Chapter

The Impact of Energy Efficiency Programmes in Ghana

Edwin Kwasi Tamakloe

Abstract

Ghana experienced widespread power shortages due to series of droughts spanning from the 1980s to the 1990s. Energy efficiency programmes were identified to solve these energy supply challenges. Consequently, the residential sector has been recognized as an important target group for energy efficiency programmes in the country. The residential sector in Ghana accounts for 47% of the total final energy use. Reducing the inefficiencies in the residential sector energy use could be an effective way of reducing global energy use and related environmental impacts. Therefore, Ghana enacted four Legislative Instruments to regulate the importation of refrigerating, air conditioning and lighting appliances and also to ensure these appliances meet the minimum energy performance standards (MEPS). The purpose of this paper was to review and establish the impact of the MEPS programmes in Ghana from 2007 to 2020. The content of this desktop review is based on data gathered through a series of reviews of available energy efficiency policy documents from governmental agencies. The results revealed that the implementation of MEPS programmes in Ghana yielded 8317.8 GWh of electricity savings, which translates into carbon emission reduction of 4.60 million tonnes of CO_2 and energy cost savings of USD 832 million in term of electricity bills.

Keywords: energy efficiency, minimum energy performance standards, standards and labelling and energy saving

1. Introduction

Globally, the building sector is accountable for 30% of the total final energy consumption and without action, the energy demand in this sector could increase by another 30% by 2060 [1]. Again, buildings represent 28% of global energy-related CO_2 emissions worldwide [2]. This sector's energy consumption is related to human programmes involving the use of equipment, lighting and other electrical appliances [3]. The household/residential sector, which forms part of the total building stocks, has been identified as one of the target groups for energy efficiency programmes [4, 5] also underscored that households can adopt and implement energy efficiency measures to reduce energy consumption significantly.

The residential sector in Ghana accounts for 47% of the total final energy consumption [6], compared to other countries such as the United States (25%), United Kingdom (30%), Japan (26%), Saudi Arabia (50%), China (15.8%) and Malaysia (15%) [5, 7–9]. Electrical appliances such as refrigerators, freezers and room air

conditioners (RACs), which are energy-intensive, are among the most common Ghanaian household appliances. Whilst refrigerators and freezers consume between 25–30% of the total residential energy use, air conditioners account for 6.5% of residential energy use in Ghana [10]. Whilst [11] indicated that most of the markets in sub-Saharan Africa (SSA) countries are inundated with "used electrical appliances" [12], assert that this phenomenon was a result of the proliferation of used or "second-hand" goods from Europe and elsewhere. For instance, it has been estimated that there were over two (2) million used and inefficient refrigerating appliances in Ghana in 2012 that were laden with hydrofluorocarbons (HFCs) [13]. This large number was primarily due to the introduction of standards and labelling in developed countries and the era of energy efficiency programmes in Europe in the early 1970s saw many of these countries disposing of their old and energy inefficient appliances into SSA [14]. The share of the used electrical appliance market in Ghana at the time was about 80%, thereby promoting climate injustice [14]. These used and inefficient refrigerating appliances consume, on average, 1200 kWh per unit per year compared to 250 kWh and 400 kWh per year in Europe and the US respectively [15].

Minimum energy performance standards (MEPS) and the introduction of more efficient appliances through energy efficiency standards and labelling (EES&L) programmes have been identified as potential means of reducing the energy consumption of these inefficient appliances. It has been noted that improving energy efficiency is the best way to simultaneously meet sustainable development goals (SDGs) 7 and 13 in the energy sector [16]. This approach, when used judiciously, frees resources for other projects, helps economies to grow and reduces environmental impacts such as greenhouse gas (GHG) emissions. MEPS programmes have also proven to be effective in stimulating the development of cost-effective, energy-efficient technologies and are said to be the cornerstone of most national energy and climate change mitigation programmes [17].

Ghana's move to improve its energy efficiency is part of a larger energy sector reform programme designed to support the country's long-term economic developmental agenda. In 2002, Ghana, therefore, identified the benefits of MEPS such as EES&L programmes for equipment and other electrical appliances such as deep freezers, RACs, refrigerators, industrial motors and lighting systems [18]. These standards and labelling programmes serve as benchmarks and catalysts in meeting the MEPS objectives.

According to [19], energy efficiency legislations and policies have continued to increase globally through energy efficiency research and developmental programmes [20]. However, several barriers attributable to the low adoption and implementation of MEPS in SSA have to be overcome. These barriers, according to [21, 22], include financial constraints, techno-economic, political-institutional barriers, market barriers, lack of incentives and lack of information (knowledge). As a result of market failures in SSA, [23] suggested in his paper, "The market for lemons: Quality and uncertainty in the market mechanism", that in markets where consumers do not have reliable and adequate information in respect of the quality of the products, it leads to the proliferation of cheaper and low-quality products. The effect of this failure is that more efficient products or appliances are pushed out of the market space.

Notwithstanding these continental constraints, Ghana was able to overcome these barriers through stakeholders' consultative engagements using the ***quadruple helix model*** of policy (government, academia, industry and the media) and marketplace innovations such as standards and labelling [14]. Four (4) Legislative Instruments (L.Is) were subsequently enacted by the Ghanaian Parliament in collaboration with the Ghana Energy Commission and Ghana Standards Authority. They include:

i. Energy efficiency standards and labelling (non-ducted air conditioners and self-ballasted fluorescent lamps) regulations 2005 (L. I 1815);

ii. Energy efficiency (prohibition of manufacture, sale or importation of incandescent filament lamp, used refrigerator, used refrigerator-freezer, used freezer and used air-conditioner) regulations 2008 (L. I 1932);

iii. Energy efficiency standards and labelling (household refrigerating appliances) regulations 2009 (L. I 1958); and

iv. Energy commission (efficiency standards and labelling (light emitting diode and self-ballasted fluorescent lamps) regulations 2017 (L. I 2353).

These standards and labelling initiatives provide a mandatory labelling regime in Ghana, where energy guide labels have to be affixed conspicuously on these appliances to indicate the minimum energy performance levels of these appliances. The indicators on these energy guide labels include annual energy consumption, type of refrigerant, climate class, star rating, manufacturer, model number, fresh and frozen volumes. This mandatory labelling regime is intended to promote energy efficiency, transform the appliances market, reduce energy demand in households and reduce Ghana's energy-related CO_2 and ozone-depleting substances (ODS) emissions. This paper reviews the impact of the first three regulations and other energy efficiency projects between 2007 and 2020.

To commence the enforcement of these regulations, the national refrigerator turn-in and rebate scheme was launched by the Government of Ghana, on the advice of the Ghana Energy Commission in July, 2012. The objective was to recover about fifty thousand (50,000) inefficient refrigerating appliances from homes and encourage individuals to use more energy-efficient ones. So, in 2013, the Ghana Energy Commission commenced the full implementation of these regulations at the ports of entry. It is therefore imperative to review and establish the impact of these regulations between 2007 and 2020.

The rest of the paper is organized as follows: the next section following the introduction looks at the methodology being employed. The concept of energy efficiency is examined in Section 3. Section 4 provides the Global and National overviews of MEPS implementations. Testing and inspection protocols for refrigerating, lighting and air-conditioning equipment in Ghana are considered in Section 5. Section 6 offers the discussion of the results of some of the real impacts due to MEPS whilst Section 7 concludes the paper.

2. Methodology of the study

This section explains the methodology adopted for this work.

2.1 Desktop review

The content of this desktop review is based on energy efficiency appliance import data, policy documents and market transformation data from the Ghana Energy Commission, Energy Foundation, Council for Scientific and Industrial Research—Institute of Industrial Research (CSIR-IIR), Ghana Revenue Authority (GRA-Custom Division) and Ghana Statistical Service (GSS). Other sources of information include the International Energy Agency (IEA) as well as other related web searches. Besides, global and SSA energy efficiency documents were also

reviewed by examining secondary data from standards, regulations, protocols, market report series and other available statistical data.

2.2 Calculation of electricity savings

The basic assumption for computing electricity savings is that without MEPS regulation and its accompanying awareness programmes. Eqs. (1)–(4) were used to estimate the annual energy saving per appliance, total energy savings for all the appliances and CO_2 emissions reductions between 2007 and 2020 as a result of MEPS implementation. Therefore, the annual electricity saving, *AES* (kWh) gained from the use of each MEPS-compliant appliance can be estimated by comparing its calculated annual electricity consumption (*AEC*) with the annual consumption of a used and inefficient refrigerator as shown by Eq. (1):

$$AES = AEC_{\text{before MEPS implementation}} - AEC_{\text{after MEPS implementation}} \tag{1}$$

where *AES* is the annual electricity saving for MEPS-compliant refrigerating appliance (kWh/year), and *AEC* is the annual electricity consumption before and after MEPS implementation. In Ghana, used and inefficient refrigerating appliances consumed on average 1200 kWh/year (consumption before MEPS implementation).

The total annual electricity saving, AES_{total} (GWh), of MEPS-compliant appliances was calculated by aggregating the products of electricity saving and the number of units sold (*NUS*) in a particular year, as shown in Eq. (2):

$$AES_{total,year} = \sum (AES \times NUS_{,year}) \tag{2}$$

2.3 Calculation of cost savings

The total cost savings from MEPS implementation are computed in terms of the electricity savings from operating a more efficient appliance. Thus, the annual electricity savings computed using Eq. (2) is used to estimate the total cost savings by multiplying the computed electricity savings with the electricity tariff as shown in Eq. (3):

$$CS = AES_{\text{total,year}} \times ET_{\text{residential}} \tag{3}$$

where $CS_{total,\ year}$ [USD] is the total cost savings in a year and $ET_{\text{residential}}$ [USD/kWh] is the average electricity tariff for the residential sector, set at USD 0.10/kWh [6]. The residential sector tariff was used because MEPS regulations in Ghana is primarily targeted at the residential sector.

2.4 Calculation of carbon emission reduction

The annual carbon emission reduction, $CER_{total,\ year}$ [$MtCO_2eq$] was evaluated based on the total annual electricity saving, $AES_{total,\ year}$ [MWh] with the help of Eq. (4).

$$CER_{\text{total,year}} = AES_{\text{total, year}} \times GEF_{\text{Ghana,year}} \tag{4}$$

where $GEF_{\text{Ghana, year}}$ is the grid emission factor for Ghana [tCO_2eq/MWh].

3. The concept of energy efficiency

Several definitions for energy efficiency have emerged over the years. Energy efficiency may be considered as investing in more energy-efficient technologies or appliances which results in more energy savings. Butler et al. [24] defines energy efficiency as "using energy cautiously and economically to sustain everyday life, live comfortably and support wellbeing". According to [25], energy efficiency is achieving the same service and performance while using technology with less energy use and therefore enhancing the security of the energy supply. For [26], energy efficiency is an effective tool for reducing electricity or energy consumption which limits greenhouse gas (GHG) emission and thereby reducing global warming.

4. Overview of MEPS and EES&L programmes

This section reviews the Global and the Ghanaian perspectives of MEPS and EES&L programmes.

4.1 Global overview of MEPS and EES&L programmes

Both minimum energy performance standards (MEPS) and energy efficiency standards and labelling (EES&L) for appliances are the two known key mitigation strategies for electricity conservation worldwide [27]. MEPS is a technique of eliminating inefficient performing appliances through the prescription of minimum efficiency (or maximum energy consumption) that manufacturers must achieve [28]. The benefits of MEPS, according to [29, 30] include the following:

i. It allows manufacturers and suppliers to increase appliance efficiency since less-efficient appliances will no longer be tolerated for sale in the regulated market;

ii. It encourages manufacturers to explore innovative and efficient technologies to gain a competitive edge;

iii. It provides market consistency and certainty, thus creating economies of scale;

iv. Consumers enjoy electricity cost savings over the lifetime of the appliance as these appliances on the market now consume less energy to operate; and

v. Appliance purchase prices are largely falling in real terms in many countries with MEPS regulations due to competition, economies of scale and marketplace innovations.

The main objectives of the EES&L regime are to [31];

i. Prevent the influx of substandard appliances on the market;

ii. Provide the consumer an appliance the needed information to make an informed choice;

iii. Provide information regarding the running cost of the appliance; and

iv. Fulfil environmental treaty commitments such as the Paris Agreement, Kyoto Accord, Kigali Amendment, Montreal Protocol, Rotterdam Convention and Basel Convention.

EES&L programmes, introduced in the 1970s, are now being implemented in over eighty (80) countries including Ghana. The programmes cover more than fifty (50) types of appliances and equipment [32]. Testing protocols are used to determine appliance performance relating to energy efficiency. These protocols are periodically revised to ensure they keep up with trends and advances in technology.

4.2 Overview of Ghana's energy efficiency (MEPS) programme

Over the past decades, Ghana has made significant progress in its energy energy efficiency programmes [33]. These programmes put Ghana on the world map as a pioneer in SSA as a result of extensive collaborations of stakeholders and institutions such as the Ghana Energy Commission, Ministry of Energy, Ghana Standards Authority, Ghana Energy Foundation and CLASP [14]. Ghana experienced widespread power shortages due to series of droughts spanning from the 1980s to the 1990s. Energy efficiency programmes were identified to solve these power shortages as it delivers benefits faster than building new generating power plants [14]. The Government of Ghana, therefore, decided to support energy efficiency standards, policies and programmes. Consequently, the Ghana Electrical Appliance Labelling and Standards Programme (GEALSP) was launched to help transform the country's appliance market. An initial assessment to determine the energy savings potential was then carried out from energy efficiency projects [10].

A comprehensive national household survey on demand-side management (DSM) was then conducted by the Ghana Energy Commission between 2003 and 2006. The results from the survey revealed that residential energy consumption, for example, was 50% of the total national energy use and refrigerating appliances accounted for nearly 59% of the residential use [15]. These used refrigerating appliances consume on average 1200 kWh per annum compared to 250 kWh and 400 kWh per annum in Europe and the US respectively [15] as illustrated in **Figure 1** for comparative energy use basis.

Energy efficiency programmes for household appliances was crucial and therefore needed to be adopted and implemented without further delay to bring Ghana's consumption down (proposed standard—the green line in **Figure 1**). According to [33], energy efficiency is considered a "***low-hanging fruit***" and "***first fuel***" of the clean energy transition due to the low marginal cost of its implementation. However, prior to the adoption and implementation of the MEPS in Ghana, the barriers identified in Section 1, needed to be addressed. The ***quadruple helix model and marketplace innovations*** were adopted in resolving these issues [14]. **Table 1** lists some of the barriers and measures implemented by Ghana to overcome these barriers [14].

Four (4) Legislative Instruments (L.Is) were subsequently enacted by the Ghanaian Parliament in collaboration with the Ghana Energy Commission and Ghana Standards Authority. The first, energy efficiency regulations for non-ducted room air conditioners (RACs) and compact fluorescent lights (L.I. 1815) was developed in 2005 [34], which mandates that all RACs imported into Ghana must meet the minimum energy efficiency ratio (EER) of 2.8 W of cooling per watt of power input, equivalent to a 1-star rating. The second energy efficiency regulations (L.I. 1932) was also enacted in 2008 to help prevent the importation or sale of used

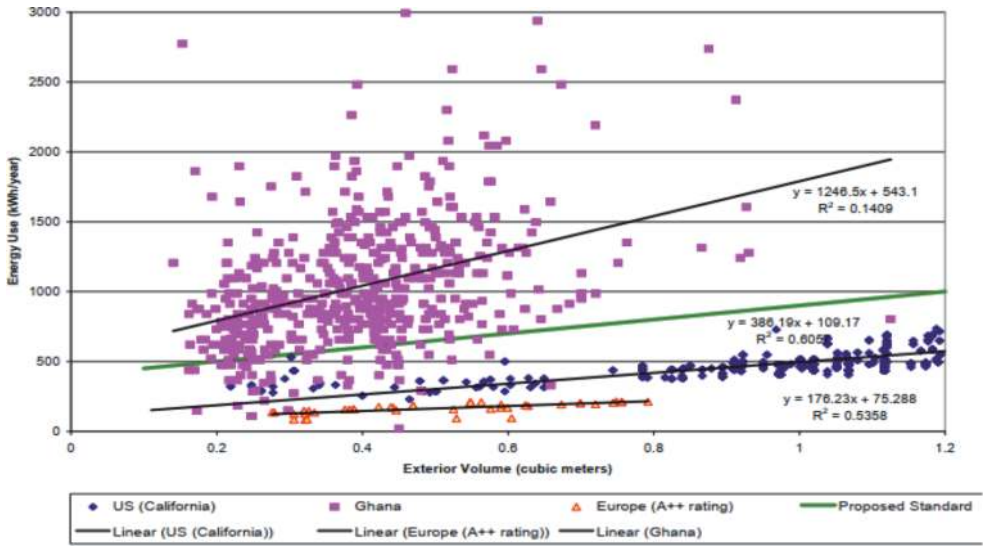

Figure 1.
Refrigerator Electricity use for Ghana, Europe and US in 2007 [14].

No	Types of barriers	Measures
1.	Financial	Implementation of tax incentives and national programmes. For instance, between 2003 and 2016, import duties and taxes were removed from the importation and sale of compact fluorescent lamps (CFLs).
2.	Market	Import duties and value-added tax (VAT) on compact fluorescent lamps (CFLs) were removed by government in April 2003, thus making them available and affordable to consumers.
3.	Lack of information (knowledge)	Organization of national energy efficiency campaigns throughout the country using both print and electronic media. Also, leaflets, brochures and flyers were printed and distributed, including town hall meetings where relevant stakeholders were engaged.
4.	Institutional	Holding stakeholders' consultations and institutional reforms. For instance, Public Utility Regulatory Commission (PURC) is mandated to set electricity tariffs independent of governmental influence and to reward efficient users and punish inefficient users of electricity. Also, the Ghana Energy Commission came in with the labelling programme in 2005 to help in transforming the appliance market.
5.	Technical	Technical cooperation with developmental partners was encouraged to offer training to Ghanaians. For instance, between 2012 and 2013, over 600 technicians were trained to carry out installation, repairs and maintenance of the new and efficient refrigerating appliances under the Ghana Energy Foundation and UNDP project to transform the appliance market.
6.	Political	Independent regulatory bodies were created to deal with the energy crisis. For instance, the Ghana Energy Commission and Public Utility Regulatory Commission were mandated to carry out technical and economic regulations of the power sector respectively. The Ghana Grid Company was also responsible for the national network, separated from the distribution operator. All these programmes were moved from the Ministry of Energy to prevent any political interference.

Table 1.
Types of energy efficiency barriers and measures to overcome them.

inefficient refrigerating and air conditioning appliances in Ghana. To ensure that only energy efficient refrigerating appliances are imported and sold in Ghana, the energy efficiency standards and labelling regulation for household refrigerating

L.I.	Regulation	Scope & targets	Year passed	Year implemented
1815	Energy efficiency standards and labelling (non-ducted air conditioners and self-ballasted fluorescent lamps) regulations.	Gives legal backing to the use of energy-efficient non-ducted air conditioners and fluorescent lamps.	2005	2014
1932	Energy efficiency (prohibition of manufacture, sale or importation of incandescent filament lamp, used refrigerator, used refrigerator-freezer, used freezer and used air-conditioner) regulations.	Places total ban on the importation and sale of incandescent filament lamp, used refrigerator, used refrigerator-freezer, used freezer and used air conditioners effective January 2012.	2008	2013
1958	Energy efficiency standards and labelling (household refrigerating appliances) regulations.	Provides for the enforcement of minimum energy efficiency and labelling for household refrigerating appliances.	2009	2013
2353	Energy commission (efficiency standards and labelling (light emitting diode and self-ballasted fluorescent lamps) regulations.	Provides for the enforcement of minimum energy efficiency and labelling for light emitting diode and self-ballasted fluorescent lamps.	2017	2020

Table 2.
Main end-use policies and regulations.

appliances (L.I. 1958) was enacted in 2009. Finally, in 2017, the energy efficiency standards and labelling for light-emitting diode and self-ballasted fluorescent regulations (L.I. 2353) was enacted. The purpose of the fourth regulation is to enforce the standards for minimum energy efficiency for self-ballasted fluorescent lamps and light-emitting diode lamps imported or manufactured in Ghana.

Details of these four regulations and standard protocols for determining the energy efficiency star ratings for (non-ducted air-conditioners, household refrigerating appliances and lamps and CFLs), categories of household refrigerators and initial luminous efficacy of the lamps are available and can be assessed under Legislative Instruments (list of L.I's for energy efficiency) at [35].

In conclusion, Ghana has developed and implemented four (4) main end-use policies, regulations and standards to promote demand-side management (DSM). Seventeen (17) other regulations are currently being developed for other electrical appliances such television (TV) sets, electric motors, washing machines, blenders, etc. **Table 2** lists the four (4) regulations, its scope and targets, the year they were enacted by the Ghanaian Parliament and their implementation dates.

5. Testing and inspection procedures

To achieve the full potential of the MEPS programmes, Ghana adopted rigorous testing, approval and inspection procedures for importing these regulated appliances into the country. Currently, Ghana does not manufacture these appliances, so testing is done by third-party accredited laboratories such as Vkan Certification & Testing Co., Ltd. (CVC), Intertek, TUV-Rhineland, DEKRA Product Testing & Certification, General Society of Surveillance (SGS) and Bureau Veritis (BVAC). These testing facilities are recommended and designated by the Ghana Standards Authority and Ghana Energy Commission. A performance test report, which details

the performance of the appliance in terms of energy consumption, approved refrigerant, climate class, star rating, etc. from these facilities, is then submitted to the Ghana Energy Commission by the importer concerning a particular model, for evaluation. Certificate of approval (COA), containing parameters of the said model, is issued to the importer for model(s) that meet the MEPS requirements as laid down in the energy efficiency guidelines [31].

The testing, approval and inspection procedures of a model are summarized in **Figures 2** and **3**.

Having reviewed all the available documents, regulations, standards, procedures and processes, the next section provides some of the real impacts resulting from MEPS implementation in Ghana since 2007.

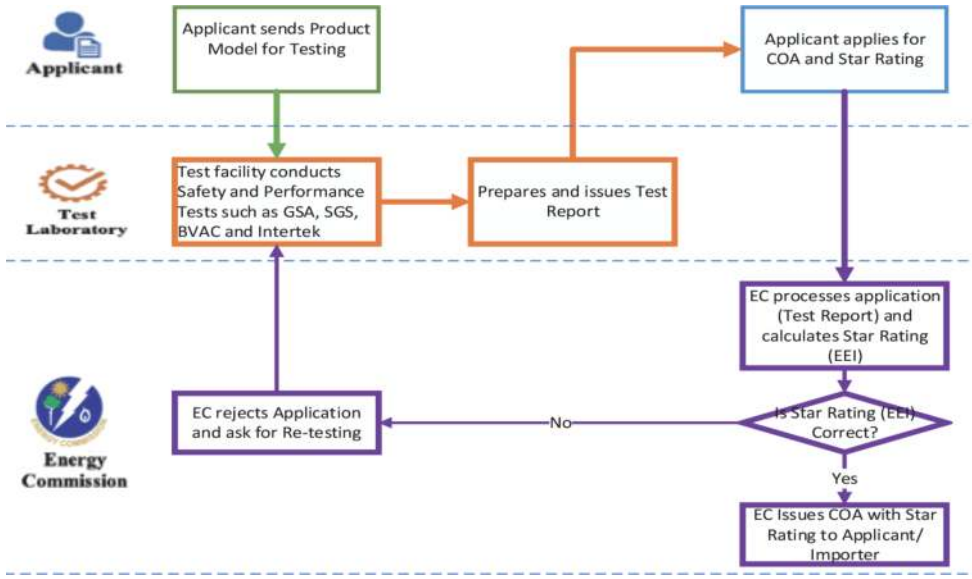

Figure 2.
Testing and approval processes for model(s) to be imported into Ghana.

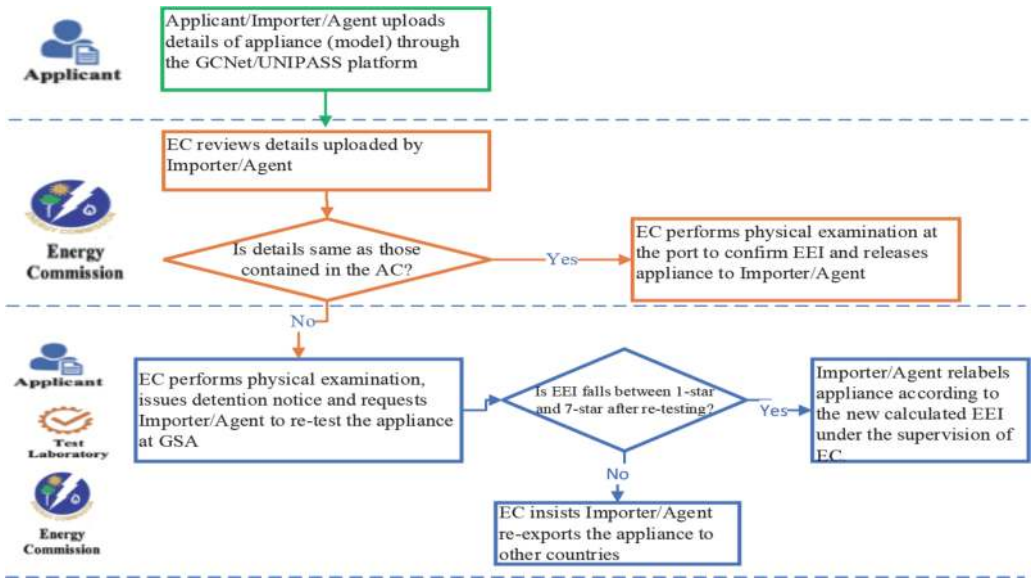

Figure 3.
Physical inspection procedures of a model at the ports of entry.

6. Results and discussion

This section discusses the impact of the major energy efficiency programmes resulting from MEPS implementation in Ghana based on Eqs. (1)–(4) between 2007 and 2020.

6.1 Ghana's efficient lighting project

In 2007, Ghana implemented an efficient lighting project (CFL exchange programme) regarding its policy directions in the area of energy efficiency. On the advice of the Ghana Energy Commission, the Government procured and distributed over six (6) million compact fluorescent lamps (CFLs) to replace the estimated six million incandescent lamps at no cost to the beneficiaries [36]. As a result of this project, incandescent lamp usage in households has reduced from 58–3% while CFLs penetration increased from 20% in 2007 to 79% in 2009 [36]. The country's peak electricity demand was accordingly reduced by 124 MW and peak electricity consumption by 72.8 GWh per year due to this policy implementation. This resulted in an energy cost saving of about US$ 39.5 million per year and carbon dioxide (CO_2) savings estimated at 105,000 tonnes per year [36]. Consequently, there was a delay in the generation expansion of thermal energy investment of US$ 105 million. At US$ 120/bbl, energy cost saving would amount to US$ 39.5 million per year [37]. The project received a Global Energy Efficiency Award in 2010 organized by the Energy Efficiency Global Forum in Brussels, Belgium (12–14 April 2011) [36].

6.2 Ghana's refrigerator turn-in and rebate scheme

Reports available at the Ghana Energy Commission indicated that the Government of Ghana, in September 2012, through the Ghana Energy Commission, launched the national refrigerator turn-in and rebate scheme with the support of the United Nation Development Programme (UNDP), Global Environment Facility (GEF) and Multilateral Fund of the Montreal Protocol (MFMP). The scheme, which encouraged consumers to exchange their old refrigerators for new and efficient ones, available at a discounted price, was to recover about 50,000 inefficient refrigerating appliances from homes and promote the use of more energy-efficient ones and transform the refrigerating appliances market in the country. By mid-June, 2016, a total of 10,472 units of old energy-inefficient appliances have been replaced across the country with new energy-efficient ones [38]. Customers who participated in the project had their consumption reduced from 1200 kWh per year to 385 kWh per year, resulting in a saving of about 400 GWh of electricity, 1.1 million tonnes of carbon dioxide (CO_2) and about 1500 kg of Chlorofluorocarbon (CFC) recovered [38]. This translated into a household income saving of about US$ 140 per year [38].

6.3 Enforcement of legislative instrument 1932

The enforcement of L.I. 1932 at Ghana's ports of entry by the Ghana Energy Commission prohibited the importation of an estimated number of 4,854,864 units of used refrigerating appliances between 2013 and 2020. A total of 5825.84 GWh of electricity would have been consumed with over 2.33 million tonnes of CO_2 released into the atmosphere if the ban was not enforced. However, data available at the Ghana Energy Commission shows that a total of 46,666 used refrigerators and 11,003 used RACs were imported through illegal means by some recalcitrant

importers. They were subsequently confiscated by the Ghana Energy Commission inspectors positioned at the ports and evacuated for e-disposal [39]. **Figure 4** shows the yearly trend in the importation of used refrigerators, particularly the downward trend between 2013 and 2020 during MEPS implementation.

The average annual energy consumptions of a used refrigerator and used RAC are 1200 kWh per year and 4000 kWh per year respectively [39]. The rigorous enforcement of L.I. 1932 since 2013, yielded a total of 100 GWh of electricity and 40,000 tonnes of CO_2 savings for those confiscated used appliances based on Eqs. (2) and (3).

6.4 Enforcement of legislative instrument 1958

Enforcing L.I. 1958 resulted in the importation of 2,378,432 new and efficient refrigerating appliances into the country between 2013 and 2020, thus preventing the importation of used and inefficient ones [39]. Data analysis indicated that 92% of all refrigerating appliances imported between 2013 and 2020 were new and efficient in accordance with L.I. 1958. About 74.8% of these appliances were 2- to 5-star rated with 87.2% of all imports laden with R600a refrigerant (hydrocarbon) [39], which has both low global warming potential (GWP) and low ozone-depleting potential (ODP) and therefore more energy-efficient [40]. The remaining 8%, which were used refrigerators were confiscated. The rise in the importation and sale of new refrigerating appliances is primarily due to strict regulations, procedures and controls implemented at the ports of entry, regular market surveillance and stringent compliance monitoring. These measures help to ensure that only appliances that meet MEPS are permitted into the Ghanaian market. **Figure 5** shows how the refrigerating appliance market in Ghana has evolved/transformed over the years (2005–2020) from being a completely used and inefficient refrigerator market (88.9% inefficient in 2005) to new and efficient ones (99.1% efficient in 2020) as a result of MEPS implementation.

The average annual energy consumption of these new and efficient appliances has dropped drastically due to MEPS implementation compared with the used refrigerators. Consumption values reduced from about 1400 kWh per unit per year to 340 kWh per unit per year [39]. **Figure 6** shows the trend in the average annual energy consumption patterns of refrigerating appliances over the years especially that during the implementation period.

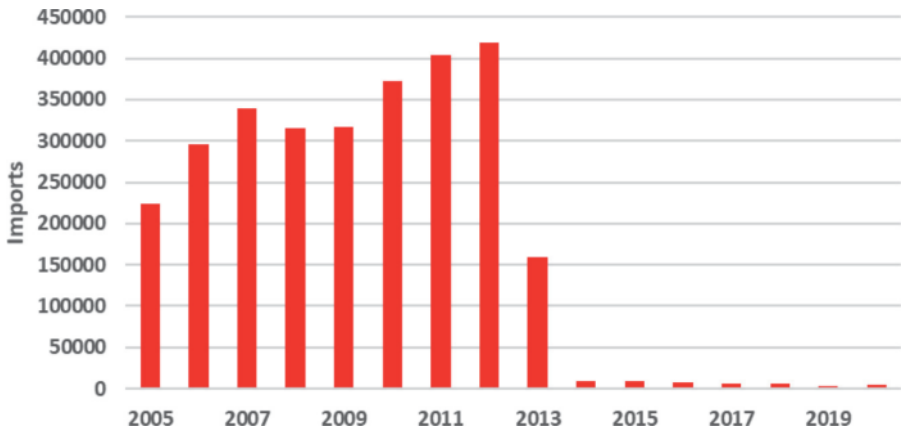

Figure 4.
Yearly imported used refrigerating appliances to Ghana from 2005 to 2020.

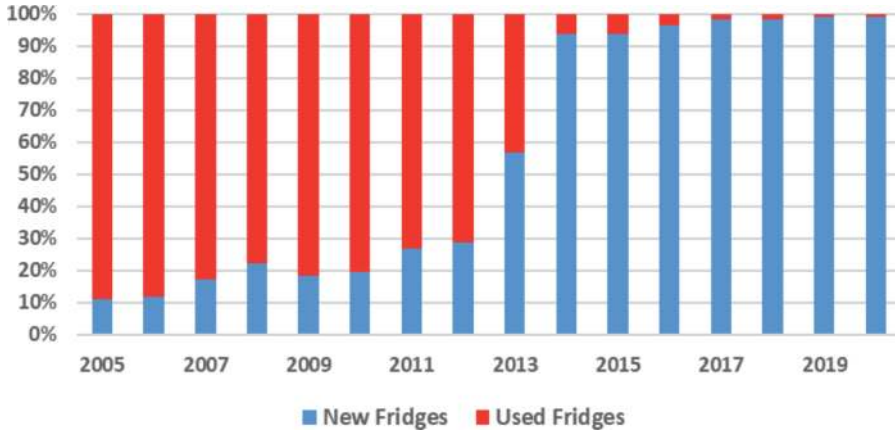

Figure 5.
Evidence of transformed market through MEPS from 2005 to 2020.

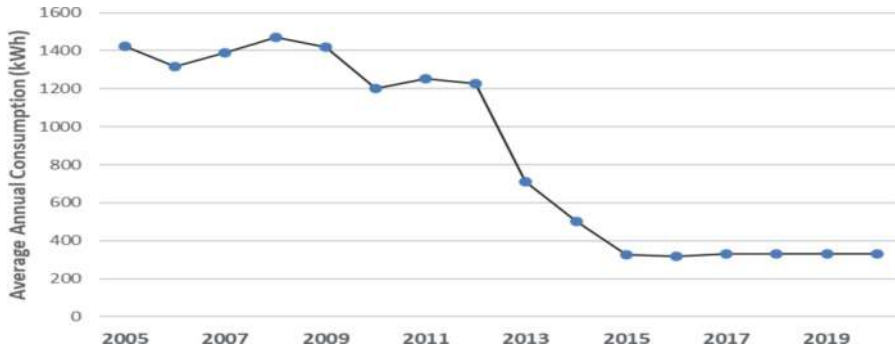

Figure 6.
Average annual energy consumption patterns for new fridges.

Assuming that 90% of the new refrigerating appliances were sold between 2013 and 2020. **Figure 7** presents the analysis of the total electricity and CO_2 emission savings based on Eqs. (1)–(3). From the analysis, a total of 5845 GWh electricity has been saved with a corresponding 2.56 million tonnes of CO_2 emission savings resulting from MEPS due to L.I. 1958 enforcement. This is equivalent to more than 3.4% of the total ***thermal electricity generated*** in 2015 [6], thereby further preventing the construction of a 667 MW power plant capacity.

6.5 Enforcement of legislative instrument 1815

A total of 904,923 new RACs were imported and inspected at the Port of Tema since 2014 [39]. About 54.6% of the RACs on the Ghanaian market are 1-star rated with an average EER of 2.87, which is above the minimum EER of 2.80 with an average annual rated power consumption of 3347.4 kWh [37]. Also, 56% of the RACs were laden with R410a refrigerant which is more energy-efficient than R22 [40]. The average annual energy consumption of a used RAC is 4000 kWh per year [39]. Therefore, 652.6 kWh of electricity has been saved per unit per year due to MEPS. Assuming that 90% of the new RACs were sold between 2014 and 2020. **Figure 8** presents the analysis of the total electricity and CO_2 emission savings using Eqs. (1)–(3). From the analysis, about 1900 GWh electricity has been saved with a corresponding 783,000 tonnes of CO_2 emission savings resulting from MEPS due to L.I. 1815 enforcement.

Year	Imports	Sales	Years Fridge in Use	Energy Savings per Unit (kWh/yr)	Total Energy savings (GWh)	Grid Emission Factor (tCO2eq/MWh) [6]	Cummulative CO2 Savings (MtCO2)
2013	209,824	188,842	8	488	737.24	0.46	0.34
2014	142,764	128,488	7	699	628.69	0.36	0.23
2015	128,697	115,827	6	800	555.97	0.31	0.17
2016	218,073	196,266	5	860	843.94	0.43	0.36
2017	390,686	351,617	4	860	1209.56	0.47	0.57
2018	373,656	336,290	3	860	867.63	0.53	0.46
2019	380,298	342,268	2	860	588.70	0.45	0.26
2020	534,434	480,991	1	860	413.65	0.40	0.17
Total	**2,378,432**	**2,140,589**			**5,845.39**		**2.56**

Figure 7.
Analysis of total electricity and CO_2 emission savings for refrigerating appliances.

Year	Imports	Sales	Years RAC in Use	Energy Savings per Unit (kWh/yr)	Total Energy savings (GWh)	Grid Emission Factor (tCO2eq/MWh)[6]	Cummulative CO2 Savings (ktCO2)
2014	104,205	93,785	7	652.6	428.4	0.36	154.23
2015	101,455	91,310	6	652.6	357.5	0.31	110.83
2016	77,137	69,423	5	652.6	226.5	0.43	97.41
2017	148,583	133,725	4	652.6	349.1	0.47	164.07
2018	139,781	125,803	3	652.6	246.3	0.53	130.54
2019	163,290	146,961	2	652.6	191.8	0.45	86.32
2020	170,472	153,425	1	652.6	100.1	0.40	40.05
Total	**904,923**	**814,431**			**1,899.80**		**783.44**

Figure 8.
Analysis of total electricity and CO_2 emission savings for RACs.

6.6 Compliance levels of refrigerating appliance and RACs

Analysis of some of the reports at the Ghana Energy Commission indicated that the compliance levels of the refrigerating appliances and RACs have been increasing over the years. Between 2017 and 2020, the compliance level of the imported refrigerating appliance increased from 92.6% to 97.0% whilst that of RACs also saw an upsurge from 79.2% to 96.8% [37, 39]. **Figure 9** shows the trends in the compliance levels of these appliances from 2017 to 2020.

The analysis further revealed that the following factors contributed to the high compliance levels in an attempt to transform the appliance market in Ghana [37, 39]:

i. Submission of performance test report by importers from third-party accredited laboratories to the Ghana Energy Commission for evaluation and approval or otherwise;

ii. Establishment of import appliance database/register;

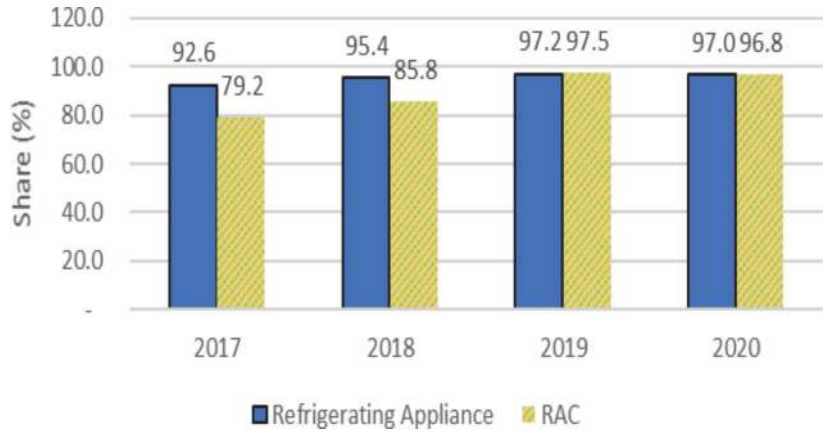

Figure 9.
Trends in compliance levels for refrigerating appliances and RACs from 2017 to 2020.

iii. Operationalization of the GCNet/ICUMS digital portals for approving only appliances that meet MEPS;

iv. Rigorous physical examination procedures/protocols put in place at the ports of entry;

v. Regular and consistent market surveillance;

vi. Stringent compliance monitoring;

vii. Removal of non-compliant appliances from showrooms for testing and re-labelling;

viii. Payment of enforcement fees for non-compliance;

ix. Verification and challenge testing procedures; and

x. Development of a Certified Appliances Mobile Application (APP) which contains all the approved appliances, nearby shops, tips on how to save energy. This APP also helps consumers to make an informed purchase decision. To download the APP, retailers and consumers are required to search for ***CERTIFIED APPLIANCE APP*** on the google play store. iPhone users will have to wait for a while as the APP is being developed for those on the iOS/iPadOS platforms.

7. Conclusion

Ghana's drive to transform the appliance market from the used and inefficient appliances to new and efficient ones has been highly recommended over the years. From this review or study, Ghana developed and implemented MEPS successfully for refrigerating appliances, RACs and lighting systems. This was done through the engagement of relevant stakeholders with complementary financial and technical assistance from development partners. Through MEPS implementation, annual average energy consumptions of refrigerating appliances and RACs have decreased drastically. The implementation of MEPS programmes in Ghana during the period under review yielded 8317.8 GWh (8.32 TWh) of electricity savings, while at the same time reducing fossil CO_2 emissions by 4.60 million tonnes. This figure roughly

corresponds to the total thermal electricity generated (8424 GWh) in 2017 [6]. At 10 US cents per kWh, about USD 832 million has been saved on electricity bills. This enormous financial saving and environmental benefit resulting from deferred electricity consumption amplifies the positive implication of energy efficiency and MEPS programmes. In conclusion, the implementation of energy efficiency programmes delayed the construction of a 950 MW power plant capacity. The 17 other regulations that are currently being developed for other electrical equipment such as television sets, electric motors, washing machines, blenders, etc. must be concluded in good time to enable further energy savings for the country.

Acknowledgements

I would like to thank the following organizations that contributed valuable information on the subject: Ghana Energy Commission, Energy Foundation, Council for Scientific and Industrial Research—Institute of Industrial Research, Ghana Revenue Authority, International Energy Agency (IEA), European Union (EU), Collaborative Labelling and Appliance Standards Program (CLASP) and Lawrence Berkeley National Laboratory (LBNL).

Conflict of interest

The author, Edwin Kwasi Tamakloe is an employee of the Ghana Energy Commission which is one of the stakeholder institutions discussed in the article. This is indicated transparently in the author affiliations.

A. Appendices and nomenclature

See **Figure A1**.

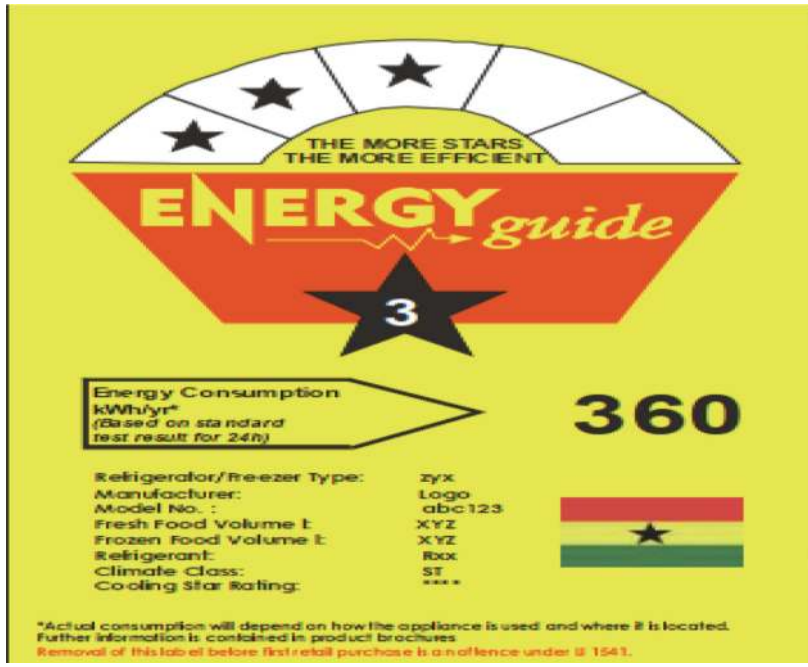

Figure A1.
Sample of a three (3) star rated energy guide label for refrigerating appliance in Ghana [41].

Author details

Edwin Kwasi Tamakloe
Energy Statistician, Energy Efficiency Inspection and Enforcement Directorate, Ghana Energy Commission, Accra, Ghana

*Address all correspondence to: edwintamakloe@yahoo.com

References

[1] International Energy Agency. Energy Efficiency in Building [Internet]. 2017. Available from: https://elearning.iea.org/courses/course-v1:IEA+BUILDINGS1+Open/courseware/e9bce3dd7e1c4dc291718549aff3e641/c2c1535f6e814152b668e559f3bc11d2/?child=first%20pdf [Accessed: 31 May 2021]

[2] Global Alliance for Buildings and Construction, International Energy Agency, the United Nations Environment Programme. Global status report for buildings and construction [Internet]. 2019. Available from: https://www.unep.org/resources/publication/2019-global-status-report-buildings-and-construction-sector.pdf [Accessed: 20 May 2021]

[3] Lu W. Potential energy savings and environmental impact by implementing energy efficiency standards for household refrigerators in China. Energy Policy. 2006;**34**(13):583-1589. DOI: 10.1016/j.enpol.2004.12.012

[4] Brounen D, Kok N, Quigley JM. Residential energy use and conservation: Economics and demographics. European Economic Review. 2012; **56**(5):931-945. DOI: 10.1016/j.euroecorev.2012.02.007

[5] Wang Z, Zhang B, Yin Y, Zhang Y. Determinants and policy implications for household electricity-saving behaviour: evidence from Beijing, China. Energy Policy. 2011;**39**(1):3550-3557. DOI: 10.1016/j.enpol.2011.03.055

[6] Ghana Energy Commission. National Energy Statistics [Internet]. 2021. Available from: http://www.energycom.gov.gh/files/National%20Energy%20Statistics%202021.pdf [Accessed: 02 May 2021]

[7] Druckman A, Jackson T. Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model. Energy Policy. 2008;**36**(8):3177-3192. DOI: 10.1016/j.enpol.2008.03.021

[8] Saidur R, Masjuki HH, Jamaluddin MY. An application of energy and exergy analysis in the residential sector of Malaysia. Energy Policy. 2007;**35**(2):1050-1063. DOI: 10.1016/j.enpol.2006.02.006

[9] Azlina AA, Engku Abdullah ES, Kamaludin MA, Radam AL. Energy conservation of residential sector in Malaysia. Journal of Business and Social Development. 2015;**3**(2):51-62

[10] Constantine S, Denver A, Hakim S, McMahon JE, Rosenquist G. Ghana Residential Energy Use and Appliance Ownership Survey: Final Report on the Potential Impact of Appliance Performance Standards in Ghana (No. LBNL-43069). Berkeley, CA, US: Ernest Orlando Lawrence Berkeley National Laboratory; 1999

[11] CLASP. Africa air conditioner market scoping study. Market Survey Report. 2018. pp. 1-43

[12] Adom PK, Adams S. Energy savings in Nigeria. Is there a way of escape from energy inefficiency? Renewable and Sustainable Energy Reviews. 2018;**81**(1): 2421-2430. DOI: 10.1016/j.rser.2017.06.048

[13] Ghana Energy Commission. Strategic National Energy Plan (SNEP II): Energy Demand Projections for the Economy of Ghana [Internet]. 2019. Available from: http://energycom.gov.gh/files/SNEP%20Demand%20Oct2019_SNEP2030_Final.pdf [Accessed: 02 May 2021]

[14] Agyarko KA, Opoku R, Van Buskirk R. Removing barriers and promoting demand-side energy

efficiency in households in Sub-Saharan Africa: A case study in Ghana. Energy Policy. 2020;**137**(1):1-11. DOI: 10.1016/j.enpol.2019-111149

[15] Hagan EB, Van Buskirk R, Ahenkorah AO, McNeil MA. Refrigerator efficiency in Ghana: Tailoring an appliance market transformation program design for Africa. Energy Policy. 2007;**35**(4):2401-2411. DOI: 10.1016/j.enpol.2006.08.017

[16] Charter E. Policies That Work: Introducing Energy Efficiency Standards and Labels for Appliances and Equipment [Internet]. 2009. Available from: https://www.energycharter.org/fileadmin/DocumentsMedia/Thematic/EE_Standards_and_Labels_2009_en.pdf [Accessed: 28 June 2021]

[17] Ellis M, Pilven Z, Evans C, McAndrew L. Compliance Counts: A Practitioner's Guidebook on Best Practice Monitoring, Verification, and Enforcement for Appliance Standards & Labelling. Washington DC: CLASP [Internet]; 2010. Available from: https://storage.googleapis.com/clasp-siteattachments/2010-09_MVEGuidebookSingle.pdf [Accessed: 16 May 2021]

[18] Ofosu-Ahenkorah AK. Transforming the West African Market for Energy Efficiency: Ghana Leads the Way with Mandatory Standards and Labels [Internet]. 2002. Available from: https://storage.googleapis.com/clasp-siteattachments/2002_CLASP_GhanaSL.pdf [Accessed: 10 May 2021]

[19] Guo Q, Wu Y, Ding Y, Feng W, Zhu N. Measures to enforce mandatory civil building energy efficiency codes in China. Journal of Cleaner Production. 2016;**15**(119):152-166. DOI: 10.1016/j.jclepro.2016.02.002

[20] Du M, Wang B, Zhang N. National research funding and energy efficiency: Evidence from the National Science Foundation of China. Energy Policy. 2018;**120**(1):335-346. DOI: 10.1016/j.enpol.2018.05.058

[21] Langlois-Bertrand S, Benhaddadi M, Jegen M, Pineau PO. Political-institutional barriers to energy efficiency. Energy Strategy Reviews. 2015;**8**(1):30-38. DOI: 10.1016/j.esr.2015.08.001

[22] Kenfack J, Bossou OV, Tchaptchet E. How can we promote renewable energy and energy efficiency in Central Africa? A Cameroon case study. Renewable and Sustainable Energy Reviews. 2017;**75**(1):1217-1224. DOI: 10.1016/j.rser.2016.11.108

[23] Akerlof GA. The market for lemons: Quality uncertainty and the market mechanism. The Quarterly Journal of Economics. 1970;**84**(3):488-500. DOI: 10.1016/B978-0-12-214850-7.50022-X

[24] Butler K, Gordon R, Roggeveen K, Waitt G, Cooper P. Social marketing and value in behaviour? The perceived value of using energy efficiently among low-income older citizens. Journal of Social Marketing. 2016;**6**(2):144-168. DOI: 10.1108/jsocm-07-2015-0045

[25] European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions [Internet]. 2011. Available from: https://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0109:FIN:EN:PDF [Accessed: 18 June 2021]

[26] Craig CA, Feng S. Exploring utility organization electricity generation, residential electricity consumption, and energy efficiency: A climatic approach. Applied Energy. 2017;**185**(1):779-790. DOI: 10.1016/j.apenergy.2016-10-101

[27] Wiel S, McMahon JE. Energy Efficiency Labels and Standards: A Guide for Appliances, Equipment and Lighting. 2nd ed. Washington, D.C., USA: Collaborative Labelling and

Appliance Standards Program (CLASP); 2005. Available from: https://escholarship.org/content/qt01d3r8jg/qt01d3r8jg.pdf [Accessed: 17 June 2021]

[28] McMahon JE, Wiel S. Governments should implement energy-efficiency standards and labels cautiously. Energy Policy. 2003;**31**(13):1403-1415. DOI: 10.1016/S0301-4215(02)00199-4

[29] Nadel S, DeLaski A. Appliance Standards: Comparing Predicted and Observed Prices [Internet]. 2013. Available from: https://appliancestandards.org/sites/default/files/Appliance_Standards_Comparing_Predicted_Expected_Prices.pdf [Accessed: 16 May 2021]

[30] Van Buskirk RD, Kantner CLS, Gerke BF, Chu S. A retrospective investigation of energy efficiency standards: policies may have accelerated long term declines in appliance costs. Environmental Research Letters. 2014; **9**(11):114010. DOI: 10.1088/1748-9326/9/11/114010

[31] Ghana Energy Commission. Energy Efficiency Guidelines. 2020

[32] International Energy Agency. Achievements of Appliance Energy Efficiency Standards and Labelling Programs: A Global Assessment in 2016, IEA Technology Collaboration Programme [Internet]. 2016. Available from: https://www.iea-4e.org/document/387/achievements-of-appliance-energy-efficiency.pdf [Accessed: 13 May 2021]

[33] Gyamfi S, Diawuo FA, Kumi EN, Sika F, Modjinou M. The energy efficiency situation in Ghana. Renewable and Sustainable Energy Review. 2018;**82**(1):1415-1423. DOI: 10.1016/j.rser.2017.05.007

[34] McMahon J, Van Buskirk R. Standards and labels: Transforming the market for energy-efficient appliances. Clean Energy Solutions Center Webinar Series. 2012

[35] Ghana Energy Commission. Regulation and Codes (List of L.I's for Energy Efficiency) [Internet]. 2021. Available from: http://www.energycom.gov.gh/regulation/regulation-and-codes.pdf [Accessed: 01 May 2021]

[36] Agyarko K. Towards Efficient Lighting Market: The case of Ghana [Internet]. 2011. Available from: http://www.ecreee.org/sites/default/files/event-att/k.agyarko-ouaga_ecreee_presentation.pdf [Accessed: 31 May 2021]

[37] Ghana Energy Commission. Regulated Appliances Market Performance Report [Internet]. 2021. Available from: http://www.energycom.gov.gh/files/Regulated%20Appliances%20Market%20Performance%20Report%20for%20Ghana%20-%202020.pdf [Accessed: 04 July 2021]

[38] Ghana Energy Commission. The success story of the Ghana Refrigerator Efficiency Project [Internet]. 2016. Available from: http://www.energycom.gov.gh/efficiency/the-success-story-of-the-eerp.pdf [Accessed: 13 June 2021]

[39] Ghana Energy Commission. Enforcement of Energy Efficiency Legislative Instruments (1815, 1932 and 1958) at Ports of Entry (with Relevant Indicators/Statistics). 2020. Available from: http://www.energycom.gov.gh/files/Enforcement%20of%20Energy%20Efficiency%20Legislative%20Instruments.pdf [Accessed: 04 July 2021]

[40] Prajapat U. CO_2 as a refrigerant in supermarket refrigeration systems: A Review. International Research Journal of Engineering and Technology. 2019; **6**(6):2472-2489

[41] Ghana Energy Commission. Regulation and Codes (List of L.I's for Energy Efficiency) [Internet]. 2021. Available from: http://www.energycom.gov.gh/files/LI1958.pdf [Accessed: 01 May 2021]