry on this process. This means that testing facilities and procedures must be developed or adopted, personnel must be trained and a culture of energy efficiency must be developed with the Ghana Standards Board, which has heretofore been primarily interested in product safety. The Customs Service (CEPS) will also have to work closely with them to prevent illegal importation of inferior used-products.

An important tool in developing this institutional capacity will be the use of product labels that provide information on energy use and efficiency. If labels are required on products imported and sold into Ghana, the information from those labels could be gathered and used in future market analyses. Several examples of effective labels are presented in Appendix 3.

[15] Porter, ME. "The Competitive Advantage of Nations." Harvard Business Review, March-April, 1990, p. 74, 87.

3. Residential energy survey – data analysis

3.1. Introduction

In September of 1998, a household survey of residential energy use and appliance ownership was carried out under the direction of the Energy Foundation with the support of Berkeley Lab. Surveyors contacted 1000 residences in six regions. Most of the coverage is in Greater Accra and Ashanti Regions, but Western, Central, Eastern, and Brong Ahafo are also covered. The survey asked respondents to supply information about their appliances, which is analyzed here. The respondents are located in urban areas and are all in areas connected to the national grid.

3.2. Refrigerators, refrigerator-freezer, and freezers

Refrigerators, refrigerator-freezers, and freezers provide utility by keeping food products at specified temperatures and prolonging their life. Refrigerators are also energy-intensive appliances - accounting for as much as 25% to 30% of a household's electricity bill. High energy consumption and a high penetration rate make refrigerators and freezers ideal candidates for minimum efficiency regulations.

3.2.1 Issues regarding minimum energy efficiency standards for refrigerators

The energy consumption of refrigerators and freezers is a function of their size and features. Not only does a larger unit typically consume more energy, but energy usage also depends upon other features that provide various utilities to the consumer. Some of the important features effecting energy consumption include method of defrosting, number of doors, whether or not anti-sweat heat is being provided, and temperature level maintained within. When establishing energy efficiency standards, it is necessary to keep in view the different effects of these features on the efficiency. A good way to account for these differences is to establish product classes so that units within the same product class have similar features and their energy use is comparable. In the U.S. different product classes exist for manual and automatic defrost units. Units also belong to different product classes based on whether the freezer section is at the top, bottom or on the side. Minimum efficiency standards are established for each of the product classes.

3.2.2 World wide energy efficiency standards

Today, many countries have either voluntary or mandatory minimum efficiency standards for refrigerators as depicted by Table 3.2.1.

Table 3.2.1. Status of refrigerator and refrigerator-freezer energy efficiency standards

Country/Region	Mandatory	Voluntary	Product
Australia	✓		Refrigerator, Freezer
Brazil		✓	Refrigerator, Freezer
Canada	✓		Refrigerator, Freezer
China	✓		Refrigerator
European Union	✓		Refrigerator, Freezer
India		✓	Refrigerator
Korea	✓		Refrigerator
Mexico	✓		Refrigerator, Freezer
US	✓		Refrigerator, Freezer

The US is a model case. U.S. energy standards for refrigerators and freezers were established in the 1987 National Appliance Energy Conservation Act, effective 1990. The government announced an update in 1989, effective in 1993. A second update was announced in 1997, effective in 2001.

Compared to 1986 new refrigerators (1074 kWh/a), the U.S. energy standards were expected to reduce annual electricity consumption per refrigerator by 9% in 1990 (actual reduction was 15%), 36% in 1993 (actual reduction was 39%), and 56% in 2001. A typical refrigerator in 1997 uses less than 2/3 the energy and has slightly more capacity than a comparable 1986 (pre-standards) model.[16]

3.2.3 Refrigerators and freezers in Ghana

According to the survey results, Ghana has an overall refrigerator, refrigerator-freezer and freezer saturation of approximately 95%. However, these numbers probably signify the saturations at the urban centers and do not represent the overall saturation for the whole country. This urban sector can be further divided into two sectors: the metropolitan regions of Greater Accra and Ashanti as one sector and then the smaller non-metropolitan but still urban areas of Western, Eastern, and Central regions and Brong Ahafo. The saturations for these sectors are approximately 95% and 94% respectively. The survey did not reach urban areas in the North such as Tamale or Bolgatanga. Gathering information from these fast growing areas should be a primary goal of future studies.

Greater Accra and Ashanti Region:

The following figures show the features of the refrigerator and freezer population in the Greater Accra and Ashanti regions. Figure 3.2.1 shows that a vast majority of units (77%) are refrigerator-freezers while freezer (13%) and refrigerators only (10%) are a distant second and third.

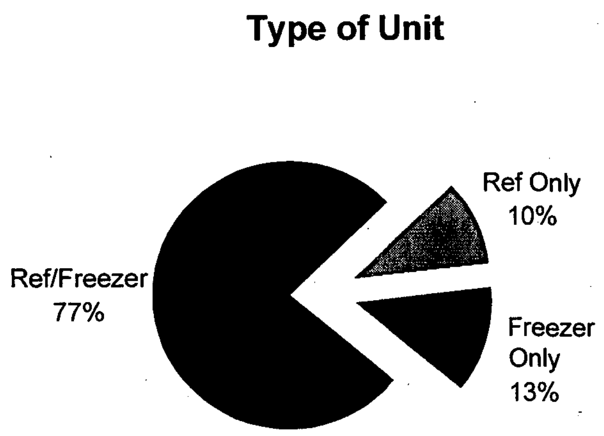


Figure 3.2.1. Type of refrigerator and freezer units in Greater Accra and Ashanti Regions.

[16] 1997 AHAM FactBook

Figure 3.2.2 indicates that units are almost equally divided between single-door units and double-door units. The survey data cannot be effectively used to determine how many of the 51% single-door units are actually freezer-only or refrigerator-only units as these are both likely to have only one door.

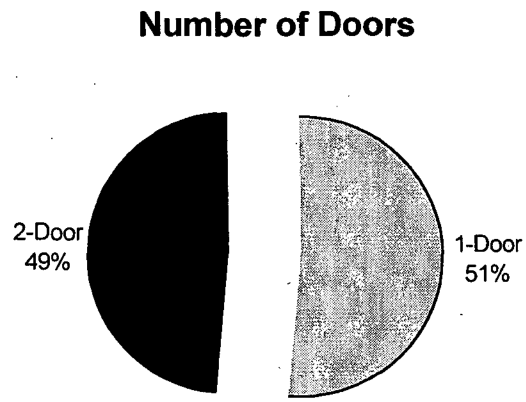


Figure 3.2.2. Division of units in Greater Accra and Ashanti Regions by number of doors

Figure 3.2.3 shows that 67% of the units are the top-mount kind where the freezer section is in the upper section of the unit and the fresh-food section is below it. There are 29% bottom-mount units while 1% are side-mount and 3% are ice-boxes.

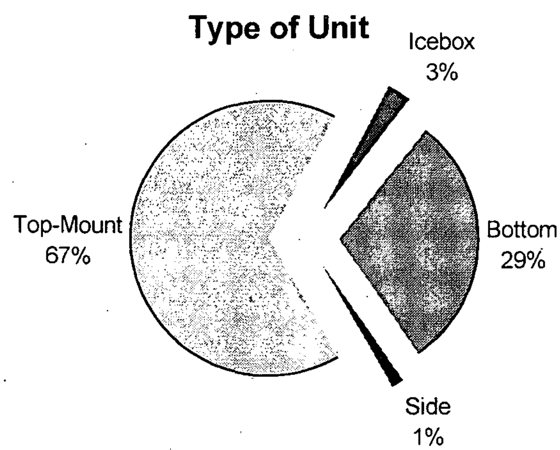


Figure 3.2.3. Division of units in Greater Accra and Ashanti Regions by cabinet configuration.

Approximately 19% of the units in the Greater Accra and Ashanti regions have automatic defrost and the other 81% have manual defrosting.

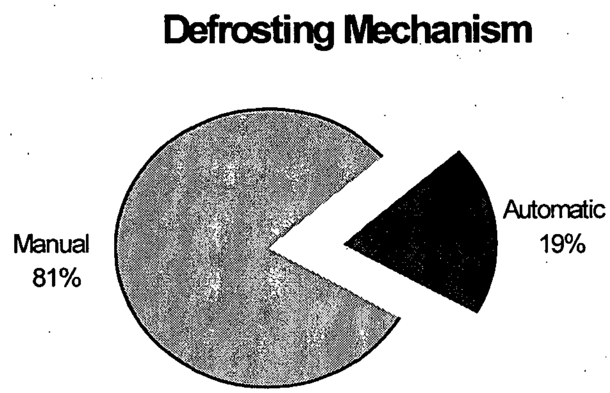


Figure 3.2.4. Division of units in Greater Accra and Ashanti Regions by method of defrosting.

Units in the Greater Accra and Ashanti regions are manufactured by a variety of manufacturers: U.S., European, Japanese, and Korean. Many of these manufacturers produce energy efficient units for sale in domestic and international markets. They do not generally have any manufacturing or assembly plants in Ghana, but an exclusive importer often represents them.

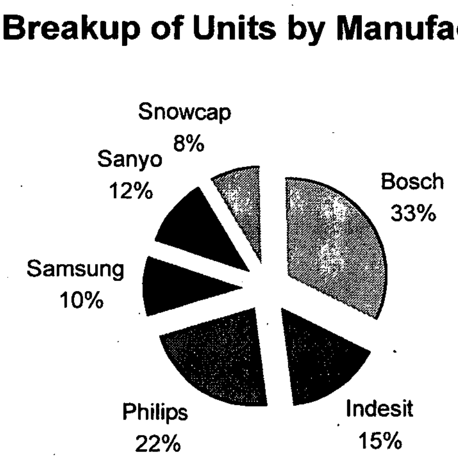


Figure 3.2.5. Units in the Greater Accra and Ashanti regions by manufacturer.

51% of the units are running all year round whereas 49% are turned off during some part of the year. The effect this practice has on annual energy use requires additional study.

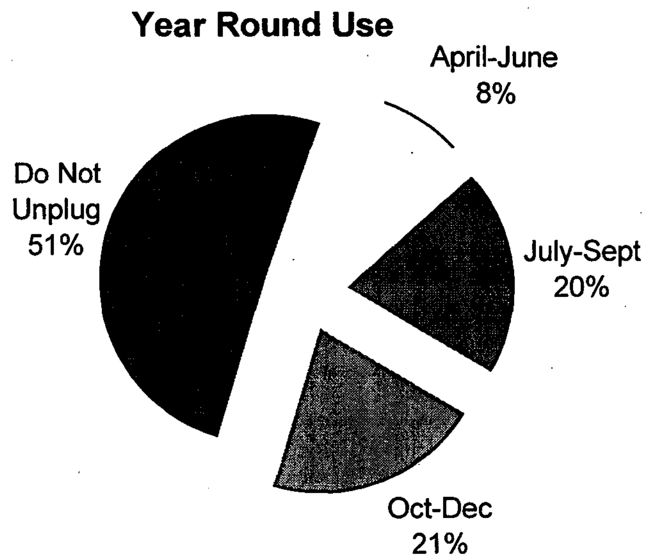


Figure 3.2.6. Units in the Greater Accra and Ashanti regions that are turned off during part of the year.

Almost 10% of the refrigerator/freezer population in Greater Accra and Ashanti regions are used for commercial purposes whereas the remaining 90% are for domestic use only. Commercial use may increase annual energy consumption, but this impact is impossible to determine from currently available data.

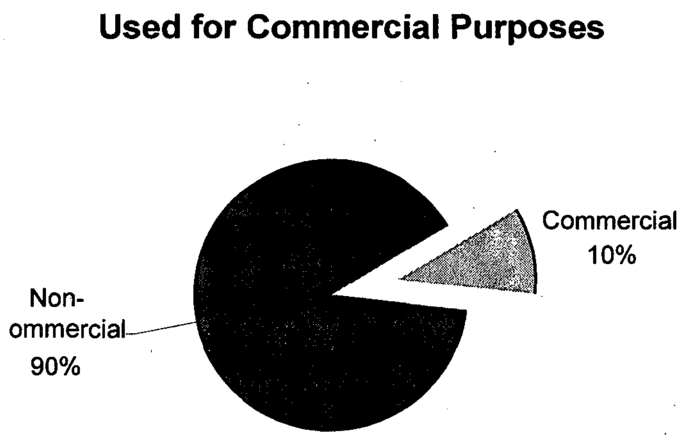


Figure 3.2.7. Units in the Greater Accra and Ashanti regions used for commercial purposes.

The most popular size of refrigerators in the Greater Accra and Ashanti region is in the 500-600 liter range. The distribution of units by volume is depicted in figure 3.2.8.

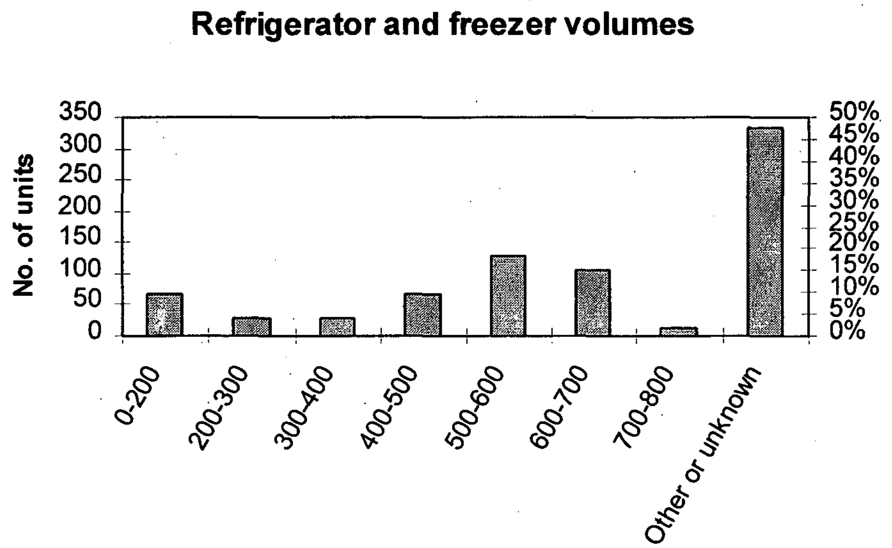


Figure 3.2.8. Distribution of units by volume in the Greater Accra and Ashanti regions.

Western, Eastern, Central Regions and Brong Ahafo:

The following figures show the features of the refrigerator and freezer population in the Brong Ahafo, Western, Eastern and Central Regions. Figure 3.2.9 shows that a vast majority of units (66%) are refrigerator-freezers while freezer (19%) and refrigerators only (15%) are a distant second and third. The data for these regions does not differ significantly from Greater Accra and Ashanti Regions, but there are interesting observations about unit volume and the different manufacturers penetrating the market. In the final analysis, it is likely that the various urban regions are more like each other than the surrounding rural areas.

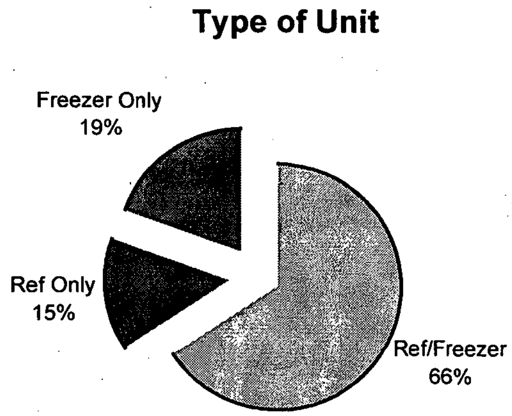


Figure 3.2.9. Type of refrigerator and freezer units in Brong Ahafo, Western, Eastern and Central Regions.

Figure 3.2.10 indicates that single-door units outnumber double-door units by 63% to 37%. The survey data cannot be effectively used to determine how many of the 63% single-door units are actually freezer only or refrigerator only units, as those are likely to have only one door. There are significantly fewer 2-door units reported in these regions than in Accra or Ashanti regions, and this may be one reason for that. Without more data, it is impossible to tell if there is some other local phenomena that could account for this.

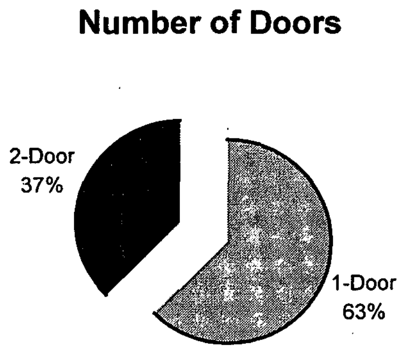


Figure 3.2.10. Division of units in Brong Ahafo, Western, Eastern and Central Regions by number of doors

Figure 3.2.11 shows that 65% of the units are the top-mount kind where the freezer section is in the upper section of the unit and the fresh-food section is below it. There are 30% bottom-mount units while 2% are side-mount and 3% are ice-boxes. This is virtually the same distribution as in the two larger metropolitan areas.

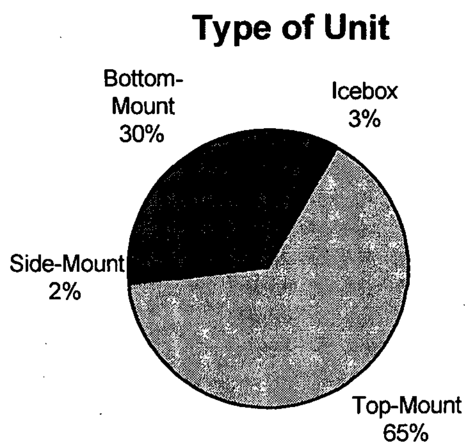


Figure 3.2.11. Division of units in Brong Ahafo, Western, Eastern and Central Regions by cabinet configuration.

Approximately half of the units in the Brong Ahafo, Western, Eastern and Central Regions have automatic defrost and the other half have manual defrosting.

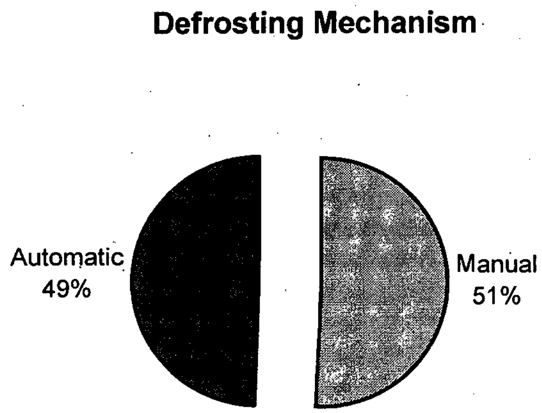


Figure 3.2.12. Division of units in Brong Ahafo, Western, Eastern and Central Regions by method of defrosting.

Just as in the other regions surveyed, units in the Brong Ahafo, Western, Eastern and Central regions are manufactured by a variety of manufacturers: U.S., European, Japanese, and Korean. However, these units represent a broader array of manufacturers. Bosch, Indesit, Samsung, and Phillips, which together cover more than ¾ of the market in Accra and Ashanti regions, only account for about ¼ of the market in the smaller urban markets. Nearly 1/3 of manufacturers represented in these regions do not appear in the survey data from the other two regions.

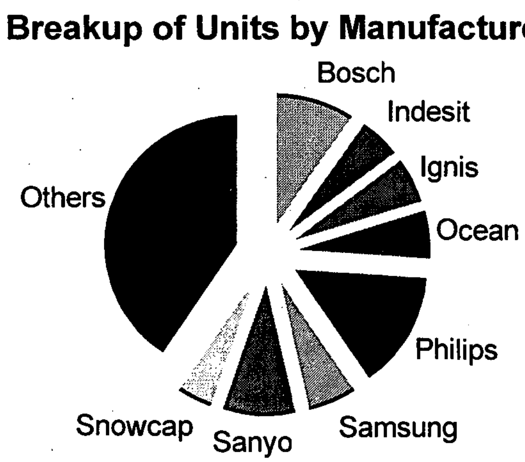


Figure 3.2.13. Units in the Brong Ahafo, Western, Eastern and Central Regions by manufacturer.

59% of the units are running all year round whereas 41% are turned off during some part of the year. The effect of this practice on annual energy requires additional study.

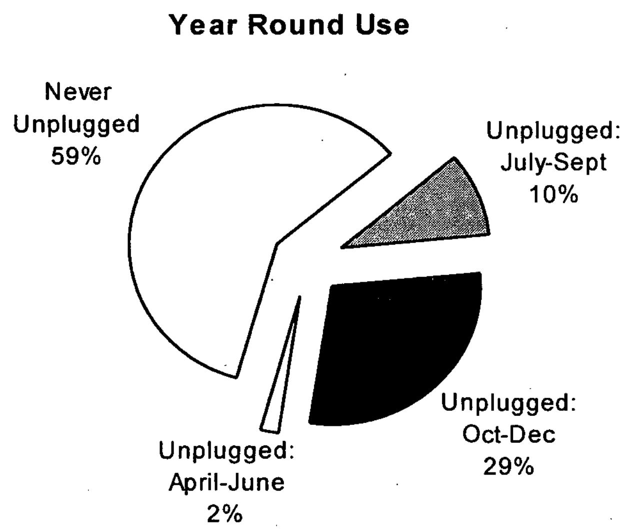


Figure 3.2.14. Units in the Brong Ahafo, Western, Eastern and Central Regions that are turned off during part of the year.

Almost 11% of the refrigerator/freezer population in Brong Ahafo, Western, Eastern and Central Regions are used for commercial purposes whereas the remaining 89% are for domestic use only. The impact of commercial use on energy consumption cannot be determined from currently available data.

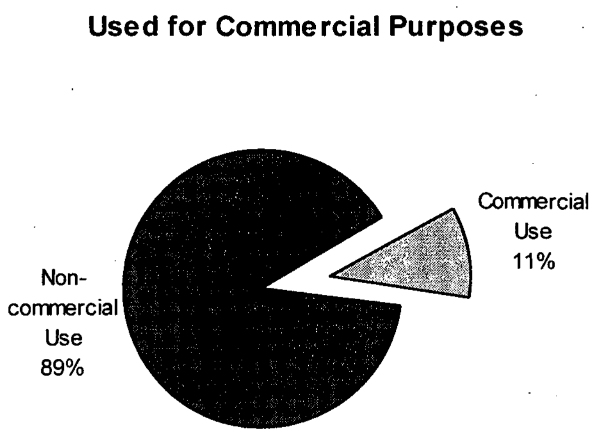


Figure 3.2.15. Units in the Brong Ahafo, Western, Eastern and Central Regions used for commercial purposes.

The most popular size of refrigerators in the Brong Ahafo, Western, Eastern and Central Regions are in the 400-500 liter range, slightly smaller than in the larger metropolitan areas. Despite the small sample size, this is probably true of units in other small urban and rural areas. The distribution of units by volume is depicted in figure 3.2.16.

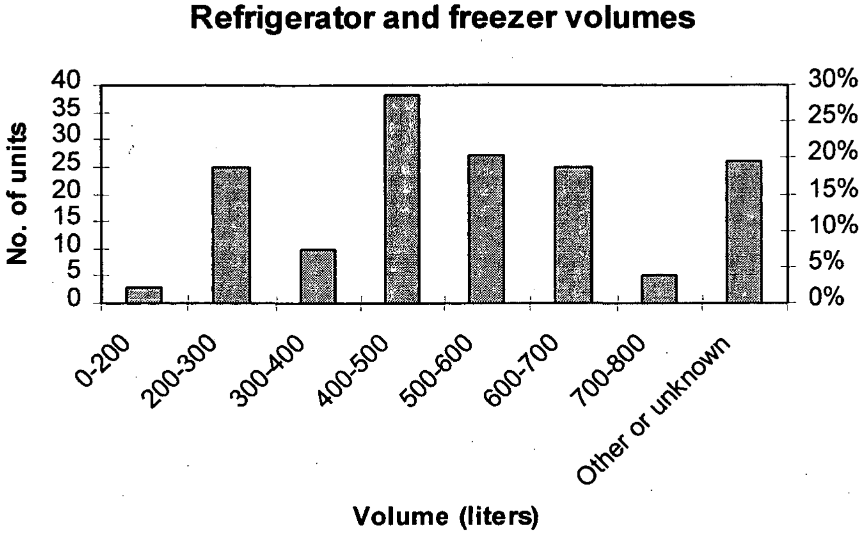


Figure 3.2.16. Distribution by volume of units in the Brong Ahafo, Western, Eastern and Central Regions.

3.3. Room air conditioners:

Room air conditioners convey conditioned air without the use of air ducts. There are two basic types of room air conditioners; window-type units and ductless split systems. A window-type room air conditioner consists of several components encased in a cabinet. The cabinet is segmented into indoor and outdoor sides that are separated by an insulated divider wall to reduce heat transfer. The evaporator and evaporator fan are on the indoor side. The outdoor side components are the compressor, condenser, condenser fan, capillary tube, and fan motor. The fan motor has a double-ended shaft that drives both the evaporator and condenser fans. As its name implies, window-type units are intended to be mounted in windows, although there are some types that are specifically designed to be installed through walls.

Ductless split systems, also referred to as mini-splits, consist of two individual assemblies; the indoor assembly, containing the evaporator and evaporator fan and fan motor, and the outdoor condensing unit, containing the compressor, condenser, condenser fan, and condenser fan motor. The indoor and outdoor units are connected via refrigerant tubing. The indoor assembly is a wall-mounted unit and typically has a sleek design. Mini-split room air conditioners, as well as window-type units, have relatively small cooling capacities ranging from 1450 to 8800 Watts (5000 to 30000 Btu/hr).

In Ghana, both types of room air conditioners are used. Figure 3.3.1 shows the breakdown of air conditioner types in those Ghanaian households using an air conditioner. Of the approximately 100 households surveyed in Ghana using a room air conditioner, a majority uses window-type units.

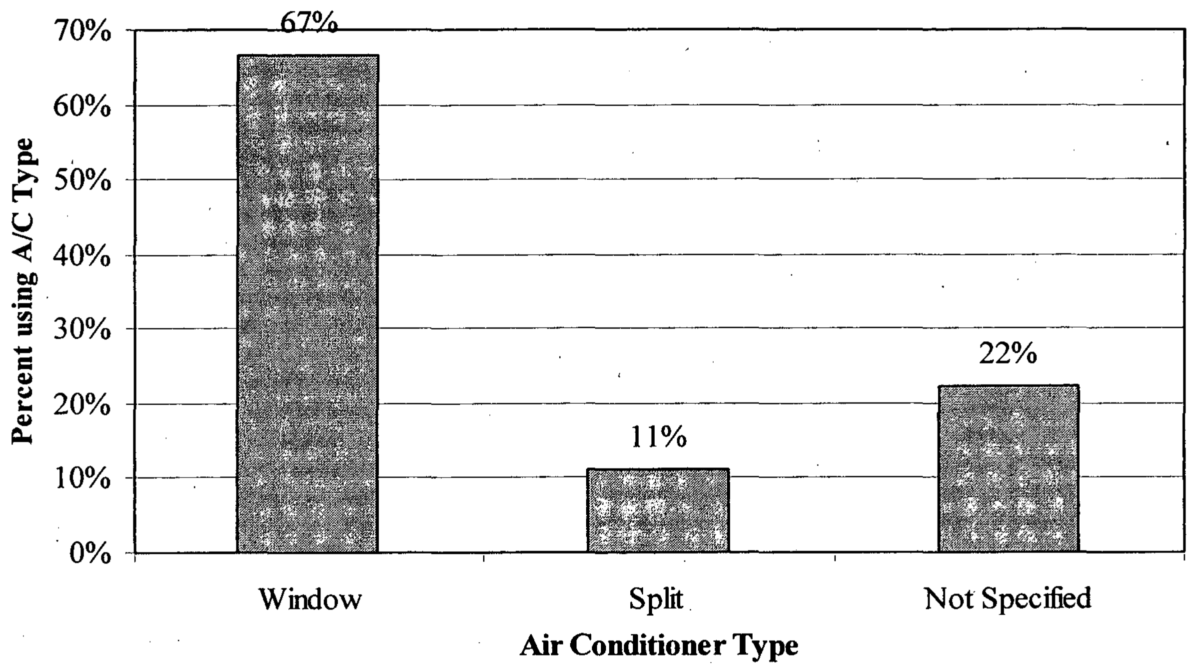


Figure 3.3.1. Ghanaian air conditioner types

3.3.1 Issues regarding minimum energy efficiency standards for air conditioners

There are a number of concerns and issues with adopting minimum energy efficiency standards for room air conditioners including: 1) the market impact of a prospective standard, 2) the need for a test procedure for establishing efficiency ratings and labeling information, and 3) the enforcement of an adopted standard.

In order to make any type of assessment of how a prospective standard may impact the room air conditioner market proper knowledge of the market is necessary. Following are some of the statistical data which are required.

- Saturation: The percentage of households owning a room air conditioner.
- Shipments: The number of units being shipped.
- Manufacturers: The manufacturers selling air conditioning equipment.
- Efficiency: The efficiency of the models being shipped.

In Ghana, very little room air conditioner market data exist. One primary reason for this lack of data is that no manufacturers currently produce air conditioners domestically, although there are several manufacturers exporting room air conditioners to Ghana. In addition, few households use air-conditioning. Of the 1000 Ghanaian households surveyed here, only 108 respondents used an air conditioner (i.e., 10.8% saturation). Some efficiency data exist in the survey, but not enough data are available to draw conclusions on what an appropriate efficiency standard may be and what impacts on the Ghanaian room air conditioner market may result. Instituting an energy efficiency labeling program is one method for generating market data. This allows the organization responsible for administering the program to compile the data provided on the label (e.g. manufacturer, model number, cooling capacity, and efficiency) into directories which can later be utilized to make assessments of the type of equipment in the market.

In order to develop the necessary capacity and efficiency information for an energy label, a test procedure must be in place. Fortunately the International Organization of Standardization (ISO) has developed an internationally accepted test procedure for room air conditioners which most countries have either adopted or directly reference in their test procedures. This test procedure, ISO 5151, rates the performance of non-ducted air conditioners utilizing a single refrigeration circuit consisting of one evaporator and one condenser. (Note that mini-splits utilizing more than one evaporator cannot be tested according to ISO 5151.) The test procedure measures a unit's cooling capacity and energy efficiency ratio (EER) at steady-state operating conditions. The EER is established by dividing the cooling capacity (measured in Watts) by the input power (measured in Watts). ISO 5151 defines moderate, cool, and hot temperature conditions for which to rate equipment, but only the moderate test condition is mandatory for rating equipment. Table 3.3.1 lists the indoor and outdoor temperature conditions of the ISO 5151 test procedure.

Table 3.3.1. ISO 5151 temperature conditions for rating non-ducted air conditioners

	Moderate		**Cool**		**Hot**	
Location	Dry Bulb *°C (°F)*	Wet Bulb *°C (°F)*	Dry Bulb *°C (°F)*	Wet Bulb *°C (°F)*	Dry Bulb *°C (°F)*	Wet Bulb *°C (°F)*
Air entering indoor-side	27 (80.6)	19 (66.2)	21 (69.8)	15 (59)	29 (84.2)	19 (66.2)
Air entering outdoor-side	35 (95)	24 (75.2)	27 (80.6)	19 (66.2)	46 (114.8)	24 (75.2)

Since most countries with room air conditioner efficiency standards utilize test procedures that are almost identical to ISO 5151, "air conditioner" harmonization already exists between countries which regulate non-ducted air conditioning equipment. In pursuing efficiency standards for room air conditioners, Ghana would be well served by also adopting ISO 5151, not only to maintain world-wide harmonization, but to also virtually eliminate the time and effort necessary for developing its own test procedure.

In instituting either a labeling program or minimum efficiency standards, enforcement of the label information and/or efficiency standard is required. In developed countries like the United States (U.S.) and Canada, the government relies on a "self-policing" program where industry trade associations ensure that manufacturers are honestly reporting product information. In the case of air-conditioning equipment, the industry trade associations (Association of Home Appliance Manufacturers and the Air-Conditioning & Refrigeration Institute) randomly pull manufacturers' equipment and have it tested at an independent privately-owned test laboratory. If it is determined that equipment does not meet specifications, manufacturers can either submit a new sample to be tested or they can re-rate the equipment. A "self-policing" enforcement program is effective in the United States because the industry is mature and extremely competitive. Manufacturers will refrain from falsifying product specifications, as they know that their competitors will likely inspect their products. The same cannot be said in developing countries or in countries with newly regulated markets. In the case of The Philippines, instead of relying on any type of "self-policing" program to enforce their newly adopted room air conditioner efficiency standards, the Office of Energy Affairs developed its own independent testing laboratory. The Fuels and Appliance Testing Laboratory is dedicated to the energy performance testing of household appliances including room air conditioners. In this manner, the government has full control of the enforcement program and can easily determine if manufacturers are complying with their newly adopted efficiency standards.

Because Ghana is strictly an import market for room air conditioners, an enforcement program may be more difficult to administer than in a country like The Philippines where all room air conditioners sold in the country are produced domestically. Certainly the Ghanaian government agency administering the program would need to coordinate with customs officials to ensure that product entering the country had proper certification. A "self-policing" enforcement program is not an option for Ghana due to its non-existent manufacturing base. Thus, any enforcement, no matter how difficult, would need to be administered by the government.

3.3.2 World wide energy efficiency standards

There are a number of countries that have already developed either mandatory or voluntary efficiency standards for window-type and mini-split room air conditioners. Figure 3.1 provides a comparison between the existing mandatory and voluntary EER standards that currently exist in the United States, Canada, Mexico, South Korea, The Philippines, China, Japan, and India for window-type and mini-split room air conditioners. As stated earlier, most countries rate room air conditioners using the ISO 5151 test procedure. The exception being the test procedures of the United States, Canada, and Mexico which are based upon temperatures using the degree Fahrenheit (°F) scale rather than the degree Celsius (°C) scale. Although the use of different temperature scales results in extremely small discrepancies in the temperature conditions that are used to rate equipment, the resulting differences in the measured EERs from the two test procedures are negligible. Thus, direct comparisons can be made between the countries' efficiency standards.

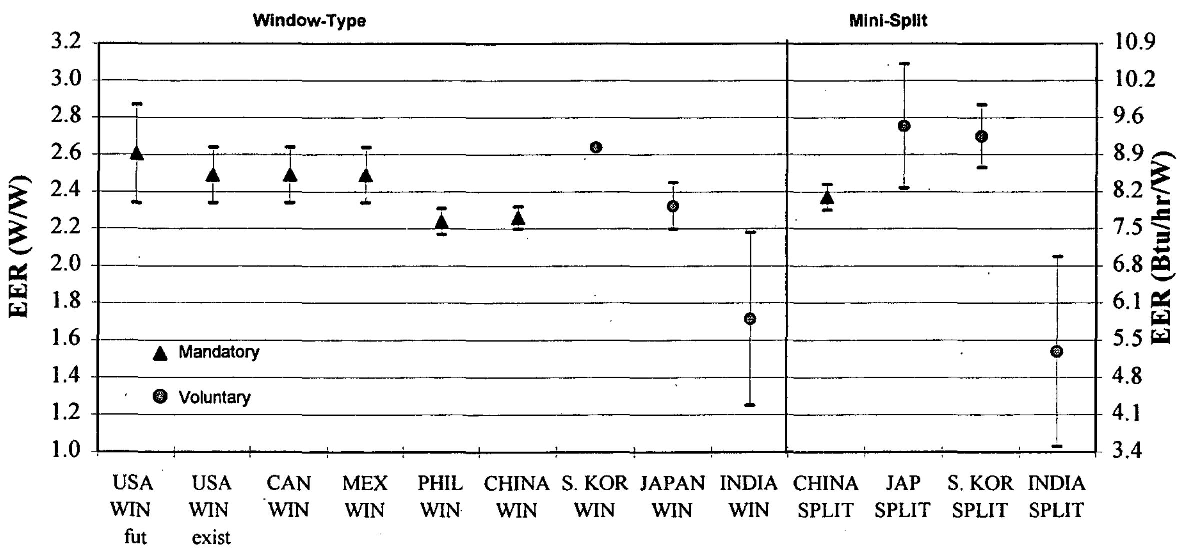
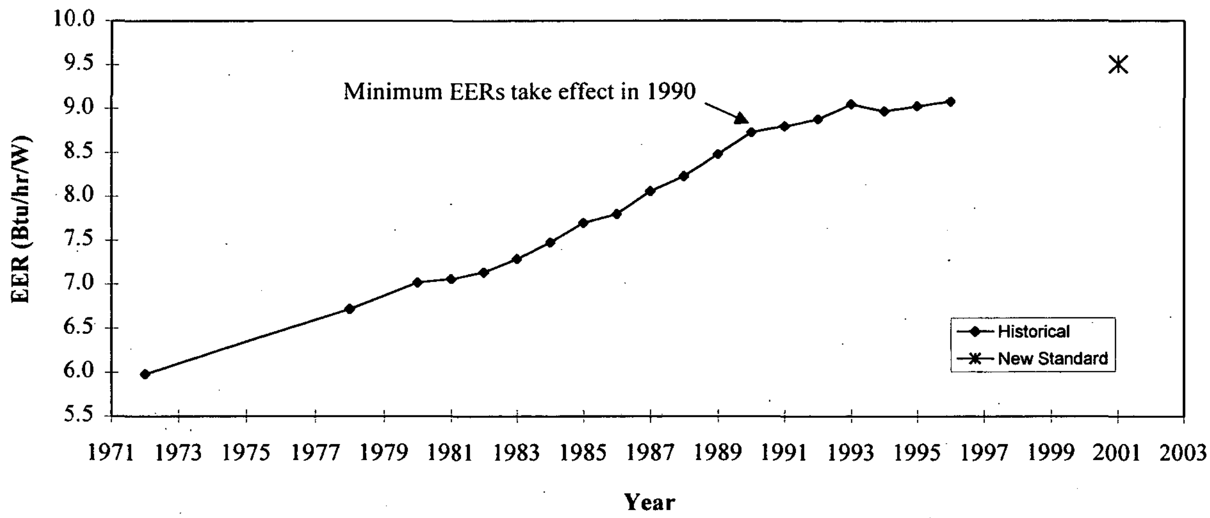


Figure 3.3.2. Comparison of world wide room air conditioner efficiency standards

In Figure 3.3.2, the range of the existing standards are provided for each country. The horizontal-axis designates the country, grouped by the type of air conditioner (window-type or mini-split). Different symbols distinguish the type of standard (mandatory or voluntary). Two ranges of mandatory standards are provided for the United States (USA); the first range (designated as *fut*) are those window-type standards that take effect in October of the year 2000 while the second range (designated as *exist*) are those standards which are currently in effect. Canada's (CAN) and Mexico's window-type standards are harmonized with the U.S.'s existing standards. The Philippines' (PHIL) and China's mandatory window-type standards are significantly lower than the North American standards. Although Japan's and South Korea's window-type standards are within the range of the North American standards, they are strictly voluntary and do not penalize manufacturers for failing to comply with the efficiency target. India's voluntary window-type standards are significantly lower than any other country's mandatory or voluntary standards. Of the four countries listed as having standards for mini-splits, only China has mandatory standards. Japan's[17] voluntary standards for mini-splits (also termed as efficiency targets) are very aggressive relative to the standards in other countries. It should be noted that the U.S. and Canada rate the performance of mini-splits with a seasonal energy efficiency ratio (SEER)[18]. The SEER and EER are not directly comparable and, thus, the U.S. and Canadian SEER standards for mini-splits are not provided in Figure 3.3.2.



Source: AHAM 1997

Figure 3.3.3. U.S. window-type room air conditioner shipment-weighted efficiency

In order to demonstrate the impact of a standard on product efficiency, Figures 3.3.3 and 3.3.4 are provided to depict the historical progression of the shipment weighted energy efficiency

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[17] Japan is currently revising their energy conservation law and will likely require mandatory rather than voluntary standards (i.e., efficiency targets) in the near future. The new mandatory standards under consideration will be set at a level which is higher than that of the product with the highest energy efficiency of the currently commercialized products (except special items).

[18] The test procedure to determine the SEER is more complex than the procedure for establishing the EER and incorporates methods for measuring the efficiency of the system during cycling conditions (i.e., the time period when the system turns on and has to achieve steady-state). Only the U.S. and Canada rate mini-splits with a SEER.

ratings of window-type room air conditioners and central air conditioners in the U.S. (Central air conditioners typically are significantly larger than room air conditioners with cooling capacities ranging from 4400 to 19,000 Watts (15,000 to 65,000 Btu/hr). Although in the U.S. mini-splits are considered to be central air conditioners, the U.S. residential central air-conditioning market is dominated by split and single package systems utilizing air ducts to convey conditioned air.)

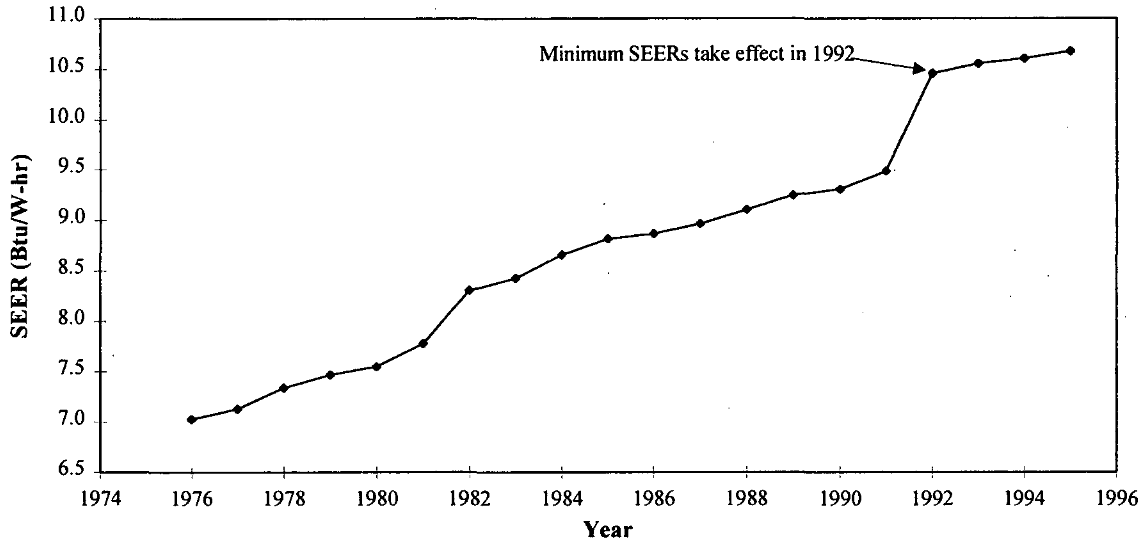


Figure 3.3.4. U.S. central air conditioner shipment-weighted efficiency

In the case of window-type room air conditioners, the trend in the efficiency as depicted in Figure 3.3.3 seemed to be only mildly affected by the imposition of the 1990 minimum efficiency standards. But the rate of the efficiency increase is noticeably lower after 1990. This situation could be due to the U.S. Department of Energy's (DOE) lengthy efforts during the past five years to update the standards for window-type air conditioners. Manufacturers may have been holding off on investing in product efficiency improvements until knowing exactly the efficiency requirements of the updated standards. As mentioned earlier, the U.S. DOE recently issued new energy efficiency standards for window-type room air conditioners that will become effective on October 1, 2000. For the most popular classes (those with cooling capacity below 5862 Watts (20,000 Btu/hr), with louvered sides, and without reverse cycle) the new minimum EERs are 2.84 and 2.87 W/W (9.7 and 9.8 Btu/hr/W). The new standards for the most popular classes are a 12 to 21% increase over the existing standards.

Figure 3.3.4 shows that minimum efficiency standards for U.S. central air conditioners had a much more dramatic effect on product efficiency than standards had on window-type room air conditioners. An increase of almost 1 SEER in the shipment weighted efficiency occurred once the 1992 standards became effective. This dramatically demonstrates the effect minimum efficiency standards can have on raising overall equipment efficiency.

In the case of both window-type and central air conditioners, technological advances have enabled U.S. manufacturers to steadily improve product efficiency and meet minimum requirements for energy efficiency. Compressor efficiency has increased right along with the overall product efficiency. Rotary compressors utilized in room air conditioners now approach EERs (at standard rating conditions) of 11 Btu/hr/W (3.22 W/W). The central air-conditioning industry has begun to move away from reciprocating compressors and now use scroll compressors where EERs exceed 11 Btu/hr/W (3.22 W/W) at standard rating conditions. Although heat exchanger face areas have seemed to increase over the years, many manufacturers now utilize internally rifled refrigerant tubing and enhanced fin surfaces. Also, permanent split capacitor fan motors, with efficiencies ranging from 50 to 65%, have virtually replaced the use of inefficient shaded pole motors.

Although advanced technologies are available to U.S. manufacturers, it is not at all evident what type of technologies is available to those manufacturers exporting room air conditioners to the Ghanaian market. Coupled with the fact that very little is known of the Ghanaian room air conditioning market, the government must proceed with caution if it is to adopt a minimum room air conditioner efficiency standard. For example, the Ghanaian government may want to use the same type of two-tier approach that was utilized by both Mexico and The Philippines in adopting standards for room air conditioners. In these countries, the first standard that took effect was meant only to institutionalize the standards setting process. That is, the standard resulted in no real adverse impacts to the air-conditioning industry. The industry was allowed to continue to sell inefficient inventory until the second more stringent standard took effect. The second standard was timed to take effect (usually two to three years after the imposition of the first standard) so that the industry had enough lead time to bring more efficient product to the market place.

3.3.3 Air conditioners in Ghana

As mentioned earlier, a survey was conducted of 1000 Ghanaian households to determine the energy consumption behavior of residential occupants. As part of this survey, data was collected to determine the following: 1) room air conditioner purchase behavior, 2) room air conditioner performance characteristics, and 3) the energy consumption due to room air conditioners.

Six regions in Ghana were surveyed. Table 3.3.2 shows the number of households sampled in each region with the accompanying number of households which had an air conditioner. The percentage of households with an air conditioner in each region is derived. This percentage value can be used as a proxy for the saturation of air conditioners in Ghanaian households.

Table 3.3.2. Percentage of households with an air conditioner

	Ghanaian Region						**Total**
	Greater Accra	Ashanti	Western	Eastern	Central	Brong Ahafo	
Households Surveyed	467	364	50	39	50	30	1000
Households with an A/C	80	21	6	0	1	0	108
Percent with an A/C	17.1%	5.8%	12.0%	0.0%	2.0%	0.0%	10.8%

As expected, the 10.8% of those households surveyed that have an air conditioner are more concentrated in regions with a greater percentage of urban area (i.e., Greater Accra and Ashanti) The exception is the Western Region. This anomaly probably has more to do with the households surveyed in the region (i.e., more affluent residences with electricity) rather than the actual percentage of households that have an air conditioner.

With regards to the type of air conditioner being used in Ghana at least 67% of the 108 households with an air conditioner have a window-type unit (refer to Figure 3.3.1).

In Ghana, there is concern that most consumers purchasing air conditioners are selecting used, inefficient products because of their low purchase price. For those households in the survey owning an air conditioner, Figure 3.3.5 shows the breakdown of the air conditioner's status (i.e., new, used, or unknown) when it was purchased.

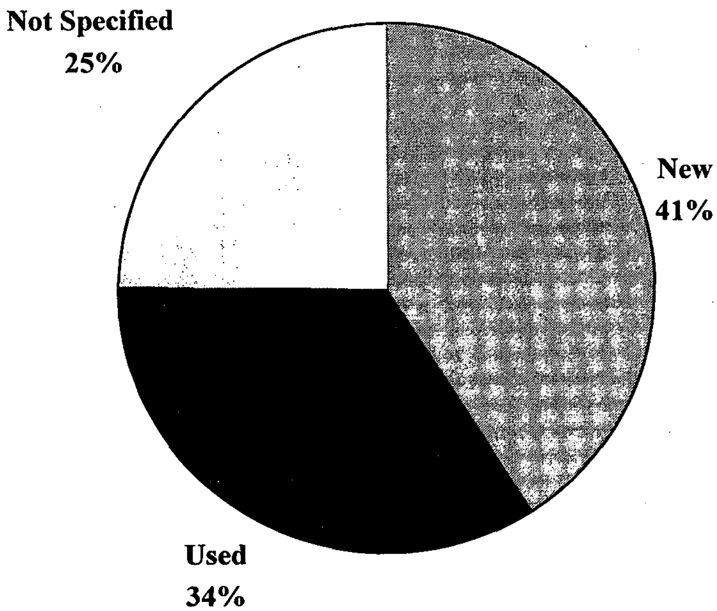
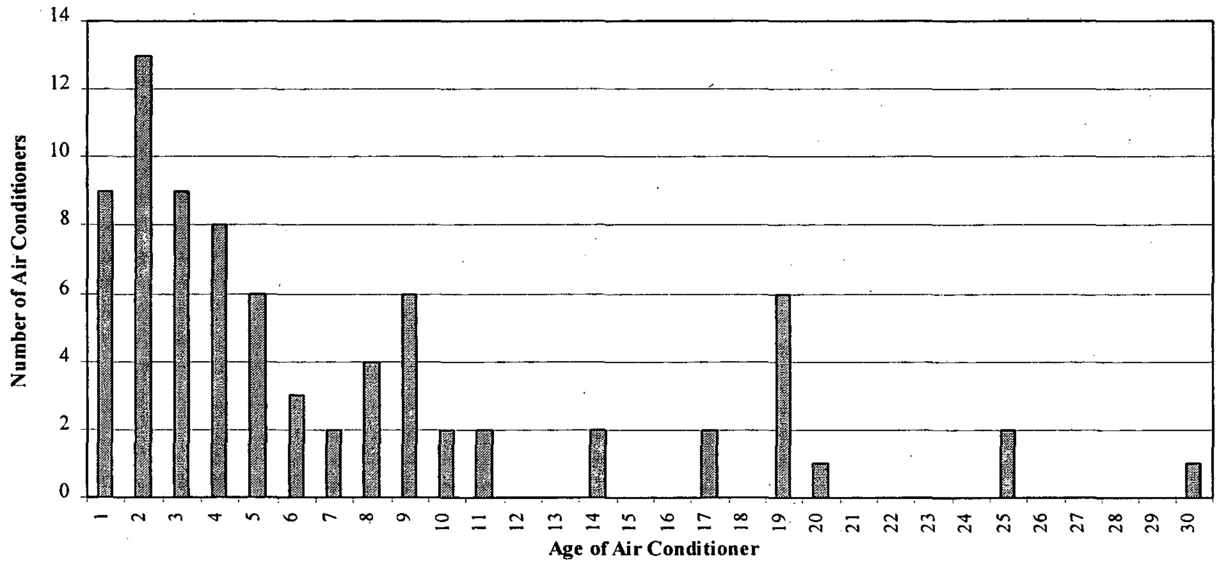


Figure 3.3.5. Breakdown of new and used room air conditioner purchases

Contrary to popular belief, for those households indicating the status of their room air conditioner purchase, a majority had purchased new equipment. It should be noted that this statistic could merely be due to the small survey size and not reflect the actual purchase decisions of Ghanaians.

Figure 3.3.6 shows the age of the room air conditioners in the survey. The age was derived from the respondent's stated date of purchase. For those respondents providing a purchase date, it is interesting to note the relatively young age of the room air conditioner stock as 45 units have an age of five years of less. This statistic seems to coincide with information in Figure 3.3.5 showing that a majority of room air conditioner owners purchased their units new.



Note: One household had a 39 year old air conditioner while 29 households did not specify the age.

Figure 3.3.6. Age of room air conditioners (by purchase date)

With regard to purchase price, only 17 of the 108 households with an air conditioner indicated what their price was. Figure 3.3.7 shows the large range of prices that those 17 consumers paid for their air conditioner

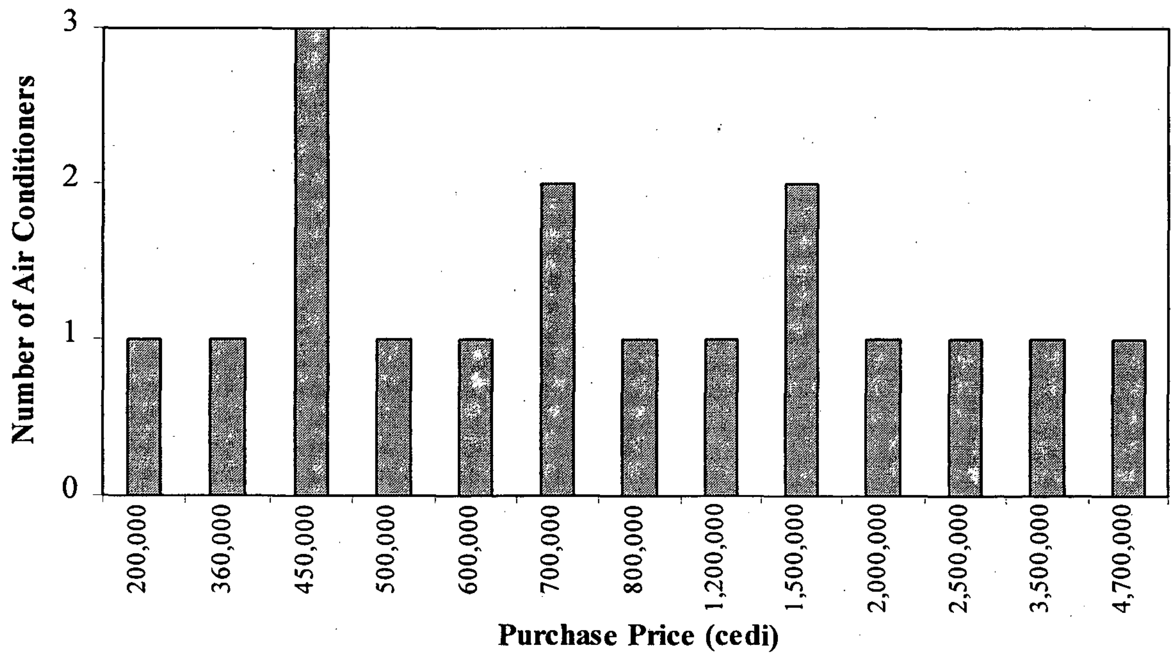


Figure 3.3.7. Purchase price of Ghanaian room air conditioners

Table 3.3.3. shows the breakdown of room air conditioners by manufacturer. Although there is diversity in the number of manufacturers supplying air conditioners, it is interesting to note the large number of air conditioners produced by White Westinghouse listed in the survey. Air conditioners manufactured by Carrier and Goldstar are a distant second and third, respectively.

Table 3.3.3. Manufacturers of air conditioners

Manufacturer	Number of Air Conditioners
AMANA	1
CARRIER	8
Chinese (mfg unknown)	1
DAIHAITSU	1
DELCHI	3
EXCEL	1
FRIGIDAIRE	3
GENERAL	1
GENERAL ELECTRIC	1
GIBSON	1
GOLDSTAR	7
HOT POINT	1
NATIONAL	5
PHANTOM	1
RICAGN	1
SANYO	5
SHARP	3
SUPERTHRUST	1
SUPRA	1
TOSHIBA	1
WATECH	1
WESTINGHOUSE	30
YORK	1
Not Specified	29

Figures 3.3.8 and 3.3.9 show the distribution of room air conditioner cooling capacities (in Btu/hr) and input powers (in Watts) from the sample. Since the air conditioner capacity can presumably only be found from the name plate information (which is difficult to locate and access for an installed unit), it is somewhat surprising that almost all of the air conditioners in the survey had both a cooling capacity and input power provided. Not surprisingly, capacities ranged from 7800 to 25,000 Btu/hr (2300 to 7300 Watts) with a majority of units having a capacity of 15,000 Btu/hr (4400 Watts).

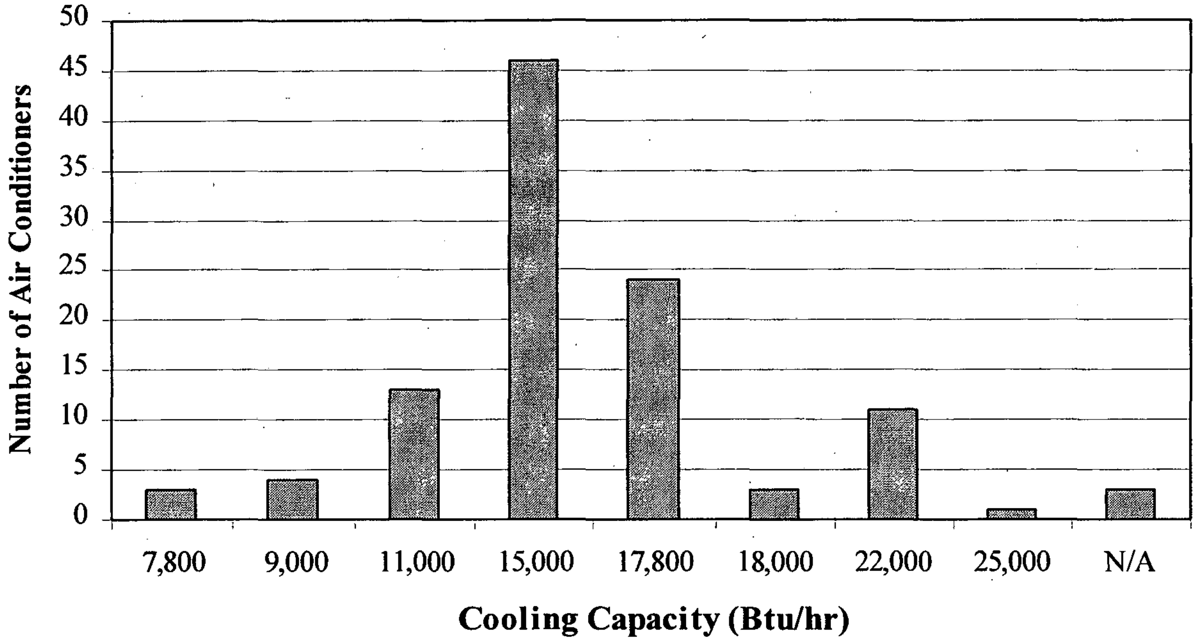


Figure 3.3.8. Cooling capacity of Ghanaian room air conditioners

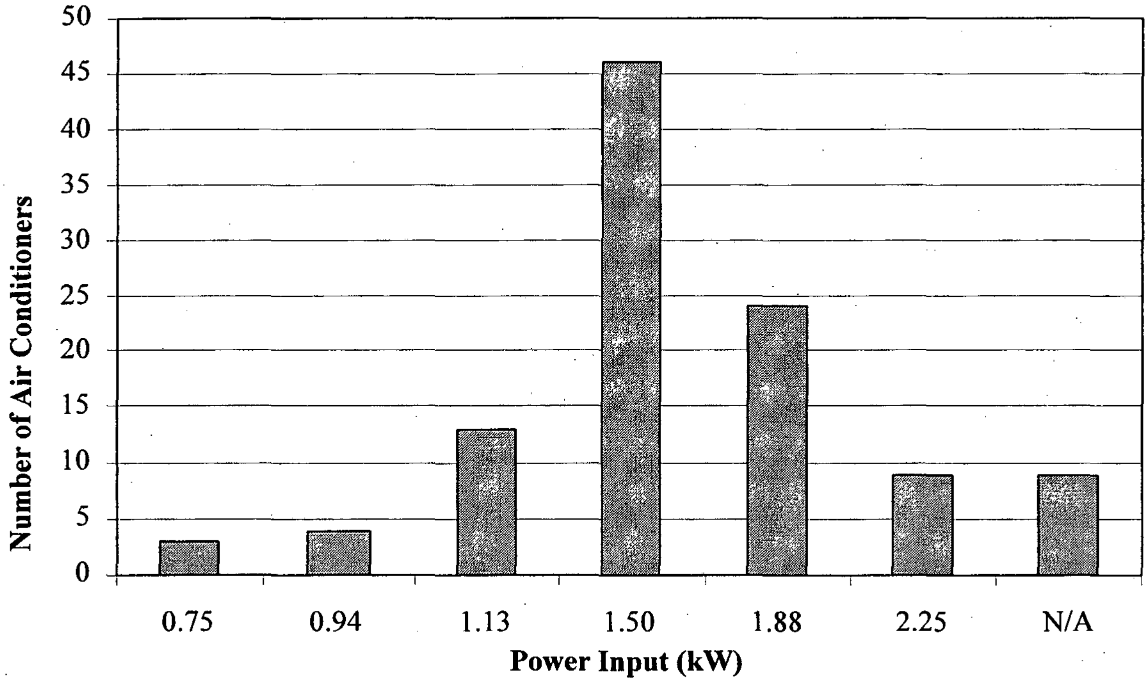


Figure 3.3.9. Power input of Ghanaian room air conditioners

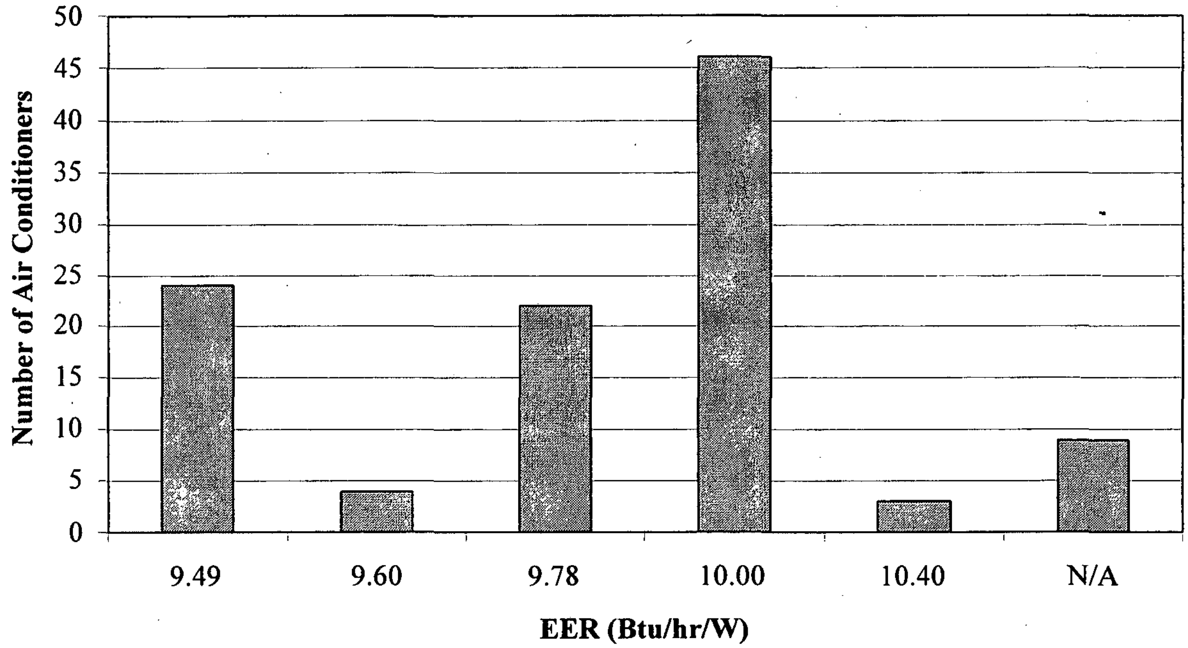


Figure 3.3.10. Energy Efficiency Ratios (EERs) of Ghanaian room air conditioners

Figure 3.3.10 shows the distribution of derived room air conditioner EERs from the survey. The EER was derived from the cooling capacity and input power. It is very surprising to note that the derived EERs are relatively high and fall within a narrow range of values (9.49 to 10.00 Btu/hr/W (2.78 to 2.93 W/W)). As a result, the accuracy of at least the input powers provided in the survey are very suspect. After all, there are several units in the sample with ages exceeding seven years and it is very difficult to believe that units of this age would have EERs of the above magnitude.

From the survey, 40 households with air conditioners provided information with regard to the number of hours per year the unit was used; 33 of the households are located in what are assumed to be major urban areas (Greater Accra and Ashanti regions) while seven are located in what are assumed to be smaller urban areas (Western and Central regions). Much of the data were provided in irregular formats and, thus, judgement had to be used in interpreting the data. As a result, firm conclusions with regard to the actual hours of use cannot be made. With that said, the hours of use for those 40 households were used to calculate their annual energy consumption based on the power input of the unit. Table 3.3.4 provides the minimum, maximum, average, and median values of room air conditioner hourly use (in hours per year) and annual energy consumption (in kWh/year). For this analysis, statistics for Greater Accra and Ashanti regions are presented as one, as are Western and Central regions. In addition, summary statistics for the entire country are presented.

Table 3.3.4. Statistics on room air conditioner use and annual energy consumption

	Use			Annual Energy Consumption		
	Gr. Accra-Ashanti *Hours*	**Western-Central** *Hours*	**Country-Wide** *Hours*	**Gr. Accra-Ashanti** *kWh/year*	**Western-Central** *KWh/year*	**Country-Wide** *KWh/year*
Minimum	8	8	8	12	16	12
Maximum	8760	1350	8760	13140	1000	13140
Average	1876	490	1639	2919	630	2518
Median	1152	315	1120	1845	375	1800

The huge discrepancy between the two groupings is enough to question the accuracy of the data. Any results using these data as inputs must be considered preliminary until further verification of household usage patterns can be offered. At the very least, the usage in the major metropolitan areas seems high, especially given the modest annual consumption in other cities.

3.4 Lighting

Residential lighting provides illumination, visibility, reading, performing tasks, security, and ambience. There are two basic types of residential lighting sources: incandescent lamps and fluorescent lamps.

Incandescent lighting has two components: a lamp (bulb) and a socket. Incandescent light sources come in a variety of wattages, shapes, bases and voltages. An incandescent lamp must be used with a socket that fits the particular lamp base, wattage, and voltage. Incandescent lamps may or may not be installed in a fixture. The most common wattages worldwide for incandescent lamps are 60 and 75.

Fluorescent lighting for use in homes falls into two general categories – linear fluorescent tubes and Compact Fluorescent Lamps (CFL). All fluorescent lamps require a ballast (transformer) to regulate the current. Currently most fluorescent ballasts are either 1) standard core and coil, referred to as magnetic or 2) solid state, referred to as electronic. Fluorescent ballasts are sold either as part of a fluorescent fixture or as replacement ballasts. A fluorescent ballast is designed for a specific number of fluorescent lamps and usually for a specific lamp type. CFLs have the lamp, base and ballast together as one and can be screwed directly into a compatible incandescent socket. CFL wattages range from 5 Watts to about 23 Watts.

The most common wattage for linear fluorescent lamps is 40-W and that lamp is usually labeled as an F40T12 lamp.

F = Fluorescent
40 = 40 Watts and denotes 4 foot lamp
T = tubular (in shape), and
12 = 12/8 of an inch in diameter

Other common T12 lamp wattages are 20 (two feet) and 75 (F96T12/eight feet). The F32T8 fluorescent is gaining in popularity. It is a four-foot 32-Watt tubular lamp that is 8/8 inch in diameter. The smaller diameter of this lamp results in a much smaller interior bulb wall area (as compared to the F40T12). The smaller bulb wall area allows for the use of higher quality phosphors resulting in superior lighting quality and higher efficacy for a slightly higher first cost.

In Ghana all sockets are wired for 220 Volts. The most common incandescent lamp wattage is 40-W. The most common wattage for the linear fluorescent lamps is also 40W. Many of the linear fluorescent lamps do not come equipped with a capacitor.

3.4.1 Lighting in Ghana

Assessing the lighting end use situation in Ghana is more complicated than simply replacing one unit with a more efficient one. Both for the sheer numbers of fixtures and lamps to be analyzed and for the disparate usage patterns found in Ghana and elsewhere, a definitive answer to the question of lighting in Ghana will require more information than could be gathered in this initial survey. The following pages illustrate some of the findings from the data analysis.

As can be seen from the pie graph below (Figure 3.4.1), a little more then half (55%) of lighting energy usage (kWh) is for interior lighting. Exterior lighting accounts for 45% of residential lighting energy usage.

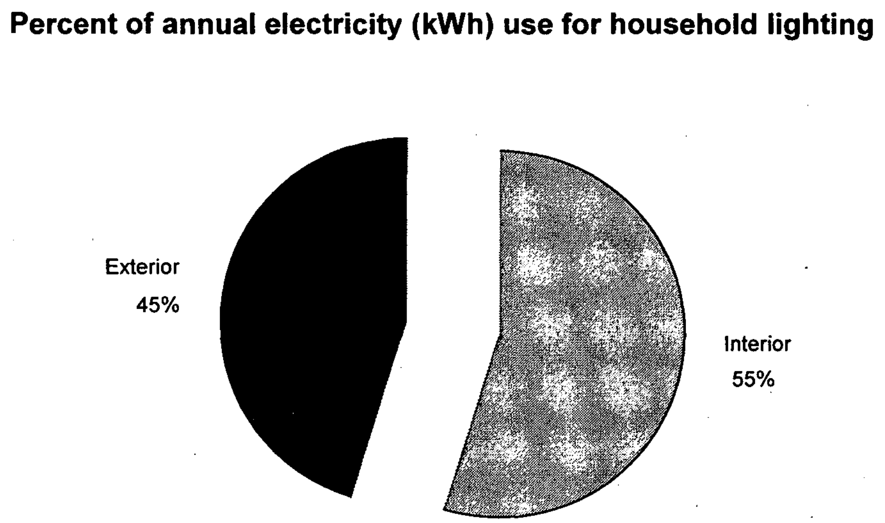


Figure 3.4.1. Percent interior and exterior kWh for surveyed houses.

For some of the regions (Brong Ahafo, Eastern, and Western) the energy used for exterior lighting exceeds 50% of the total lighting energy use. (see Figure 3.4.2 below)

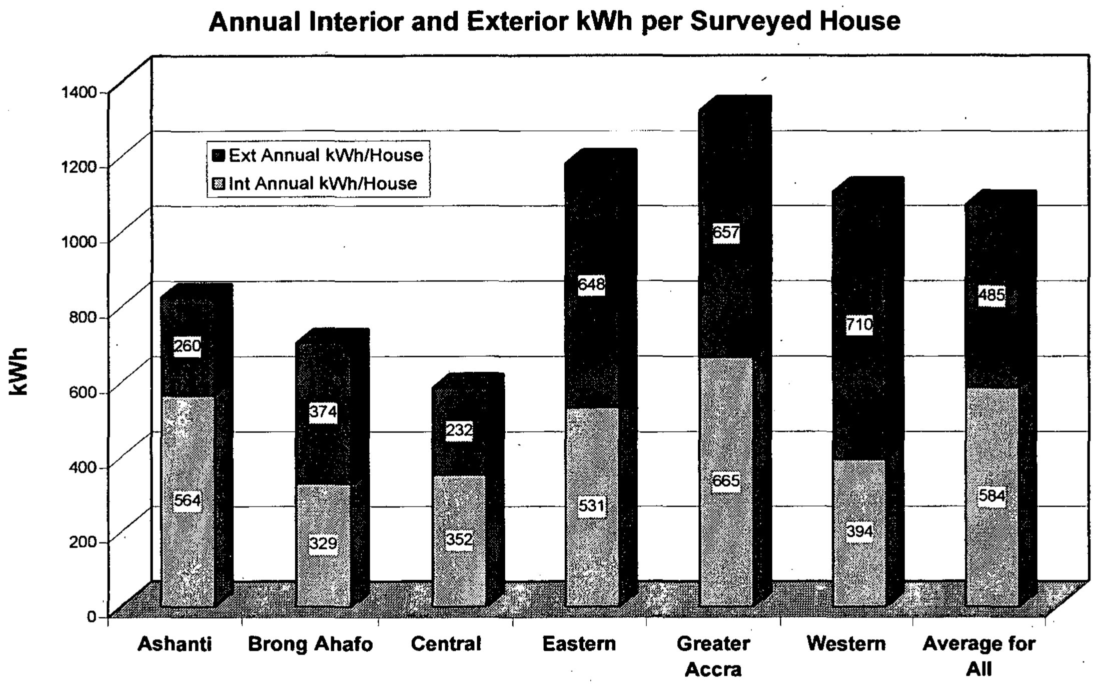


Figure 3.4.2. Annual interior and exterior kWh for houses surveyed

Figure 3.4.3 shows that incandescents are responsible for 59% of the cost of exterior lighting. The range is from 25% for the Western Region up to 88% for Brong Ahafo.

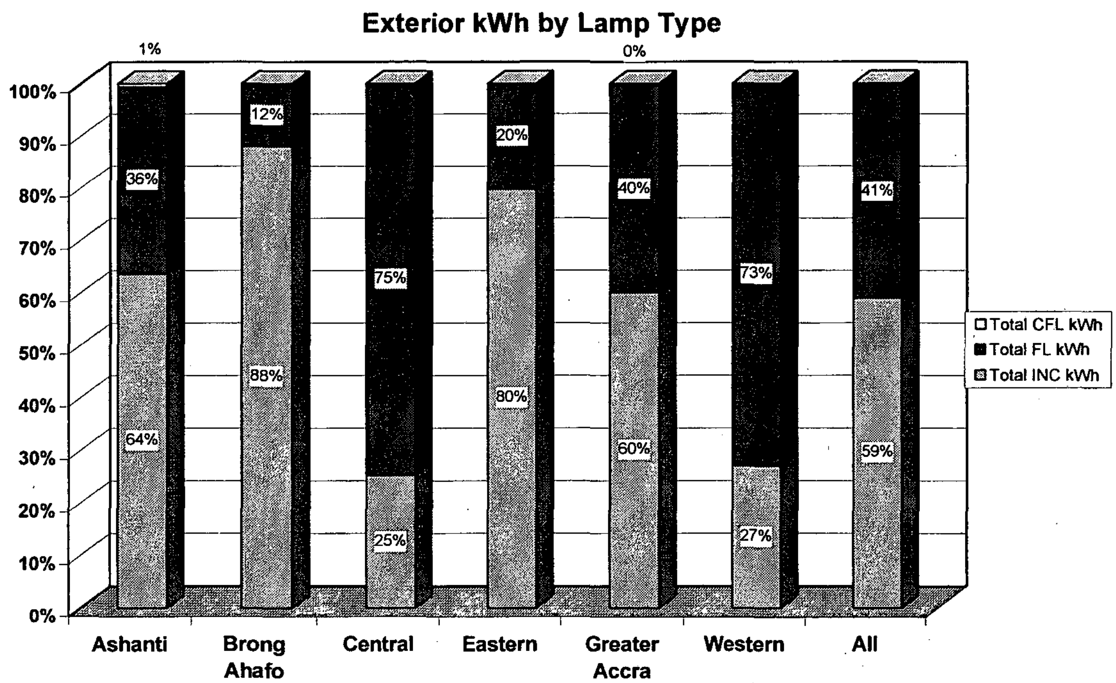


Figure 3.4.3. Exterior kWh by lamp type

Although Ghanaian homes have more incandescent lamps than fluorescent or CFL lamps, most of the interior and exterior light is provided by the fluorescent lamps. This is explained by the higher efficiency of fluorescent compared to incandescent lamps. Figure 3.4.4, below, shows the breakdown of exterior light supplied to residential homes from incandescent, fluorescent, and CFL sources. The light output of a lamp, or the amount of "luminous flux," is measured in lumens. A typical 40-W incandescent lamp produces 495 lumens. A 40-W fluorescent lamp (F40T12/CW) produces 3050 initial lumens.

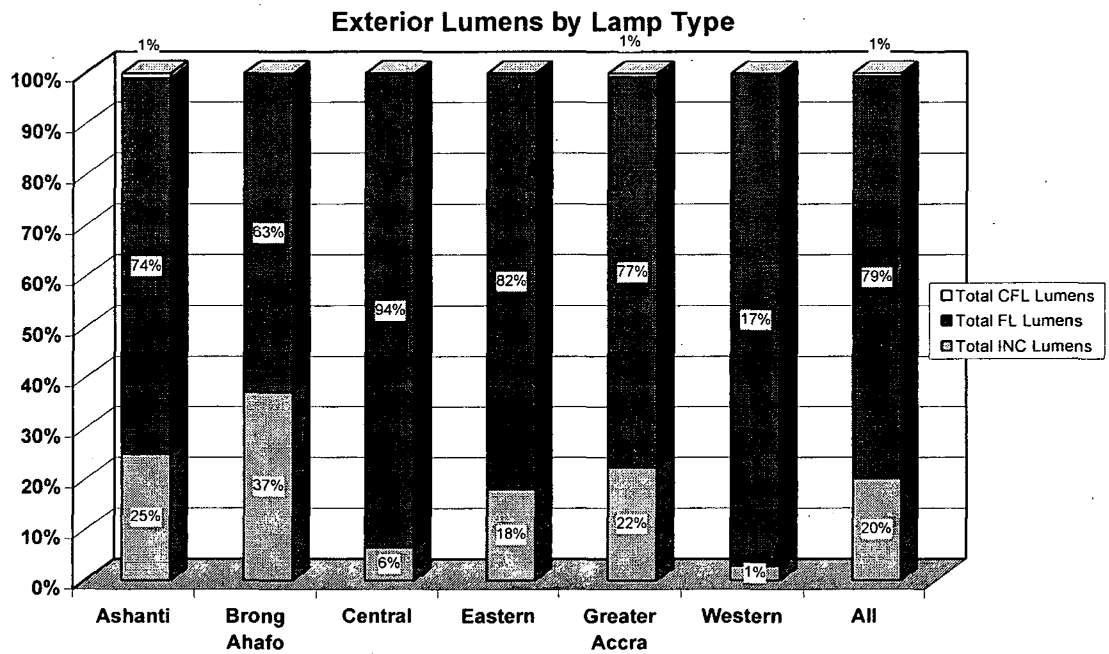


Figure 3.4.4. Exterior lumens by lamp type

As Figure 3.4.4 shows incandescent lamps currently provide an average of 20% of the exterior lumens. It ranges from 1% in the Western Region up to 37% in Brong Ahafo.

Figure 3.4.3 shows that incandescents also have the highest percentage of the exterior lighting energy use (55%), despite their poor performance in terms of usable illumination. The innate inefficiency of an incandescent lamp is exacerbated by the long hours of operation (usually 12) for exterior lighting.

Interior lighting follows the same general pattern as exterior lighting except that the percentage of incandescent lamps is higher. Incandescents account for an average of 68% of interior lighting sources as compared to 22% for exterior lighting. Consequently incandescent lighting accounts for 85% of the total interior light bill.

However incandescent lights provide less than 42% of the interior lumens, as shown in Figure 3.4.5. Some of the data may be anomalous, as in the (relatively) high penetration of CFLs in Western Region. This may be a function of the houses included in the survey being a biased sample, or it may reflect a local phenomenon.

Figure 3.4.6 shows the difference in kWh/lamp type for interior lighting. Once again, flourescents account for a significantly smaller portion of lighting demand while still providing more useful light.

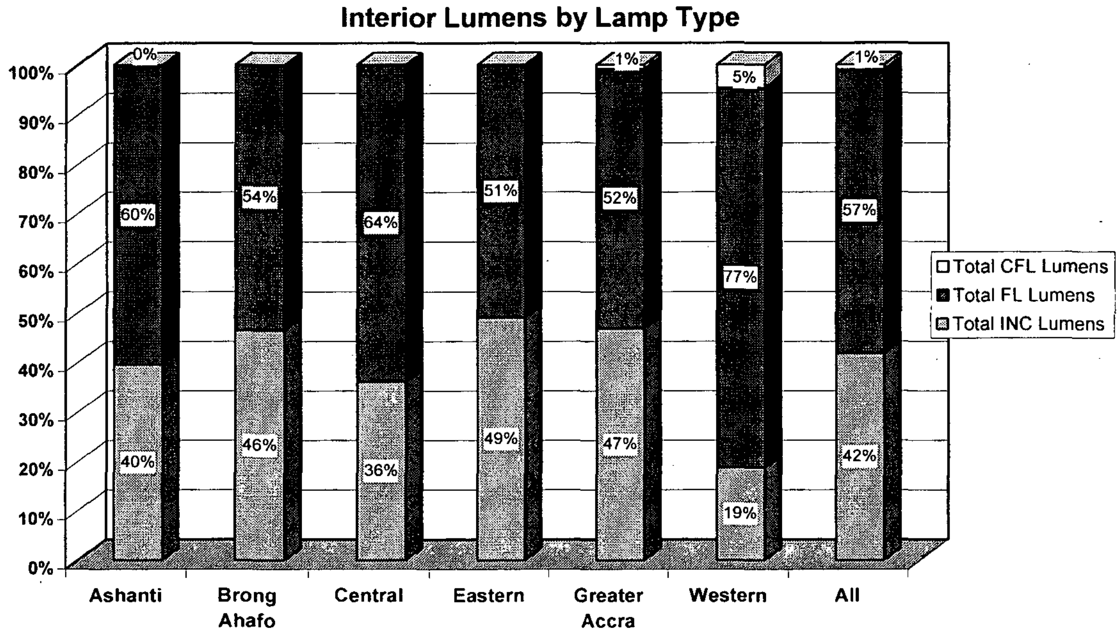


Figure 3.4.5. Interior lumens by lamp type

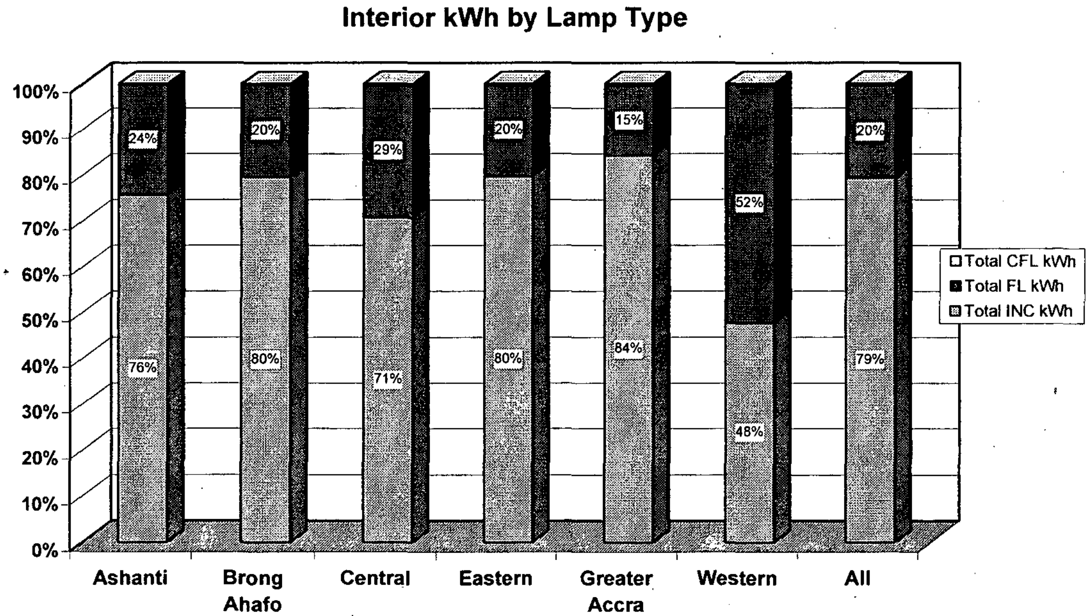


Figure 3.4.6. Interior kWh by lamp type

The final set of charts illustrates the sector-wide breakdown of Watts, Lumens, and kWh by lamp type. Figure 3.4.7 shows the dominance of the incandescents in terms of wattage. Figure 3.4.8 demonstrates that the fluorescent lamps, however, are the source providing an average of 65% of the light for the surveyed homes (as measure in lumens). Figure 3.4.9 shows the dominance of incandescent lamps in terms of the amount of energy consumed for lighting and consequently it represents 66% of the average lighting energy bill for a home in Ghana (see Figure 3.4.10)

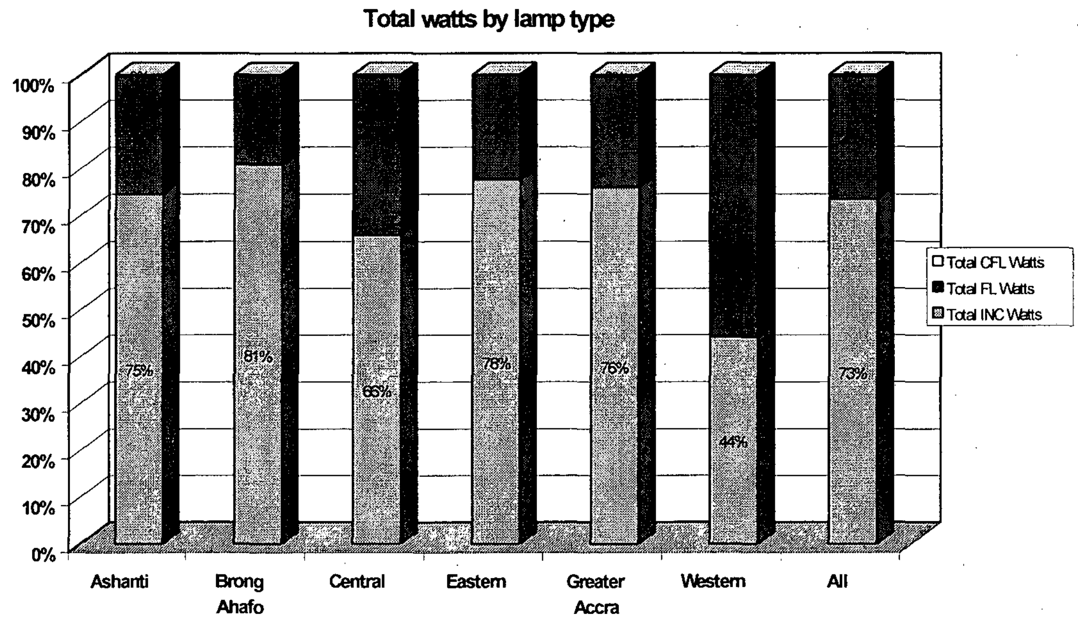


Figure 3.4.7. Total watts by lamp type

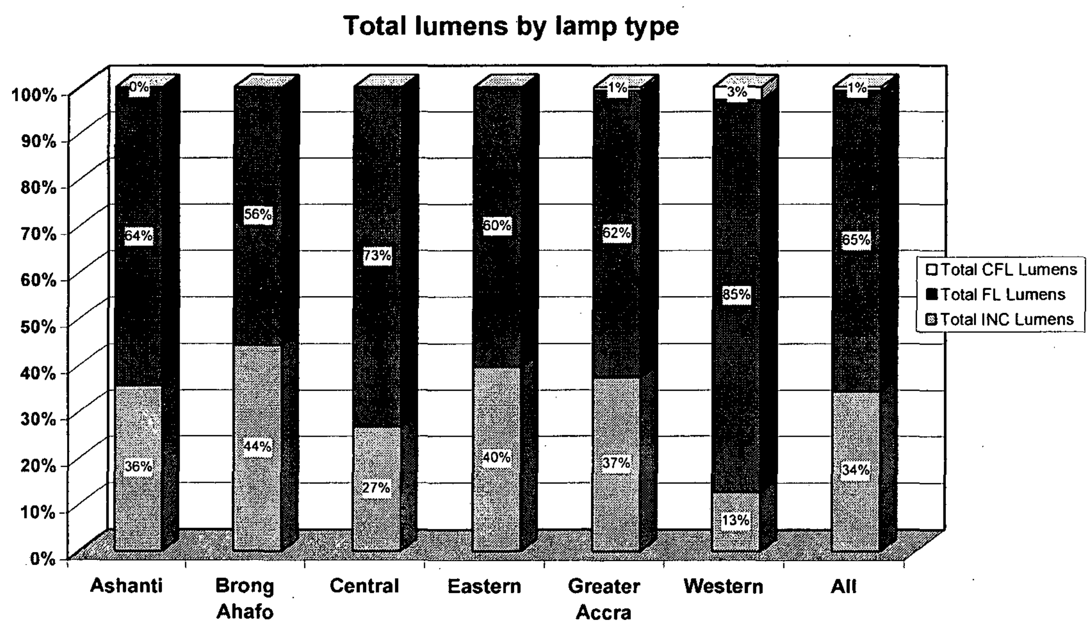


Figure 3.4.8. Total lumens by lamp type

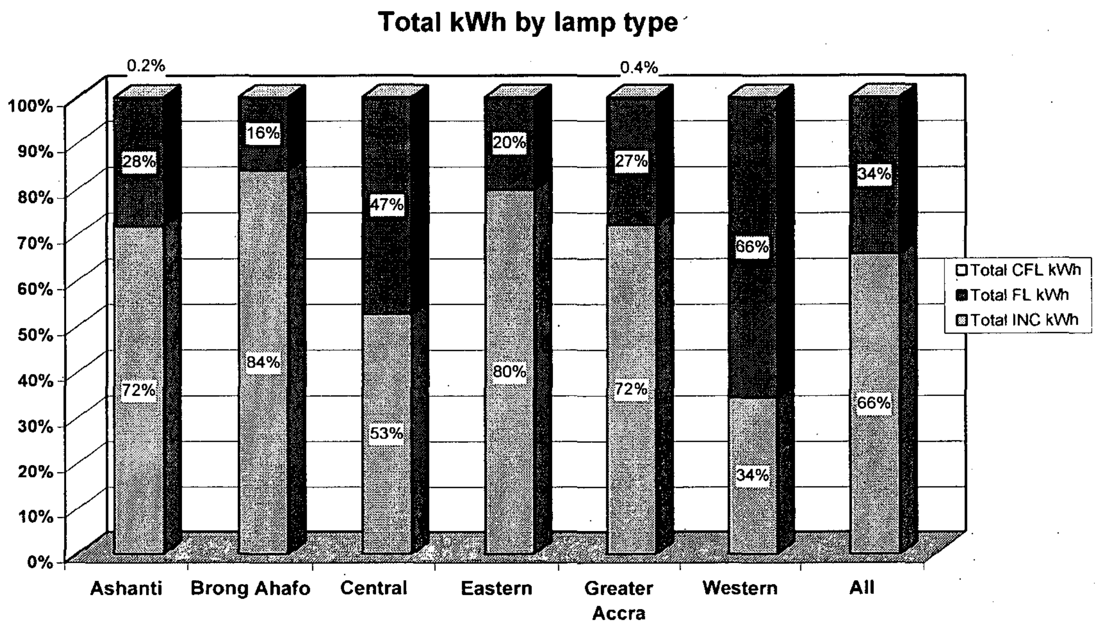


Figure 3.4.9. Total kWh by lamp type

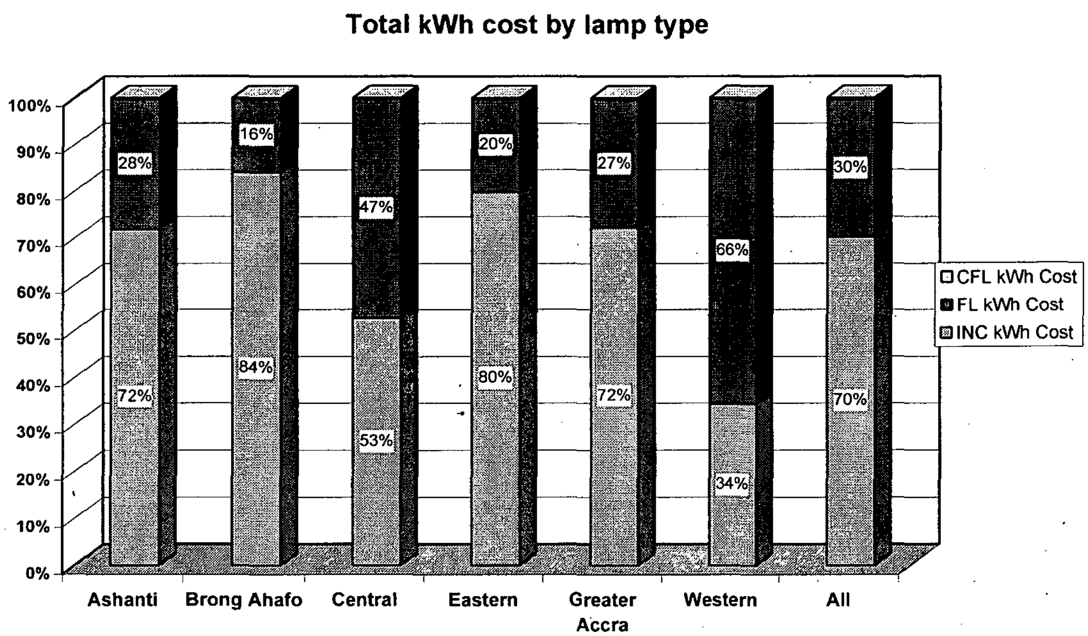


Figure 3.4.10. Energy costs by lamp type

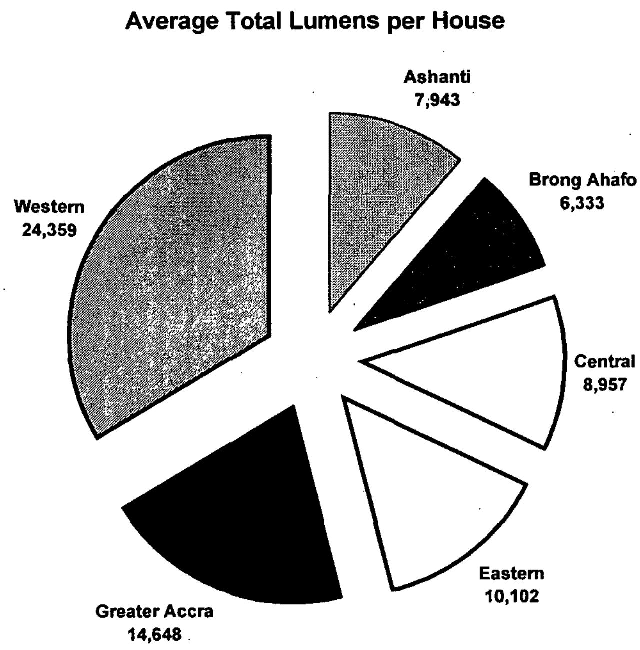


Figure 3.4.11 Average total lumens per house

Figures 3.4.11 and 3.4.12 present the information needed to make estimates of residential savings from a given lighting standard or policy.

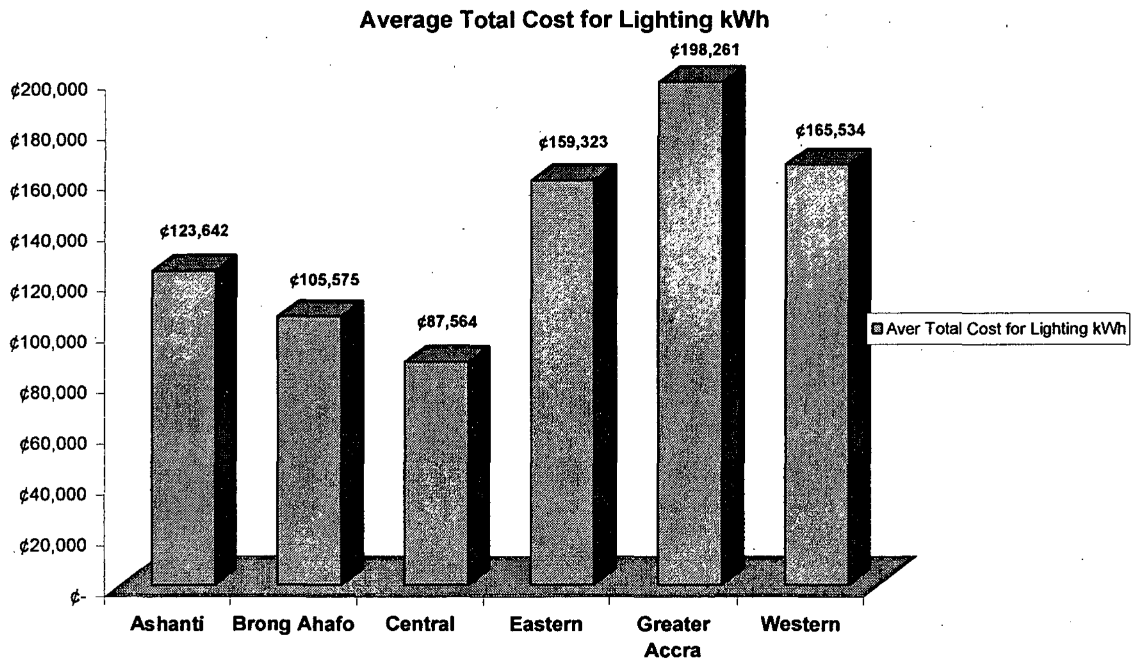


Figure 3.4.12. Average total cost for lighting kWh

4. Modelling the impact of standards

4.1 Introduction

Although the appliance survey provided some useful insights, much of the data needed to model the effects of Minimum Energy Performance Standards was lacking. The LBNL team derived shipment and Unit Energy Consumption information from small samples within the survey data set, and calibrated them using knowledge gained in past experiences with this process. A spreadsheet model was used for both refrigerators and room air conditioners. Lighting is more complex, and thus results are presented in a more general fashion. In all cases, some effort has been made to create resources that can be used and improved as more data become available.

4.2 Refrigerators

The impact on national energy consumption from adopting a refrigerator efficiency standard can be based roughly on the following equation:

National Energy Savings = $(UEC_{standard} - UEC_{stock}) \bullet SAT \bullet HOUSE$

Where

$UEC_{standard}$ =	Annual Energy Use of a Refrigerator meeting new efficiency standard
UEC_{stock} =	Annual Energy Use of average Refrigerator in housing stock
SAT =	Saturation of Refrigerator in housing stock
$HOUSE$ =	Number of households

Statistics from section 3.2 on refrigerators can be used to establish an approximate value for the amount of national energy that can be saved on a yearly basis in urban and rural areas from a refrigerator standard. Table 4.2.1 summarizes the necessary information for performing the calculation. Saturations are based on information in the previous section and estimates for rural usage patterns. Annual energy use values are based on data in the commercial literature and from European Standards documentation. Rural annual energy use is consistent with the energy use reported in the smaller urban areas. The number of households is from the survey data. Shipment and stock figures were developed using age and purchase date information from the appliance survey.

Table 4.2.1. Refrigerator statistics for determining national energy savings

	Urban	**Rural**
Saturation	**95%**	**2%**
Average Annual Energy Use (kWh/year)	**591**	**591**
Households	**962,000**	**1,638,000**
% annual change in stock	**16%**	**16%**
Average annual shipments (to 2010)	**88,000**	**n/a**

In 1991/92, European refrigerators in the R6 category (refrigerators with a freezer compartment designed to operate at Tc < -18 °C) had an average of 355 liters of adjusted storage volume (AV) and used around 591 kWh/year.[19] This is a plausible estimate of average annual unit energy consumption of refrigerators in Ghana, considering both their age and size. In all likelihood, this is an underestimate of the baseline annual unit energy consumption, given the prevalence of used refrigerators, and the possibility of less than optimal maintenance.

If the current European (EU) standards are enforced and assuming that the typical unit falls in the R6 category, the maximum unit energy allowed will be obtained from:

$$UEC = 0.573AV + 206$$

where AV is adjusted volume which in this case is 355 liters. Hence, the maximum allowable is

$$UEC = 0.573x355+ 206 = 409.4 \text{ kWh/a}$$

Energy savings against this baseline model would be 182 kWh/a.

Using this as a guide, the LBNL model estimates the following consumer savings from adopting a European type standard in Ghana. Savings are the reduction in household energy bills. Costs are the incremental costs of purchasing an efficient refrigerator, as opposed to what would have been available in the absence of regulation. In the U.S. no significant cost increase has been observed under standards. However, in Ghana, regulations will presumably prevent some consumers from buying a used refrigerator thus increasing the purchase cost.[20]

Table 4.2.2. Net benefits from a refrigerator energy performance standard

Discounted at 5% to year 1998 ***From 2000 to 2010***	**US $** (bill)	**Ghana ¢** (bill)
Total Energy Bill Savings	**0.047**	**107**
Total Equipment Cost	**0.020**	**46**
Net Present Benefit	**0.027**	**61**
Benefit/Cost Ratio	**2.3**	**2.3**

Table 4.2.2 shows the net benefits to consumers from a refrigerator standard. These savings are likely underestimated, since most of the older models in the existing stock will use considerably more than 591 kWh/year. Also, without standards, used appliances will continue to come into the country and use more energy than the baseline estimated here.

[19] Waide, P, B Lebot, and M Hinnells, " Appliance energy standards in Europe." Energy and Buildings 26 (1997) 45-67.

[20] LBNL estimates a $25 increase (57,500 cedis) (As long as the increased equipment cost is less than $58, the benefits exceed the costs.)

Table 4.2.3 summarizes the potential national energy and carbon emission savings. A key assumption here is that future electricity production will not come exclusively from hydro, but will include a significant proportion of thermal fired plants.

Table 4.2.3. National energy and carbon impacts from a refrigerator standard

	Annual in 2010	Cumulative to 2010
Site Energy Savings	204 GWh	1170 GWh
Primary Energy Savings[21]	.002 Quads	.012 Quads
CO2 Emission Savings[22]	141,000 tonnes	845,000 tonnes
Carbon Emission Savings	38,000 tonnes	230,000 tonnes

Over the next ten years, as many as 1.2 million refrigerators and refrigerator-freezers will be sold in Ghana, even if a standard reduced the saturation rate by more than half of the recent trend. In 2010, over 130,000 new refrigerators will be sold, bringing the total stock to almost 1.8 million units. If standards are not passed quickly, all of those units could be inefficient older models and it would be years before Ghanaian consumers could economically replace them with more modern ones.

All the estimates presented here are based on the assumptions presented in Table 4.2.1 and inherent in the LBNL Refrigerator model. For example, the costs presented are an estimate of the incremental cost consumers will pay for their new efficient appliance, and the product lifetimes are assumed the same as in the U.S. This simultaneously has the effect of overestimating costs and underestimating savings. Still, they give an order of magnitude to the savings and benefits from refrigerator standards. The LBNL spreadsheet model will be available for use by stakeholders and policy makers.

4.3 Room air conditioners

The impact on national energy consumption from adopting a room air conditioner efficiency standard can be based roughly on the following equation (similar to refrigerators):

National Energy Savings = $(UEC_{standard} - UEC_{stock}) \bullet SAT \bullet HOUSE$

Where

$UEC_{standard}$ = Annual Energy Use of Room A/C meeting new efficiency standard
UEC_{stock} = Annual Energy Use of average Room A/C in housing stock
SAT = Saturation of Room A/C in housing stock
$HOUSE$ = Number of households

[21] We assume annual site energy to source energy conversions that average 10661 BTU/kWh over the period 1999-2010

[22] The annual emission factors average 70 mt CO_2/Quad and 19 mt Carbon/Quad over the period 1999-2010

Statistics from section 3.3 on room air conditioners can be used to establish an approximate value for the amount of national energy that can be saved on a yearly basis in urban and rural areas from a room air conditioner standard. Table 4.3.1 summarizes the necessary information for performing the calculation. Saturations are based on information in Table 3.3.2 and estimates for rural usage patterns. Annual energy use values are based on data in Table 3.3.4. Rural annual energy use is consistent with the energy use reported in the smaller urban areas. The number of households is from the survey data. Shipment and stock figures were developed using age and purchase date information from the appliance survey.

Table 4.3.1 Room air conditioner statistics for determining national energy savings

	Urban	**Rural**
Saturation	10.8%	0.5%
Average Annual Energy Use (kWh/year)	2919	630
Households	962,000	1,638,000
% annual change in stock	16%	16%
Average annual shipments (to 2010)	12,500	n/a
Price of Electricity ($/kWh)	$.06	$.06
Exchange Rate (Cedis/$)	¢2300	¢2300
Discount Rate	5%	5%

Assuming a room air conditioner standard can save 10% on per unit annual energy consumption, the following static national energy savings will result:

Urban National Energy Savings = 2919 kWh × 10% × 10.8% × 962,000
= 30 GWh/year

Rural National Energy Savings = 630 kWh × 10% × 0.5% × 1,638,000
= .5 GWh/year

A more dynamic model would require more information about existing stock and annual shipments of new Room Air Conditioners. LBNL has designed a spreadsheet model that can be used to estimate the national impacts of a Room Air Conditioner Standard. Table 4.3.2 shows the net benefits to consumers based on the assumptions above.

Table 4.3.2. Net benefits from a 10% savings in energy use for room air conditioners

Discounted at 5% to year 1998	**US $**	**Ghana ¢**
From 2000 to 2010	*(billion)*	*(billion)*
Total Energy Bill Savings	**0.0076**	**17**
Total Equipment Cost	**0.0054**	**12**
Net Present Benefit	**0.0022**	**5**
Benefit/Cost Ratio	**1.4**	**1.4**

Table 4.3.3 summarizes the national energy and carbon emission savings. A key assumption here is that future electricity production will not come exclusively from hydro, but will include a significant proportion of thermal fired plants.

Table 4.3.3. National energy and carbon impacts of a 10% savings in energy use for room air conditioners

	Annual in 2010	Cumulative in 2010
Site Energy Savings	33 GWh	191 GWh
Primary Energy Savings	.0003 Quads	.0020 Quads
CO_2 Emission Savings	22,000 tonnes	138,000 tonnes
Carbon Emission Savings	6,000 tonnes	38,000 tonnes

In 2010, nearly 16,000 new air conditioners for residential use will be sold in Ghana, bringing the total to over 140,000 units in stock. Between now and then, 133,000 units will be sold. If standards are not passed quickly, all of those units could be inefficient older models and it would be years before Ghanaian consumers could economically replace them with more modern ones.

All the estimates presented here are based on the assumptions presented above and they should not be taken as a given. Still, they give an order of magnitude to the savings and benefits from room air standards in the residential sector. Even greater savings may be achievable in the commercial sector. The LBNL spreadsheet model will be available for use by stakeholders and policy makers.

4.4 Lighting

Overall, lighting accounts for the largest portion of residential electricity load. For households hooked up to the grid, lighting alone uses more than half of per capita consumption. In 1996 in round numbers, each house used about 1700 kWh and lighting was over 1000 kWh of that.

While it is difficult to model, several points can be made about the lighting sector in Ghana. Table 4.4.1 presents some useful details for making estimates of the impact of certain policies.

Table 4.4.1. Household lighting summary

Region	Ashanti	Brong Ahafo	Central	Eastern	Greater Accra	Western	All
Lumens/House	7,943	6,333	8,957	10,102	14,648	24,359	11,982
Lighting kWh /House	824	704	584	1,062	1,322	1,104	1,064
Lighting Cost /House	¢ 123,642	¢ 105,575	¢ 87,564	¢ 159,323	¢ 198,261	¢ 165,534	¢ 159,629

Using the same population data, and assuming a near 100% saturation of lighting in Urban areas, total lighting load on the national grid is about 1020 GWh, or 60% of total residential load. Of that total, 460 GWh are from exterior lighting. Regulating exterior lighting for new residential construction in Ghana would require a two-pronged approach.

Exterior lighting is already predominantly fluorescent. Light sources more efficacious than fluorescent (metal halide and high pressure) require higher mounting and are therefore not appropriate for residential properties. Policies to encourage lamp-type switching would be ineffective. A well-planned and executed government streetlighting program is the next logical step. The Ghana Energy Foundation could work with LBNL staff to research streetlighting standards from several sources (cities, states and countries) and design a streetlighting program that is appropriate for Ghana. Not all streets and areas require the same average maintained light level (measured in lux). The final part of the design would be the selection of lamp types, wattages, fixture types, mounting heights and pole spacing. The goal for "good" street and security lighting is to maintain uniform light levels. Light levels generally range from 5 lux to 50 lux depending on the area and the perceived level of safety.

In conjunction with streetlighting, there should be building codes to limit the amount of watts per square meter of house that could be used for exterior lighting. One possible method would be to establish an exterior lighting wattage allowance based on the area of the house's footprint – perhaps in the range of one to two watts per 5 square meters. To ensure that all exterior lights are not used during daylight hours, all exterior lighting should be equipped with a photo sensor. A wattage credit could be given to residents who install incandescent lights that are equipped with motion sensors (and with photo sensors.) The motion sensors would ensure that the light only turns "on" when it senses movement within its range and it can be set to turn the lights "off"1 to 15 minutes after it last sensed movement. By incorporating such a policy into building codes and standards, and by working to provide well planned and designed street lighting, Ghana can make great strides in reducing waste in this area.

Ghanaian's use of fluorescent light sources inside their homes is widespread. In the 1000 homes in the survey, 62% of the interior lighting, as measured in lumens, was from fluorescent lighting. In the US, one aspect of the state of California's energy code (Title 24) has been to require that the ambient lighting in bathrooms and kitchens be fluorescent. Ambient lighting is throughout an area and provides general illumination. Title 24 requires that the first light switch encountered when one enters a room must turn on a fluorescent light fixture and that fixture must provide the ambient lighting for that space. Any additional task lighting need not be fluorescent. Task lighting is light directed toward a special surface, area or task. Given Ghanaian's acceptance of fluorescent lighting in their homes, Ghana should include in it's residential building codes a requirement similar to California's Title 24; however, it should apply to all rooms (not just bathrooms and kitchens).

Included in Ghana's list of energy efficient appliances that would either be subject to no import tariff or to a reduced tariff should be any linear fluorescent fixture that is equipped with a 265 milli-Amp (mA) magnetic ballast. A 265 mA ballast is designed to operate

T8 lamps. It is not recommended that current users of T12 fluorescent lamps replace them with the narrower T8 lamps.

The existing fluorescent fixtures in Ghana are probably equipped with a 460 milli-Amp (mA) 220-Volt magnetic ballast with a switch start. This type of ballast has been on the market for a number of years and is one of the least expensive ballasts. An F40T12 lamp is designed to operate at 425 mA and usually operates at about 400 mA on these ballasts. When this ballast is used to power one F40T12 lamp the input watts are in the range of 40 to 45 Watts. An F32T8 lamp is designed to operate at 230 mA. When a T8 lamp is operated on a 460 mA ballast the current drops to about 150 Volts, the lamp operates at about 250 mA, and the input watts for the one lamp are in the range of 45 to 50 Watts. Instead of saving energy this combination of lamp and ballast consumes more energy.

There are many options for reducing the lighting load in Ghanaian homes. Policies that encourage more use of both compact and linear flourescents, require better controls, especially on exterior lighting, and prevent the importation of inefficient ballasts and fixtures all have the potential to improve the lighting efficiency of the residential sector. If only 10% of the residential load could be reduced through standards and policy, over 100 GWh of annual use would be available for other purposes. At a rate of $.06/kWh, that translates to consumer bill savings of ¢13.8 billion and that is only counting urban customers. The Carbon and CO_2 reductions would amount to 24,000 tonnes and 86,000 tonnes respectively. Of course, many of these same savings would be available in the commercial sector as well, without any additional legislation or policy directives.

5. Market survey conclusions and recommendations

The time is now for Ghana to act and take a leadership role in promoting energy efficiency in the region. With so many reforms taking place in the energy sector, appliance energy performance standards can only enhance the ability of the Ghanaian economy to move ahead in the next decades.

Significant energy savings are achievable in Ghana through the judicious use of government regulations. Performance standards for domestic appliances have the potential to save not only energy, but to provide consumers with net economic benefits and to reduce future carbon emissions. The information gained from this survey suggests several steps to improve the energy and economic efficiency of the Ghanaian economy.

The following are the major conclusions and recommendations of this report:

5.1 General

From this exercise it is apparent that more information is warranted to facilitate the design of effective appliance and lighting standards. Labels are warranted as a means not only of informing consumers of their energy choices, but of gathering data for future analysis. (see Appendix 3 for examples)

In addition, having discussed the present legislative authority and support, the current energy situation, and the likelihood of continued "dumping," it is evident that the sooner some preliminary action is taken, the better. This report supports legislation expected to be submitted to Parliament that lays out a standards program, including a proposed standard level for several products, a test procedure, and a means for including and updating future standards.

It is sufficient for the initial standards to set an easily achievable goal for manufacturers since it will not likely be cost effective for Ghana to force manufacturers to comply with stringent standards given the size of the economy and the lack of leverage on the international market. Initial standards must avoid causing unduly high appliance purchase costs and must not encourage manufacturers and distributors to circumvent the legislation.

Initial standards in this context are not only an energy saving measure in their own right, they are also a preparatory step for future more stringent standards. A rigorous market assessment is therefore less important than a thorough understanding of the international market context for Ghana appliance standards. Synthesizing the available information and analysis with this in mind is a primary goal for LBNL in drafting the final report.

There is a need in the medium term for testing capabilities by the Government of Ghana. Enforcement will not be practical or effective without this capacity. In addition, a testing facility could serve as a regional example, allowing Ghana to export its experience and expertise to neighbors and trading partners in the West African Region.

The process of developing standards would be strengthened by stakeholder involvement. Industry may find it to their advantage to promote energy performance standards in Ghana. Consumers will benefit from becoming aware of the advantages of energy conservation and efficiency.

5.2 Refrigerators

It would be beneficial to Ghana to adopt one of the existing international test procedures for refrigerators rather than develop a unique Ghanaian test procedure. Ghana's market power in the international appliance market is not enough to justify a seperate effort.

Refrigerator standards would be worthwhile for Ghana. They will save consumers money and free up grid resources, as well as abating future carbon emissions. LBNL estimates that adopting a European type standard could save as much as **¢107 billion (cumulative) by 2010 (US$50 million)** for consumers, and reduce **carbon emissions** over the same period by **230,000 tonnes**.

In the absence of standards Ghana will lose an opportunity to rationalize its energy future for a long time to come as refrigerator saturation increases rapidly.

5.3 Room air conditioning

Ghana should adopt the ISO 5151 test procedure for room air conditioners.

Room air conditioning is predominantly used in the commercial and public sector (government offices) and electricity use for this purpose is likely to increase significantly. Increasing saturation of residential air conditioning units could also become a source of high demand.

Preliminary data suggests that a 10% savings in energy consumption for room air conditioners could save residential consumers nearly **¢18 billion (US$8 million)** and reduce **carbon emissions** by **38,000 tonnes**. Savings in the commercial sector are likely to be even higher. More study on this issue is strongly recommended.

5.4 Lighting

It would be worthwhile for both the interior and exterior lighting codes to be incorporated in new building codes as soon as possible. Large savings can be realized if the first light switch upon entering a room in a new residence turns on a fluorescent fixture that provides ambient lighting. A code that limits the amount of exterior lighting watts must be implemented in conjunction with a well-planned and designed streetlighting plan.

Lighting Standards also produce bill savings for consumers and likely will dramatically reduce residential demand growth in the near term, especially if controls are developed for exterior lighting.

A well-designed lighting system requires that all components be examined individually and interactively as a system. The critical components of a lighting system include lamps, ballasts, fixtures, and controls. A well-designed energy efficient lighting system not only looks at the components separately and collectively but it also ensures that the appropriate level and quality of illumination is delivered to the area or task requiring illumination. All of the components and the system as a whole should provide illumination only when it is needed. Because a CFL or a linear fluorescent lamp is not always desirable to replace incandescent lamps in fixtures, lighting codes and standards need to be developed by people who are well-versed in lighting design. The hallmark of the California's 1992 Title 24 energy codes for lighting was the fact that the lighting advisory group comprised the top lighting professionals in the United States.

Additional training for energy professionals at Ghana Standards Board, the Energy Foundation, and the Ministry of Mines and Energy would ensure that those institutions propose energy efficient lighting codes and standards that reduce energy consumption and meet the recommended practices of good-lighting design. At least one or two people involved in developing Ghana's lighting codes and standards should be knowledgeable in lighting designs as well as lamp, ballast, and fixture technologies, uses, and applications. With a rising middle class in Ghana, there will be an increasing need for lighting designers. If the first lighting designers are also energy efficient lighting designers, acceptance of energy efficient lighting sources and controls by Ghana's commercial and residential sectors would be unparalleled in the region.

Appendix 1 Residential Energy Use and Appliance Ownership Survey

Ghana, 1998

Survey ID #____________

Residential Energy Use and Appliance Ownership

Energy Foundation/LBNL Survey: 1998 Residential Energy Use and Appliance Ownership

Name of Surveyor: ____________ **Start Time:** ______

Date of Survey: ______ **End Time:** ______

Survey ID #: ____________

The demand for electricity in Ghana is growing very rapidly, sometimes resulting in brownouts or blackouts. To assist the Government of Ghana in evaluating residential demand the Energy Foundation, a registered NGO, is conducting a survey of homes to determine patterns of appliance usage and ownership. Your cooperation in providing information on your household usage is requested. All the information provided will be kept confidential. Please answer each question to the best of your ability. A short amount of your time now will be a tremendous help in improving the overall fitness of the energy sector in Ghana. Thank you in advance for your participation.

Location Data

1) Street Address: ____________ **1a) Apt #** ____

(include city and district) ____________ **2) Region** ____

3) Name of Respondent: ____________

3a) Name of Head of House: ____________

Household Characteristics

4) How many people are in the household? ______

4a) How many are under 18 years old? ______ **4b) Over 60 years old?** ______

5) What is the Head of Households Education level?

- ❑ None
- ❑ SSS
- ❑ Primary School
- ❑ University/Technical
- ❑ JSS
- ❑ Post-Graduate

6) What is the average monthly income?

- ❑ ¢0-¢49,000
- ❑ ¢250,000-¢499,000
- ❑ ¢50,000-¢99,000
- ❑ ¢500,000-¢999,000
- ❑ ¢100,000-¢249,000
- ❑ ¢1 million +

Dwelling Characteristics

7) What type of home do you have? (check one)

- ❑ Detached Single Family
- ❑ Small Compound
- ❑ Row House
- ❑ Large Compound
- ❑ Apartment
- ❑ Other

8) Do you rent or own the home?

- ❑ Rent
- ❑ Own

9) What year was your home built? ______ **10) What year did you move in?**______

11) What type of walls do you have?

- ❑ Concrete Block
- ❑ Rough Hewn Wood/Poles
- ❑ Poured concrete
- ❑ Stabilized Mud Bricks
- ❑ First Class Wood
- ❑ Mud
- ❑ Stone
- ❑ Other (e.g. thatch, etc.)

12) What type of roof do you have?

- ❑ Tile
- ❑ Stabilized Mud
- ❑ Zinc/Aluminum
- ❑ Thatch
- ❑ Wood
- ❑ Other
- ❑ Concrete

specify:__________

13) How big is your house/unit?

- ❑ 50-99m²
- ❑ 200-249m²
- ❑ 100-149m²
- ❑ ≥250m²+
- ❑ 150-199m²

13a) How big is the Kitchen? ______m²

13b) How big is the Living Room? ______m²

13c) How big is the main Bedroom? ______m²

14) How many floors/stories does you building have? ______

15) How many rooms does your home have? **(do not include halls, stairwells, or porch/balconies)** ______

16) How many bedrooms in your home? ______

Energy Use (home use only, do not include transportation)

17) Which of the following types of fuel do you purchase/use? **(mark all that apply)**

- ☐ Electricity
- ☐ LPG
- ☐ Kerosene
- ☐ Fuel for Generator
- ☐ Charcoal
- ☐ Fuelwood
- ☐ Batteries
- ☐ Other:________________

18) What is the average monthly expenditure on the following?

LPG: ________cedis
Kerosene: ________cedis
Batteries: ________cedis
Fuel for Gen.: ________cedis

19) Do you receive an electricity bill?

- ☐ Yes
- ☐ No

19a) If yes, what is the cost per unit? ________cedis/kWh
19b) How many units per month? ________kWh
19c) Per year? ________kWh

Appliance Ownership

Please fill out the following table regarding the appliances you have in your home. If you have **electric lights, an electric refrigerator**, or an **air conditioner**, please fill out the appropriate sections at the end of the survey.

Appliances	#	Price Paid	Manufacturer/ Model	Hours of Use per Day	Date Purchased (month/day/year)
Lights*					
Elec. Refrigerator/ Freezer*					
Gas Refrigerator/ Freezer					
Air Conditioner*					
Evaporative Cooler*					
Gas Stove					
Electric Stove					
Fan					
VCR					
TV					
Gas Oven					
Electric Oven					
Clothes Iron					
Clothes Washer					
Gas Clothes Dryer					
Electric Clothes Dryer					
Radio					
Stereo					
Microwave					
Other					

20) Please check any of the following which you plan to purchase or replace in the next 1-3 years.
- ❑ Refrigerator/Freezer
- ❑ Air Conditioner
- ❑ Lighting Systems
- ❑ Other: specify______________________

21) Purchase or replace in the next 4 or more years?
- ❑ Refrigerator/Freezer
- ❑ Air Conditioner
- ❑ Lighting Systems
- ❑ Other: specify______________________

Refrigerator/Freezers

Purchase Information (Primary Unit)

22) Did you purchase this refrigerator/freezer new or was it used when you bought it?
- ❑ New
- ❑ Used
- ❑ D/K

22a) How old was it when you purchased the unit?
_____years
- ❑ D/K

23) When did you purchase/acquire this unit?
________,19___
- ❑ D/K

24) How much did you pay for this unit?
________cedis
- ❑ D/K

25)Where did you purchase this unit?
- ❑ Local Retailer
- ❑ Foreign Purchase
- ❑ Importer/Large Retailer
- ❑ Other

Please provide name and address of firm:*
_________________________ ____________
_____________________ ______________

Unit Information
Mark one in each column.

26) Type	27) Doors	28) Configuration	29) Defrost Control
❑ Refrigerator/Freezer Combination	❑ Single	❑ Top Mount	❑ Manual
❑ Refrigerator Only	❑ Double	❑ Bottom Mount	❑ Automatic
❑ Freezer Only		❑ Side by Side	
		❑ Icebox	
		Freezer Only:	
		❑ Upright	
		❑ Chest	

30) Manufacturer: ____________________ **30a) Country:** ____________________
31) Model Number: ____________________ **31a) Model Name:** ____________________
32) Serial Number: ____________________

Energy Label Information

33) Is there/was there an Energy Label? (if 'no' skip to next section)
- ❑ Yes
- ❑ No
- ❑ D/K

33a) Country of Label: ____________________
33b) Rated Energy Use: ____________________
33c) Test Procedure: ❑ ISO ❑ USDOE ❑ Other

Load Information

34) Refrigerator Volume: ____________ liters or ____________ cm^3
35) Freezer Volume: ____________ liters or ____________ cm^3

36) Special Features (check all that apply)
- ❑ Automatic ice maker
- ❑ Through the door ice
- ❑ Through the door water
- ❑ Other

If 'Other,' please describe:______________________

Use Information

37) Are there certain times of the year when you normally turn off or unplug your refrigerator?
- ❑ Yes
- ❑ No
- ❑ D/K

38) What season?
- ❑ Hot Season 1 (April-June)
- ❑ Wet Season (July-Sept.)
- ❑ Hot Season 2 (Oct.-Dec.)
- ❑ Dry Season (Jan.-Mar.)

39) Do you use the appliance for commercial purposes? (e.g. icewater or minerals)
- ❑ Yes
- ❑ No

Room Air Conditioners

Purchase/Unit Information (Primary Unit)

40) Did you purchase this air conditioner new or was it used when you bought it?
- ❑ New
- ❑ Used
- ❑ D/K

40a) How old was it when you purchased the unit?
_____years
- ❑ D/K

41) When did you purchase/acquire this unit?
________,19___
- ❑ D/K

42) How much did you pay for this unit?
_________cedis
- ❑ D/K

43)Where did you purchase this unit?
- ❑ Local Retailer
- ❑ Foreign Purchase
- ❑ Importer/Large Retailer
- ❑ Other

Please provide name and address of firm:*
____
____

44) What type of Unit is this?
- ❑ Window
- ❑ Split
- ❑ Evaporative Cooler

44a) Manufacturer: ______________________
44b) Model: ______________________
44c) Serial Number: ______________________

Check the nameplate/boilerplate, label, or measure for the following information.
45) Power Input (incl. units-e.g. Watts, BTUs/hr, etc.): ______________________
46) Cooling Capacity (incl. units-e.g. Watts, BTUs/hr, etc.): ______________________
47) External Dimensions of Unit? (for split units, measure outside part) _____ X _____ X _____ cm

Energy Label Information

48) Is there/was there an Energy Label? (if 'no' skip to next section)
- ❑ Yes
- ❑ No
- ❑ D/K

48a) Country of Label: ______________________
48b) Rated Energy Use: ______________________
48c) Test Procedure: ❑ ISO ❑ USDOE ❑ Other

Load Information

49) What is the size of the room being cooled? __________m^2

50) How many windows in the room? __________

51) What type of windows?
- ❑ Louvered
- ❑ Single Pane
- ❑ Double Pane

Use Information

52) How many hours per day do you use the A/C? _______hrs/day

53) How many days per week do you use the A/C? _______days/week

54) How many days per month? _______days/mon.

55) How many months per year? _______mon./yr.

55a) Which seasons?
- ❑ Hot Seas. 1 (April-June)
- ❑ Wet Seas. (July-Sept.)
- ❑ Hot Seas. 2 (Oct.-Dec.)
- ❑ Dry Seas. (Jan.-Mar.)

Misc. Information

56) If you have a split A/C, who installed the unit?
- ❑ Self/Owner
- ❑ HVAC Technician
- ❑ Electrician
- ❑ Building Contractor
- ❑ Other

Lighting Systems

	Type of Lamp		Type of Bulb			Type of Socket			Watts (W)	Location	Usage (hrs/day)	Time of Use				
Bulb #	Fixed	Standing/Table	Linear Flourescent	Incandescent	CFL	Screw Type	Pin Type	Bayonette Type				Morning	Day	Evening	Night	
ex.	x		x						60W	Kitchen	8hrs./day					
1																
2																
3																
4																
5																
6																
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20																

Survey ID #______________

Residential Energy Use and Appliance Ownership: Supplemental Information

Refrigerator/Freezers

Purchase Information (Additional Unit)

1) Did you purchase this refrigerator/freezer new or was it used when you bought it?

❑ New ❑ D/K
❑ Used

1a) How old was it when you purchased the unit?

_____years
❑ D/K

2) When did you purchase/acquire this unit?

________,19___
❑ D/K

3) How much did you pay for this unit?

_________cedis
❑ D/K

4)Where did you purchase this unit?

❑ Local Retailer ❑ Foreign Purchase
❑ Importer/Large Retailer ❑ Other

Please provide name and address of firm:

____
____

Unit Information

Mark one in each column.

5) Type	6) Doors	7) Configuration	8) Defrost Control
❑ Refrigerator/Freezer Combination ❑ Refrigerator Only ❑ Freezer Only	❑ Single ❑ Double	❑ Top Mount ❑ Bottom Mount ❑ Side by Side ❑ Icebox **Freezer Only:** ❑ Upright ❑ Chest	❑ Manual ❑ Automatic

9) Manufacturer: ______________ **9a) Country:** ______________
10) Model Number: ______________ **10a) Model Name:** ______________
11) Serial Number: ______________

Energy Label Information

12) Is there/was there an Energy Label? (if 'no' skip to next section)

❑ Yes
❑ No
❑ D/K

12a) Country of Label: ______________
12b) Rated Energy Use: ______________
12c) Test Procedure: ❑ ISO ❑ USDOE ❑ Other

Load Information

13) Refrigerator Volume: __________ liters or __________ cm^3
14) Freezer Volume: __________ liters or __________ cm^3

15) Special Features (check all that apply)

❑ Automatic ice maker
❑ Through the door ice
❑ Through the door water
❑ Other

If 'Other,' please describe:______________
____

Use Information

16) Are there certain times of the year when you normally turn off or unplug your refrigerator?

❑ Yes
❑ No
❑ D/K

17) What season?

❑ Hot Season 1 (April-June)
❑ Wet Season (July-Sept.)
❑ Hot Season 2 (Oct.-Dec.)
❑ Dry Season (Jan.-Mar.)

18) Do you use the appliance for commercial purposes? (e.g. icewater or minerals)

❑ Yes
❑ No

Residential Energy Use and Appliance Ownership: Supplemental Information

Room Air Conditioners

Purchase/Unit Information (additional units)

1) Did you purchase this air conditioner new or was it used when you bought it?
- ❑ New
- ❑ Used
- ❑ D/K

1a) How old was it when you purchased the unit?
______years
- ❑ D/K

2) When did you purchase/acquire this unit?
________, 19___
- ❑ D/K

3) How much did you pay for this unit?
_________cedis
- ❑ D/K

4) Where did you purchase this unit?
- ❑ Local Retailer
- ❑ Foreign Purchase
- ❑ Importer/Large Retailer
- ❑ Other

Please provide name and address of firm:*
____
____

5) What type of Unit is this?
- ❑ Window
- ❑ Split
- ❑ Evaporative Cooler

5a) Manufacturer: ______________
5b) Model: ______________
5c) Serial Number: ______________

Check the nameplate/boilerplate, label, or measure for the following information.

6) Power Input (incl. units-e.g. Watts, BTUs/hr, etc.): ______________
7) Cooling Capacity (incl. units-e.g. Watts, BTUs/hr, etc.): ______________
8) External Dimensions of Unit? (for split units, measure outside part) ______ X ______ X ______ cm

Energy Label Information

9) Is there/was there an Energy Label? (if 'no' skip to next section)
- ❑ Yes
- ❑ No
- ❑ D/K

9a) Country of Label: ______________
9b) Rated Energy Use: ______________
9c) Test Procedure: ❑ ISO ❑ USDOE ❑ Other

Load Information

10) What is the size of the room being cooled? ____________m^2
11) How many windows in the room? ____________

12) What type of windows?
- ❑ Louvered
- ❑ Single Pane
- ❑ Double Pane

Use Information

13) How many hours per day do you use the A/C? _______hrs/day
14) How many days per week do you use the A/C? _______days/week
15) How many days per month? _______days/mon.
16) How many months per year? _______mon./yr.

16a) Which seasons?
- ❑ Hot Seas. 1 (April-June)
- ❑ Wet Seas. (July-Sept.)
- ❑ Hot Seas. 2 (Oct.-Dec.)
- ❑ Dry Seas. (Jan.-Mar.)

Misc. Information

17) If you have a split A/C, who installed the unit?
- ❑ Self/Owner
- ❑ Building Contractor
- ❑ HVAC Technician
- ❑ Other
- ❑ Electrician

56

Appendix 2 Surveyor's Report (Survey Codes)

OCTOBER 10TH. 1998
SURVEY OF RESIDENTIAL ENERGY USE AND APPLIANCE OWNERSHIP

Introduction

Technan Engineering Works Limited was engaged by the Ministry of Mines And Energy to undertake a survey of residential energy use and appliance ownership. The primary objective of the survey was to capture data to be used as a basis for the development of codes and standards for residential appliances imported or produced for use in Ghana. The ultimate objective is to allow the use of only highly energy efficient appliances in the country. This is therefore one further prong in the strategies for energy conservation adopted by the Energy Foundation.

Survey Methodology

The first component of the survey carried out was to review the questionnaire submitted by the Energy Foundation for the survey. A copy of the questionnaire used is attached in the appendix. Next, ten student and national servicemen were selected as surveyors and trained in interviewing and completion of the questionnaire.

The survey area was then determined and discussed with the Energy Foundation for suitability of coverage. The final distribution of 1000 residences covered an area as follows:

Greater Accra Region	467 Houses
Ashanti Region	364
Western Region	50
Eastern Region	39
Central Region	50
Brong Ahafo	30

The field work was carried out by 10 field workers each visiting about 100 sites. A total of 1000 residential premises were visited and the questionnaires were completed on site.

Data from the questionnaires were next entered in Excel spreadsheet format provided by the Foundation.

Problem Areas

The major problem encountered by surveyors was the unwillingness of most residents to provide data that they considered as sensitive. In some cases respondents called back on the telephone numbers provided in the letters of introduction in order to cross check the references of the surveyors.

A great deal of suspicion was cast on questions on income level and appliance model numbers. In the case of income levels some respondents thought the question was too personal, and might be used against them for tax purposes. Model and serial numbers were difficult to obtain because most people kept such records for security reasons and thought they might be used against them in the wrong hands. This was inspite of all the explanations and assurances to the contrary.

Observation:

The attached tables and charts in the appendix show selected summaries of data from the survey. It was clear that there is a preponderance of incandescent lighting both for indoor and outdoor lighting. The use of compact fluorescent lighting is at a very low level. Most consumers were not even aware of them.

Refrigerators

There is a high penetration of refrigerators in the consuming public. However, these are mostly limited small sizes. These units are bought used at the time of importation.

Air-conditioners

Air-conditioners are used by under ten percent of the population. Used models at the point of sale are slightly more than units acquired as new, as shown in the charts.

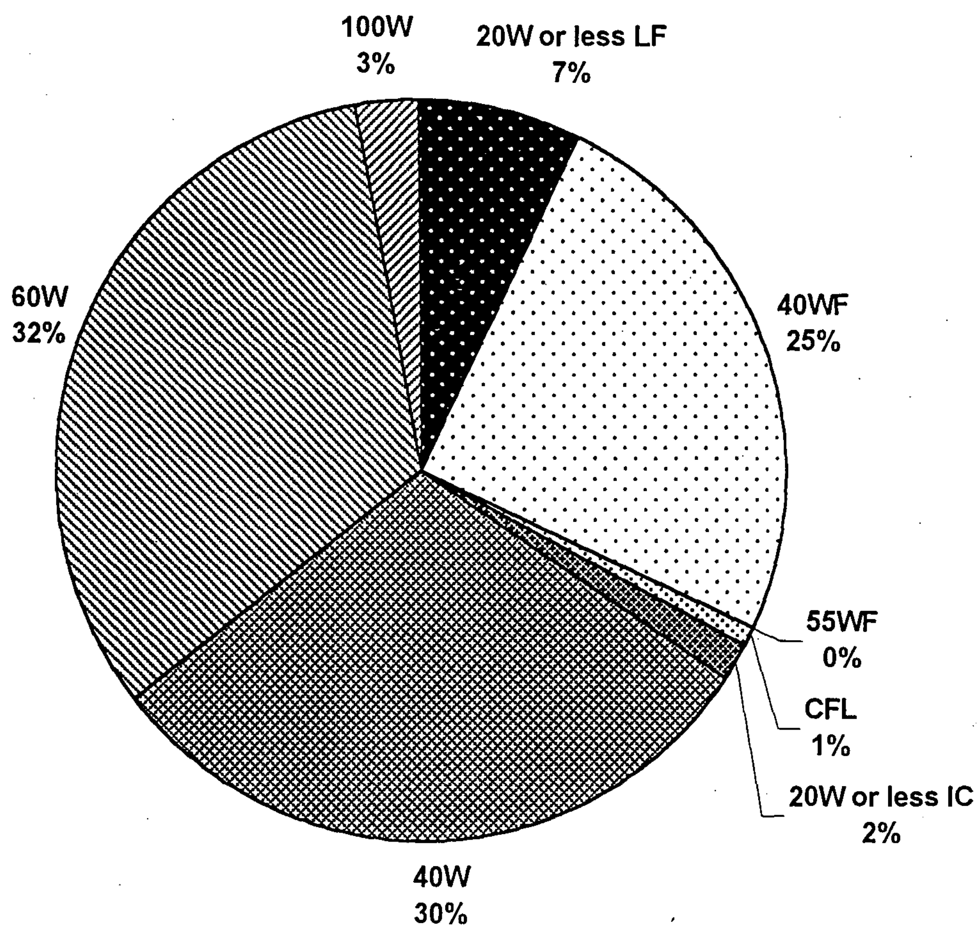
Other Appliances

Summarised data on other appliance ownership is shown in the appendix. There is a high penetration of stoves, fans, television sets, clothes irons, radios and stereo equipment, as expected. Appliances such as evaporative coolers, and microwave ovens have very little penetration in the areas surveyed.

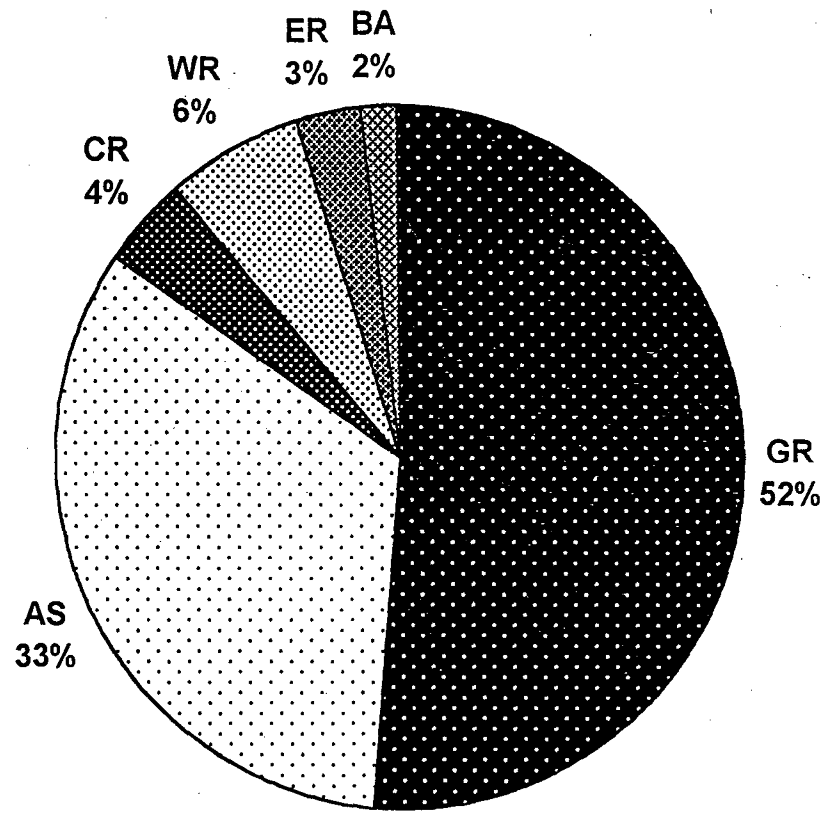
SUMMARY OF LIGHTING USE

Region	No. Of Houses	Total No.(Lamps	No. Of Flurescent lamps				No. Of Incandescent Lamps			
			20W or less LF	40WF	55WF	CFL	20W or less IC	40W	60W	100W
Greater Accra	467	5710	393	1426	0	65	15	2007	1625	179
Ashanti	364	3709	253	755	8	24	10	1054	1480	125
Central	50	465	20	113	0	0	166	29	133	4
Western	50	695	111	333	0	0	0	79	161	11
Eastern	39	342	29	71	0	0	0	89	153	0
Brong Ahafo	30	197	0	40	0	0	0	81	76	0
TOTALS	1000	11118	806	2738	8	89	191	3339	3628	319

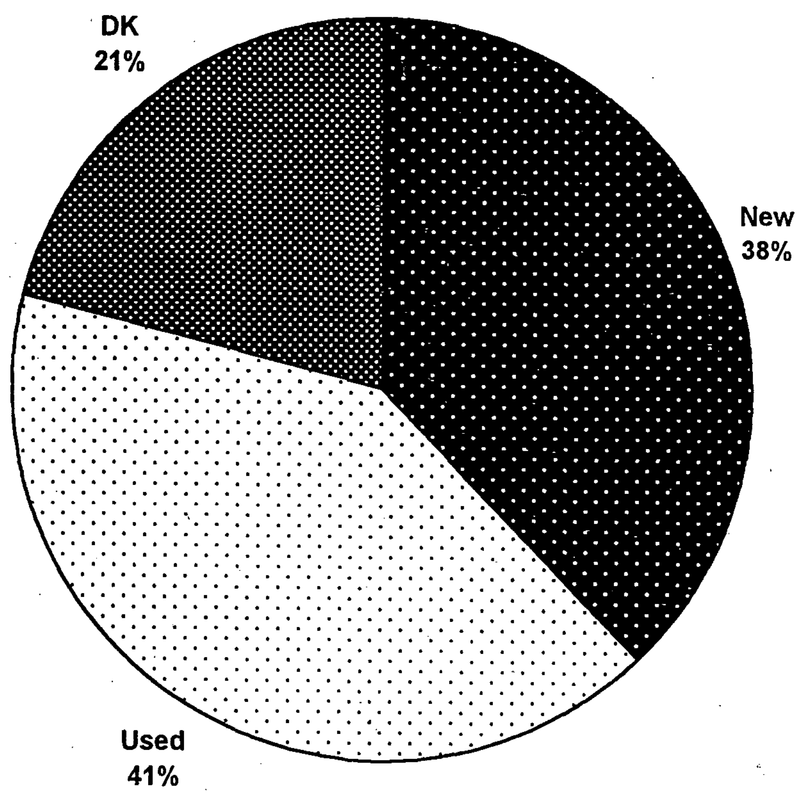
Summary Of Lighting Survey



Surveyed Lighting By Region



Summary Of Refrigerator Use



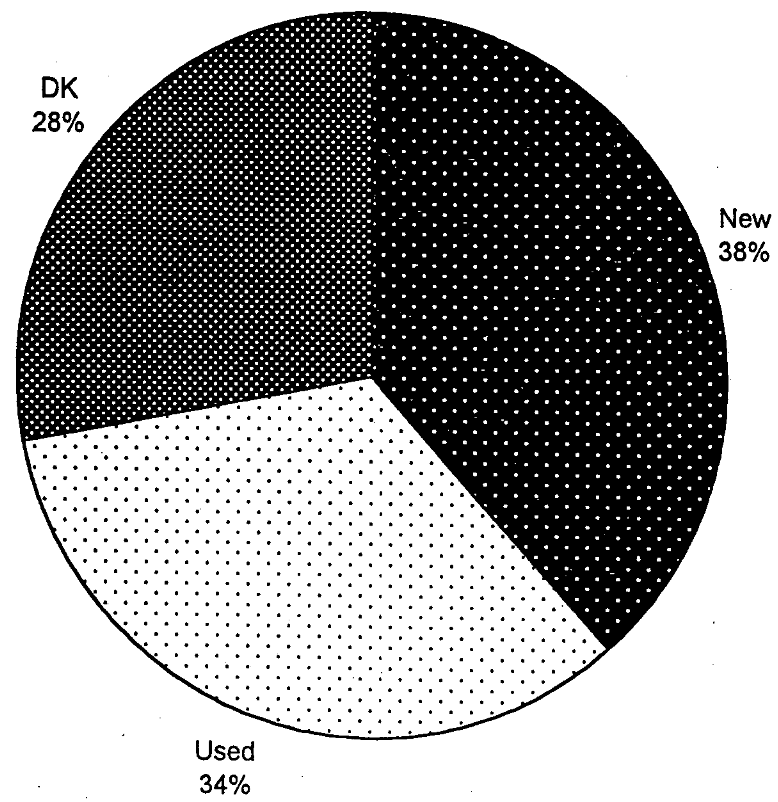
SUMMARY OF REFRIGERATOR USE

	No. Of Refrigerators			
Region	New	Used	DK	Total
Greater Accra	309	262	207	778
Ashanti	107	204	80	391
Central	37	16		53
Western	42	31		73
Eastern	9	27		36
Brong Ahafo	9	16		25
TOTALS	513	556	287	1356

SUMMARY OF AIR-CONDITIONER USE

Region	No. Of Air-Conditioners			
	New	Used	DK	Total
Greater Accra	71	63	69	203
Ashanti	16	17	0	33
Central	1	0	0	1
Western	5	1	0	6
Eastern	0	0	0	0
Brong Ahafo	0	0	0	0
TOTALS	93	81	69	243

AIR CONDITIONER USE



APPLIANCE OWNERSHIP

Region	No. Of Houses	Cooler	Stove	Fan	VCR	TV	Oven	Iron	Washer	Dryer	Radio	Stereo	Microwave	Other	Heater
Greater Accra	467	20	419	909	270	653	99	600	54	4	400	431	64	97	82
Ashanti	364	0	145	446	128	385	35	343	10	6	145	300	24	0	54
Central	50	0	45	79	7	54	12	61	1	0	24	51	0	28	16
Western	50	0	10	113	23	56	6	52	0	0	18	49	0	3	0
Eastern	39	0	8	60	3	37	0	34	0	1	20	35	1	4	1
Brong Ahafo	30	0	6	34	12	26	3	28	0	0	26	8	0	0	0
Totals	1000	20	633	1641	443	1211	155	1118	65	11	633	874	89	132	153

Documentation For Interpretation Of Survey Spreadsheets.

The following codes have been used in accordance with your earlier instructions. Where information could not be obtained a "99" has been entered in the data. However, if a house has no air conditioner, for instance, then the subsequent data spaces in the air conditioning section will appear as blanks. In the case of dates, blank spaces mean "don't know".

The coding used in data entry is explained as follows:

Item 5.	None	Primary School	JSS	SSS	Univ/Tech	Post- Graduate
Code	1	2	3	4	5	6

Item 5a		code
	0 - 49,000	1
	50-99,000	2
	100-249,000	3
	250-499,000	4
	500-999,000	5
	1 million cedis +	6

Item 6		Code
	Professional/Doctor/Teacher/Business	1
	Clerical/Secretarial	2
	Manual laborer	3
	Contractor/Craftsman	4
	Farmer	5

Item 7		Code
	Detached Single Family	1
	Row House	2
	Apartment/Flat	3
	Small Compound	4
	Large Compound	5
	Other	6

Item 8		Code
	Rent	1
	Own	2
	Other	3

Item 11		Code
	Concrete Block	1

	Aggregate/Poured concrete		2
	First Class Wood		3
	Stone		4
	Rough Hewn Wood/Poles		5
	Stabilized Mud Bricks		6
	Mud		7
	Other		8
Item 12	Tile	Code	1
	Zinc/Aluminum		2
	Wood		3
	Concrete		4
	Stabilized Mud		5
	Thatch		6
	Other		7
Item 19	Yes	Code	1
	No		2
Item 20	Refrigerator/freezer	Code	1
	Air Conditioner		2
	Lighting Systems		3
	Other		4
Item 21	Fridge/Freezer	Code	1
	Air Conditioner		2
	Lighting Systems		3
	Other		4
Item 25	Local Retailer	Code	1
	Direct Importer/Large Retailer		2
	Foreign Purchase		3
	Other		4
Item 26	Fridge/Freezer Combination	Code	1
	Refrigerator only		2
	Freezer only		3
Item 27	Single	Code	1
	Double		2
Item 28	Top-Mount	Code	1
	Upright		1
	Bottom-Mount		2

	Chest		2
	Side-by-Side		3
	Other		3

Note: **Code selected in Item 28 to be matched with selected code in Item 26.**

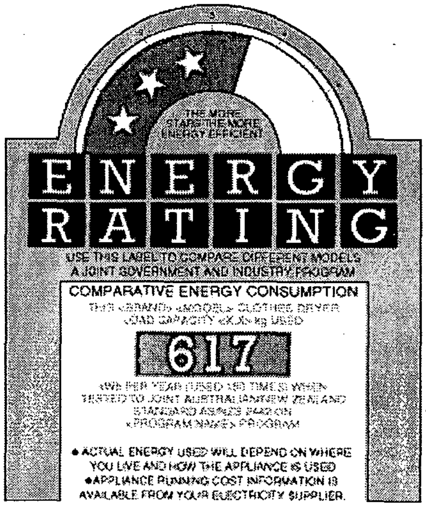
Item 29	Automatic	Code	1
	Manual		2
Item 33	Yes	Code	1
	No		2
	D/K		3
Item 33c	ISO	Code	1
	USDOE		2
	Other		3
Item 36a	Yes	Code	1
	No		2
	D/K		3
Item 36b	Yes	Code	1
	No		2
	D/K		3
Item 36c	Yes	Code	1
	No		2
	D/K		3
Item 37	Yes	Code	1
	No		2
	D/K		3
Item 38	Once per day	Code	1
	1-4 times per week		2
	Less than once per week		3
Item 39	Yes	Code	1
	No		2
	D/K		3
Item 40	Yes	Code	1
	No		2
	D/K		3
Item 43	Local Retailer	Code	1
	Direct Importer/Large Retailer		2

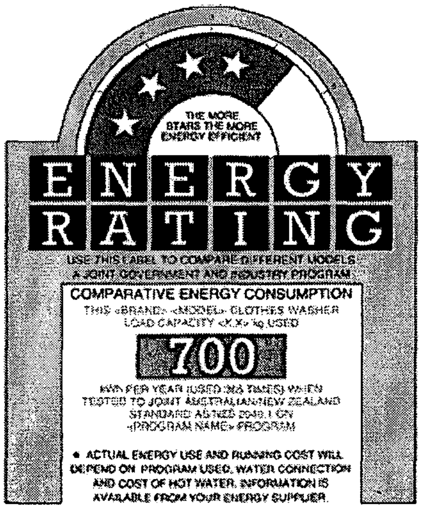
	Foreign Purchase		3
	Other		4
Item 44	Window	Code	1
	Split		2
	Evaporative Cooler		3
Item 48	Yes	Code	1
	No		2
	D/K		3
Item 48c	ISO	Code	1
	USDOE		2
	Other		3
Item 49	Small	Code	1
	Medium		2
	Larger		3
Item 51	Louvered Clear	Code	LC
	Louvered Opaque		LO
	Single Pane		SP
	DoublePane		DP
	Other		OT
Item 56	Self/Owner	Code	1
	HVAC Technician		2
	Building Contractor		3
	Other		4

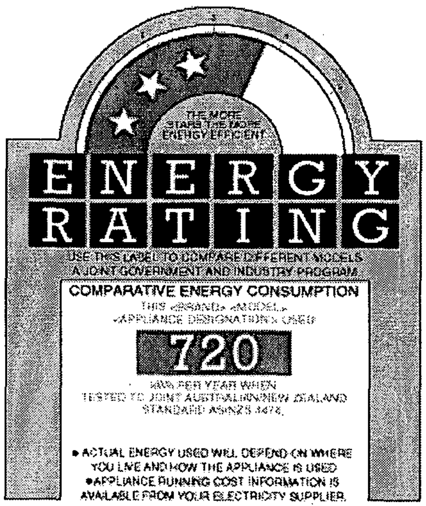
Appendix 3 International Appliance Labels

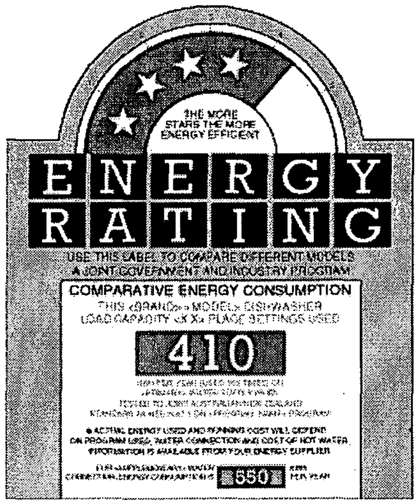
List of Examples

Australia and New Zealand Labels

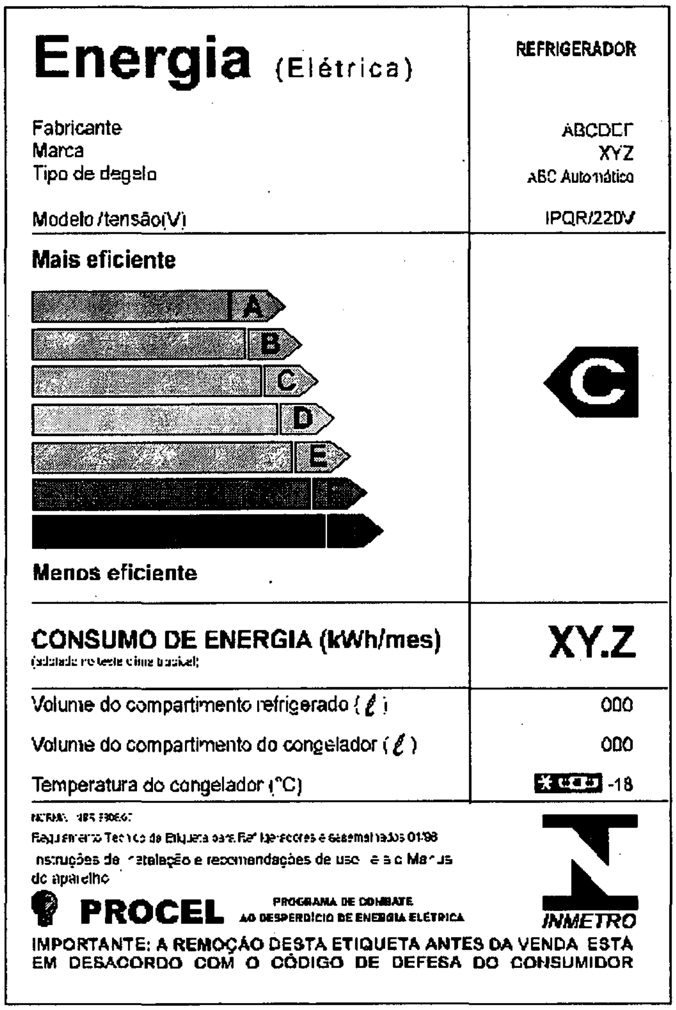








Brazilian Refrigerator Label



Canadian Appliance Label

ENERGUIDE

Energy consumption / Consommation énergétique

1015 kWh

per year / par année

▼This model / Ce modèle

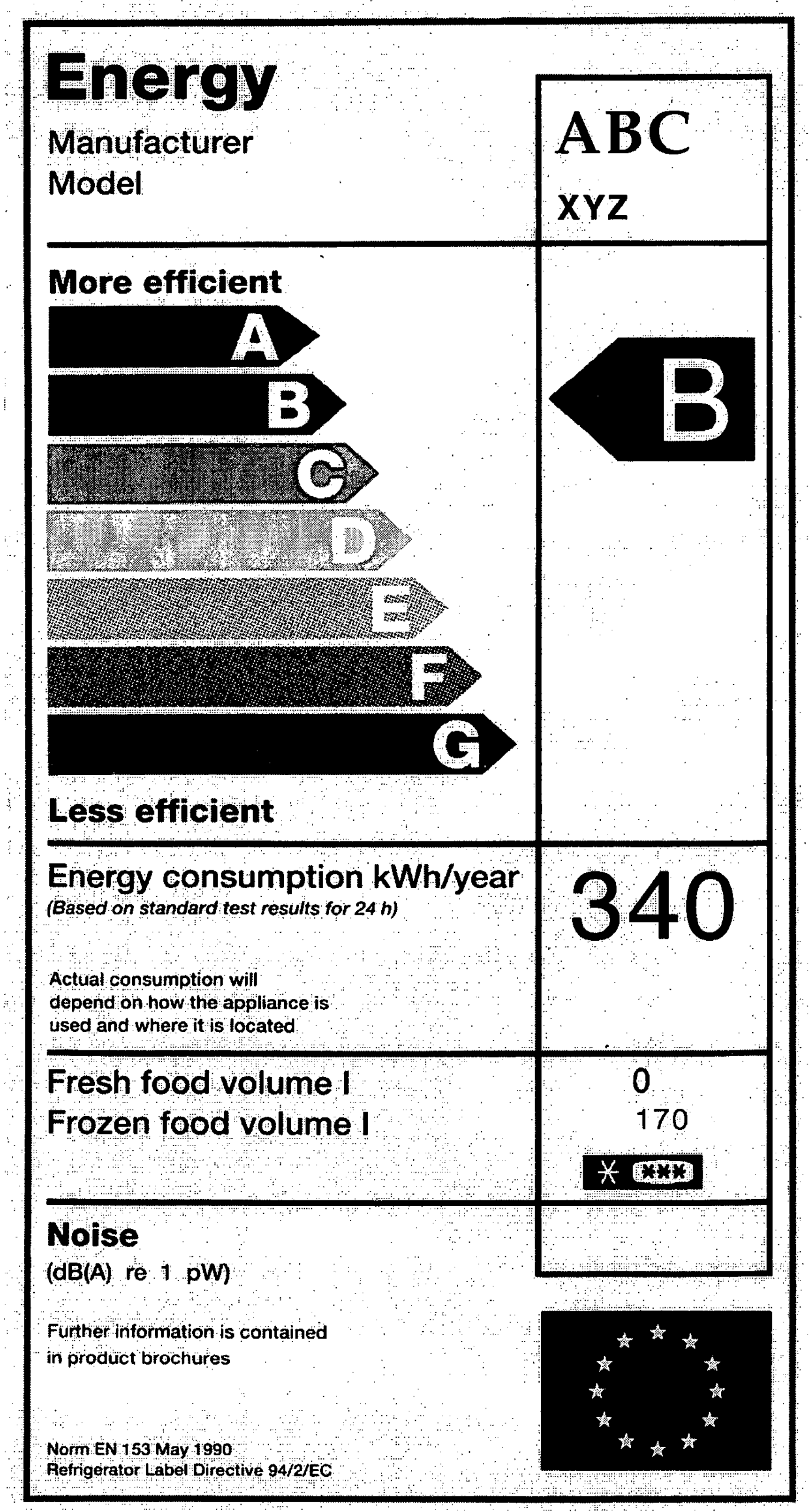
643 kWh — 1500 kWh

Uses least energy / Consomme le moins d'énergie		**Uses most energy / Consomme le plus d'énergie**
Similar models compared	**Standard**	Modèles similaires compares
Model number	**XYZ**	Numéro de modèle

Removal of this label before first retail purchase is an offense (S.C. 1992. c.36)
Le retrait de cette étiquette avant le premier achat au détail consititue une violation de la loi (S.C. 1992 c.36)

0000000

EU Refrigerator Label



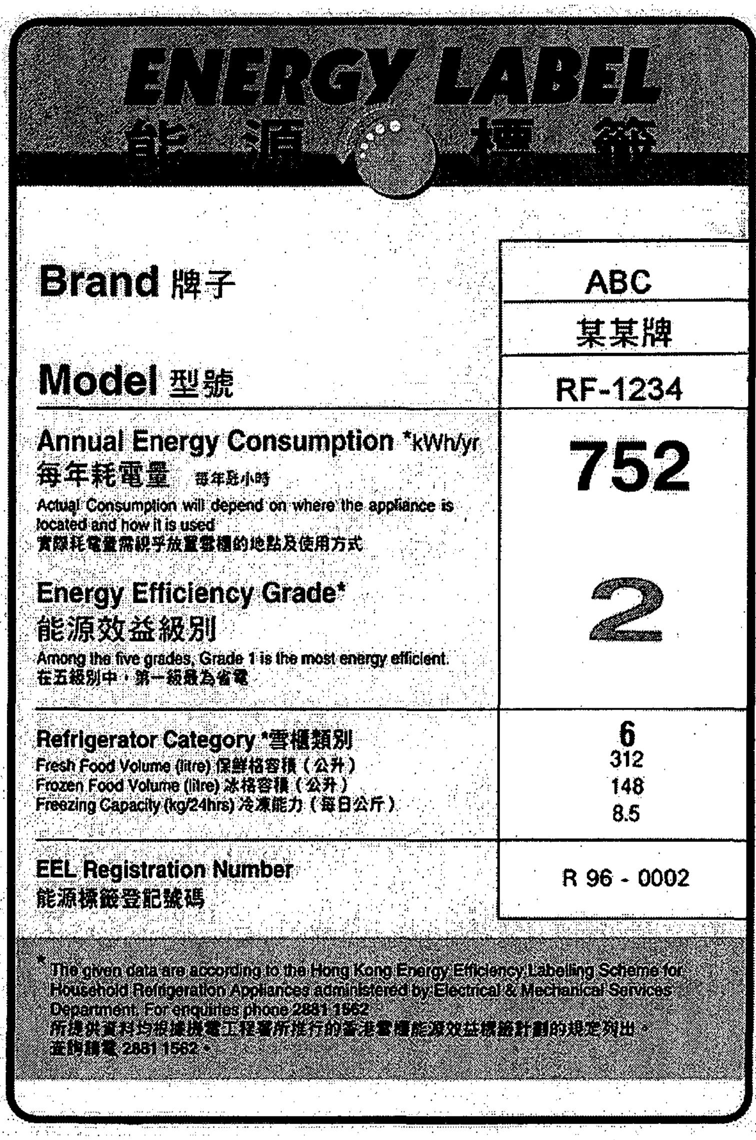
Honk Kong Air Conditioner Label

ENERGY LABEL 能源標籤

Brand 牌子	ABC 某某牌
Model 型號	AC-4321
Annual Energy Consumption *kWh/yr 每年耗電量 每年度小時 Actual consumption will depend on where the appliance is located and how it is used. Assumed 1200 hrs/yr operation. 其耗電量視乎冷氣機的安裝地點及使用方式。現假設每年使用率為1200小時	**1212**
Energy Efficiency Grade* 能源效益級別 Among the five grades, Grade 1 is the most energy efficient. 在五級別中，第一級最為省電。	**2**
Room Cooler Category* 冷氣機類別	1
Cooling Capacity (kW) 製冷量	2.43
Refrigerant 製冷劑	R22
EEL Registration Number 能源標籤登記號碼	C 96-0003

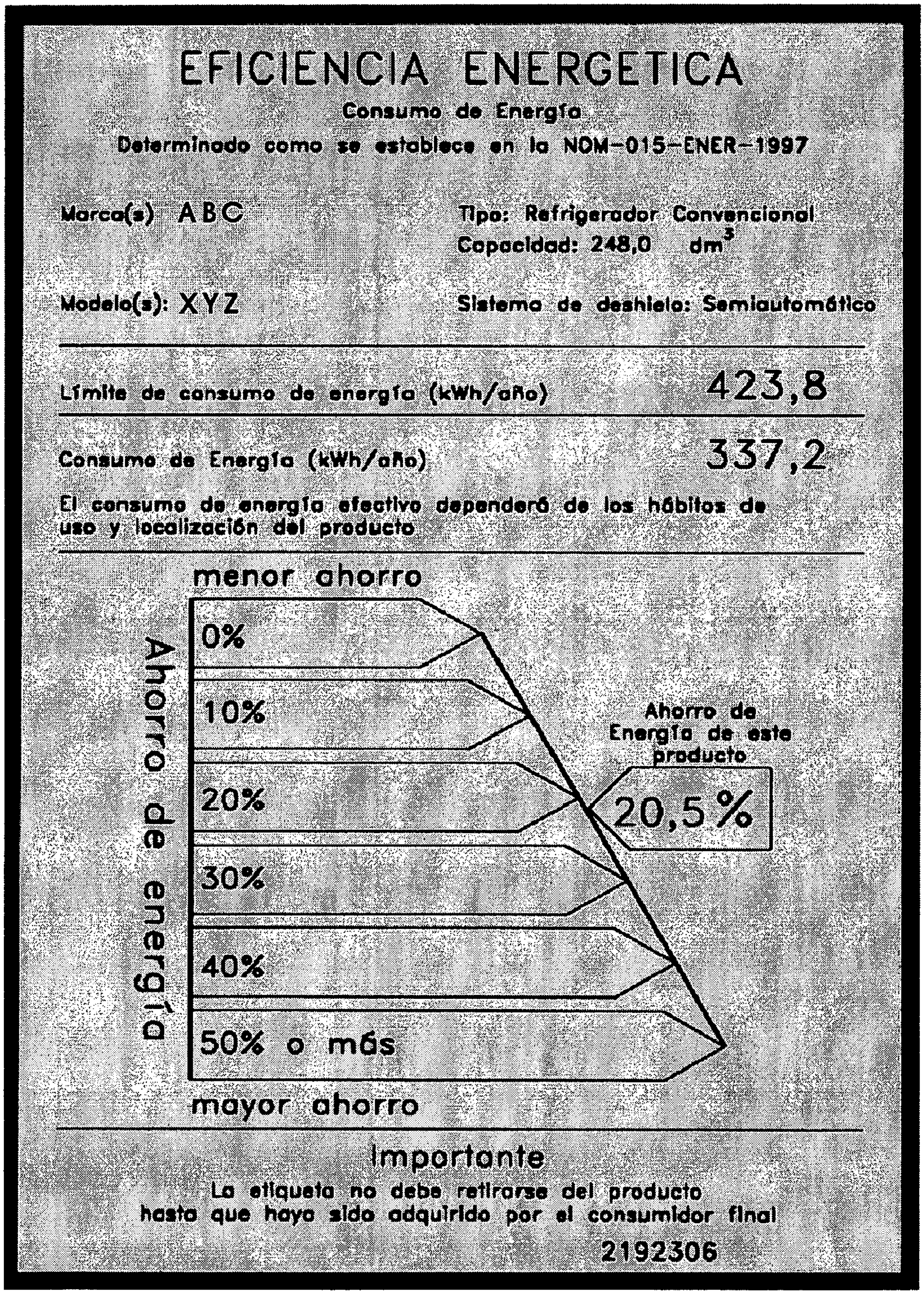
* The given data are according to the Hong Kong Energy Efficiency Labelling Scheme for Room Coolers administered by Electrical & Mechanical Services Department.
For enquiries phone 2881 1562
所提供資料均根據機電工程署所推行的香港冷氣機能源效益標籤計劃的規定列出。
查詢請電 2881 1562。

Honk Kong Refrigerator Label



Korean Air Conditioner Label

Mexican Refrigerator Label



Thai Air Conditioner Label

84

Thai Refrigerator Label

US Refrigerator Label

Based on standard U.S. Government tests

ENERGYGUIDE

Refrigerator-Freezer
With Automatic Defrost
With Side-Mounted Freezer
With Through-The-Door Ice Service
Capacity: 22 Cubic Feet

ABC
Model XYZ

Compare the Energy Use of this Refrigerator with Others Before You Buy.

This Model Uses
700 kWh/year

Energy use (kWh/year) range of all similar models

Uses Least Energy	Uses Most Energy
561	967

kWh/year (kilowatt-hours per year) is a measure of energy (electricity) use. Your utility company uses it to compute your bill. Only models with 20.5 to 22.4 cubic feet and the above features are used in this scale.

Refrigerators using more energy cost more to operate. This model's estimated yearly operating cost is:

$61

Based on a 1995 U.S. Government national average cost of 8.67¢ per kWh for electricity. Your actual operating cost will vary depending on your local utility rates and your use of the product.

Important: Removal of this label before consumer purchase is a violation of Federal law (42 U.S.C. 6302). 000 0000

Appendix 4 Description of Spreadsheet Models and Inputs

General Description

The analysis presented in the main text is based on a simple spreadsheet model developed by LBNL to calculate the impacts of a given energy savings on consumers and the nation as a whole. Several input fields allow users to tailor the analysis according to available data. Only refrigerators and room air conditioners (RAC) have been modeled in this fashion, but the methodology and cell calculations could be applied to other appliances as appropriate. Lighting is more complex and would require additional programming effort.

Each of the two product specific spreadsheets is organized into the following worksheets:

- Input
- Baseline
- Standard
- Energy
- Elec Conversion
- Fuel Price
- Retirement Function

Input Worksheet

The Input worksheet contains input fields for the following data

- **Standard Level (% Savings** for RAC) – currently set at 409kWh/year for refrigerators and 10% savings for RAC, this specifies the maximum annual unit energy consumption after a given standard is enacted.
- **Discount Rate** – currently set at 5%, this is used to discount future costs and benefits to net present value for the baseline year.
- **Discount Year** – the baseline year for calculations of net present value.
- **Electricity Price** – currently estimated at 6 cents per kWh, this is the unit price of domestic electricity service.
- **Baseline UEC** – currently estimated at 591 kWh/year for refrigerators and 2518kWh/year for RAC (from the survey data), this specifies the average annual energy consumption of the appliance.
- **Purchase Price** – estimated at $500 for refrigerators and $565 for RAC, this specifies the average purchase price of the appliance, converted to US$ based on the January, 1999 exchange rate.
- **% Price Increase** – currently estimated to be 5% for refrigerators and 10% for RAC, this specifies the price increase associated with more efficient appliances required by a proposed standard.
- **Population** – currently estimated at 18 million, this is simply the current population of Ghana, used to calculate total energy use and # of households
- **% Urban Population** – the percentage of the population in urban areas (37% according to the World Bank).
- **% Rural Population** – the percentage of the population in rural areas (63%)
- **Persons per Household** – currently estimated at 7 per HH according to the survey data, this is used to determine the number of Households in the country, which gives some idea of the number of potential consumers of large residential appliances.
- **Saturation Rate** – the rate at which the saturation of the appliance is expected to increase after standards (6.8%). RAC further distinguishes between the urban saturation rate and the rural/semi-urban rate, since urban saturation is not yet very high. For refrigerators, urban saturation is very close to 100% according to the survey, and so most purchases are just replacements.
- **Population increase** – the rate at which the population is expected to grow in the medium term (currently 2.7% per year).
- **Historical saturation rate** – the rate at which saturations have grown historically (in the absence of standards). Derived from reported age and purchase data from the survey.

In general, it should be noted that this is a static model. For example, the ratio of urban to rural population is held constant over the period of analysis. These can be altered directly in the worksheets, but using the input fields will simply hold all values constant. An important issue is the price of electricity, which can reasonably be expected to change over time, but for this analysis is held at a constant level. Also, baseline UEC may have changed even in the absence of standards.

All of the input fields will automatically update all calculations and generate new output tables, which are also found in the Input worksheet. The following tables reflect the inputs used for this analysis:

Table A-1 Population projections

Year	Population	Urban Pop.	Rural Pop.
	(millions)	*(millions)*	*(millions)*
1998	18.00	6.66	11.34
1999	18.49	6.84	11.65
2000	18.99	7.02	11.96
2001	19.50	7.21	12.28
2002	20.02	7.41	12.62
2003	20.56	7.61	12.96
2004	21.12	7.81	13.31
2005	21.69	8.03	13.66
2006	22.28	8.24	14.03
2007	22.88	8.46	14.41
2008	23.50	8.69	14.80
2009	24.13	8.93	15.20
2010	24.78	9.17	15.61

*Based on 2.7% population growth rate
(ratio of Urban to Rural population held constant)

Table A-2 Number of Households (estimate based on population projections and survey data)

Year	Total HH*	Urban HH	Rural HH
	millions	*millions*	*millions*
1998	2.57	0.95	1.62
1999	2.64	0.98	1.66
2000	2.71	1.00	1.71
2001	2.79	1.03	1.75
2002	2.86	1.06	1.80
2003	2.94	1.09	1.85
2004	3.02	1.12	1.90
2005	3.10	1.15	1.95
2006	3.18	1.18	2.00
2007	3.27	1.21	2.06
2008	3.36	1.24	2.11
2009	3.45	1.28	2.17
2010	3.54	1.31	2.23

*Based on 2.7% population growth rate
(ratio of Urban to Rural population held constant)

Table A-3 Net benefits from a refrigerator standard (EU-1999)

Discounted at 5% to year 1998 *From 2000 to 2010*	US $ (bill)	Ghana ¢ (bill)
Total Energy Bill Savings	**0.047**	**107**
Total Equipment Cost	**0.020**	**46**
Net Present Benefit	**0.027**	**61**
Benefit/Cost Ratio	**2.3**	**2.3**

Table A-4 Summary table of impacts from a refrigerator standard

Year	Stock	Shipments	Energy Savings	CO2 Savings	Carbon Savings	Bill Savings*
	millions	*millions*	*Quads Primary*	*10^6 tonnes*	*10^6 tonnes*	*bill. US$*
1998	0.94	0.136	0	0	0	0
1999**	1.00	0.064	0.000	0.009	0.003	0.0007
2000	1.07	0.068	0.000	0.019	0.005	0.0014
2001	1.14	0.073	0.000	0.029	0.008	0.0022
2002	1.20	0.078	0.001	0.040	0.011	0.0031
2003	1.27	0.083	0.001	0.050	0.014	0.0040
2004	1.33	0.088	0.001	0.062	0.017	0.0049
2005	1.40	0.094	0.001	0.073	0.020	0.0060
2006	1.46	0.101	0.001	0.085	0.023	0.0071
2007	1.53	0.108	0.001	0.098	0.027	0.0082
2008	1.60	0.115	0.002	0.112	0.030	0.0095
2009	1.67	0.123	0.002	0.126	0.034	0.0108
2010	1.73	0.131	0.002	0.141	0.038	0.0123
Cumulative Total:		1.262	0.012	0.845	0.230	0.070

*Undiscounted 1998 US$

**Shipments are expected to drop as a result of a standard, in this case the saturation rate decreases by 50%

Table A-5 Historical refrigerator shipments

Year of Purchase	Survey Data		LBNL National Estimates			
	Units	Growth Rate	Units*	Shipments	Urban Units	Rural Units
		%	mill	mill	mill	mill
pre-1988	148	-	-	-	-	-
1989	20	14%	0.228	0.033	0.220	0.008
1990	54	32%	0.267	0.039	0.257	0.009
1991	26	12%	0.312	0.045	0.301	0.011
1992	55	22%	0.365	0.053	0.352	0.013
1993	44	15%	0.427	0.062	0.412	0.015
1994	93	27%	0.500	0.073	0.482	0.017
1995	69	16%	0.585	0.085	0.564	0.020
1996	86	17%	0.684	0.099	0.660	0.024
1997	59	10%	0.800	0.116	0.773	0.028
1998	44	7%	**0.936**	0.136	0.904	0.032
TOTALS	698	17%	0.936	0.741	0.904	0.032

*1998 Total Units are from the survey data plus an assumed 2% saturation in rural and semi-urban areas.
All other data derives from 1998 base.

Table A-6 Refrigerator shipment projections (with a refrigerator standard)

Year	Total Stock*	Urban Stock	Rural Stock	Total Saturation	Urban Saturation**	Rural Saturation†	Total Shipments
	millions	millions	millions	%	%	%	millions
1998	0.94	0.90	0.03	36%	95%	2%	-
1999	1.00	0.97	0.03	38%	99%	2%	0.06
2000	1.07	0.99	0.07	39%	99%	4%	0.07
2001	1.14	1.02	0.11	41%	99%	7%	0.07
2002	1.20	1.05	0.15	42%	99%	9%	0.08
2003	1.27	1.08	0.19	43%	99%	10%	0.08
2004	1.33	1.11	0.23	44%	99%	12%	0.09
2005	1.40	1.14	0.26	45%	99%	14%	0.09
2006	1.46	1.17	0.30	46%	99%	15%	0.10
2007	1.53	1.20	0.33	47%	99%	16%	0.11
2008	1.60	1.23	0.37	48%	99%	17%	0.12
2009	1.67	1.26	0.40	48%	99%	19%	0.12
2010	1.73	1.30	0.44	49%	99%	20%	0.13

*Based on 6.8% saturation rate
**Full Urban saturation <100% (1 unit per HH)
†Rural saturation rate increases as the urban market becomes saturated

Table A-7 Energy and capacity savings from a refrigerator standard

Year	Baseline	Efficiency Standards	Annual Savings	Capacity Savings
	mill kWh	mill kWh	mill kWh	MW
1998	553	553	0	0
1999	591	579	12	2
2000	631	607	24	3
2001	671	634	37	5
2002	710	659	51	7
2003	749	683	66	9
2004	788	706	82	11
2005	827	727	99	14
2006	865	748	118	16
2007	905	767	137	19
2008	944	786	158	22
2009	984	804	181	25
2010	1025	821	204	28

Table A-8 Net Benefits from a 10% unit energy savings for room air conditioners

Discounted at 5% to year 1998	**US $**	**Ghana ¢**
From 2000 to 2010	*(billion)*	*(billion)*
Total Energy Bill Savings	**0.0076**	**17**
Total Equipment Cost	**0.0054**	**12**
Net Present Benefit	**0.0022**	**5**
Benefit/Cost Ratio	**1.4**	**1.4**

Table A-9 Historical room air conditioner shipments

Year of Purchase	Survey Data		LBNL National Estimates			
	Units	Growth Rate	Units*	Shipments	Urban Units	Rural Units
		%	*mill*	*mill*	*mill*	*mill*
pre-1988	16	-	0.023	-	-	-
1989	2	13%	0.027	0.004	0.024	0.002
1990	6	33%	0.032	0.005	0.032	0.002
1991	4	17%	0.037	0.005	0.037	0.003
1992	2	7%	0.043	0.006	0.040	0.003
1993	3	10%	0.051	0.007	0.043	0.003
1994	6	18%	0.059	0.009	0.051	0.004
1995	8	21%	0.069	0.010	0.062	0.005
1996	9	19%	0.081	0.012	0.074	0.006
1997	13	23%	0.095	0.014	0.091	0.007
1998	9	13%	0.111	0.016	0.103	0.008
TOTALS	78	17%	0.111	0.088	0.103	0.008

*1998 Total Units are from the survey data plus an assumed .5% saturation in rural and semi-urban areas. All other data derives from 1998 base.

Table A-10 Summary table of impacts from a 10% room air standard

Year	Stock	Shipments	Energy Savings	CO2 Savings	Carbon Savings	Bill Savings*
	millions	*millions*	*Quads Primary*	10^6 tonnes	10^6 tonnes	*bill. US$*
1998	0.11	0.016	0	0	0	0
1999	0.11	0.008	0.00002	0.002	0.000	0.0001
2000	0.11	0.008	0.00004	0.003	0.001	0.0002
2001	0.11	0.009	0.00007	0.005	0.001	0.0004
2002	0.12	0.009	0.00009	0.007	0.002	0.0005
2003	0.12	0.010	0.00012	0.008	0.002	0.0007
2004	0.12	0.010	0.00014	0.010	0.003	0.0008
2005	0.13	0.011	0.00017	0.012	0.003	0.0010
2006	0.13	0.012	0.00020	0.014	0.004	0.0012
2007	0.13	0.013	0.00024	0.016	0.004	0.0014
2008	0.14	0.014	0.00027	0.018	0.005	0.0016
2009	0.14	0.015	0.00031	0.020	0.006	0.0018
2010	0.14	0.016	0.00034	0.022	0.006	0.0020
Cumulative Total:		0.149	0.002	0.138	0.038	0.011

*Undiscounted 1998 US$

Table A-11 Projections of room air conditioner shipments with a 10% standard

Year	Total Stock*	Urban Stock	Rural Stock	Total Saturation	Urban Saturation	Rural Saturation	Total Shipments
	millions	*millions*	*millions*	*%*	*%*	*%*	*millions*
1998	0.11	0.10	0.01	4.2%	10.8%	1%	0.016
1999	0.11	0.11	0.01	4.2%	11.2%	0.5%	0.008
2000	0.11	0.12	0.01	4.2%	11.7%	0.5%	0.008
2001	0.11	0.13	0.01	4.1%	12.1%	0.6%	0.009
2002	0.12	0.13	0.01	4.1%	12.6%	0.6%	0.009
2003	0.12	0.14	0.01	4.1%	13.1%	0.6%	0.010
2004	0.12	0.15	0.01	4.1%	13.7%	0.6%	0.010
2005	0.13	0.16	0.01	4.1%	14.2%	0.7%	0.011
2006	0.13	0.17	0.01	4.1%	14.8%	0.7%	0.012
2007	0.13	0.19	0.01	4.1%	15.4%	0.7%	0.013
2008	0.14	0.20	0.02	4.1%	16.0%	0.7%	0.014
2009	0.14	0.21	0.02	4.1%	16.6%	0.8%	0.015
2010	0.14	0.23	0.02	4.1%	17.3%	0.8%	0.016

*Based on 6.8% saturation rate

Table A-12 Energy and capacity savings from a 10% room air conditioner standard

Year	Baseline	Efficiency Standards	Annual Savings	Capacity Savings
	mill kWh	*mill kWh*	*mill kWh*	*MW*
1998	270	270	0	0
1999	278	276	2	2
2000	284	280	4	3
2001	289	283	6	5
2002	294	285	8	7
2003	300	289	11	10
2004	310	296	14	12
2005	320	304	16	14
2006	329	310	19	17
2007	337	315	23	20
2008	344	318	26	23
2009	352	323	29	26
2010	362	330	33	29

Baseline Worksheet

The Baseline worksheet is based on data collected in the survey and projected into the future assuming a static market. The following column(s) are included:

- Year
- New Shipments (millions)
- Surviving Units by Vintage (millions) based on the retirement function worksheet
- Total surviving stock
- Unit price (from Input worksheet)
- Unit Energy Consumption (from Input worksheet)
- Net annual energy consumption, expressed in quads of primary energy, based on the elec conversion worksheet
- Total (national) operating cost, expressed in billions of US$ and based on the fuel price worksheet and column AF
- Total (national) site energy consumption

Standard Worksheet

The Standard worksheet is based on the projected impacts of a standard, again assuming a static market after the standard is implemented. The columns are the same as above, with the following additional columns to calculate the savings from the given standard:

- Annual primary energy savings
- Cumulative primary energy savings
- Annual cost savings
- Delta unit price (change in per unit purchase price)
- Equipment cost, expressed as the total additional cost of units meeting the standards and based on the delta unit price (i.e. the cost of a standard to consumers)
- Discount factor, used to discount future costs and savings, based on the discount factor from the input worksheet
- Annual site energy savings
- Annual capacity savings, expressed in MW of capacity freed by the site energy savings, based on Conservation Load Factors (CLF) from the USDOE Utility Analysis and Environmental Assessment Draft Methodology

Energy Worksheet

The Energy worksheet presents the annual and cumulative energy savings in a table format, as well as providing estimates of the reductions in pollutants based on emission factors from a mix of power plants.

Elec Conversion Worksheet

The Elec Conversion worksheet presents the site kWh to primary BTU conversion factor for each year in the analysis, based on the 1998 Annual Energy Outlook projections from USDOE-EIA. Appropriate conversion factors for Ghana may be available in the future and should be substituted here.

Fuel Price Worksheet

The Fuel Price worksheet presents the annual cost of electricity units to consumers, based on the data from the Input worksheet. This model assumes a static (constant) price if the input field is used.

Retirement Function Worksheet

The Retirement Function worksheet is used to predict the survival of appliance units by vintage, based on empirical observation of units in the US market(various sources).

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