INDUSTRIAL DECARBONIZATION ACCELERATOR

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May 2022

Industrial Energy Efficiency Market Assessment in Ghana

United Nations Industrial Development Organization (UNIDO)

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Project team and authors

Name	Company / Organization
Ali Hasanbeigi, Ph.D (Lead Author)	Global Efficiency Intelligence, United States
Stephen Duodu	Energy Foundation, Ghana
Shadrack O. Nyarko	Enercom Africa, Ghana
Prof Francis Kemausuor	The Brew-Hammond Energy Centre, KNUST, Ghana
Dr. Richard Opoku	The Brew-Hammond Energy Centre, KNUST, Ghana
Chibuzo Igwe	Enercom Africa, Ghana
Dr. Charles K.K Sekyere	The Brew-Hammond Energy Centre, KNUST, Ghana
Prof Emmanuel A. Frimpong	The Brew-Hammond Energy Centre, KNUST, Ghana
Charles Acquaah	Enercom Africa, Ghana
Emmanuel Aheto	Enercom Africa, Ghana
Dr Richard Afriyie Oduro	Enercom Africa, Ghana
Dr Akosua B. K. Amaka-Otchere	The Brew-Hammond Energy Centre, KNUST, Ghana
Kwesi Annan-Takyi	Energy Foundation, Ghana
Yoshinari Suzuki	UNIDO, Austria
Nurzat Myrsalieva	UNIDO, Austria
Eric Gyenin	UNIDO, Ghana

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Executive Summary

Industry sector in Ghana contributes to around 30% of its GDP and employs about 21% of the population. Ghana is a developing country and industrialisation is part of a rapid development goal, like many other developing countries.

The industry value added in Ghana (in Billion 2015 US$) more than doubled between 2010 and 2020. Industry sector energy use will continue to increase in Ghana which will pose a challenge to both energy security as well as meeting its Paris Agreement goals stated in Ghana's Nationally Determined Contribution (NDC). Ghana's industrial sector has emerged as a significant driver of growth in recent years as the country leverages its abundant natural resources to diversify the economy and attract investment.

In line with this target, the United Nations Industrial Development Organization (UNIDO) and the National Designated Authority (NDA) at the Ministry of Finance-Ghana, and with funding from the Green Climate Fund (GCF) is supporting the Ghana government in an Industrial Energy Efficiency Readiness Project.

The aims of the project are to support the implementation of Ghana industry related NDC targets through: (i) Detailed policy formulation for government on Industrial Energy Efficiency; (ii) Developing an initial pipeline of Industrial Energy Efficiency projects; and (iii) Capacity building of local financial institutions on Energy Efficiency assessment.

Our analysis shows that the industrial energy intensity (in MJ/2015 US$) and energy-related CO_2 emissions intensity (in kg CO_2 /2015US$) in Ghana declined during 2010-2017 and increased slightly between 2017 and 2020. We estimated that industrial motor systems in Ghana used around 3,851 GWh of electricity in 2020 while industrial boilers and steam systems used around 20,854 Terajoules (TJ) fuels in 2020.

We also reviewed the current energy efficiency policy and landscape in Ghana and conducted interviews of various stakeholders to identify institutional needs and gaps, barriers to industrial energy efficiency and suitable policies and programs to enhance energy efficiency in Ghana. Our survey showed that technology standards and labels, maximum energy use standards, energy audit and assessment in industries, and financial incentives for industries on investment on energy efficient technologies are the top four (4) policy measures which are likely to be most effective in Ghana.

We also analyzed various energy-efficiency technologies and measures for different industrial motor systems. Using the bottom-up energy-efficiency cost curve model, we estimated cost-effective electricity-savings potentials for each industrial motor systems type in Ghana, separately. We also estimated total technical electricity-savings potentials (what is technologically possible), assuming 100% adoption of series of efficiency measures. Table ES-1 summarizes the energy-savings results.

Our assessment further revealed that the share of total technical electricity-savings potential for industrial pump systems compared to total industrial pump systems energy use is 48%. The share of total technical electricity-savings potential for industrial fan systems compared to total industrial fan systems energy use in Ghana is 38%. Furthermore, the share of total technical electricity-savings potential for industrial compressor systems compared to total industrial compressor systems energy use is 39%.

Table ES-1. Industrial motor systems electricity-savings potential in Ghana in 2020

	Cost-Effective Energy Saving Potential (GWh/yr)	Technical Energy Saving Potential (GWh/yr)
Pump systems	316	325
Fan systems	193	199
Compressed air systems	172	208

Using the average CO_2 emissions factor of the electricity grid in Ghana, we also calculated the CO_2 emissions reduction associated with the electricity-savings potential. The CO_2 emissions reduction will help the country to meet its greenhouse gas (GHG) emissions reduction targets.

To achieve the deep decarbonization goal for industry, five decarbonization pillars (i.e. demand reduction and material efficiency, energy efficiency, fuel switching and electrification, transformative technologies and carbon capture, utilization and storage) must be vigorously pursued in parallel.

Finally, we have presented some of the international best practices in industrial energy efficiency and decarbonization policies and also developed policy recommendations and action plans for industrial decarbonization in Ghana. We have also developed a specific policy proposal for design, implementation and expansion of "Top-100 Energy-Consuming Enterprise Program in Ghana".

Energy efficiency in industry stimulates economic growth and creates jobs in a variety of ways (direct, indirect, and induced jobs creation). Investment in energy efficiency creates more jobs per dollar invested than traditional energy supply investments. Energy efficiency also creates more jobs in the local economy. In addition, the reduction in demand for electricity generation and energy use in industry will help to reduce the emissions of air pollutants and improve local and regional air quality in cities in Ghana.

1. Introduction

Ghana is the 8th largest economy in Africa and has a population of 31 million people (World Bank 2022). Ghana is a developing country and industrialization is a major part of its development goal, like many other developing countries. Industry sector energy use will continue to increase in Ghana which will pose a challenge to both energy security and meeting its Paris Agreement goals stated in Ghana's NDC. Ghana's industrial sector has emerged as a significant driver of growth in recent years as the country leverages its abundant natural resources to diversify the economy and attract investment.

The Government of Ghana as part of its commitment to the Nationally Determined Contribution (NDC) towards climate change mitigation, has set up a target of **improving energy efficiency in the industrial sector by 20% by 2030, subject to the provision of climate finance, technology and capacity building support from the international community.**

Industry sector in Ghana contributes to around 30% of its GDP and employs about 21% of the population (Statista 2022a,b). Although Ghana has sufficient power plant capacities, it often experiences challenges with the reliable supply of fuel to its power stations, both on the provision of gas to thermal power plants and availability of sufficient water levels to operate hydropower plants. As a result, Ghana has been experiencing occasional shortages in power supply, significantly impacting its economy and industries. The estimated damage caused to industries due to the shortage of power in 2014 was about USD 680 million in loss of revenue, translating into about 2% of GDP (Ghana Energy Commission, 2018). Thus, increasing the energy efficiency in Ghana's industrial sector can both lower its susceptibility to power supply shortages, as well as contribute to preventing the shortages in the first place, by lowering demand.

Furthermore, due to unstable power supply, there has been a significant surge in the installation of diesel-powered back-up generators by industrial customers. This back-up generation further increases the carbon intensity of the industrial sector, strengthening the case for improved energy and resource efficiency measures.

Ghana's energy efficiency policies primarily target residential sector and focus on phase out of inefficient household appliances and lighting systems. Energy efficiency in the industrial sector remains at the development stage. There is no baseline data available nor a government program or policy in place to support industrial energy efficiency.

There is a pressing need for industries to become more energy and resource efficient to cope with increasing energy prices and reduce the reliance on highly polluting and expensive diesel-powered generators. Industries lack the necessary tools, capacity and skills to effectively reduce their energy consumption and strengthen their competitiveness. As a result, the energy efficiency potential within the industrial sector remains largely unrealized and the market for industrial energy efficiency services and technologies remains underdeveloped.

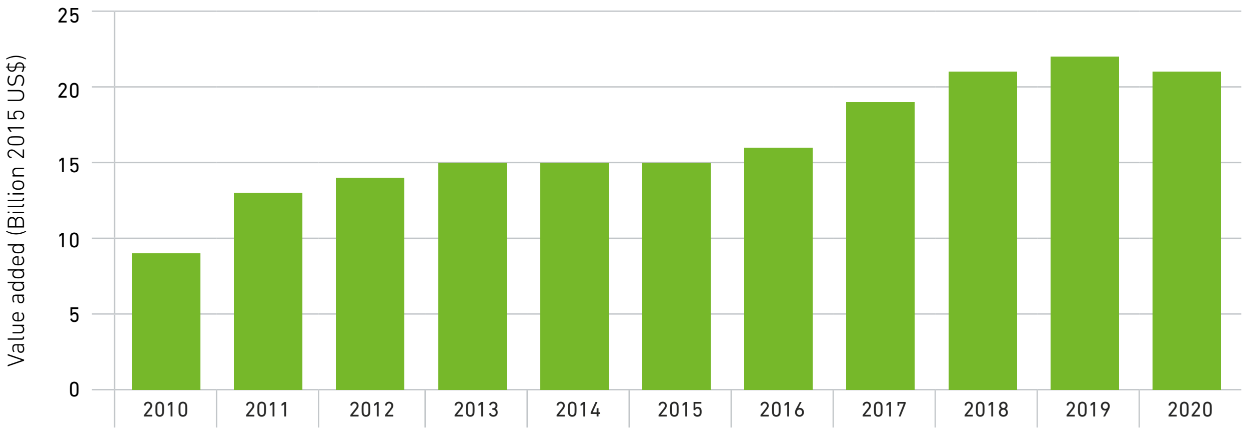
In line with the target of achieving 20% industrial energy efficiency improvement by 2030, the United Nations Industrial Development Organization (UNIDO) and the National Designated Authority (NDA) at the Ministry of Finance-Ghana, and with funding from the Green Climate Fund (GCF) is supporting the Ghana government in an industrial energy efficiency Readiness Project.

The aims of the project are to support the implementation of Ghana industry related NDC targets through: (i) Detailed policy formulation for government on Industrial Energy Efficiency; (ii) Developing an initial pipeline of industrial energy efficiency projects; and (iii) Capacity building of local financial institutions on energy efficiency assessment.

This report presents information on industrial energy use and CO_2 emissions in Ghana and also discusses the policy landscape and barriers to industrial energy efficiency and decarbonization in Ghana. We also discuss institutional needs and gap based on the result of the survey we conducted in Ghana. In addition, we have conducted quantitative analysis to estimate energy efficiency potential in industrial motor systems in Ghana. Also, we discuss qualitatively the main deep decarbonization pillars for industry in Ghana. Furthermore, we discuss international best practices in industrial energy efficiency and decarbonization policies. Finally, we present policy recommendations and action plan to enhance industrial energy efficiency in Ghana.

2. Industrial value added, energy use and CO_2 emissions in Ghana

Like many other developing countries, the industry sector in Ghana has been growing. Figure 1 shows that the Industry value added in Ghana (in Billion 2015 US$) more than doubled between 2010 and 2020. It should be noted that the industry sector includes mining and construction sectors in addition to the manufacturing sector.

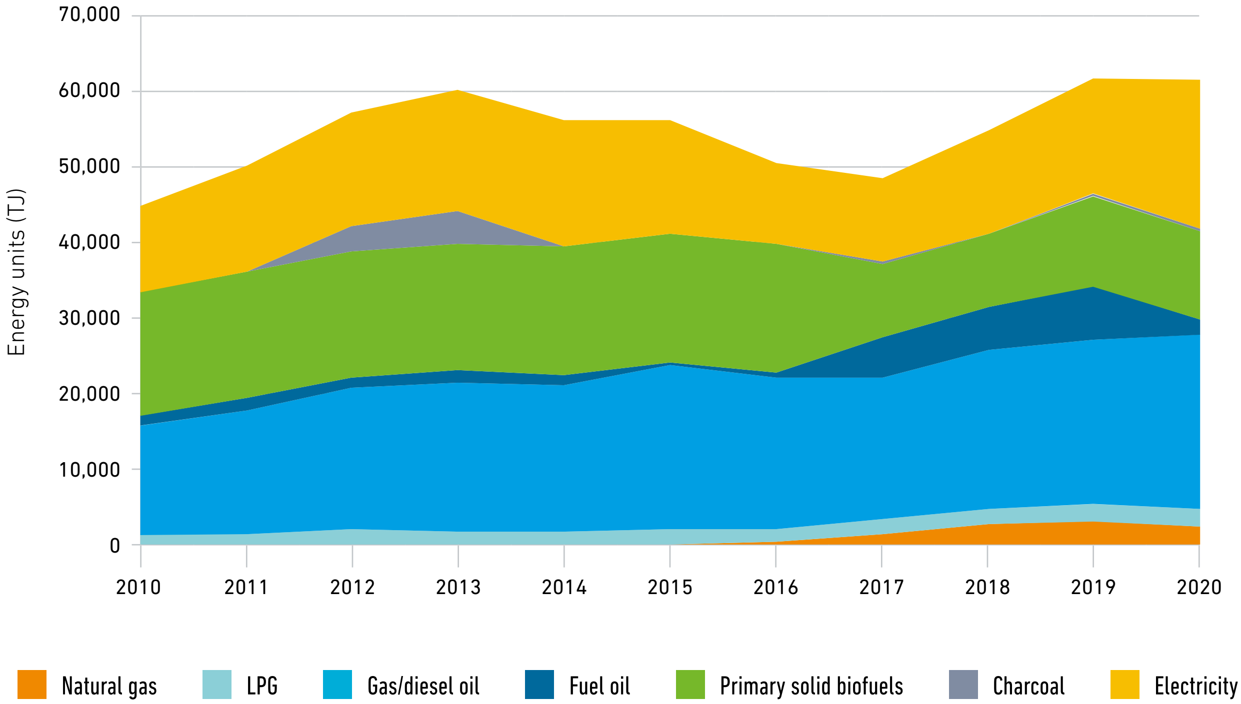


Note: industry includes mining and construction sector in addition to the manufacturing sector.

Figure 1. Industry value added in Ghana (Billion 2015 US$) (World Bank 2021)

Figure 2 shows the energy use in industry sector in Ghana during 2010-2020. It is evident that industrial energy use declined between 2013 and 2017. This was primarily due to inadequate natural gas supply to run most of the thermal power plants, resulting in electricity supply shortages. The shortage in electricity generation to meet the demand resulted in economic slowdown in Ghana during that period which affected the industry sector as well. But the recovery after that period pushed the industrial energy use higher than the 2013 level in recent years.

From the industrial energy use and value-added data, we calculated the energy intensity of industry sector in Ghana during 2010-2020. Figure 3 shows that the industrial energy intensity (in MJ/2015 US$) in Ghana declined during 2010-2017 and increased slightly between 2017 and 2020.



Note: industry includes mining and construction sector in addition to the manufacturing sector.

Figure 2. Energy use in industry sector in Ghana, 2010-2020 (IEA 2021)

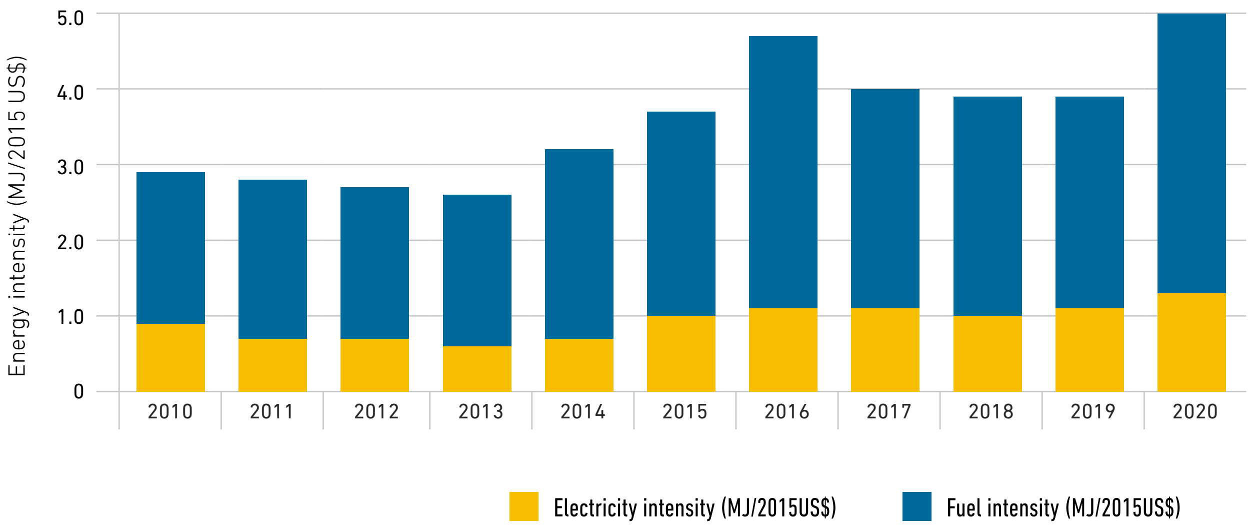


Figure 3. Energy intensity of industry in Ghana, 2010-2020 (MJ/2015 US$)

Using the CO_2 conversion factors for fuel and electricity in Ghana (IPCC 2006), we estimated the total energy-related CO_2 emissions of industry in Ghana in 2010 – 2020. Figure 4 shows both electricity- and fuel-related emissions in industry, separately. Also, Ghana uses substantial amount of biomass as fuel in industry. If biomass is considered carbon-neutral, then there are no CO_2 emissions associated with it. But the carbon-neutrality and sustainability of biomass is increasingly questioned by many scientists.

We have also shown in Figure 4 the CO_2 emissions related to burning biomass in industry in Ghana using the Intergovernmental Panel on Climate Change's (IPCC's) emissions factor for biomass.

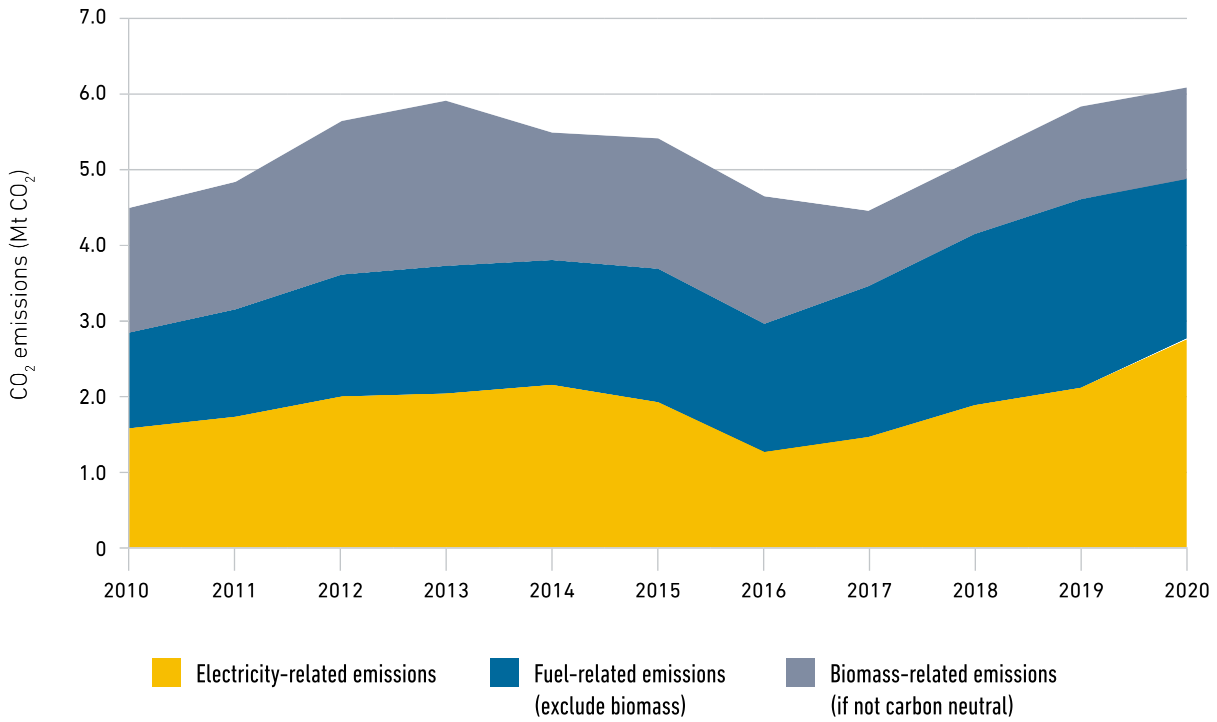


Figure 4. Total energy-related CO_2 emissions of industry in Ghana (Mt CO_2)

Figure 5 shows the calculated energy-related CO_2 emissions intensity of industry in Ghana (in kg CO_2 /2015US$). The industrial CO_2 emissions intensity has a similar trend as the energy intensity shown above with a decrease till 2017 and a slight increase afterwards.

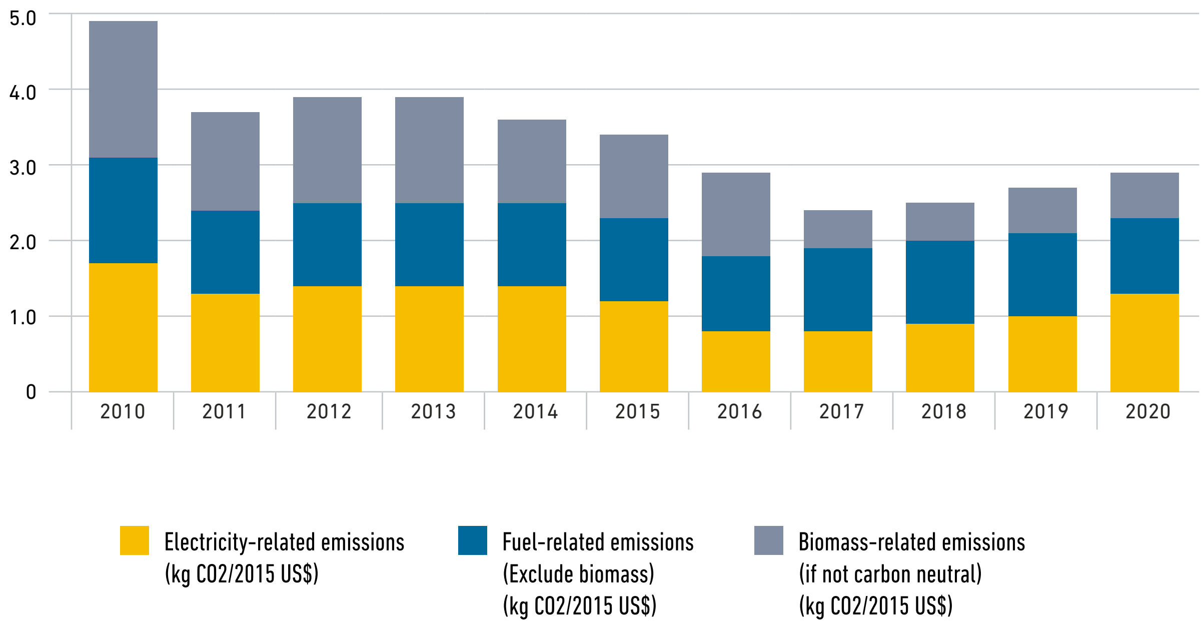


Figure 5. Energy-related CO_2 emissions intensity of industry in Ghana (kg CO_2 /2015US$)

Unfortunately, the energy use data disaggregated by industrial subsectors are not available in Ghana. That is why we were not able to do any subsector level analysis in this study. Also, there is no energy use data for industrial systems (motor systems, steam systems, process heating systems, etc.) in Ghana. We have made an attempt below to estimate the energy use for industrial motor systems and steam systems in Ghana based on several international studies and sources (McKane and Hasanbeigi 2010; US DOE 2022; IEA, 2016a).

According to the International Energy Agency (IEA), industrial electric motor systems account for about 70% of total global industrial electricity usage (IEA, 2016a). Also, the data from US DOE (2022) and analysis by Hasanbeigi and McKane (2011) of industrial motor systems energy use and energy efficiency potential in different countries and regions provide similar range for industrial motor systems energy use. Therefore, we used this 70% share to estimate industrial motor systems electricity use from total electricity use in industry in Ghana (Figure 6).

Another important industrial energy systems are industrial boilers and steam systems. Steam is used extensively as a means of delivering energy to industrial processes. Steam holds a significant amount of energy on a unit mass basis that can be extracted as mechanical work through a turbine or as heat for process use. In addition, steam can be used to control temperatures and pressures during chemical processes, strip contaminants from process fluids, dry paper products, and in other miscellaneous applications. Equipment that uses steam varies substantially among industries and is generally process- and site-specific.

Because there is no data reported on energy use in industrial boilers and steam systems, we tried to estimate the energy use by these important industrial systems using the international sources. Industrial boilers and steam systems (including combined heat and power) can account for about half of total fuel used in industry (US DOE 2022, Hasanbeigi et al. 2014). We used this 50% share to estimate the fuel used in industrial boilers and steam systems in Ghana (Figure 7).

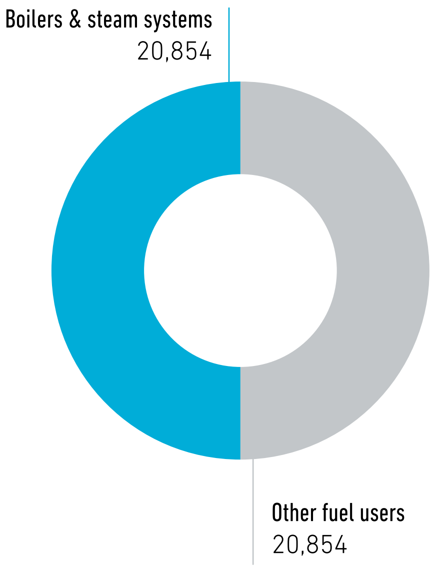


Figure 6. Estimated electricity use in industrial motor systems in Ghana in 2020 (values in GWh)

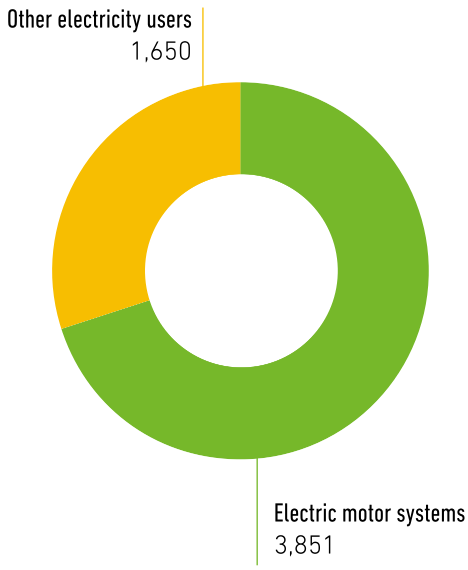


Figure 7. Estimated fuel use in industrial boilers and steam systems (including combined heat and power) in Ghana in 2020 (values in TJ)

3. Industrial energy efficiency policy landscape in Ghana

3.1. Stakeholder mapping in Ghana

The stakeholders of the energy efficiency sub-sector identified in the UNIDO-Ghana industrial energy efficiency Policy Framework Development have been categorized according to their influence and roles in public policy formulation process as Policy Decision Makers; Policy Formulation Contributors & Advisors; Industry Associations; Financial Sector Participants; Individual Company representatives; Energy Efficiency and Renewable Energy Experts; Sustainable Energy Service Centers and Policy Support. All these stakeholders exert various levels of influence on the sub-sector and have a strong inter-relationship amongst them depending on their needs and subject matter.

Ghana IEE Stakeholder mapping

Stakeholders Inter-relationships

Policy Decision Makers	• MoE	• MoF	• MESTI
Policy Formulation Contributors & Advisors	• EC • EF • GSA • NDPC	• Minerals Commission • GFZA • VRA • GRIDCo	• ECG • NEDCo • EPC Ghana
Industry Associations	• AGI • GCM • C-MAG	• SMAG • AGAM • PMAG	• PEF • CIPDIB Ghana
Financial Sector Participants	• Ecobank • Cal Bank • GCB Bank	• ABSA Bank • Stanchart • Stanbic Bank	• Shaham Insurance • Hollard Insurance
Individual Companies	• Steel Company • Cement Company • Mining Company	• Manufacturing Company • Palm Oil Company • Quarrying Company	• Pharmaceutical Company
EE/RW Experts & Consultants	• Association of Solar Installers • Energy Efficiency Services Companies	• Biogas Expert • RE & EE Technologies Importers	
Energy Service Centres	• AGI ESC • KNUST-ESC	• UENR-ESC • ATU-ESC	
Policy Development & Implementation Support	UNIDO, GCF, GIZ and other Donor Community Members		

MoEn	Ministry of Energy	GCM	Ghana Chamber of Mines
MoF	Ministry of Finance,	CMAG	Cement Manufacturers Association of Ghana
MESTI	Ministry of Environment, Science, Technology and Innovation	SMAG	Steel Manufacturers Association of Ghana
EC	Energy Commission	AGAM	Association of Ghana Apparel Manufacturers
EF	Energy Foundation	PMAG	Pharmaceutical Manufacturers Association of Ghana
GSA	Ghana Standards Authority	PEF	Private Enterprise Federation
NDPC	National Development Planning Commission	CIPDiB	Chamber of Independent Power Producers, Distributers and Bulk Consumers
GFZA	Ghana Free Zones Authority	ESC	Energy Service Center
VRA	Voltage Riva Authority	KNUST	Kwame Nkrumah University of Science and Technology
GRIDCo	Ghana Grid Company Limited	UENR	University of Energy and Natural Resources
ECG	Electricity Company of Ghana	ATU	Accra Technical University
NEDCo	Northern Electricity Distribution Company Limited	UNIDO	United Nations Industrial Development Organization
EPC	Enclave Power Company	GCF	Green Climate Fund
AGI	Association of Ghana Industries	GIZ	German Agency for International Cooperation

Figure 8. key stakeholders of industrial energy efficiency in Ghana

3.2. Review of existing regulations, policies, and programs

Policy makers have in the past, paid little attention to the advantages offered by industrial energy efficiency with respect to the impact on climate mitigation, security of energy supply and sustainability (UNIDO, 2007). However, over the last two decades, many governments across the globe, including that of developing countries, are beginning to place huge emphasis on energy efficiency with a particular focus on industrial energy efficiency. The focus on industrial energy efficiency is particularly important because the industrial sector represents more than one third of both global primary energy use and energy related carbon dioxide emissions (UNIDO, 2018). It has now become evident that emerging economies with a fast-expanding industrial infrastructure can increase their competitiveness by applying energy efficiency practices.

Several policies and programs have been implemented in different countries to improve industrial energy efficiency. A summary is provided below from the Lawrence Berkeley National Laboratory.

A. Regulations / Standards

B. Fiscal Policies

C. Agreements / Targets

D. Reporting / Bench Markers

E. Energy Audits /Assessments

F. Information Dissemination & Demonstration

G. Research and Development

These policies and programs are usually implemented for specific sectors of the industry. Then using an integrated approach, a number of policies and programs are put together to create an overall industrial energy efficiency policy to address a variety of needs in the industrial sector. Example of such integrated energy efficiency policies and programs include the Danish Agreements on Industrial Energy Efficiency, Long-Term Agreements on energy efficiency in The Netherlands, the Canadian Industry Program for Energy Conservation, and the Norwegian industrial energy efficiency Network. These policies and programs are described briefly below:

A. Regulations / Standards

Regulations and standards are mandatory policies for improving energy efficiency. They are applied to specific equipment such as boilers and motors. The regulations will sometimes require industries to employ energy managers, conduct energy audits, among others.

B. Fiscal Policies

Imposition of tax, tax rebate, investment tax credits and establishment of investment bank lending criteria for promotion of energy efficiency. Taxation policies can be a mandatory means for implementing energy efficiency. For example, the Danish government provide tax subsidies for energy managers.

C. Agreements / Targets

This involves the use of agreements to meet certain industrial energy efficiency, usually between the government and industry to facilitate desirable outcomes. Agreements can be formulated in different ways. The two common ways of doing this are:

1. Based on specific energy efficiency improvement targets; and
2. Based on specific energy use or carbon emissions reduction commitments.

Examples of industrial sector agreements and target programs include the following:

Australia: Energy Smart Business Program

Canada: Industry Program for Energy Conservation

Denmark: Agreements on industrial energy efficiency

France: Voluntary Agreements on CO_2 Reductions

Finland: Agreements on Industrial Energy Conservation Measures

Germany: Declaration of German Industry on Global Warming Prevention

D. Reporting / Benchmarking

Some policies that require reporting and bench marking have been implemented in some countries. Reporting on energy consumption is proven to be an effective way of raising internal management awareness of energy consumption trends.

E. Energy Audits / Assessments

Assessments and audits done in industrial facilities provide managers with data regarding energy usage patterns as well as opportunities to reduce energy through the implementation of energy efficiency measures.

F. Information Dissemination and Demonstration

This involves the designation of special support networks to gather data on energy efficiency technologies and practices which would rather have been difficult for individual industries to gather for decision making. Examples of these programs are the U.S. Industrial Assessment Centers under the Department of Energy, Norway's Industrial Network for Energy Conservation, and the Australia's energy efficiency Best Practice Program.

G. Research and Development

Research and development of technologies is a systematic way to increase the knowledge pool about people, culture, and society. The knowledge gathered is used to pioneer innovations to improve industrial energy efficiency. Industrial energy research and development can be done by governments, think tanks and private companies. Research and development is very crucial for developing countries for the adaption of technologies to local conditions.

Information available in Ghana suggests that not much has been done with regards to the development and implementation of industrial energy efficiency Policies. It is best to say that industrial energy efficiency policies are still in incubation stages in Ghana. While existing energy policies, plans and programs touch on industrial energy efficiency, there are huge gaps when compared with international convention, such as the items summarized above.

Some further work will be done to understand the state of the current policy framework in Ghana to identify gaps that could be addressed with policy formulation.

4. Assessment of institutional needs and capacity gaps

Global and national commitments to reduce energy intensities of countries is a driving force for most industrial energy efficiency policies (Blanco et al., 2015). Energy efficiency improvement yields benefits to industries in terms of energy savings, which ultimately reduces production cost and make firms more competitive in times of higher energy prices (Chowdhury et al., 2018).

It is thus expected that the motivation for adopting energy efficiency programs should come from shareholders and managers of industries who are usually neoclassical profit maximizing. Evidence abounds that, though industrial energy efficiency benefits seem obvious (in high NPVs and returns), they are not sufficient to incentivize industry players to invest in industrial energy efficiency and thus reflect the low adoption of industrial energy efficiency technologies- efficiency paradox (Decanio, 1998). Where internal motivation is deemed sufficient, industry players may also have to navigate through some other barriers and challenges (Hasanbeigi et al., 2010) that could increase the level of uncertainties in industrial energy efficiency investments. Usually, companies that actively manage their energy use tend to upgrade efficiencies of their equipment and processes, partly due to their internal organizational context which supports energy efficiency (Apeaning, 2012) but also due to enabling external factors.

Therefore, to increase affinity for industrial energy efficiency uptake, it is appropriate for governments to incentivize industry players. From many international reviews on industrial energy efficiency policies, there is evidence that these policy mechanisms abound and though quite similar, they are also unique in many ways and designed to fit a country's context.

Ghana in the 1980s initiated policies and programs for improving energy efficiency in general. Plans for the development and promotion of appliance energy efficiency in Ghana was initiated by the erstwhile National Energy Board in the 1980s and later implemented by the Ministry of Energy and the Ghana Energy Foundation, emphasizing on industrial, public, commercial and residential electrical energy use (CLASP, 2002). Ghana's Electrical Appliance Labelling and Standards Program (GEALSP), the first for sub-Saharan Africa, was therefore launched and customized to meet the country's energy needs, culture and economy. As part of activities towards the energy efficiency programs, the Ghana Energy Commission conducted a national survey between 2003-2006, into appliance electricity consumption in the residential sector. The results of the national survey marked the watershed of an aggressive energy efficiency campaign in Ghana (Agyarko et al. 2020).

The survey revealed that residential electricity use was about 50% of the total national consumption (Agyarko et al. 2020). Energy efficiency interventions, since then has focused on the residential sector. In recent times however, increase in energy demand for the commercial and industrial sectors is calling for attention for energy efficiency measures. Energy efficiency measures targeting commercial and industrial entities in Ghana is therefore of national interest to meet the aspirations of the Nationally Determined Contributions (NDCs) towards climate change mitigation and adaptation.

Recent developments in the country's NDCs to improve industrial energy efficiency by 20% by 2030 demands that requisite policies are designed to achieve that. It is therefore important to review the existing policies as well as investigate possible barriers and challenges of policy makers that inhibit the promotion of industrial energy efficiency.

Policy-related activities required of policy makers in Ghana

In this task, the views of policy makers and regulators were elicited with the following objectives:

- review and understand the existing policy framework (policies, laws, and regulations) for promoting industrial energy efficiency in Ghana;
- understand the challenges and barriers of promoting industrial energy efficiency;
- identify and assess capacity gaps and institutional needs; and
- get the perspectives of policy makers on how to overcome key challenges and barriers.

To achieve the above objectives, the local consortium conducted a survey on relevant policy makers in the energy efficiency space. The local consortium employed a semi-structured questionnaire to gather responses that were subsequently analyzed. In Ghana, the major energy agencies whose core mandates are to formulate energy efficiency policies needed in the industrial sector are the Energy Commission, Ministry of Energy, Ministry of Trade and Industry, and the Environmental Protection Agency, amongst others. Table 1 shows the list of expected policy actions to be undertaken by these agencies.

The study revealed that, for the above to be implemented, the institutions and policy makers ought to be well resourced to enable them to execute these policy actions effectively. Getting the right skilled personnel, motivating management to prioritize and perform well on industrial energy efficiency, and providing funding for industrial energy efficiency programs are some of the strategies to address institutional needs.

Table 1. List of industrial energy efficiency policy-related activities required of policy makers in Ghana

1	Encouraging top management to actively support and become involved in energy efficiency, as well as appointing energy managers.
2	Developing and running training programs and literature on industrial energy efficiency
3	Specialist staff advising on aspects of industrial energy efficiency
4	Organizing regular national energy management conferences and exhibitions aimed at both the private and public sectors of industry and commerce
5	Collecting data from selected representative plants to gain insights into the overall operating efficiencies and the potential areas for energy savings
6	Providing incentives to equipment manufacturers and suppliers to undertake research and development in new and improved energy saving technologies which may prove cost-effective
7	Offering financial assistance and appointment of a monitoring organization that are able to demonstrate new or improved technologies which will bring about energy efficiency
8	Executing and/or encouraging regular energy efficiency audits or assessments in industries

The following section presents information gathered from a survey conducted on policy makers involved in energy efficiency activities in Ghana.

Policy makers survey results

Seven institutions that formulate policy and/or provide support that could influence policy regarding aspects of industrial energy efficiency issues were targeted for this category of respondents. The institutions that were interviewed are: Ministry of Energy (MoEn), Ministry of Trade and Industry (MOTI), Ministry of Finance (MoF), Ministry of Environment, Science, Technology and Innovation (MESTI), Ghana Standards Authority (GSA), Environmental Protection Agency (EPA), and Energy Commission (EC).

The survey questions included issues such as availability of energy efficiency policies; responsibility regarding various aspects of industrial energy efficiency; availability of experts and units within the institutions to support energy efficiency activities; source of funding for energy efficiency programs; support needed to develop energy efficiency programs; data availability, among others.

The survey brought to light the fact that current energy efficiency policies in Ghana largely target home appliances (i.e., ACs, refrigerators and light bulbs). There is presently no clear energy efficiency Act or policy on industrial appliances/equipment, and this is largely due to lack of data and benchmarks for industrial energy efficiency in Ghana. MoEn has no coherent policy on industrial energy efficiency and its agency in charge of technical regulation of the energy sector, Energy Commission, has no specific regulation that bothers on industrial energy efficiency. Although the Cleaner Production Centre (CPC) of the Environmental Project Agency (EPA) does provide some audit support for industries, there is no clear target in place for minimum energy performance standards (MEPS) for various equipment used in industry. It is interesting, however, to note that there are some policy statements scattered across a number of documents including Ghana's NDCs, the National Energy Policy, the Energy Efficiency and Demand Side Management Program. Examples include the policy on Power Factor Correction (Lee et al., 2019) and the NDC policy statement that targets 20% improvement in industrial energy efficiency in Ghana. The following sections highlight some of the challenges to industrial energy efficiency identified from the perspectives of the policy makers.

From the survey response, it was realized that four out of the seven policy-making institutions have designated directorates responsible for general energy efficiency issues. While the responsible directorates appear to have adequate human resources within their offices, they complained of limited outreach staff who would go out to promote energy efficiency programs in industries.

Funding is also a major issue. The energy efficiency directorates are poorly resourced financially, which makes their tasks arduous. Some of the responses include 'we don't have enough staff numbers to undertake outreach programs; we are limited in funds to undertake such programs; our staff don't have the requisite skills to undertake such programs; there is the need to improve on staff capacity building and staff strength'. Funding from international partners and development agencies has been the main financial support for implementing energy efficiency in industries in Ghana. There is high competition for international funding though and it is difficult getting access. Also, international funding sources sometimes require government counterpart funding which is very difficult to commit.

On the issue of data availability, the institutions do collect some data on general energy consumption and industry production data. There have also been instances of industrial energy efficiency data collection by the EC and the EPA. However, there are usually issues of data discrepancies and quality. Data collection frequency is usually once a year or once every two years.

To further ascertain some of the policy-related industrial energy efficiency issues, the institutions were asked to rank ten industrial energy efficiency policies and programs that would be most appropriate for Ghana. Each institution had to select four out of the ten, in order of preference, with 1 being the most preferred. The results obtained are summarized in Table 2.

Since there were more than four items to rank, all items not selected by an institution were given an automatic fifth score to enable easy tallying. Following the ranking, the four topmost items were:

a. Energy standards: technology standards and labels

b. Energy standards: maximum energy use standards

c. Energy audit and assessment in industries

d. Subsidies for industries on investment on energy efficient technologies

To promote industrial energy efficiency, the institutions were of the view that the following support are needed:

a. Funding to conduct baseline industrial energy efficiency study to establish the energy efficiency status of the industrial sector

b. Funding to develop and implement industrial energy efficiency programs/policies

c. Funding / technical support to monitor and evaluate impacts of industrial energy efficiency programs / policies

d. Funding for awareness creation and promotion of Industrial Energy Efficiency

e. Technical / financial support for training industrial energy audit and management professionals.

Table 2. Ranking of industrial energy efficiency policies and programs

Issue	Ranking by institutions							Total/Average score	
	EC	EPA	GSA	MESTI	MoF	MOTI	MoEn	Total*	Avg.
Energy audit and assessment in industries	1	4	1	5	5	4	5	25	3.6
Energy standards: technology standards & labels	2	2	5	1	5	2	5	22	3.1
Energy standards: maximum energy use standards	3	3	2	2	5	5	4	24	3.4
Energy use reporting by plants and benchmarking	4	5	5	5	5	3	5	32	4.6
Information dissemination and demonstration	5	1	5	5	5	5	1	27	3.9
Subsidies for industries on investment on energy efficient technologies	5	5	5	3	4	1	3	26	3.7
Energy tax without recycling of revenue generated	5	5	5	4	2	5	5	31	4.4
Energy tax with recycling of revenue generated	5	5	5	5	1	5	5	31	4.4
Support for Research, Development and Dissemination (RD&D)	5	5	3	5	3	5	2	28	4.0

5. Barriers to and drivers of industrial energy efficiency in Ghana

Energy efficiency has been widely recognized as a powerful tool for improving the energy productivity and reducing emissions in all sectors, globally. Energy efficiency can help in increasing energy security, reducing carbon emissions and alleviating grid strain. Although energy-efficiency practices are gaining impetus globally, their uptake is still less than optimal.

In Ghana for example, energy efficiency practices in industries are generally poor. It is therefore imperative to understand the specific barriers that hinder the implementation of industrial energy efficiency programs in Ghana. In this section, we present some findings on challenges and barriers to industrial energy efficiency in Ghana. Analysis of the barriers to the uptake of industrial energy efficiency as presented here is based on data obtained from survey conducted in some industries in the year 2021. These industrial sub-sectors covered in the survey included Iron & Steel; Cement; Paper & Printing; Textiles & Leather, Cols Stores; Food & Beverages; Irrigation. A number of specific questions were posed to industrial participants and the number of responses obtained in the form of rankings, indicative of availability of certain practices, etc., were used for the analysis. The results from the survey are presented in the following sections.

Management Systems Certification

Management systems certification for industries is important to the efficient utilization of resources in order to ensure quality, safety and consistency in the manufacturing / delivery / running of products, services, and systems.

Lack of adequate management systems certification for industries in any jurisdiction is symptomatic of the existence of wasteful management of resources, little or no regard for global environmental concerns and sustainability. The ISO 9001 defines the criteria for meeting a number of quality management principles, making it a key standards certification requirement for all industries. Table 3 summarizes the percentages of the industries who have or do not have certification for the standards indicated. It can be observed that only 53% of industries have ISO 9001 certification. The ISO 14001 is the standard for environmental management systems (EMS) and the most widely used EMS in the world. Results show that only 21% of the surveyed industries are ISO 14001 certified.

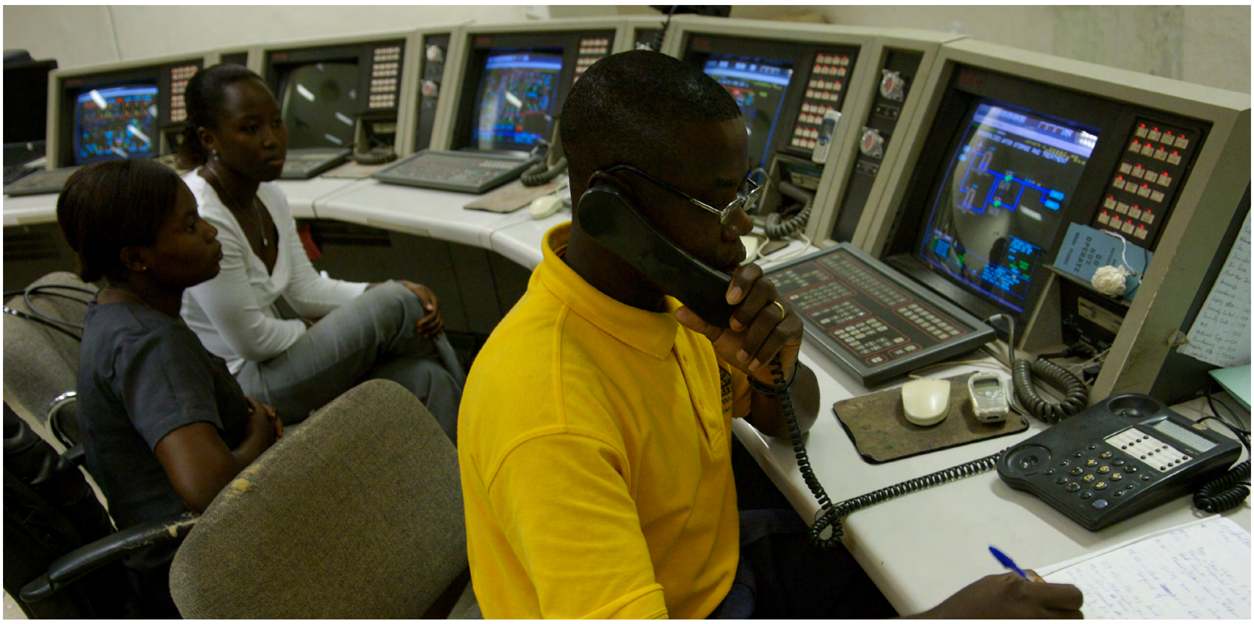


Table 3. Management system standards certification in surveyed industrial companies in Ghana

Certification standards	Number of firms certified	Percentage (%) out of surveyed industries
ISO 9001	18	53
ISO 14001	7	21
ISO 2200	4	12
ISO 50001	2	6
HACCP Management system	2	6
OHSAS 18001	4	12
Do not have any of the above certifications	13	38

ISO 50001 specifies requirements for establishing, implementing, maintaining and improving an energy management system. ISO 50001 demands continuous improvement to achieve desired goals. ISO 50001 certification is the bedrock of industrial energy efficiency since it is directly related to a significant number of other management systems. Data obtained from the field survey shows that only 6% of industries have ISO 50001 certification (see Table 3 above). This extremely low figure could indicate the poor level of awareness and unpreparedness on the part of the industrial sector and key sector stakeholder institutions as far as industrial energy efficiency is concerned.

The OHSAS 18001 certification scheme is designed to enable industries to control risks and improve performance in the area of Occupational Health and Safety. Analysis shows that only 12% of industries involved in the survey were OHSAS 18001 certified.

From Figure 9, it is also observed that 38% of industries do not have certification for any of the indispensable management standards. The extremely low level of management systems certification as revealed by this study clearly shows a yawning gap in efforts to promote industrial energy efficiency in Ghana. Developing and enforcing policies to ensure that all industries receive basic management systems certification as a prerequisite for licensing will be crucial for ensuring sustainability in industries in Ghana.

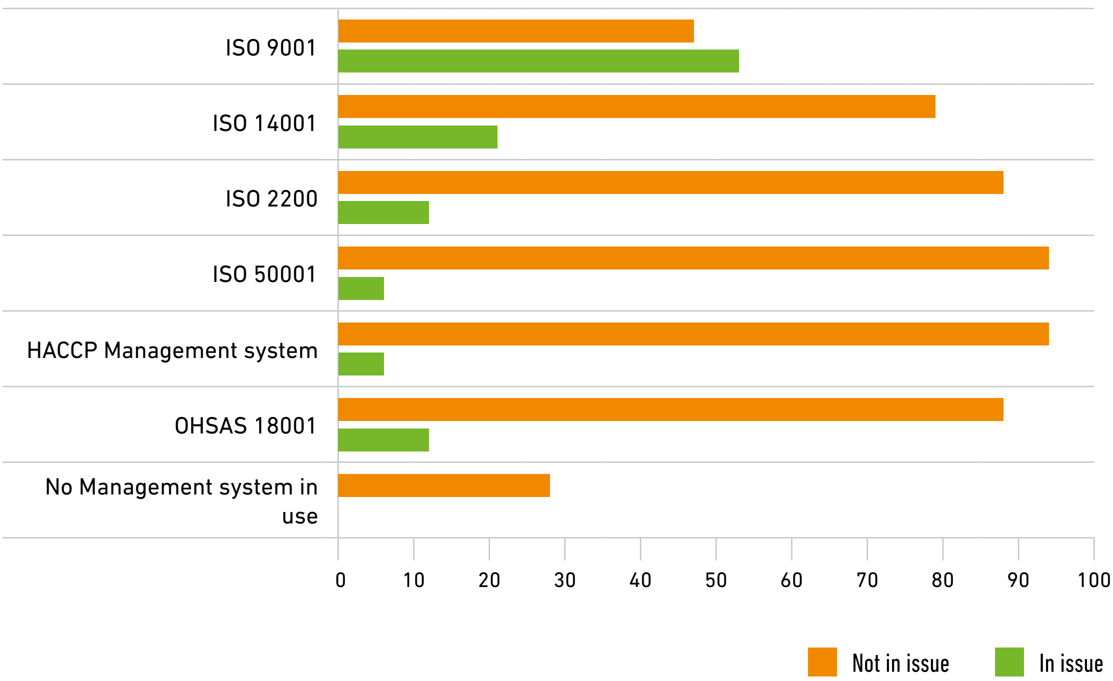


Figure 9. Status of management systems standards certification in surveyed industrial companies in Ghana

Drivers for industrial energy efficiency

Figure 10 below shows the main reasons why companies give attention to energy efficiency. The rankings done show that about 59% of industries consider production cost/control as the main motivation for adopting measures to improve energy efficiency. This is followed by Need to Reduce Energy Cost with a ranking of 27% and Improved Product Quality following closely with 24% ranking as the 3rd highest priority ranking. Corporate image/social responsibility, improved product quality and market/client were regarded as lowest order priorities drivers for companies' attention to energy efficiency with percentage rankings of 18%, 15% and 12% respectively. One of the industrial energy efficiency attention drivers which received unusually low rankings in terms of priority is CO_2 emission reduction. It must be pointed out that energy efficiency and sustainability go hand-in-hand with cleaner production technology deployment. The low ratings arising from the analysis with respect to emission reduction is a clear indication that companies are deficient in their knowledge of the drive to attain the SDGs in respect of industrial energy efficiency. This is seen as a major barrier to the uptake to industrial energy efficiency in Ghana.

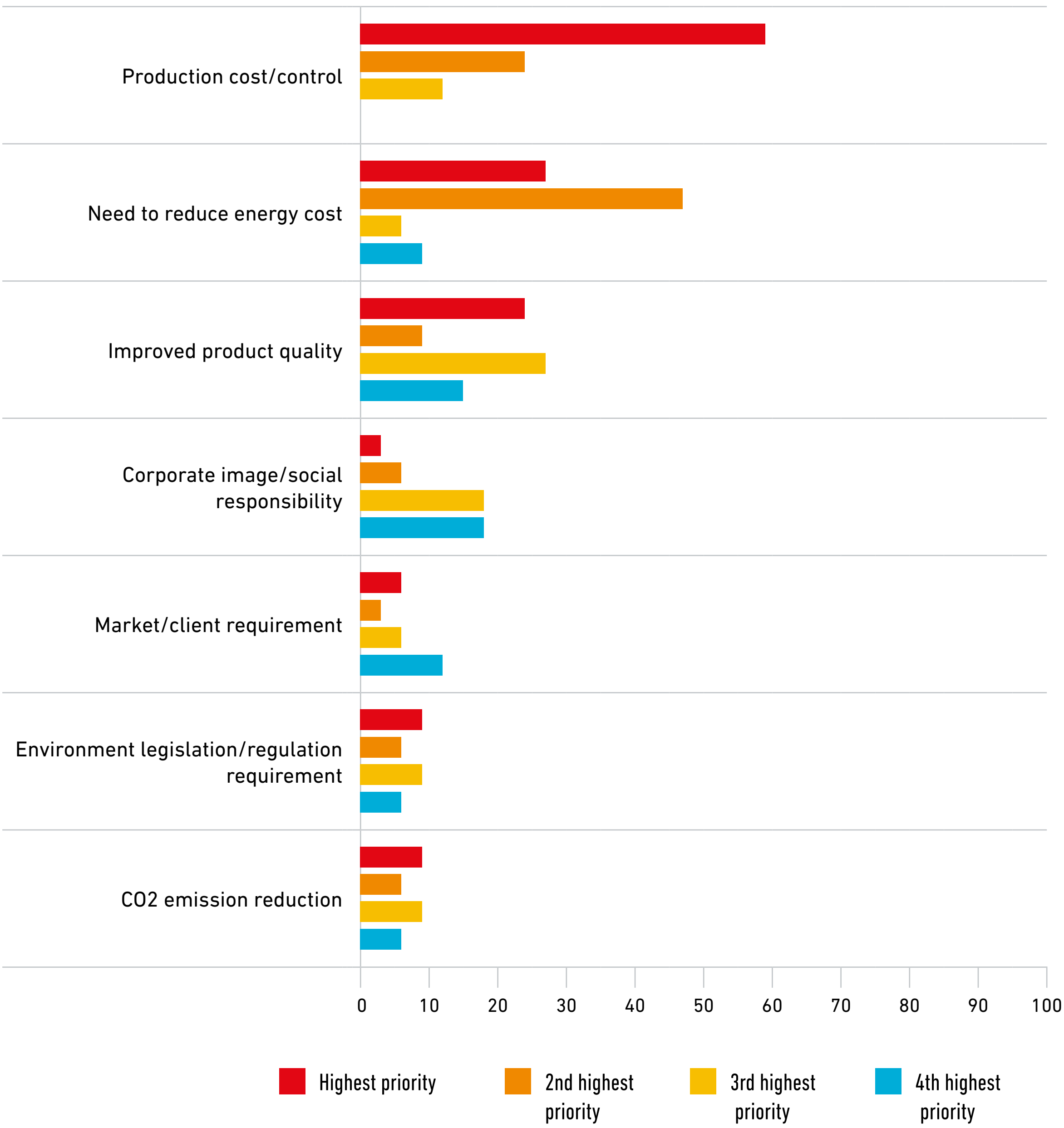


Figure 10. Main drivers of energy efficiency in surveyed industrial companies in Ghana

The creation of special units/departments for the efficient management of energy and resources is pertinent to the realization of energy efficiency goals in an industry/organization. Adequate adherence to energy management practices and standards cannot thrive without the designation of individuals for the handling of Energy Management and Energy Audit.

There must be structures/organogram in place that clearly defines what goes into planning of energy and resource management, periodic industrial energy efficiency evaluation, establishment of effective mitigation measures, benchmarking, effective project costing, implementation, monitoring and verification, and other related energy and resource management practices per established standards. With effective allocation of resources to such units and strict devotion to systematic deployment of standard certification protocol as discussed earlier, high gains can be made in industrial energy efficiency.

Energy management professionals in industries

A key component of the survey sought to determine from respondents whether personnel were assigned to energy management and energy efficiency in their respective industries. Figure 11 shows the result of the presence (or otherwise) of energy management professionals in the surveyed industries.

Figure 11. Status of energy management and energy efficiency professionals in surveyed industrial companies in Ghana

Responses show that 47% of industries engaged had personnel designated for Energy Management, 50% do not have such designation and 3% simply have no knowledge of the existence of such positions in their companies. It must be noted that the 47% is relatively significant but not sufficient enough to prepare the grounds for effective uptake of industrial energy efficiency in Ghana. It is also important to highlight that our interaction with some of these assigned personnel show that they do not have the required knowledge to conduct investment grade energy audit that could potentially result in energy efficiency projects in their industries. They also did not have the tools and equipment needed to conduct an investment grade energy audit. This is seen as a major lapse which is mostly attributable to lack of awareness and the existence of specific industrial energy efficiency policies and adequate awareness. Secondly, the existence of such personnel does not guarantee effective implementation of standard procedures with regards to energy management and energy efficiency because there are currently no accredited institutions to conduct training for industrial energy efficiency managers.

Energy audit and evaluation of industrial equipment energy efficiency

A crucial step in the actualization of Energy Management Standard protocols in industry is to plan and implement an energy efficiency evaluation schedule for key energy intensive industrial equipment such as motors, pumping systems, air compressors, HVAC systems, boilers/steam generators, gensets, ovens, mechanical dryers, etc. Figure 12 shows results drawn from analysis of responses organized under three categories for each equipment captured in the survey.

The YES category represents the percentage of companies that evaluate energy efficiency for their equipment. The NO category indicates the percentage of companies that use such equipment but do not carry out energy efficiency measurements on them. The N.A. (Not Applicable) shows companies that do not use the equipment under discussion. Around 38% of companies measure motor efficiency, 15% measure pumping system efficiency, 35% measure compressed air system efficiency, 18% measure steam systems efficiency, 15% measure process heat systems efficiency and 12% measure refrigeration systems efficiency.

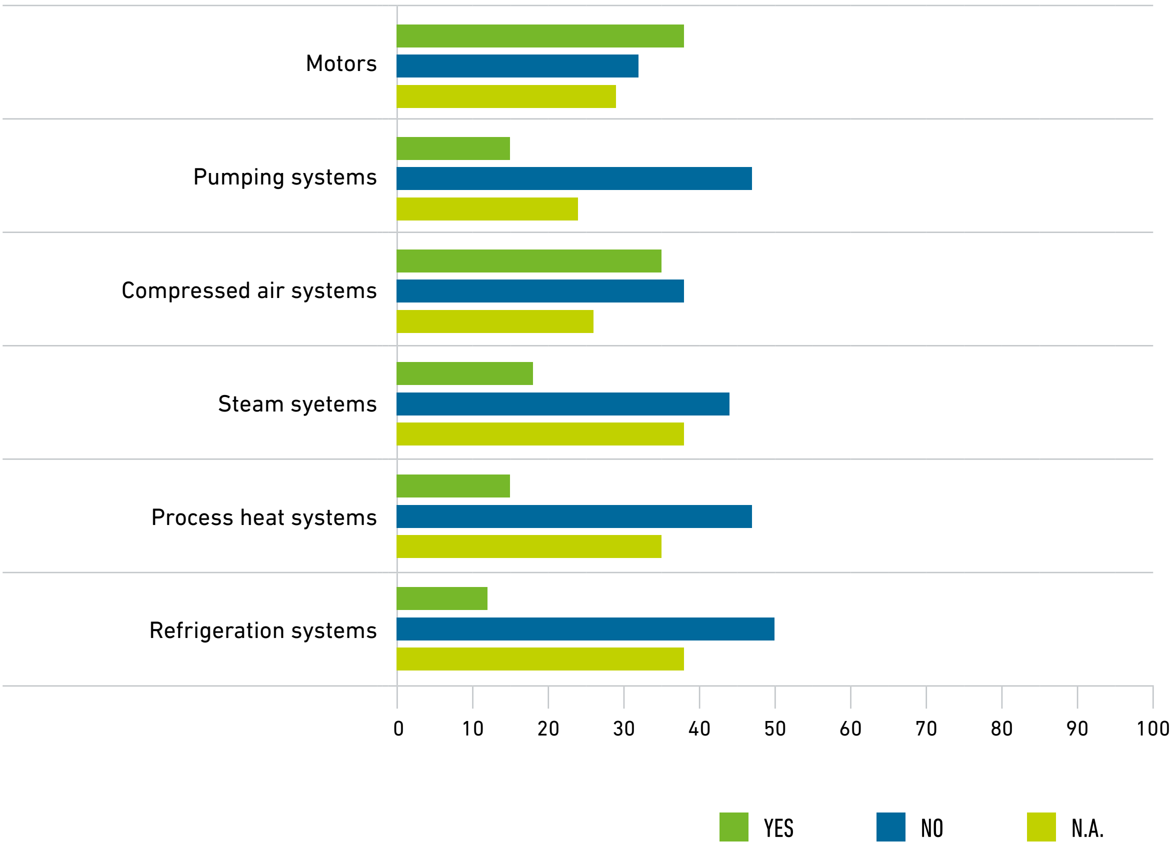


Figure 12. Energy efficiency measurement of key energy intensive industrial equipment in surveyed industrial companies in Ghana

The corresponding percentages of companies that do not conduct such measurements vary between 32% and 50%. These statistics could be due to the poor level of awareness with respect to the need to improve industrial energy efficiency in Ghana. Lack of equipment to conduct such measurement is also a barrier. Secondly, it appears most companies lack the motivation to go into practices that promote energy efficiency.

Since equipment/machines setup for the purposes of industrial production/manufacturing do become inefficient with time because of friction, environmental inputs and other related factors, it is of utmost importance to periodically carry out energy audit in order to determine measures needed to improve energy efficiency in the industrial setup.

Figure 13 shows that a staggering 71% of companies surveyed do not perform energy audit on their installations as opposed to 29% of companies that find energy audit a necessity to enhancing productivity. The consequence of this revelation is a chaotic management of energy intensive equipment leading to heightened energy losses in the industrial sector with the accompanying cost.

The high incidence of companies not practicing energy audit can be attributed to total lack of awareness and the absence of a state institution that champions the course of industrial energy efficiency in Ghana.

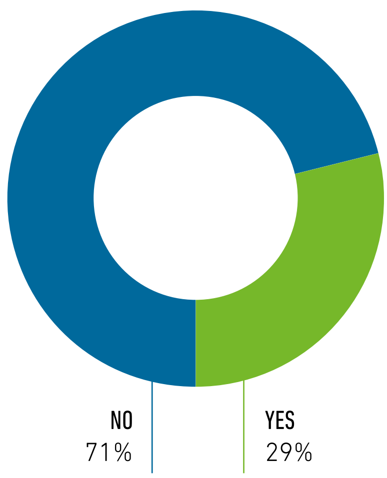


Figure 13. The energy audit in surveyed industrial companies in Ghana

Skills and experience of technical staff in industrial energy efficiency

Figure 14 below provides an overview of knowledge and skills evaluation of technical staff in the various companies in industrial energy efficiency. Respondents were required to rate the experience and skill levels of their technical staff in implementing energy and resource efficiency projects as high value, medium value and low value.

The ratings show that 35% of technical staff are competent in energy management practice, 18% are competent in assessing potential for energy saving and identifying projects, 18% are competent in estimating energy and resources savings, calculating payback period and preparing investment case; and 18% have knowledge of best practice and available technologies.

The statistics also show that 35% have inadequate knowledge in energy management practice; 24% have insufficient knowledge in assessing energy saving potential and identifying projects; 50% barely understand how to apply various financial models to potential energy saving projects in order to determine their feasibility; and 38% have little knowledge of best practice and available technology. Unfortunately, some significant percent of respondents do not know the competence level of their staff with respect to this important knowledge requirements for effective handling of Industrial Energy Efficiency.

The knowledge deficit enumerated by this analysis poses a severe challenge to the uptake of industrial energy efficiency in Ghana since the whole practice hinges on having adequate knowledge of execution and implementing schemes as well as experience in relation to the practice. This can be attributed to the lack of institutional structures for promulgation of the importance of Industrial Energy Efficiency, the need for adequate training and certification of industrial technical staff, and the enforcement of industrial energy efficiency policies.

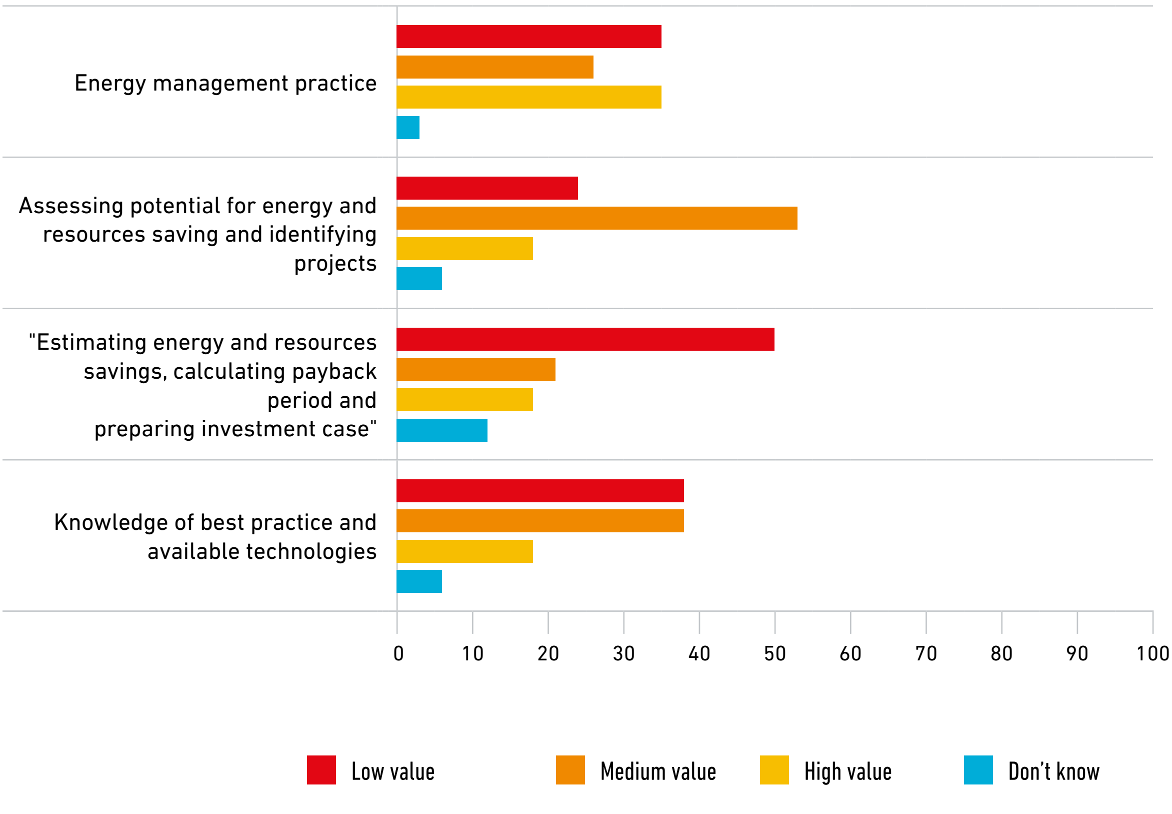


Figure 14. Skill levels and experience of company technical staff in implementing energy efficiency projects in surveyed industrial companies in Ghana

Planned capital investments or changes in production capacity

To achieve high overall gains in Industrial Energy Efficiency, industries must systematically invest in identified energy saving measures in their plant/machinery setup. A widely recognised workable option is to evaluate the energy performance of energy intensive industrial equipment including Heating, ventilation, and air conditioning (HVAC) equipment, refrigeration systems, pumps, motor/drive systems, heat recovery systems, etc.

Figure 15 shows that as much as 71% of companies are planning to invest in production expansion which shows that most companies are experiencing increases in demand for which reason production capacity expansion becomes an obvious option.

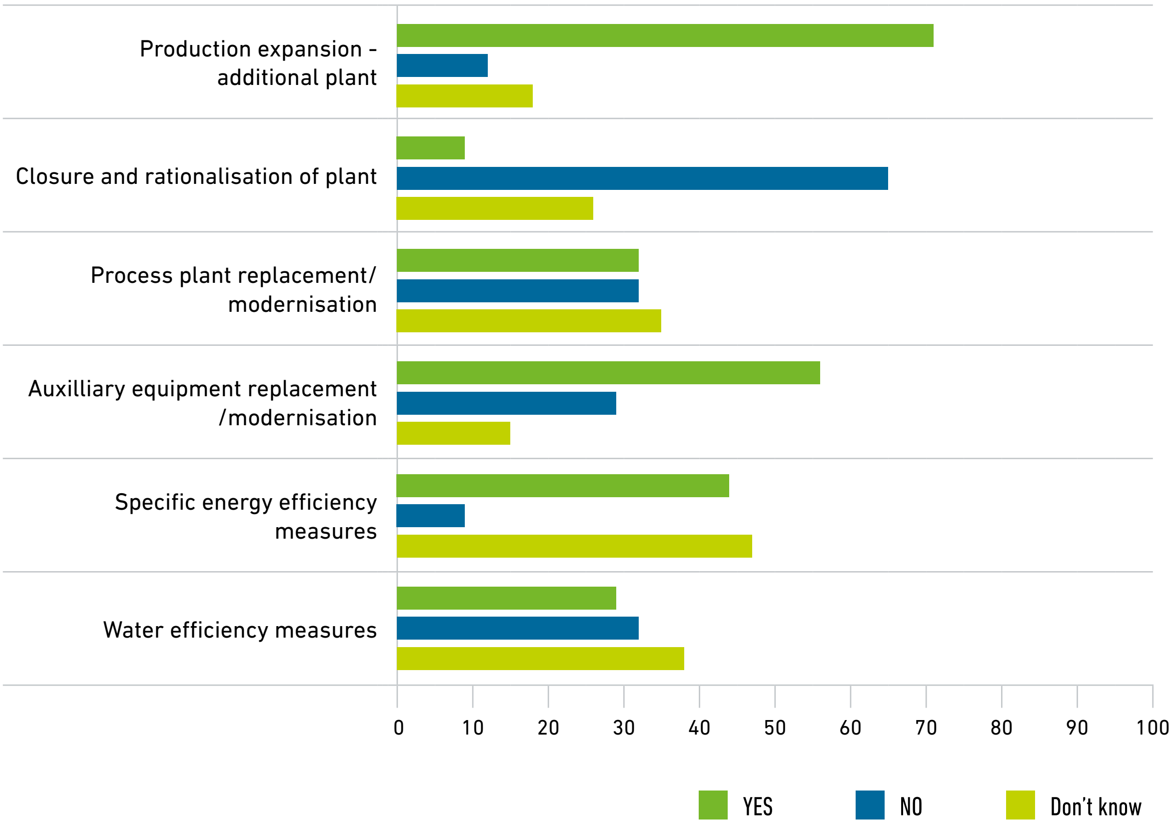


Figure 15. Capital investments being planned for the next 2-3 years in surveyed industrial companies in Ghana

However, the percentage of companies which are planning to embark on process plant/replacement/modernization (i.e., 32%), the implementation of specific energy efficiency measures (i.e., 44%) and water efficiency measures (i.e., 29%) is not sufficient considering that these practices have a significant impact on industrial energy efficiency improvement.

It appears most companies prefer to hold on to the use of relatively older and less efficient equipment than to acquire/adopt modern and energy efficient systems and measures in order to improve industrial energy efficiency.

Figure 16 below shows that a fairly reasonable percentage of industries are planning to invest in process equipment/technology (59%), improved process control (65%), lighting system improvement (68%) and energy efficient lighting (62%). However, the numbers for waste utilization for energy production (21%), heat recovery (18%) and replacement of inefficient non-star rated split AC systems with star-rated types (26%) are so much on the lower side. Waste utilization for energy production and heat recovery are effective ways of improving energy efficiency and reducing the harmful effects of waste disposal on the environment. Secondly, the 38% of companies that are planning to invest in the improvement of motor/drive systems is also seen as a major disadvantage in this case since motor/drive systems account for a large percentage of industrial energy consumption. This can be attributed to lack of education on these matters.

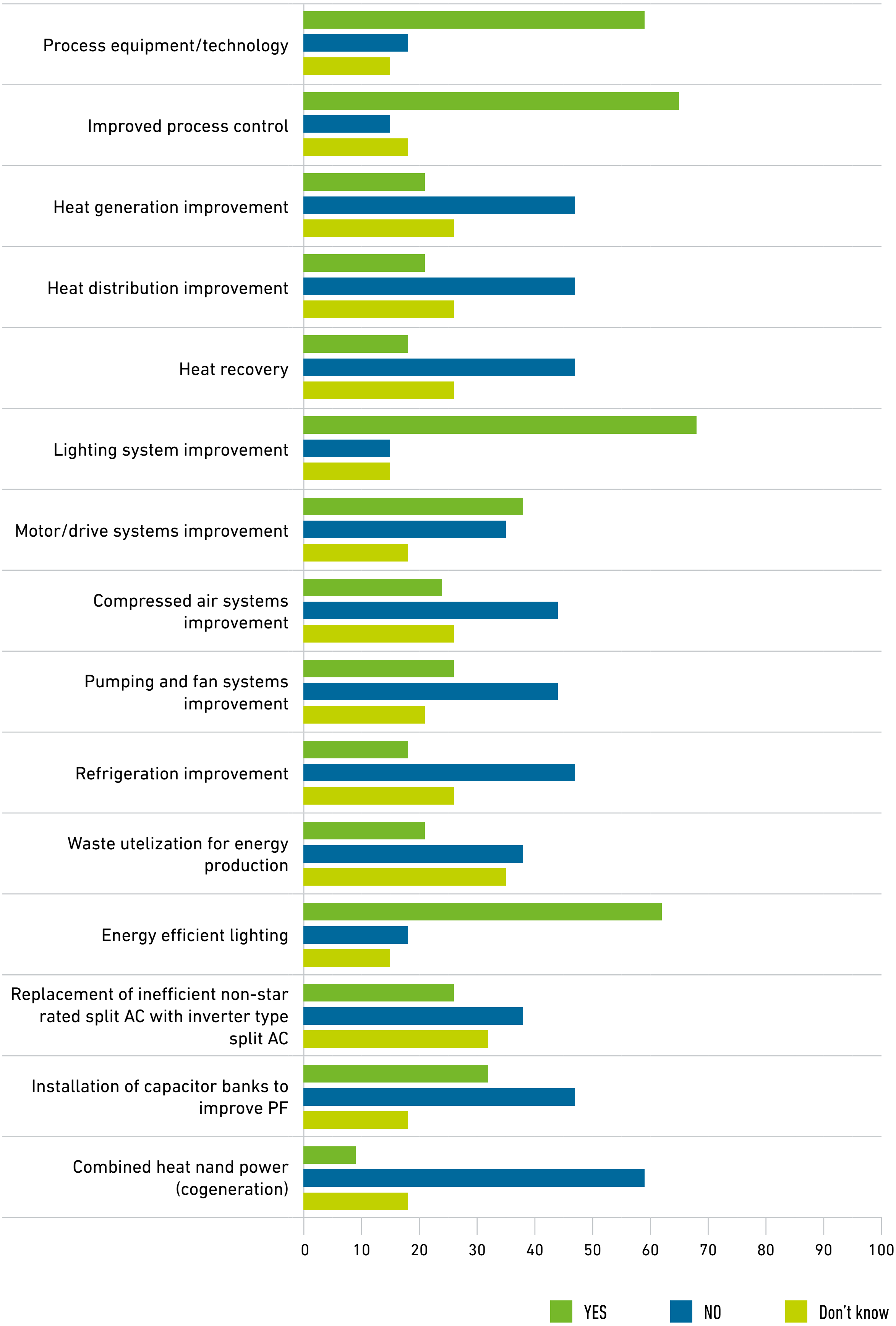


Figure 16. Investment in new energy efficient systems, plant and/or equipment over the next 3 years in surveyed industrial companies in Ghana

Ranking of barriers to industrial energy efficiency

The top ranked barriers/challenges to industrial energy efficiency are summarized in Table 6.

Table 6. Top ranked barriers to industrial energy efficiency in surveyed industrial companies in Ghana

Top Barriers	No. of Responses
Existing national industry policies are inadequate to promote and support energy efficiency in industry	22
Poor availability of commercial credit and loans	19
Difficulty in obtaining funds for energy efficiency projects	19
The market does not place any added value on energy efficiently performing companies	17
There is insufficient information on costs and benefits of potential energy efficiency projects	17
Company staff lack expertise and/or training to implement energy efficiency measures	17

Out of the 34 companies surveyed, nearly 65% of the companies ranked "Existing national industry policies are inadequate to promote and support energy efficiency in industry" as the most applicable and major barrier to industrial energy efficiency uptake in Ghana (Table 6 above). A little over 55% of the companies ranked "Poor availability of commercial credit and loans" and "*Difficulty in obtaining funds for energy efficiency projects*" as the second two major barriers to the uptake of industrial energy efficiency in Ghana.

Summary of survey findings:

From the diagnostic assessment conducted at the industries, the following points are summarized as the main barriers to industrial energy efficiency in Ghana:

- Lack of adequate standards certification
- Production cost/control takes precedence over cleaner production methods as a driver for achieving industrial energy efficiency
- A significant number of companies do not have personnel/units responsible for energy efficiency
- 32-50% of companies do not measure energy efficiencies for energy intensive industrial equipment
- 70% of companies have never performed energy audit
- 35% have inadequate knowledge in energy management practice
- 24% have insufficient knowledge in assessing energy saving potential and identifying projects
- 50% barely understand how to apply various financial models to potential energy saving projects in order to determine their feasibility
- 38% have little knowledge of best practice and available technologies.
- Only 38% of companies are planning to invest in the improvement of motor/drive systems
- More than 90% of the firms are unwilling to expend funds to improve the knowledge and skill of their workforces through energy management workshops or training courses. Hence, in many companies, there is frequently a lack of skilled technical personnel.
- Lack of knowledge about cost of energy savings technologies
- Lack of awareness, education, and training
- Lack of information in energy efficiency and savings technology
- Lack of expertise and competences to identify inefficiencies and opportunities and implement energy efficient measures
- Lack of the integrated technical capability required for implementing new technologies
- Lack of skilled technical personnel and lack of staff awareness or motivation

6. Industrial energy efficiency and decarbonization potential in Ghana

In this chapter, we first take a deep dive in analyzing energy efficiency and decarbonization potential in industrial motor systems which are key energy systems in industry in Ghana and account for around 70% of total electricity use in Ghana. We will then discuss a framework for deep decarbonization of industry in Ghana and five key pillars that need to be implemented for decarbonization of industry in Ghana.

6.1. Energy efficiency and decarbonization potential in industrial motor systems Ghana

According to the International Energy Agency (IEA), industrial electric motor systems account for about 70% of total global industrial electricity usage (IEA, 2016a). Industrial motors are normally part of larger systems, and a key way to reduce motors' electricity consumption is to optimize other parts of the system in addition to the motor. Losses within electric motors are only a small share of the total losses experienced in the entire system of which the motor is a part. Figure 17 illustrates a typical industrial motor system made up of connected components. The efficiency of each component is important to the efficiency of the entire system.

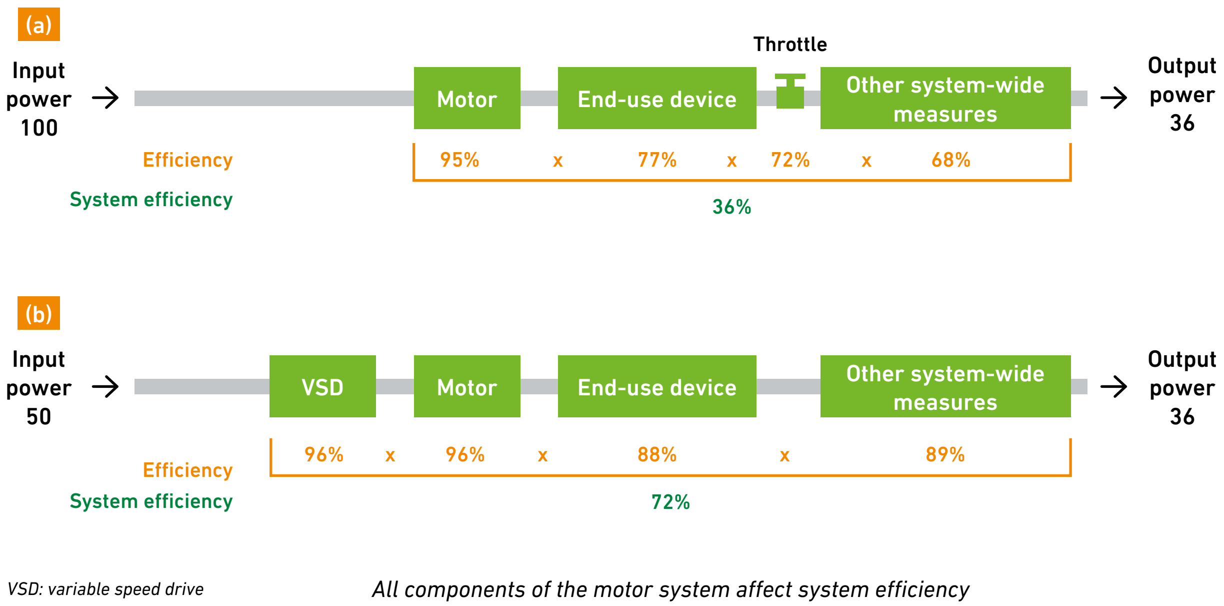


Figure 17. Illustration of two industrial electric motor-driven systems: (a) normal and (b) efficient (IEA, 2016a)

In general, motors are usually fairly efficient, especially in developed and developing countries that have robust minimum energy performance standards (MEPS). MEPS are being adopted in more and more countries as well as becoming more stringent in countries where they have been established for a period of time. IEA predicts that, by 2040, premium efficiency standard (IE3) motors or better will account for approximately 60% of the electricity used by motor systems. Because motor efficiency improvements will only marginally increase the motor system's efficiency, industry must look to improve the efficiency of the equipment that are driven by motors. Optimization measures such as predictive maintenance, avoiding oversized motors, and matching motor systems to specific needs could improve the energy efficiency of motor-driven systems significantly (IEA, 2016). Even more savings can be achieved by looking not only beyond the motor to the whole motor system but beyond the system to the end-use device, as shown in Figure 17.

In our analysis for industrial motor systems, we focus on pump systems, fan systems and compressed air systems which represent three main types of motor systems that together account for around half of electricity use in industrial motor systems. The share of electricity used by pump, fan, and compressed air systems varies among manufacturing subsectors.

One of the major barriers to effective policy making and increased global action to improve energy efficiency in industrial motor systems is lack of information and data on the magnitude and cost-effectiveness of the energy-savings potential in industrial motor systems in individual countries. This lack of information creates an obstacle to developing a comprehensive strategy and roadmap for improving motor systems efficiency. It is far easier to quantify the incremental energy savings of substituting an energy-efficient motor for a standard motor in a motor system than it is to quantify the energy savings of applying other energy-efficiency practices to an existing motor system.

To address these barriers, we conducted a study on industrial motor systems in Ghana. This analysis focuses on energy use, energy efficiency, and CO_2 emissions-reduction potential in industrial motor systems in Ghana.

Based on the methodology explained in the Appendix, we constructed energy-efficiency cost curves for the industrial motor systems in Ghana. Our purpose was to capture separately the cost-effective potential and total technical potential for electricity efficiency improvement in these systems by implementing eight energy efficiency measures. We also calculated the CO_2 emissions reduction potential associated with the electricity savings. These potentials are the total existing potentials for energy-efficiency improvement in industrial motor systems for the year 2020. In other words, the potential represented here assumes a 100% adoption rate. We are aware that a 100% adoption rate is not likely and that values approaching a high adoption rate would only be possible over a period of time. However, assuming different penetration rates for the energy-efficiency measures in the future was beyond the scope of our study. Note that the energy-savings analysis in this report excludes motor systems used for process cooling and refrigeration.

6.1.1. Energy-Efficiency Cost Curve for Industrial Pump Systems in Ghana

Figure 18 shows the energy-efficiency cost curve for industrial pump systems in Ghana. The y-axis on the graph shows the cost of conserved electricity (CCE), and the x-axis shows the cumulative annual electricity savings potential of efficiency measures. Table 7 lists the measures on the cost curve along with the cumulative annual electricity-savings potential and final CCE of each measure as well as the cumulative CO_2 emissions-reduction potential. The energy-efficiency measures in the grey area of the table are cost effective (i.e., their CCE is less than the unit price of industrial-sector electricity in Ghana in 2020), and the efficiency measures that are in the white area are not cost-effective.

Out of eight energy-efficiency measures, seven are cost-effective. The most cost-effective measure for pump systems in Ghana is "isolating flow paths to non-essential or non-operating equipment", which has a CCE equal to zero. The second and third most-cost-effective measure are "Trim or change impeller to match output to requirements" and "Use pressure switches to shut down unnecessary pumps". Installing variable-speed drives (VSDs) on pumps has one of the largest energy saving potential and is also cost-effective.

The least-cost-effective measure (i.e., the one with the highest CCE) for Ghana's industrial pump systems is one that is commonly chosen: "replacing motors with more efficient types". Another interesting and possibly counter-intuitive finding is that the energy-savings potential from replacing motors is smaller than the energy-savings potential of all other efficiency measures studied. Furthermore, replacing motors also appeared not to be cost-effective. Note that this analysis is intended to support policy makers, but is not a substitute for individualized assessments of motor system efficiency opportunities at a specific facility.

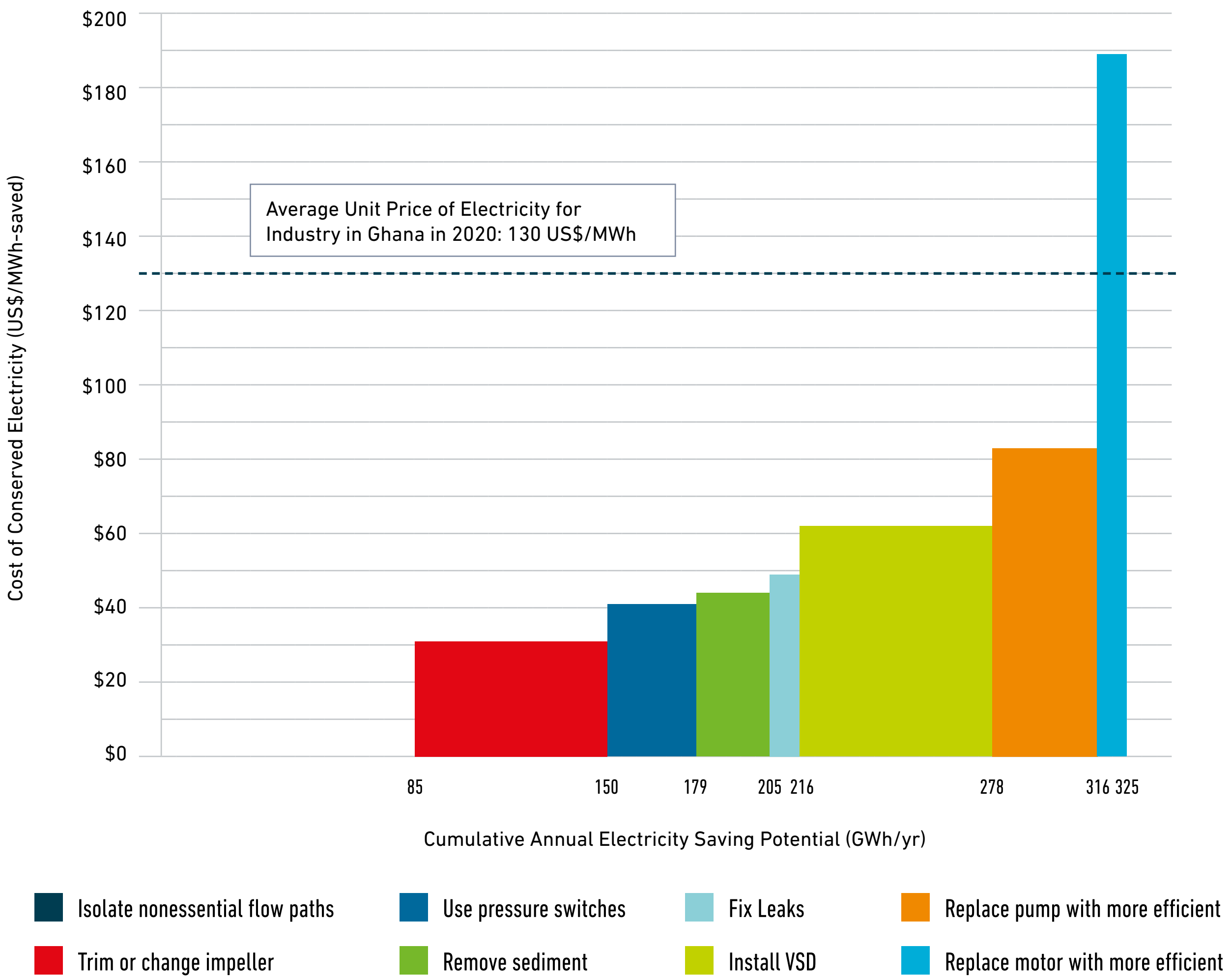


Figure 18. Energy efficiency cost curve for industrial pump systems in Ghana
Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

Table 7. Cumulative annual electricity saving and CO_2 emission reduction potential for efficiency measures in industrial pump systems in Ghana ranked by final CCE

No.	Energy Efficiency Measures	Cumulative Annual Electricity Saving Potential (GWh/yr)	Final Cost of Conserved Energy (US$/MWh- Saved)	Cumulative Annual CO_2 Emission Reduction Potential (kton CO_2 /yr)
1	Isolate flow paths to nonessential or non-operating equipment	85	0	42
2	Trim or change impeller to match output to requirements	150	31	75
3	Use pressure switches to shut down unnecessary pumps	179	41	90
4	Remove sediment/scale buildup from piping	205	44	103
5	Fix Leaks, damaged seals, and packing	216	49	108
6	Install variable speed drive	278	62	139
7	Replace pump with more energy efficient type	316	83	158
8	Replace motor with more efficient type	325	189	162

Notes: 1) Energy savings are based on 100% adoption of the efficiency measures. 2) The energy and CO_2 savings presented for each measure are the cumulating savings from that measure and all previous measures with lower CCE. 3) This analysis provides an indication of the cost-effectiveness of system energy efficiency measures at the country level. The cost-effectiveness of individual measures will vary based on plant-specific conditions. Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

Table 8 shows that the total technical energy-savings potential is 48% of total industrial pumping system electricity use in Ghana in 2020. This is a significant saving potential primarily because we assumed that pump systems in Ghana have LOW efficiency base case. This is in line with our previous studies for other developing countries (e.g. Thailand, Brazil, Vietnam, Egypt). Ghana's industrial pump systems have a cost-effective potential of 47% of total industrial pumping system electricity use in Ghana in 2020.

Table 8. Total annual cost-effective and technical energy saving and CO_2 emissions reduction potential in industrial pump systems in Ghana

	Cost-effective Potential	Technical Potential
Annual electricity saving potential for pump systems in Ghana's industry (GWh/yr)	316	325
Share of saving from the total pump system energy used in Ghana's industry in 2020	47%	48%
Share of saving from the total electricity used in Ghana's industry in 2020	5.8%	5.9%
Annual CO_2 emission reduction potential from Ghana's industry (kton CO_2/yr)	158	162

Notes: 1) Savings are based on 100% adoption of the energy efficiency measures. 2) Systems larger than 1000 hp are excluded from the energy saving and cost analyses. 3) The energy saving potential exclude pump systems that are in process cooling and refrigeration.

As explained in the methodology section in Appendix, the implementation of one measure can influence the efficiency gain from the next efficiency measure implemented. That is, when one measure is implemented, the base-case efficiency is improved. Therefore, the efficiency improvement from the second measure will be less than if the second measure had been implemented first or was considered alone. Because of this, our analysis treated the measures in relation to each other (as a group). In other words, the efficiency improvement from implementation of one measure depends on the efficiency improvement achieved by the previous measure(s) implemented. We call this the *synergy effect*.

In this method, the *cumulative* electricity savings are calculated by taking into account the synergy effect of the measures rather than treating the measures in isolation from one another. For instance, the cumulative annual electricity savings from the implementation of measure #3 includes the efficiency gains from all the previous measures implemented (measures #1 and #2).

However, if policy makers want to assess the impact of a single efficiency measure without considering the implementation of other measures, savings should be calculated for that particular measure implemented in isolation. Figure 19 compares the energy-savings potential for each efficiency measure implemented in isolation to the energy-savings potential for each measure implemented along with other measures; the latter is the savings value that we use on the energy-efficiency cost curve.

The measures that are less cost-effective on the efficiency cost curve and that appear at the top of the graph in Figure 19 show the largest differences between the energy savings calculated for the measure in isolation versus the energy savings calculated for the measure in combination with other measures. Note that summing up the energy savings of individual measures implemented in isolation will give an inaccurate result because of the synergy effect explained above.

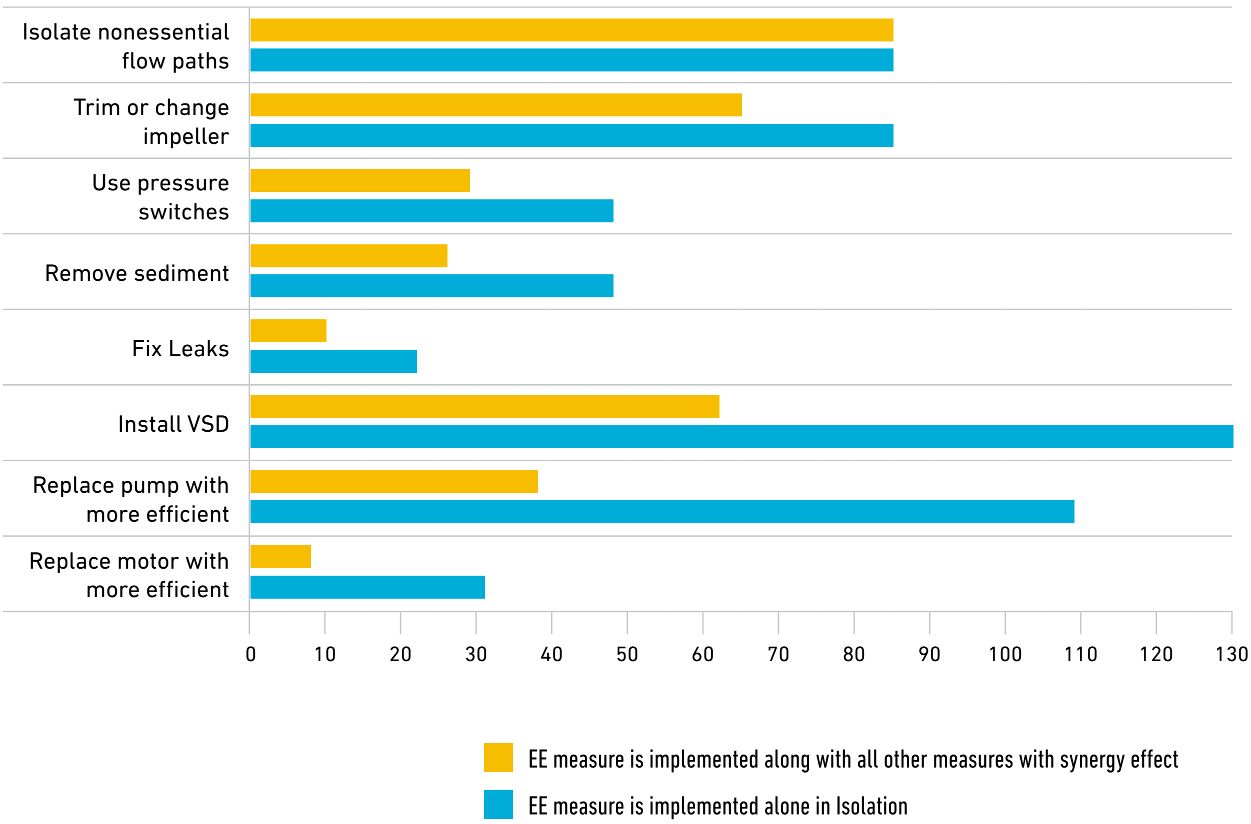


Figure 19. Comparison of energy saving potential (GWh/yr) for each efficiency measure in industrial pump systems in Ghana when each measure is implemented in isolation or is implemented along with other measures

Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

6.1.2. Energy-Efficiency Cost Curve for Industrial Fan Systems in Ghana

Figure 20 shows the energy-efficiency cost curve for industrial fan systems in Ghana. The y-axis on the graph shows the CCE, and the x-axis shows the cumulative annual electricity savings potential of efficiency measures. Table 9 lists the measures on the cost curve along with the cumulative annual electricity-savings potential and final CCE of each measure as well as the cumulative CO_2 emissions-reduction potential. The energy-efficiency measures in the gray area of the table are cost effective (i.e., their CCE is less than the unit price of industrial-sector electricity in Ghana in 2020), and the efficiency measures that are in the white area are not cost-effective.

Out of eight energy-efficiency measures, seven are cost-effective. The most cost-effective measure for fan systems in Ghana is "Isolate flow paths to nonessential or non-operating equipment" which has the lowest CCE. Installing variable-speed drives (VSDs) on fans has the largest energy saving potential and is also cost-effective.

The least-cost-effective measure (i.e., the one with the highest CCE) for Ghana fan systems is one that is commonly chosen: replacing motors with more efficient models. By contrast, installing a VSD on fan systems, which results in the highest saving potential, is cost-effective in Ghana. Another interesting and possibly counter-intuitive finding is that the energy-savings potential from replacing motors is smaller than the energy-savings potential of all other efficiency measures studied and this measure is not cost-effective.

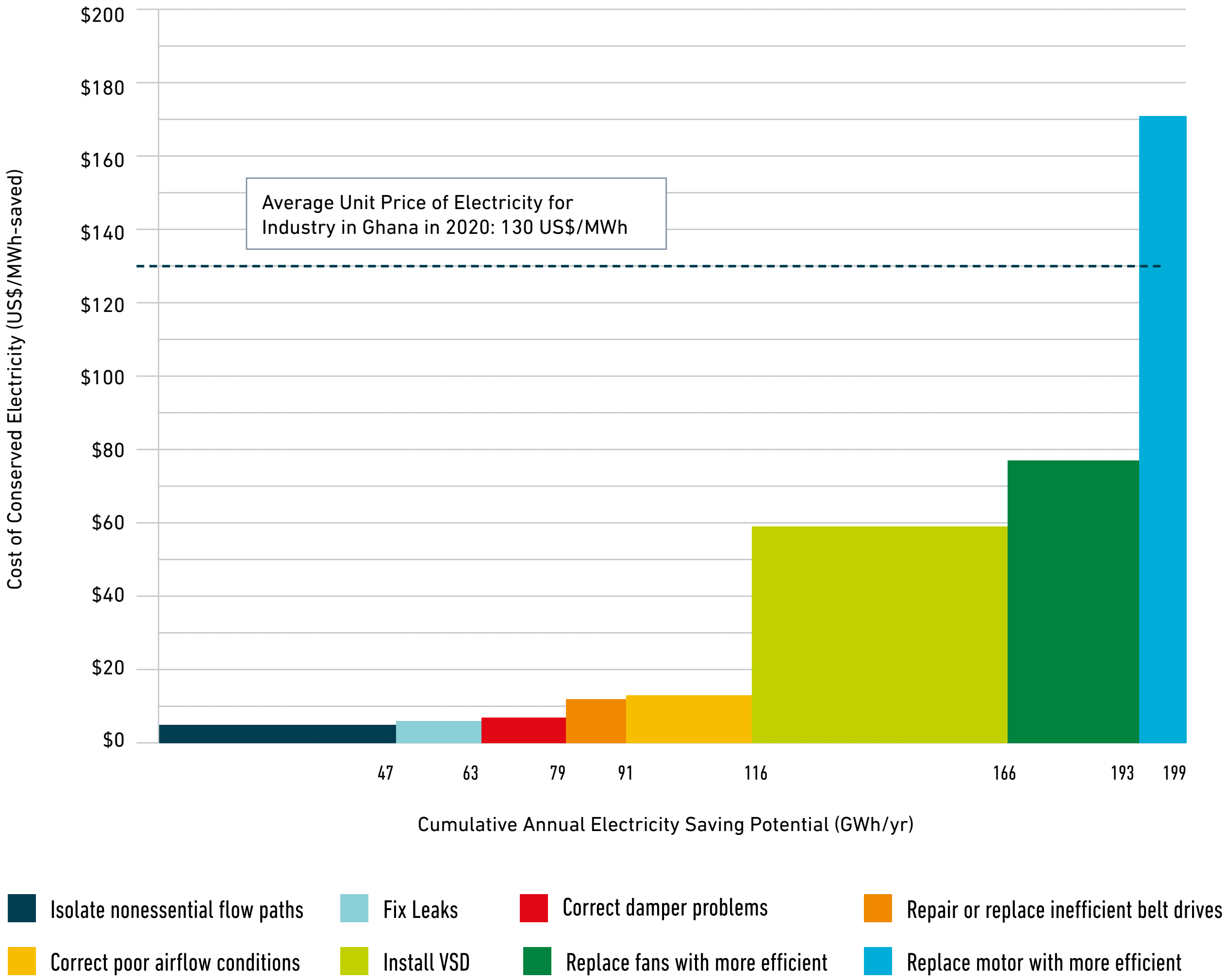


Figure 20. Energy efficiency cost curve for industrial fan systems in Ghana

Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

Table 9. Cumulative annual electricity saving and CO_2 emission reduction potential for efficiency measures in industrial fan systems in Ghana ranked by final CCE

No.	Energy Efficiency Measures	Cumulative Annual Electricity Saving Potential (GWh/yr)	Final Cost of Conserved Energy (US$/MWh- Saved)	Cumulative Annual CO_2 Emission Reduction Potential (kton CO_2 /yr)
1	Isolate flow paths to nonessential or non-operating equipment	47	4.9	23
2	Fix Leaks and damaged seals	63	5.5	32
3	Correct damper problems	79	7.3	39
4	Repair or replace inefficient belt drives	91	11.7	46
5	Correct poor airflow conditions at fan inlets and outlets	116	13.3	58
6	Install variable speed drive	166	59.0	83
7	Replace oversized fans with more efficient type	193	77.4	96
8	Replace motor with more energy efficient type	199	170.7	100

Notes: 1) Energy savings are based on 100% adoption of the efficiency measures. 2) The energy and CO_2 savings presented for each measure are the cumulating savings from that measure and all previous measures with lower CCE. 3) This analysis provides an indication of the cost-effectiveness of system energy efficiency measures at the country level. The cost-effectiveness of individual measures will vary based on plant-specific conditions.

Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

Table 10 shows that the total technical energy-savings potential is 38% of total industrial fan system electricity use in Ghana in 2020. This is in line with our previous studies for other developing countries (e.g. Thailand, Brazil, Vietnam, Egypt). We assumed that fan systems in Ghana have LOW efficiency base case. Ghana's industrial fan systems have a cost-effective potential of 37% of total fan system electricity use in Ghana in 2020.

Table 10. Total annual cost-effective and technical energy saving and CO_2 emissions reduction potential in industrial fan systems in Ghana

	Cost-effective Potential	Technical Potential
Annual electricity saving potential for fan systems in Ghana's industry (GWh/yr)	193	199
Share of saving from the total fan system energy used in Ghana's industry in 2020	37%	38%
Share of saving from the total electricity used in Ghana's industry in 2020	3.5%	3.6%
Annual CO_2 emission reduction potential from Ghana's industry (kton CO_2/yr)	96	100

Notes: 1) Savings are based on 100% adoption of the energy efficiency measures. 2) Systems larger than 1000 hp are excluded from the energy saving and cost analyses. 3) The energy saving potential exclude fan systems that are in process cooling and refrigeration and non-process facility Heating, ventilation and air conditioning (HVAC).

Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

The measures that are less cost-effective on the efficiency cost curve and that appear at the top of the graph in Figure 21 show the largest differences between the energy savings calculated for the measure in isolation versus the energy savings calculated for the measure in combination with other measures. Note that summing up the energy savings of individual measures implemented in isolation will give an inaccurate result because of the synergy effect explained above.

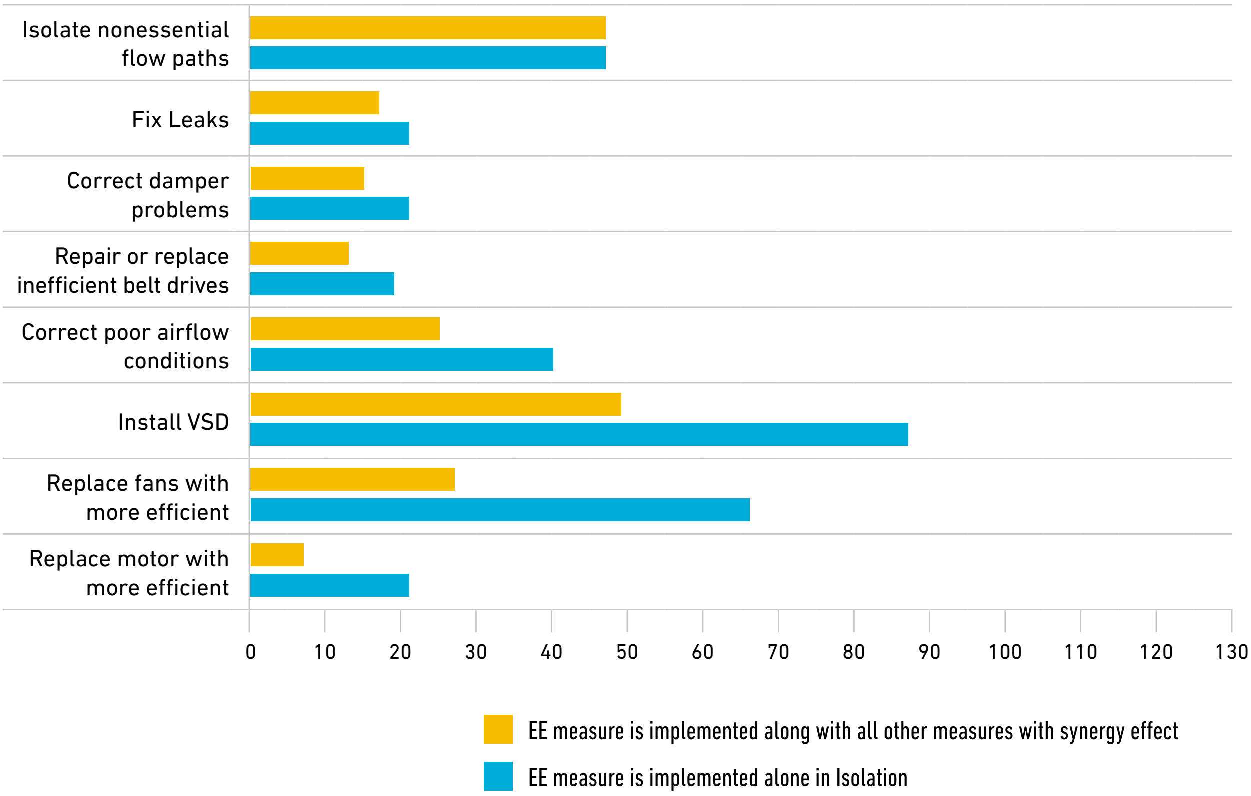


Figure 21. Comparison of energy saving potential (GWh/yr) for each efficiency measure in industrial fan systems in Ghana when each measure is implemented in isolation or is implemented along with other measures

Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

6.1.3. Energy-Efficiency Cost Curve for Industrial Compressed Air Systems in Ghana

Figure 22 shows the energy-efficiency cost curve for industrial compressed air systems in Ghana. The y-axis on the graph shows the CCE, and the x-axis shows the cumulative annual electricity savings potential of efficiency measures. Table 11 lists the measures on the cost curve along with the cumulative annual electricity-savings potential and final CCE of each measure as well as the cumulative CO_2 emissions-reduction potential. The energy-efficiency measures in the grey area of the table are cost effective (i.e., their CCE is less than the unit price of industrial-sector electricity in Ghana in 2020), and the efficiency measures that are in the white area are not cost-effective. Out of ten energy-efficiency measures, seven are cost-effective. The most cost-effective measure for compressed air systems in Ghana is "Fix Leaks, adjust compressor controls, establish ongoing plan" which has the lowest CCE followed by "Initiate predictive maintenance program".

The least-cost-effective measure (i.e., the one with the highest CCE) for Ghana compressed air systems is "Improve trim compressor part load efficiency; i.e. variable speed drive". Also, it should be noted that the most cost-effective measure, "Fix Leaks, adjust compressor controls, establish ongoing plan", has the largest energy saving potential as well.

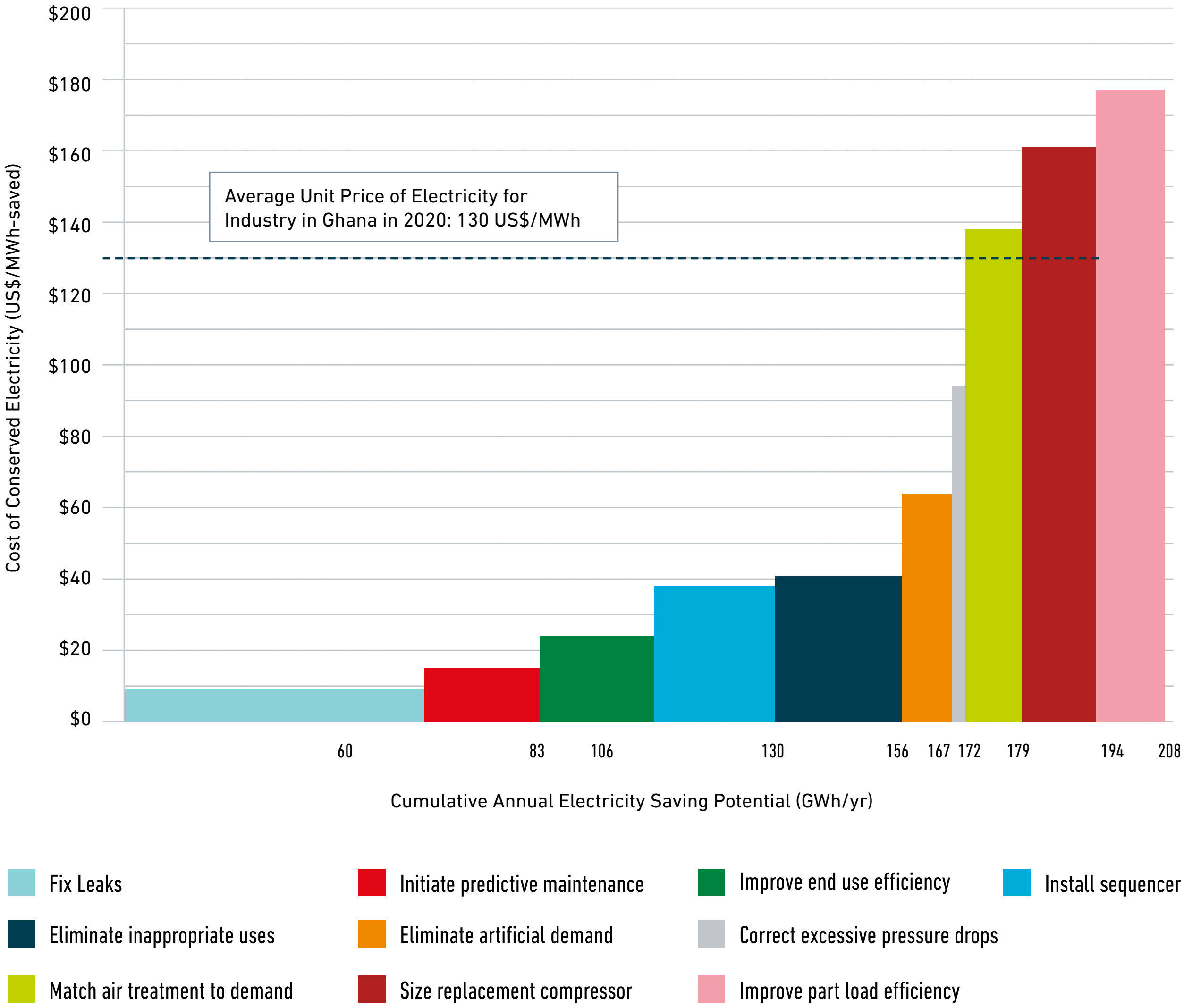


Figure 22. Energy efficiency cost curve for industrial compressed air systems in Ghana

Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

Table 12 shows that the total technical energy-savings potential is 39% of total industrial compressed air system electricity use in Ghana in 2020. This is a significant saving potential primarily because we assumed that compressed air systems in Ghana have LOW efficiency base case. Ghana's industrial compressed air systems have a cost-effective potential of 33% of total industrial compressed air system electricity use in Ghana in 2020.

Table 11. Cumulative annual electricity saving and CO_2 emission reduction potential for efficiency measures in industrial compressed air systems in Ghana ranked by final CCE

No.	Energy Efficiency Measures	Cumulative Annual Electricity Saving Potential (GWh/yr)	Final Cost of Conserved Energy (US$/MWh-Saved)	Cumulative Annual CO_2 Emission Reduction Potential (kton CO_2 /yr)
1	Fix Leaks, adjust compressor controls, establish ongoing plan	60	9	30
2	Initiate predictive maintenance program	83	15	41
3	Improve end use efficiency; shut-off idle equip, engineered nozzles, etc.	106	24	53
4	Install sequencer	130	38	65
5	Eliminate inappropriate compressed air uses	156	41	78
6	Eliminate artificial demand with pressure optimization/control/ storage	167	64	83
7	Correct excessive pressure drops in main line distribution piping	172	94	86
8	Match air treatment to demand side needs	179	138	90
9	Size replacement compressor to meet demand	194	161	97
10	Improve trim compressor part load efficiency; i.e. variable speed drive	208	177	104

Notes: 1) Energy savings are based on 100% adoption of the efficiency measures. 2) The energy and CO_2 savings presented for each measure are the cumulating savings from that measure and all previous measures with lower CCE. 3) This analysis provides an indication of the cost-effectiveness of system energy efficiency measures at the country level. The cost-effectiveness of individual measures will vary based on plant-specific conditions.

Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

Table 12. Total annual cost-effective and technical energy saving and CO_2 emissions reduction potential in industrial compressed air systems in Ghana

	Cost-effective Potential	Technical Potential
Annual electricity saving potential for compressed air systems in Ghana's industry (GWh/yr)	172	208
Share of saving from the total compressed air system energy used in Ghana's industry in 2020	33%	39%
Share of saving from the total electricity used in Ghana's industry in 2020	3.1%	3.8%
Annual CO_2 emission reduction potential from Ghana's industry (kton CO_2/yr)	86	104

Notes: 1) Savings are based on 100% adoption of the energy efficiency measures. 2) Systems larger than 1000 hp are excluded from the energy saving and cost analyses. 3) The energy saving potential exclude compressed air systems that are in process cooling and refrigeration and non-process facility Heating, ventilation and air conditioning (HVAC).

Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

The measures that are less cost-effective on the efficiency cost curve and that appear at the top of the graph in Figure 23 show the largest differences between the energy savings calculated for the measure in isolation versus the energy savings calculated for the measure in combination with other measures. Note that summing up the energy savings of individual measures implemented in isolation will give an inaccurate result because of the synergy effect explained above.

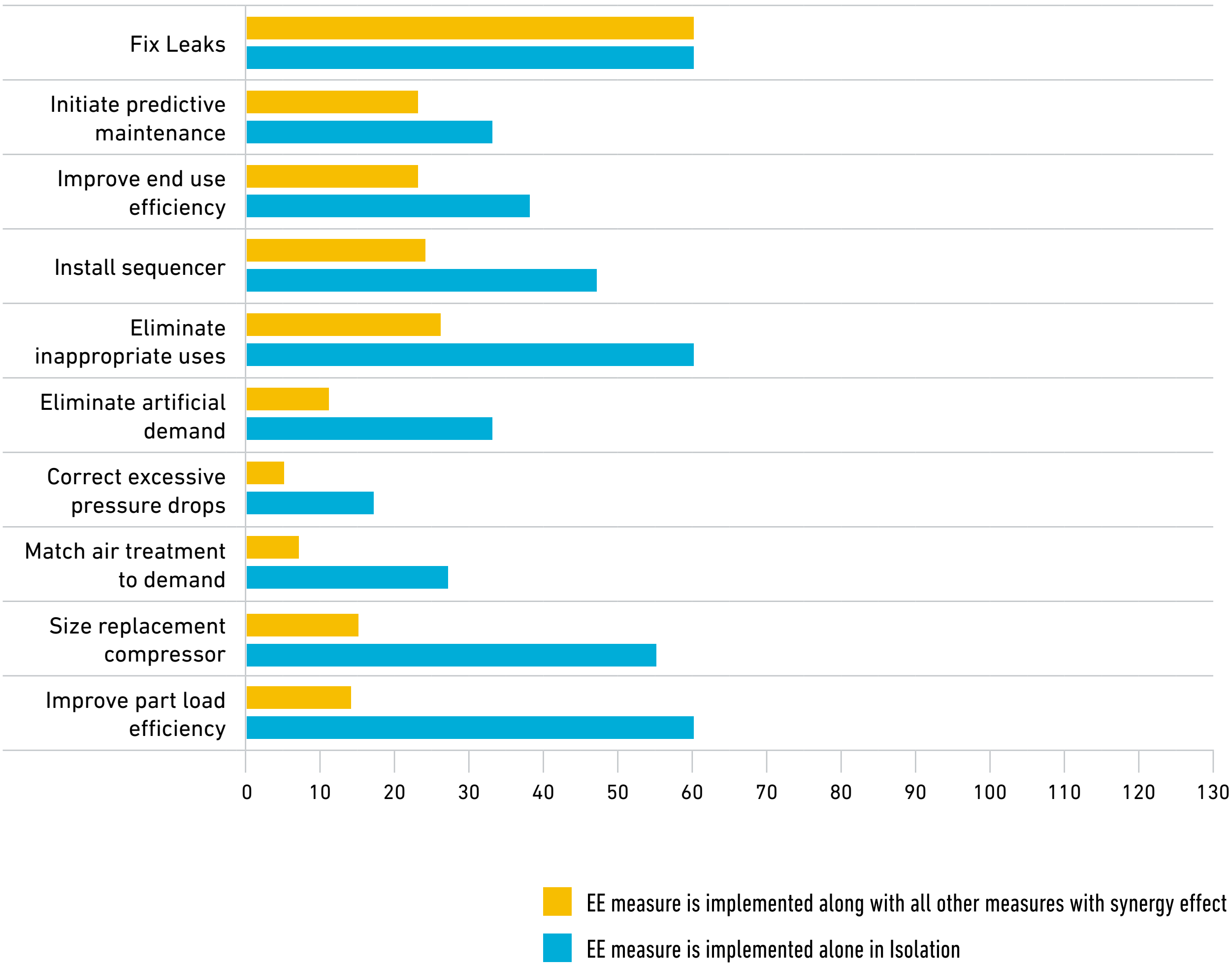


Figure 23. Comparison of energy saving potential (GWh/yr) for each efficiency measure in industrial compressed air systems in Ghana when each measure is implemented in isolation or is implemented along with other measures

Source: Global Efficiency Intelligence's Analyses (Methodology in Appendix)

In general, CCE has a direct relationship with the discount rate (see methodology in the Appendix on how the discount rate is used in formulas). For example, reductions in the discount rate will result in reductions in CCE, which can increase the cost-effective energy-savings potential (depending on energy prices). A higher energy price can result in more energy-efficiency measures being cost-effective by causing their CCEs to fall below the energy price line.

It should be noted that some energy-efficiency measures provide productivity, environmental, and other benefits in addition to energy savings; however, quantifying these benefits is difficult and beyond the scope of this report. Including quantified estimates of other benefits could decrease CCE for the efficiency measures and thereby increase the number of measures that are cost-effective. In addition, it is important to highlight that electricity is a final form of energy. If we convert the electricity saving calculated in this report to primary energy saving using average power generation efficiency and transmission and distribution losses, the primary energy saving can be up to around 3 times of the electricity saving values.

The approach used in this study and the model developed for this purpose should be viewed as a screening method and tool that can identify energy-efficiency measures and their energy-savings potential and costs to aid national and local governments, policy makers, and utilities in designing energy-efficiency policies. Actual energy-savings potentials and costs of energy-efficiency measures and technologies will vary in relation to plant-specific conditions. Effective energy-efficiency policies and programs are needed to realize (and ultimately exceed) current cost-effective potentials.

6.2. Industrial decarbonization pillars for Ghana

Industry faces numerous drivers and challenges to transform its energy and GHG footprint, reduce carbon dependence (decarbonization), and grow while meeting new societal needs. The variation of energy sources, multiple uses (energy, feedstock, reductant), diverse product mix (chemicals, refining, food, etc.) and reliance on carbon for products is part of the challenge. To achieve the deep decarbonization goal for industry, five decarbonization pillars (Figure 24) will need to be vigorously pursued in parallel in coming decades in Ghana.

Demand Reduction	Energy Efficiency	Fuel Switching & Electrification	Transformative Technologies in Sectors	Abatement
Higher quality products and materials	Energy-efficient commercial and emerging technologies	Lower carbon fuels (RNG, Biomass, etc.)	Emerging production technologies	Carbon capture and storage
Process intensification	System optimization	Renewable energy Hydrogen	Hydrogen, Direct reduction iron steelmaking	Carbon utilization
Circular economy/ material efficiency	Efficient equipment & operations design	Beneficial Electrification	producing iron by electrolysis of iron ore	Direct air capture
By-product synergy/ waste reduction	Strategic energy management/Energy management system	Hybrid/dual - source applications (hybrid boilers)	Bio-based chemical products	Bio-based approaches (reforestation)
Low carbon material substitution	Combined heat and power		Hydrogen-based production of ammonia methanol etc.	
Carbon intensity, use intensity				

Figure 24. Deep decarbonization pillars for industry.

Demand reduction and material efficiency

There is significant potential to reduce the carbon footprint of industry and use through its life cycle. There are various ways to reduce material demand through optimization of material consumed in the products at the design stage, the use stage, and the end of life stage. Measures such as light-weighting, reduced over-design, longer lifetimes, improved product quality, reduced waste during manufacturing, re-manufacturing, repurposing, re-use, and recycling of products can be considered under this pillar. There are potentials to replace energy-intensive materials such as steel and concrete with alternative materials such as enhanced wood products, composites, etc. for various applications, considering resource availability in Ghana in order to lower the carbon footprint of final products.

Energy efficiency

The application of energy efficiency measures and technologies reduces fuel and electricity use and their associated CO_2 emissions in industry. The technologies and measures are often well-known and cost-effective, providing immediate actions that can be taken in near-term to reduce overall demand for energy from industry. Substantial CO_2 emissions reduction can be achieved through application of commercialized energy efficiency technologies and measures in industry in Ghana.

Fuel switching and electrification

Switching to lower carbon-intensive fuels can help to significantly reduce CO_2 emissions associated with fuel use in the industry. The extent to which the industry in Ghana use fossil fuels and the potential for switching to lower carbon fuels (biomass, renewable natural gas (RNG), green hydrogen for heat) should be investigated. Such investigation could build the case for such fuel switches and look into potential, fuel availability, and technological aspect of using fossil fuels versus low carbon fuels in industry sector in Ghana.

Electrification of industry

Industrial process heating operations include drying, heat treating, curing and forming, calcining, smelting, and other operations. Process heating technologies can be grouped into four general categories based on the type of energy consumed: direct fuel-firing, steam-based, electric-based, and hybrid systems (which use a combination of energy types). In process heating, material is heated by heat transfer from a heat source such as a flame, steam, hot gas, or an electrical heating element by conduction, convection, or radiation—or some combination of these. In practice, lower-temperature processes tend to use conduction or convection, whereas high-temperature processes rely primarily on radiative heat transfer. Energy use and heat losses from the system depend on process heating process parameters, system design, operating practices, and other factors (ORNL, 2017).

Around 30% of the total U.S. industrial heat demand is required at temperatures below 100°C. Two-thirds of process heat used in U.S. industry are for applications below 300°C (Figure 25) (McMillan, 2019). In the food, beverage, and tobacco, transport equipment, machinery, textile, and pulp and paper industries, the share of heat demand at low and medium temperatures is about, or even above, 60% of the total heat demand. With a few exceptions, it is generally easier to electrify low-temperature processes than high-temperature processes. Therefore, there is significant potential for electrification of industrial processes for low or medium heating applications. Figure 26 shows the share of industrial head demand by temperature in selected industries.

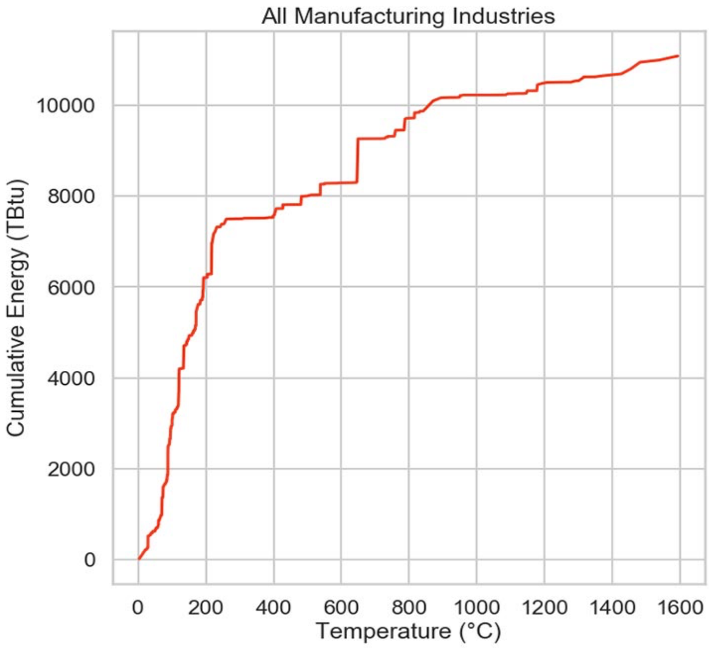


Figure 25. Cumulative process heat demand by temperature in 2014 (McMillan, 2019).

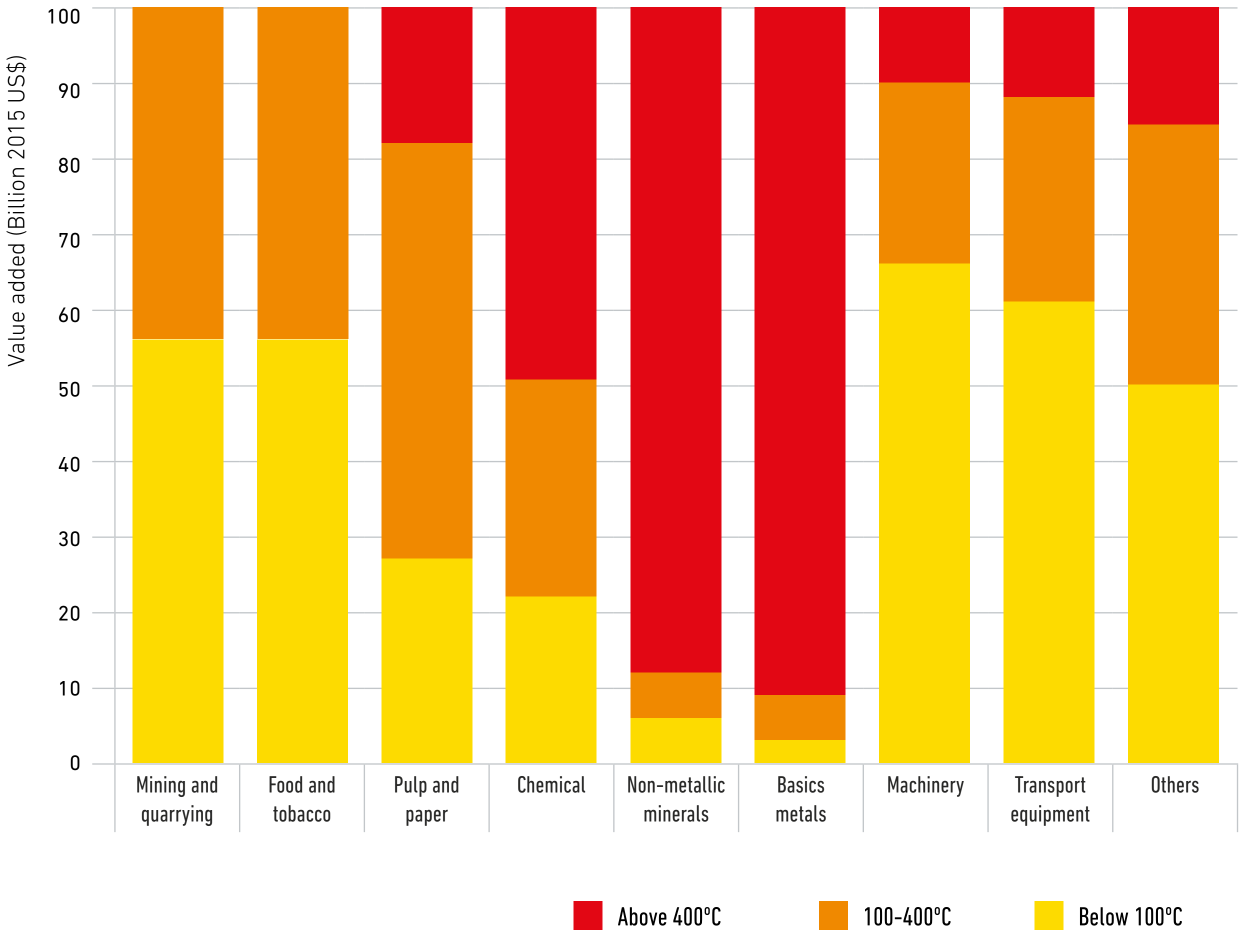


Figure 26. Share of industrial head demand by temperature in selected industries (Caludia et al., 2008)

There is a significant opportunity to decarbonize the industrial sector by shifting heat production away from carbon-intensive fossil fuels to clean sources such as electrification where low- or zero-carbon electricity is used.

Transformative steel production technologies

In addition to current dominant production technologies, there are other alternative technologies that are being developed which could reduce energy use and/or CO_2 emissions of industrial production significantly. Example of these emerging technologies for the steel industry are:

- **Hydrogen DRI-EAF:** Using renewable electricity to produce hydrogen and then use the hydrogen to produce direct reduced iron (DRI) that would otherwise be produced using natural gas or coal.
- **Electrolysis of iron ore:** Direct use of electricity to reduce iron ore by the electrolysis process.
- **Upgraded smelting reduction:** Maximizes the CO_2 content of the off-gases through pure oxygen operation, facilitating CO_2 capture and avoiding the need for coke or sinter.
- **Carbon capture,** utilization and storage (CCUS)

While there has been some progress, most CCUS technologies are in the research and development (R&D) or pilot stage. Nonetheless, there are several promising emerging technologies that can be implemented in the industry sector to capture carbon emissions from industrial plants. The latest status of emerging CCUS technologies for industry should be assessed to identify those that are promising for adoption in the industry sector in Ghana.

The applicability and selection of these decarbonization pillars will vary for sectors and trade-offs in cost (energy and operational costs (e.g., cost of CO_2 capture), local energy or carbon storage availability, infrastructure, etc. will influence choices. Investment and pursuit of multiple pillars in parallel will be vital for sectors to reach net/near zero CO_2 as illustrated in Figure 27. The in-depth study of the decarbonization pillars and quantification of their impact on GHG emission of industry in Ghana was beyond the scope of this study. This can be the topic of future studies in Ghana.

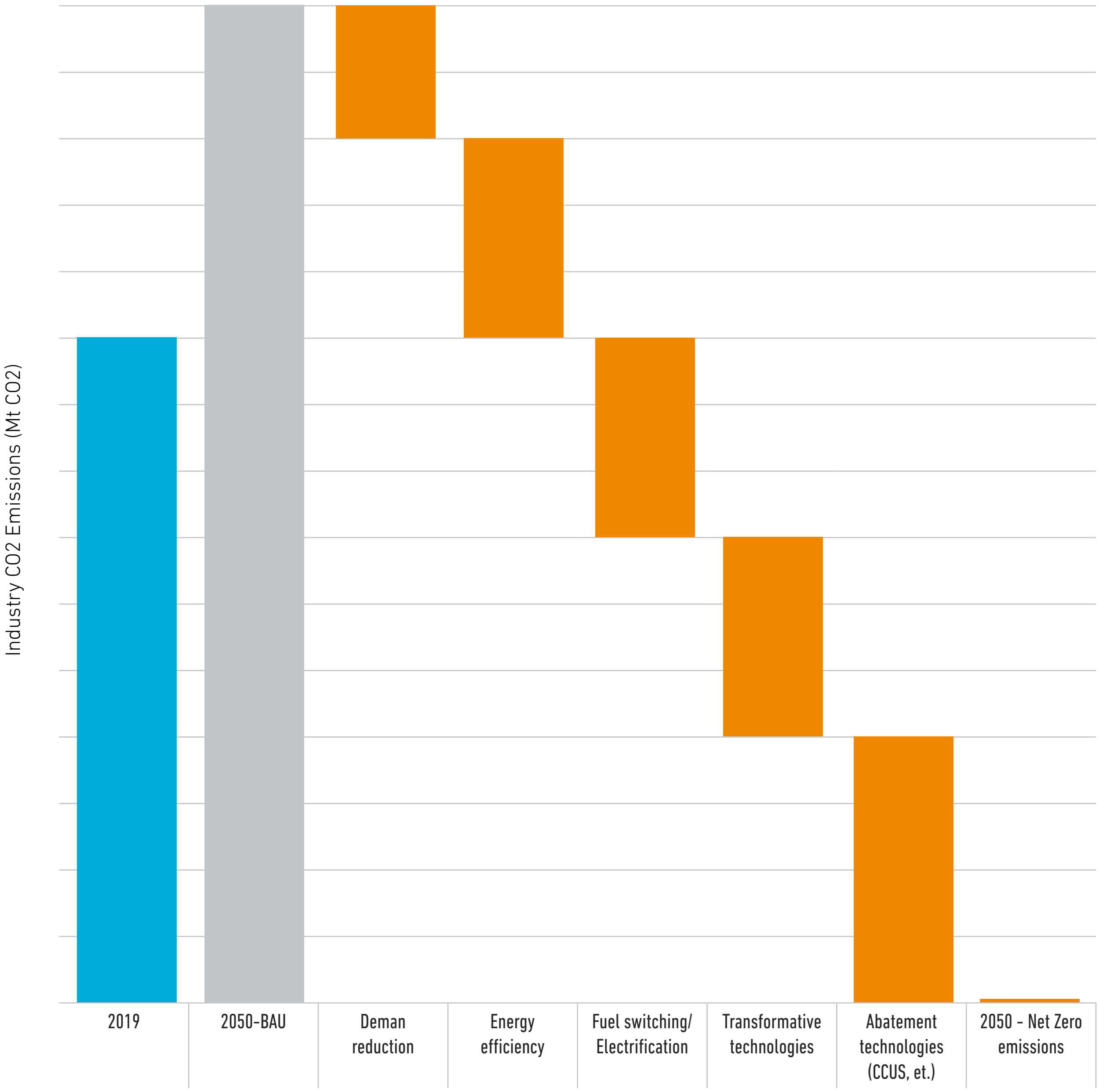


Figure 27. Illustration of decarbonization pillars.

7. International best practices on industrial energy efficiency policy

7.1. Overarching Programs to Incentivize Industrial Energy Efficiency

7.1.1. Voluntary Agreements

Agreements to meet specific energy-use or energy efficiency-targets are used in the industrial sector in many countries around the world. Such agreements can be viewed as a tool for developing a long-term strategic plan for increasing industrial energy efficiency that fully engages not only the engineers and management at industrial facilities, but also includes government, industry associations, financial institutions, and others. An agreement or target can be formulated in various ways. Two common methods are those based on specified energy-efficiency (or energy intensity) improvement targets and those based on absolute energy use or greenhouse gas emissions reduction commitments. Either an individual company or an industrial subsector, as represented by a party such as an industry association, can enter into such agreements.

Voluntary agreements on energy savings often exist with the ETS. As a result, in many countries, including Germany, Belgium, Finland, Netherland, and the UK, voluntary agreements on energy savings also apply to participating enterprises in the EU Emissions Trading System (ETS). Generally, under a voluntary agreement, participants negotiate a target with the government and by achieving the target, participants can get a variety of support and benefits from the government including technical assistance for energy efficiency, subsidies for energy audits and energy efficiency investments, tax relief or reduction, etc. There are also countries that use voluntary agreements with non-ETS participants and the mechanism and benefits are similar.

The key elements of voluntary agreement programs are the assessment of the energy-efficiency potential of the participants as well as target-setting through a negotiated process with all parties. The targeting setting process enables enterprises to better understand their energy efficiency opportunities. In addition, voluntary agreement programs often include supporting programs and policies, such as audits, assessments, benchmarking, monitoring, information dissemination, and financial incentives, which provide information, technical assistance and financial incentives to participants (Price, et al. 2003).

For example, the Netherlands has implemented the third generation of the Long-Term Agreements (LTAs) since 2007. This program covers small and medium size energy users (energy consumption < 0.017 Mtce/yr)[1] and includes energy savings throughout the entire product chain. All participants are required to develop energy efficiency Plans and implement all profitable measures. The government provides technology list with payback periods developed at the sector level to assist participants in choosing appropriate energy efficiency measures. Benefits of participating in the program and achieving the targets include regulatory benefits and financial benefits: 1) participating and compliance companies will no longer be subject to supplementary national policy governing CO_2 reduction or energy conservation; 2) participating and compliance companies will no longer be subject to specific national energy tax; 3) participating and compliance companies will no longer pay the costs of buying carbon credits in the field of the Joint Implementation, the Clean Development Mechanism (CDM) or emissions trading (IIP, 2015c).

7.1.2. Energy and Carbon Trading

Carbon emissions trading schemes have been adopted in a number of countries as a means to price carbon, reduce CO_2 emissions, and save energy. Emissions trading schemes are used to incentivize enterprises to invest in energy efficiency and emissions reduction projects through raising the cost of using energy and generating CO_2 emissions by charging enterprises a price per ton of CO_2 emitted (Aflaki, et al. 2012; Altmann, et al. 2013). Energy trading schemes are similar, but instead of trading carbon allowances, energy trading schemes

1 Large industrial energy users (companies with an energy consumption of at least 0.5 PJ per year) were covered by the 1st generation LTAs from 1992 to 2000 and then were covered by the Benchmarking Covenant until 2012, and are now covered by the LTA on energy efficiency (LEE), which is specifically designed for enterprises that participate in the EU ETS.

use energy savings certificates. We review the white certificate scheme, the Perform, Achieve, Trade scheme in India.

India's Perform, Achieve, Trade (PAT) Scheme for Energy-intensive Industries

India's Perform, Achieve, Trade (PAT) program is a market-based, energy efficiency trading scheme that aims to improve energy efficiency in energy-intensive industries. The PAT Scheme is being implemented in phases. The PAT scheme is the first cap-and-trade program for energy efficiency in developing countries. The scheme aims to enable industrial firms to continue expanding their activities, as long as they operate in an environmentally conscious manner. The scheme has also created an institutional structure to enable online data submission, annual audits and verification by designated auditors. It also helps enhance capacity-building in enforcing policies, collecting data, conducting monitoring and verification, and assessing compliance and levying penalties, which are all prerequisites for successfully implementing the scheme. PAT Cycle-I was designed to improve efficiency in eight energy intensive sectors: Aluminium, Cement, Chlor- Alkali, Fertilizer, Iron & Steel, Paper & Pulp, Thermal Power Plant and Textiles. The achievement in PAT Cycle-I is 8.67 Million Tonne of Oil Equivalent (Mtoe). PAT Cycle-II and III have added many more industrial plants and several new sectors and aim to achieve higher energy saving (Bureau of Energy Efficiency, n.d.).

The Ministry of Power's Bureau of energy efficiency (BEE) is responsible for setting mandatory, specific targets for energy consumption for larger, energy-intensive facilities (CDKN, 2013; IIP, 2015b). BEE sets energy efficiency targets for each Designated Consumer (DC) by calculating their baseline production, baseline energy consumption, and analyzing their potential for energy efficiency improvement. The government will set stricter target (percentage of reduction relative to baseline energy consumption) for historically less-efficient DCs than more-efficient ones. DCs report their energy efficiency efforts and progress to achieve their targets during the compliance period. If DCs save more energy than their targets, they will receive energy savings certificates (1 certificate=1 Mtoe), equaling to the amount of energy they have saved minus the amount of targeted savings. These certificates can be traded on two power exchanges, and a platform developed by BEE specifically for the trading of energy saving certificates (IETA, 2015; CCAP, n.d.).

The PAT scheme is the first cap-and-trade program for energy efficiency in developing countries (IETA, 2013b). In theory, the scheme should enable industrial firms to continue expanding their activities, as long as they operate in an environmentally conscious manner. The scheme has also created an institutional structure to enable online data submission, annual audits and verification by designated auditors. It also helps enhance capacity-building in enforcing policies, collecting data, conducting monitoring and verification, and assessing compliance and levying penalties, which are all prerequisites for successfully implementing the scheme (CDKN, 2013).

7.2. Key Supporting Mechanisms

7.2.1 Information to Inform Decision-makers and Spur Competitiveness

High-quality information on energy efficiency potential and the benefits of investing in energy efficiency can give decision-makers the knowledge needed to undertake energy efficiency investments. Such information can be provided to decision-makers through studies, guidebooks, networks, and industrial associations as well as through high-quality energy audits.

A. High-quality Information on energy efficiency Potential Including Technology Performance, Costs, Savings

High-quality information on energy efficient technologies, as well as high-quality information regarding the overall potential for energy savings and emissions reductions in industrial facilities or industrial sectors, is essential for setting realistic energy efficiency targets, establishing energy efficiency investment plans, and spurring meaningful action. High-quality information on energy efficient technologies include information on technology performance (e.g. quality, lifetime), upfront capital and installation costs, energy savings compared to conventional efficient technologies, and other benefits such as reduced labor costs for maintenance, reduced product waste, and reduced emissions of pollutants. The information is usually supported by guidebooks, criteria and other supplemental materials to help enterprises understand and utilize the information. It can be provided or managed directly by the government, by independent entities designated by the government, or networks or organizations established by enterprises.

Sources of High-Quality energy efficiency Information

Industrial Energy Accelerator:

The Industrial Energy Accelerator is a UNIDO-led network of international initiatives working to inspire global action on industrial energy efficiency. It showcases the vast opportunities that industrial energy efficiency and related efforts can provide for people, businesses, economies. In emerging and developing economies, their local teams of experts help drive momentum for energy efficiency with tailored training for industries, improved access to finance for entrepreneurs and policy advice for governments. The Industrial Energy Accelerator is a rich source of information for industrial energy efficiency.

The Industrial Energy Accelerator works to increase the uptake of measures and technology to boost efficient energy use. This involves designing solutions tailored to specific country needs and taking what we learn to inspire global action on industrial energy efficiency. Its network operates programs in over 10 countries which are home to large and growing industrial sectors with huge energy efficiency potential. Working in-country allows the Accelerator to forge critical relationships with local governments and industry players. These partnerships enable the Accelerator network to convene and build on existing work undertaken by various local and international organizations. Collaboration across sectors, stakeholders and countries is encouraged to improve knowledge sharing and collective impact. At a global level we share our collective experience with the world, showcasing best practice through stories of impact and knowledge resources, with the aim of inspiring greater global action on industrial energy efficiency (Industrial Energy Accelerator 2021).

U.S. Department of Energy's Technology Guidebooks[2]:

The U.S. Department of Energy's Advanced Manufacturing Office (AMO) partners with industry, small business, universities, regional entities, and other stakeholders to identify and invest in emerging clean energy technologies. AMO has published series of guidebooks on energy efficiency technologies and measures in different industry subsectors and energy systems (e.g., motor systems, steam systems, process heating systems, etc.). Also, AMO has supported the development and publication of several energy assessment tools for industrial plants and energy systems.

U.S. Environmental Protection Agency's Energy Star Program:

The U.S. Environmental Protection Agency (EPA) Energy Star Program has an Industrial Energy Management information center[3] designed to be a useful resource for industrial energy managers, and contains energy management information tailored

2 Link to tools published by AMO: http://www.energy.gov/eere/amo/software-tools

3 Link to the Industrial Energy Management Information Center: https://www.energystar.gov/buildings/facility-owners-and-managers/industrial-plants/industrial-energy-management-information-center

to industries or focused on specific plant utility and process improvements. This center provides information on energy efficiency technologies through various guidebooks for each industry subsector. It also provides tools and information for energy intensity benchmarking of industrial plants (EPA, 2015).

UK's Carbon Trust

The UK's Carbon Trust is an independent entity that assists businesses and the public sector to reduce carbon emissions. The Carbon Trust identifies carbon emissions reduction opportunities and provides resources and tools to help enterprises improve energy efficiency (Carbon Trust, 2016). Carbon Trust also help the UK government manage its Energy Technology List, which provides eligible technologies and products that are qualified for tax relief based on the ECA scheme (UK Gov. 2015c).

European Learning Energy Efficiency Networks:

Recently, the concept of energy efficiency Networks has had a significant success and interest in Europe. Learning Energy Efficiency Networks (LEEN) is a concept developed in Switzerland back in the 1990s. Since then, the approach has been successfully transferred to Germany, France and Austria. With these networks, 10 to 15 regionally based companies from different sectors share their energy efficiency experiences in moderated meetings. After the companies have formed the network, the process starts with an energy review and the identification of profitable energy efficiency measures in each company. Afterwards, the participants decide upon a joint target, which is allocated to the partners according to their efficiency potential. The subsequent networking process enables a continuous exchange on energy efficient solutions provided by the experiences of the network partners as well as external experts. The performance of each company is continuously monitored and controlled on a yearly basis. The network's operating period is typically from three to four years.

LEEN provides services such as initial energy diagnosis, survey and on-site evaluation. LEEN also provides suggestions on energy efficiency and carbon reduction measures and their economics. LEEN works with enterprises to help them set energy efficiency goals and organizes workshops and experience exchange activities. LEEN also helps to evaluate energy saving performance in the end. LEEN facilitates the communication between enterprises and provides expertise and knowledge to enterprises, which not only saves information searching and decision-making costs, but also improves energy efficiency awareness in enterprises and provides a healthy environment for enterprises to compete with and learn from each other on energy efficiency efforts. In addition, as a network and group, enterprises benefit from a louder and better voice to the government and the public, and could obtain better service from ESCOs more easily.

Government has a vital role in supporting the LEEN concept and encouraging enterprises to participate. For example, Swiss established "Carbon Emissions Law" and "Electricity Law" to either encourage or require enterprises to participate in the network to get tax relief. In Germany, after the initial establishment of the LEEN, the government improved its training and certification system for LEEN and set up energy efficiency network standard, which was later certified by ISO 50001. After these efforts, Germany included energy efficiency network into its National Energy Efficiency Action Plan. The German government could provide up to 80% of consultancy fee and financial support for some energy efficiency measures (OFWeek, 2016).

B. High-quality Energy Audits

An industrial energy audit is a necessary first step for understanding a facility's energy consumption by end-use and identifying key areas for energy saving in industrial operations. An industrial energy audit can also provide important impetus for industrial facilities to implement energy-efficiency measures and technologies.

High-quality energy audits can provide detailed cost-effective analyses of all identified measures and technologies, based on a plant's specific operating conditions and can provide packages of customized recommendations for plants to consider. Energy audits are sometimes funded by the government or public utilities and are usually partially subsidized or provided entirely free of charge to industry. Energy audits could be performed through a stand-alone energy auditing program, or implemented as a supporting policy tool for policies such as voluntary agreements or emissions trading programs.

A stand-alone energy auditing program largely focuses on the energy audit itself, and asks participants to perform energy audits. An integrated energy audit program combines energy audits with other policy measures to better motivate participants, to help decision-makers set reasonable yet ambitious energy-saving targets, and to achieve the broader goals of the program. Since energy-efficient technologies and measures improve over time, energy audits should not be viewed as one-time events, but should be performed regularly and can be combined with other policies and mechanisms to continuously promote industrial energy efficiency.

To ensure that energy auditing programs are successful, they should be supported by regulations, standards, and guidelines for conducting standardized energy audits, collecting energy auditing results, analyzing and evaluating energy audits, as well as incentives and supporting measures for participants. Quality control and monitoring of energy audits, as well as information dissemination are also important to robust energy auditing programs. Energy audit programs should also provide training and certification of energy auditors, since they will have a significant impact on the quality and output of the energy audits. Some countries provide a directory or network of accredited auditors or consultants to perform the audits, such as Australia's (former) EEAP and Norway's IEEN and Enova (MURE II, 2005; WEC, 2003). The U.S. Office of Industrial Technologies (OIT) Best Practices Program works with the selected facility to identify potential candidates to help with the audits (U.S. DOE OIT, 2005). For large energy consumers with advanced energy efficiency programs, the UK's Carbon Trust works directly with clients to address specific needs (Price, et al. 2005a).

Stand-alone Energy Auditing programs

Stand-alone energy auditing programs were identified in six countries. These programs were established by the national governments to stimulate demand for industrial energy audits, especially for small-and-medium enterprises (SMEs). The stand-alone energy auditing programs can be grouped into two categories (see Table 13): 1) programs that offer energy audits to facilities free-of-charge, and 2) programs that provide subsidies to companies to partially cover the costs of energy audits.

Table 13. Types of Stand-Alone Energy Auditing Programs

Category	Program Examples
Free energy audits	US Industrial Assessment Centers (US Department of Energy)
	UK Carbon Surveys (Carbon Trust)
	Japan Industrial Energy Audits (Energy Conservation Center of Japan)
	Ireland Energy Advice to SMEs (Sustainable Energy and Authority of Ireland)
Subsidized energy audits	Swedish Program of Energy Audits for Companies (Swedish Energy Agency)
	French Program of Energy Auditing for SMEs (Ministry of Economy, Finance and Industry)

There are several common features of the stand-alone energy auditing programs. First, these national programs are all voluntary and are open to all interested participants. Second, except for the Program of Energy Audits for Companies in Sweden, all other programs focus on SMEs. SMEs often do not have the resources that large enterprises possess in terms of expertise and information related to energy-efficiency (Nagesha and Balachandra, 2006; Worrell and Price, 2001). Typically, due to the pressing issues of economic survival and limited management capacity, SMEs either are not interested in energy audits or do not have the financial resources to afford a professional energy audit. Thus, a government-initiated energy auditing program can be a convenient channel for SMEs to seek expertise or financial support.

Stand-alone energy auditing programs typically focus on SMEs and are offered for free or with the costs shared between the industry and government. Stand-alone energy auditing programs often emphasize how to build an effective, standardized, and practical system and are designed to ensure that industrial participants can implement the proposed cost-effective measures. They also emphasize that energy audits be conducted in a comparable and coherent manner, and that the results be measurable, verifiable and useful to other manufacturers. Subsidies for energy audits, training and certification of energy auditors, standardized tools and guidebooks, energy audit databases, post-audit follow-ups and dissemination of case studies are critical to a robust and high-quality stand-alone energy auditing program.

Integrated Energy Auditing Program

Many industrial energy-efficiency policies and programs include industrial energy audits as a key component which is combined with other policy measures to better motivate participants and to achieve broader goals. Sixteen programs in 14 countries and the European Union have integrated industrial energy-efficiency policy programs that include energy audits.

The integrated policy programs include voluntary agreement schemes and mandatory regulations. Voluntary agreements (agreements signed between industry and the government) have been widely used (Price, 2005) and in many cases require energy audits for participants. Mandatory requirements are regulations or legal mandates established by national governments, which often require facilities to conduct energy audits, or meet energy-efficiency improving targets, or establish a certified energy/ environmental management system. Often, energy audits have been utilized as one of the effective tools to achieve broader goals of the national regulations.

Integrated industrial energy-efficiency policy programs with energy audits use an array of other policies or programs in combination with energy audits. These may include the use of certified energy or environmental management systems, requiring the establishment of energy-efficiency improvement targets or goals, requiring the establishment of energy action plans, exemptions from energy and/ or CO_2 taxes, the threat of applying an energy or CO_2 tax if targets or goals are not reached, financial support for investments, subsidies for energy audits, and recognition labels and awards. Based on country-specific conditions, energy auditing program developers (e.g., policy makers) decide which program type to use (either voluntary or mandatory), and which measures to include in their country-specific programs.

C. Providing Technical Assistance Through Enterprise Performance Rating Systems

Many enterprise performance rating programs in the U.S. help enterprises save energy and costs, through providing technical assistance or by requiring adoption of a standardized energy management system. Enterprises that participate in the program can get assistance, guidance or training on identifying and understanding energy efficiency opportunities.

Better Plants and Better Plants Challenge Program

The U.S. Department of Energy (DOE)'s Better Plants Program is a national partnership initiative to drive significant improvement in energy efficiency across U.S. industry. Manufacturers sign a voluntary agreement with DOE to reduce energy intensity by 25% over ten years with DOE. DOE in turn provides technical assistance to manufacturers to help them establish key energy performance metrics, evaluate energy saving opportunities, and organize plant-level training events. About 150 industrial companies, representing about 2,300 facilities and close to 11% of the total U.S. manufacturing energy footprint have participated in the program. The Better Plants Program is a broader-based initiative, which allow companies to make long- term commitments to energy efficiency and report their progress once a year.

Besides the Better Plants Program, the U.S. DOE also offers a Better Plants Challenge Program, which require more commitment from participating companies. The Better Plants Challenge requires partners to take on additional commitments to openly share their energy performance data and market-leading energy efficiency strategies (DOE, 2015d). Manufacturers can partner with DOE through either the Better Plants Challenge or the Better Plants Program.

Superior Energy Performance Program

In 2007, DOE partnered with the U.S. Council for Energy Efficient Manufacturing (U.S. CEEM), American National Standards Institute (ANSI), and the ANSI-ASQ National Accreditation Board (ANAB) to establish the Superior Energy Performance (SEP) Program. SEP certifies industrial facilities that implement an energy management system that meets the ISO 50001 global energy management system standard and achieves improved energy performance. An independent third party audits each facility to verify achievements and qualify it for recognition at the Silver, Gold, or Platinum level, based on performance. To date, the program participants achieved annual savings of $87,000 to $984,000 using no-cost or low-cost operational measures, with an average of 10% reduction in energy costs within 18 months of SEP implementation and 6% to 25% improvement in energy performance over three years (DOE, 2015c).

The Superior Energy Performance program requires manufacturers to implement an ISO 50001 certified energy management system, which can identify current energy practices and energy improvement opportunities. With the implementation of an energy management system that provides data and analysis to inform decision-making, the plants are not only able to make better decisions on energy improvement, but also document their performance and increase their recognition and credibility (McKane 2014; DOE, 2015c). The SEP program provides guidance, tools and recognition, which is essential to the implementation of energy management.

D. Providing Favorable Tax Treatment or Incentives Through Technology Promotion List

Many countries provide tax reduction and other financial incentives to enterprises that install targeted energy efficiency technologies that are included in a technology promotion list. The UK's Enhanced Capital Allowance Scheme is an example of such a technology promotion list. Enterprises that invest in energy-saving technologies specified in the "Energy Technology List", can deduct the capital costs of those technologies against their taxable profits for the investment year (HM Revenue & Customs, 2008).

7.2.2 Reducing energy efficiency investment risk

A. Use of Green Bank to Reduce Investment Risk and Provide Technical Assistance

Green banks are financial institutions that assist their customers with purchase of clean energy technologies. Green banks have been established to address cost concerns and administrative complexities associated with direct incentive programs such as grants and rebates (Belden, et al. 2015).

The UK Green Investment Bank (GIB) is the first green bank to provide funding for green and profitable infrastructure projects. Supported technologies in the energy efficiency area include building retrofits (e.g., lighting, insulations, glazing), on-site generation (e.g. CHP, renewable heat, heat pumps), industrial process (e.g. motors, pumps, kilns), and Infrastructure (e.g. streetlighting, heat networks). From 2014-2015, funding of $324 million (£260 million)[4] was provided to energy efficiency projects, including sheltered housing boiler replacement, street-lighting project, data center retrofit, and a SME energy efficiency platform. The total investment in energy efficiency projects accounted for 14% of the bank's total investment (GIB, 2015).

The Union of Concerned Scientists evaluated six state governments (Connecticut, New York, Pennsylvania, Kentucky, Iowa, and Massachusetts) in the US and one national government (Germany) that have developed green banks (Belden, et al. 2015). The study shows that green banks have helped promote investments in clean energy and these clean energy financing programs have successfully engaged diverse stakeholders to help mobilize capital. The study provides some important insights on the role of government administrators and collaborative efforts (Belden, et al. 2015):

"Government administrators have: 1) made use of in-house energy expertise to reduce the financial risks of private-sector loans for clean energy projects; 2) educated, and were educated by, the financial sector; 3) enabled a broad array of individuals, businesses, and institutions to achieve savings from clean energy investments."

And collaborative efforts have also been included 1) to "make use of existing contractor networks to help roll out financing programs"; 2) to "consult with the financial community to build trust and identify sustainable funding sources"; 3) and to "draw on local utilities" experience in delivering programs to their customers to avoid duplication and maximize effectiveness.

B. Loans and Grants to Provide Financing

The DOE Loan Guarantee Program was created in 2005 under Section 1703 of Title XVII of the Energy Policy Act of 2005 to support innovative clean energy technologies that are typically unable to obtain conventional private financing due to high technology risks. These technologies include: biomass, hydrogen, solar, wind/hydropower, nuclear, advanced fossil energy coal, carbon sequestration practices/technologies, electricity delivery and energy reliability, alternative fuel vehicles, industrial energy efficiency projects, and pollution control equipment (DOE, 2015e).

The UK's Carbon Trust provided interest-free loans to small- and medium-sized enterprises (SMEs) (Carbon Trust, 2008). Interest-free loans were available to eligible SMEs in Wales and Northern Ireland that wish to upgrade to more energy efficient equipment and renewable technologies. Carbon Trust provided $1,246 of loan for every 1.5 tCO_2 energy efficiency project is expected to save per annum within the range from $2,729 to $249,290[5] (Carbon Trust, 2015).

Australia implemented a Clean Technology Investment Program in 2012. It provided $615 million (800 million AUD)[6] grants for over 7 years for capital investment in energy efficient equipment and low emissions technologies, processes and products. Manufacturers that meet a minimum energy or emissions threshold can apply (IEA, 2015).

C. Public Private Partnerships to mobilize energy efficiency Investment

Public-private partnerships (PPPs) for energy efficiency finance are "mechanisms that use public policies, regulations, or financing to leverage private-sector financing for energy efficiency projects" (IEA, 2011). There are three main forms of PPPs in the energy efficiency area: 1) dedicated credit lines; 2)

4 1 British Pound=1.245 US Dollar as of November 3, 2016.

5 1 British Pound=1.245 US Dollar as of November 3, 2016. Carbon Trust provides £1,000 of loan for every 1.5 tCO2 energy efficiency project is expected to save per annum within the range from £3,000 - £200,000.

6 1 Australian Dollar=0.77 US Dollar as of November 3, 2016.

risk-sharing facilities; and 3) energy performance contracting (EPC).

Dedicated Credit Lines

Dedicated credit lines are mechanisms to encourage local financial institutions (LFIs) to offer sub-loans to implementers of energy efficiency projects. Public entities, such as government, international financial institutions, and donor organizations, provide funds to private-sector organizations such as banks and LFIs, at a low interest rate to encourage them to provide and lend more funds for energy efficiency projects, which usually have higher interest rates. Local financial institutions earn profits from these loan transactions (IEA, 2011).

Dedicated credit lines help LFIs improve their awareness of the benefits and characteristics of energy efficiency financing. Public entities leverage dedicated credit lines to encourage LFIs to provide funds to expand the scale of the fund available for financing from public entities. Governments also provide technical assistance to LFIs to build and enhance the capacity of LFIs (IEA, 2011).

For example, Thailand initiated the Energy Efficiency Revolving Fund (EERF) in 2003 to incentivize financial institutions in Thailand to lend for energy efficiency measures (Grüning et al. 2012). For industry, eligible projects included “improvement in combustion efficiency of fuels; prevention of energy loss; recycling of energy wastes; substitution of one type of energy by another; more efficient use of electricity through improvements in power factors, reduction of maximum power demand during peak demand, use of appropriate equipment and other approaches; and use of energy efficiency machinery or equipment as well as use of operation control systems and materials that contribute to energy conservation” (IEA 2011). The source of funding for the EERF was the government budget collected from a tax on petroleum products.

The EERF was successful in stimulating financial institutions in Thailand to finance energy efficiency, and also represented a shift in the role of government from “enforcer and regulator to facilitator and supporter” (Grüning et al. 2012; USAID, 2009). Success factors included: 1) simplified procedures for project application, appraisal, reporting, and loan processing; 2) offering loans with interest rates lower than the market rate to attract commercial banks; and 3) technical assistance and education from the Department of Alternative Energy Development and Efficiency (DEDE) (IEA 2011, Grüning et al. 2012, USAID 2009). To obtain EERF financing, the owner of an industrial or commercial facility or ESCOs conducted energy audits to identify energy efficiency projects. Then commercial banks conducted financial analysis of the project if they have the technical staff, and if not, DEDE helped them conduct the technical assessment (USAID, 2009). A DEDE official also paid a visit to all banks in Thailand to promote the EERF and explain the application process and the eligibility criteria (Grüning et al. 2012).

Streitferdt and Chirarattananon (2015) explain, however, that an external financial mechanism such as EERF can damage the market and impede it from becoming mature since the mechanism couldn’t “induce banks to experiment with different credit provision models” and the technical support was superficial and failed to sufficiently “transfer the technical and credit lending advice to the banks”. They also pointed out the there is a lack of demand for energy efficiency projects and finance from customers, which may result from a lack of mandatory regulation on energy efficiency improvement or a lack of implementation and enforcement of these regulations (Streitferdt and Chirarattananon, 2015).

Risk-sharing Facilities

Risk-sharing facilities are mechanisms where a public entity offers guaranteed product to reduce energy efficiency project financing risks to private sector. Government, multilateral banks, or donor organizations absorb some energy efficiency project financing risks by providing a partial guarantee that covers a percentage of the loss due to loan defaults. Risk-sharing facilities also include some technical assistance and capacity building, as in the case of dedicated credit lines (IEA, 2011).

Two examples of risk-sharing facilities are the Commercializing Energy Efficiency Finance (CEEF) Program in Europe that operated from 2003 to 2008 and the Partial Risk Sharing Facility for energy efficiency (PRSF) in India since 2015. The CEEF was launched by the International Finance Corporation (IFC) and the Global Environment Facility (GEF). The PRSF was an agreement between the World Bank and the Indian government with funding from GEF and the Clean Technology Fund (CTF) under the Climate Investment Fund (CIF). Both programs have a risk sharing component where IFC or the Small Industries Development Bank of India (SIDBI) guaranteed a certain amount of project risk to the participating financial institutions. The CEEF offers 50% of the project risk and PRSF guarantees the partial credit to 40-75% of the energy efficiency loan (IEA, 2011; WB, 2015).

The two programs also have technical assistance and capacity building components, which help financial institutions market and develop their energy efficiency financial services, prepare projects for investment, improve capacities for energy efficiency project financing, and help ESCOs to develop energy efficiency projects and their business capacities. Technical assistance is considered very important and participants appreciated the trainings and seminars provided (IEA, 2011). It is also very important to have a local presence from the granting agency in the countries where the program is implemented, as local staff of the agency can help participants to continue their work and ensure take-off of the projects (IEA, 2011).

The market maturity of energy efficiency and general acceptance of the guarantee product is also very important. The IEA points out that the CEEF has been more successful in the countries with more developed energy efficiency markets than in the countries where financial institutions are less interested in energy efficiency financing and there are fewer ESCOs (IEA, 2011).

Energy Performance Contracting and ESCOs

Energy Performance Contracting (EPC) is a mechanism that uses private sector investment and expertise to deploy energy efficiency retrofits in buildings, industries, and other types of facilities (Shen, et al. 2015). ESCOs and public agencies will make performance-based agreement and ESCOs will get payments contingent on demonstrated performance (IEA, 2018).

About 40 countries around the world have ESCO activities. ESCOs started in the US, Canada, Sweden and the UK in the 1970s and early 1980s, and were then established in many other countries in the late 1980s, 1990s and even today (Vine, 2005; Goldman, et al. 2005). Studies on the experiences of these countries have identified the following success factors and actions to further promote ESCOs (Vine 2005; Bertoldi, et al. 2006):

1. Provide training to energy managers and financial institutions to increase their awareness of ESCO services and projects. To disseminate ESCO information, a third-party financing network can

also be established to include all key players in the market, including ESCOs and their associations, energy efficiency agencies at the national and local level, financial institutions, equipment manufacturers, and other stakeholders.

2. Establish accreditation systems for ESCOs, such as the US ESCO accreditation system implemented by the National Association of Energy Service Companies (NAESCO), to ensure that they provide qualified and reliable service.

3. Develop funding and financing sources for ESCOs to market, prepare, and develop their projects. Funding sources could be traditional, such as private financial institutions, multi-lateral funders such as the World Bank and IFC, and could also be innovative, such as revolving funds.

4. Standardize energy performance contracts, and measurement and verification (M&V) so that facilities and financial institutions can better understand and develop EPCs. For example, NAESCO worked with industry to develop the International Performance Measurement and Verification Protocol (IPMVP), which is used to measure and evaluate energy-efficiency projects.

These three approaches - dedicated credit lines, risk-sharing facilities and EPC - can be applied in different market environments. Dedicated credit lines are most suitable in financial markets that are less mature and LFIs are in need to provide better understanding of the benefits and characteristics of energy efficiency projects. Dedicated credit lines also require greater funding from public sectors as they have to finance LFIs (IEA, 2011). Risk-sharing programs are applicable to markets that are somewhat mature and LFIs want to finance energy efficiency but are worried about the high risks associated with those projects (IEA, 2011). EPCs are most useful in mature financing markets with enough liquidity of LFIs and enough awareness and capability to provide energy efficiency financing. EPCs have the potential to scale up LFI financing, which is difficult to achieve through dedicated credit lines and risk-sharing programs (IEA, 2018, Zhu 2020, US DOE n.d.).

D. Tax Incentives to incentivize energy efficiency Investment

As mentioned above in the technology promotion list with tax incentives, many countries have utilized tax incentives and tax relief to boost investment in energy efficient products, equipment, and technologies. IEA (2015, 2012) identified 13 IEA countries that have implemented tax relief programs for industrial equipment: Belgium, Canada, France, Germany, Ireland, Italy, Japan, the Republic of Korea, Netherlands, Norway, Portugal, the United Kingdom, and the United States.

Tax rebates are programs in which companies deduct the cost of energy-efficient equipment from their annual profits and are found in Japan, Korea (Republic of), the Netherlands, and the UK. In the Republic of Korea, a 5% income tax credit is available for energy-efficiency investments such as replacement of old industrial kilns, boilers, and furnaces; installation of energy-saving facilities, co-generation facilities, heat supply facilities, or energy-saving equipment; alternative fuel using-facilities; and other facilities that reduce energy use by 10% (UNESCAP, 2000). In Japan, there is a "Green Investment Tax Reduction" program to provide small and medium enterprises business operators that purchase eligible energy savings or CO_2 emissions reduction equipment with a special depreciation of 30% against the standard purchase prices or a 7% tax deduction (IEA, 2016).

In the Netherlands, under the Energy Investment Deduction (Energie Investeringsaftrek, EIA) program, originally 40% and now 55% of the annual investment costs of energy saving equipment can be deducted from the fiscal profit of the calendar year in which the equipment was procured, up to a maximum of US $116 M (€107M). Qualifying equipment is provided on an "Energy List" and the costs associated with obtaining advice for purchased equipment can also be included. Approval is granted by SenterNovem, an agency under the Dutch Ministry of Economic Affairs. The UK's Enhanced Capital Allowance Scheme discussed above is also an example of tax relief, which provides 100% write-off in the first year of purchase (Price, et al. 2005b). Germany has implemented a Tax Cap ("Spitzenausgleich") since 2013, which provides tax relief for industrial companies that take energy efficiency measures such as implementation of energy management systems and achieving energy efficiency targets that are required for receiving the exemption (IEA, 2015).

However, the real effectiveness of tax relief is difficult to measure because of limited data and free-rider issues[7] (Ryan, et al., 2012; Price, et al. 2005b). Programs should be designed such that they avoid providing tax relief for technologies that are already profitable (de Beer et al., 2000).

7 The free rider issue "is a market failure that occurs when people take advantage of being able to use a common resource, or collective good, without paying for it, as is the case when citizens of a country utilize public goods without paying their fair share in taxes". (Investopedia, n.d.)

8. Policy recommendations and action plan

Economically viable energy efficiency options in the industry sector of Ghana represent substantial potential for energy savings (see section 6). However, according to the results of the survey of policy makers in Ghana, improvement in the industrial energy efficiency of Ghana faces many challenges such as inadequate data collection, inadequate financing mechanism, inadequate availability of technical expertise and information.

The following subsections presents policy recommendations and action plan for the industry sector in Ghana to address the barriers and improve its energy efficiency and reduce carbon emissions in industry. These recommendations are formulated from the survey of policy makers and stakeholders in Ghana as well as two technical workshops that hosted different stakeholders in Ghana to discuss barriers, needs, and opportunities for industrial energy efficiency and decarbonization in Ghana.

8.1. Policy options for industrial energy efficiency and decarbonization in Ghana

Energy standards and labels for industrial equipment:

One of the ways of accelerating the deployment of energy-efficient technologies and encouraging industry to invest in energy-efficient technologies could be to develop and mandate the standards and labels for the industrial equipment (United Nations Industrial Development Organization (UNIDO), 2018). The standards and energy efficiency labels can then be used to adopt minimum energy performance standards (MEPS) in the industry (For example, many countries have adopted MEPS for electric motors). The standards and labeling programs was among the top ranked policies in the survey we conducted in Ghana.

Innovative funding mechanisms, grants and subsidies:

Investment in industrial energy efficiency can be encouraged by subsidizing the loans for industrial energy efficiency projects using public funding i.e., soft loans which are offered at an interest rate lower than the market interest rate. Innovative funds can be a combination of funds from ESCOs, guarantee funds, revolving funds or venture capitalists and grants from the public sector to encourage investments in industrial energy efficiency measures typically until they achieve the market acceptance level and then be funded on their own. This policy tool can be of particular interest to developing economies such as Ghana since it is usually more difficult to raise finances for industrial energy efficiency investment in high-risk market conditions (United Nations Industrial Development Organization (UNIDO), 2007). Similar funding scheme used in Ghana in 2012-2013 for domestic refrigerators – “Refrigerator Rebate Scheme” that rolled out national program encouraging users through subsidies to go for energy efficient refrigerators and deep-freezers could be adopted for industrial equipment in Ghana.

Along with grants and innovative funding policies, the Government of Ghana can encourage the investment in industrial energy efficiency by providing other fiscal incentives like tax exemptions on the purchase of equipment for energy conservation projects or by providing an exemption on import duties on energy-efficient technologies as well as fiscal penalizations like application of fines for non-compliance with energy efficiency laws/regulations. These fines can then be used to set up some sort of energy efficiency fund. The fund can be used to provide financial support for other aspects of industrial energy efficiency program (United Nations Industrial Development Organization (UNIDO), 2018)).

Target agreements with financial incentives:

Large energy-intensive industries from the manufacturing sector can enter into a voluntary target agreement with the Government of Ghana to improve industrial energy efficiency and reduce GHG emissions. The target agreements can be set up with or without financial incentives (Fernando Castro-Alvarez, 2018). As part of the target agreements, the participating companies undergo an energy audit by the government or a third-party auditing agency and a list of cost-effective energy efficiency measures is suggested. The cost-effectiveness of investments in energy-saving projects can be enhanced through market-based mechanisms like tradable excess energy savings certificates (ESCert or white certificates). These white certificates are issued to the company for surpassing the saving targets set in a voluntary agreement and the companies that do not meet the targets set in the agreements are obligated to buy those certificates (e.g., PAT scheme from India). Financial incentives can also be provided in the form of future threats of regulation/CO_2 tax or currently existing CO_2 tax can also be used to incentivize the companies to commit to voluntary target agreements (Price, 2005).

The data from the implementation of industrial energy efficiency measures from the voluntary target agreements can also be used to create a database of industrial energy efficiency measures under the technology/knowledge sharing programs. Regional clusters can also be created to encourage knowledge and technology sharing within the clusters.

Energy management standards:

Energy management systems like ISO 50001, a system of voluntary standards provide a set of protocols and procedures for the management of energy consumption. Such energy management systems can be used to identify the opportunities, set and track internal goals for industrial energy efficiency improvement and GHG emission abatement. Certifications like ISO 50001 can be used voluntarily, or compliance can be mandated for selected large consumers by the government. Facilitation/encouragement of energy management systems can be an attractive tool for industrial energy efficiency improvement in developing countries like Ghana since it is one of the effective ways for private sector actors to systematically improve energy efficiency and reduce GHG emissions. Moreover, the governments can also provide technical support directly to the staff to implement monitoring systems and to identify energy-saving measures (USAID, 2020). Data obtained from our field survey shows that only 6% of industrial plants surveyed have ISO 50001 certification. This shows a great potential for capacity building and support to increase Energy management systems certification in industry in Ghana.

Enabling energy service companies (ESCOs) market

ESCOs are private or public companies that can provide technical, commercial and financial services needed for industrial energy efficiency projects. ESCOs can take project performance risks, arrange financing and may also take customer credit risks in some cases. ESCOs can operate through shared saving contracts (where performance and credit risks are assumed by ESCOs) or through the guaranteed saving contract (where the finance is arranged by ESCO, but the loan contract is between the bank and the customer) (USAID, 2020).

8.2. Skills and capacity building programs for industry in Ghana

Effective implementation of an energy efficiency program requires a group of experts to identify the energy efficiency opportunities, implement the measures as well as evaluate and keep track of the program at various stages and levels. Capacity building programs should be focused on producing a cadre of such experts within the country. These programs can contribute significantly to overcoming the barrier of lack of skills and knowledge related to energy efficiency improvement. Skills and capacity building programs ideally include theoretical as well as hands-on intensive training workshops targeted towards key market enablers from private as well as public sectors (e.g., equipment manufacturers, government agencies, consulting companies). The training program is usually coupled with recognition for competency through a certificate.

Our survey of the companies in Ghana showed that a significant number of companies do not have personnel/units responsible for energy efficiency, many companies have inadequate knowledge in energy management practice, many companies do not have knowledge on how to apply various financial models to potential energy saving projects in order to determine their feasibility, and overall there is a major lack of capacity, awareness, education, and training both for companies and policy makers in Ghana.

The governments of developing countries such as Ghana can seek assistance for technical capacity building from international organizations in the form of funding or expertise. An example of one such program is UNIDO's China Motor System Energy Conservation Program through which many engineers were trained in motor system optimization techniques which resulted in the identification of nearly 40 million kWh in energy savings through the assessment of 38 plants (United Nations Industrial Development Organization (UNIDO), 2007).

Along with the organization of technical workshops the government of Ghana can also encourage the educational institutions that are producing engineers, economists, and other technical professionals to provide training related to energy efficiency such as system optimization and energy auditing by introducing courses.

Market transformation, one of the important goals of industrial energy efficiency program can be achieved through the government's focus on building research and development capacities within the country so that local manufacturers can benefit from the expertise and will be able to upgrade and develop their products to meet the highest degree of energy efficiency.

Building capacity programs for educational and research and development institutes can be supported through regional collaboration programs like the Centre for Renewable Energy and energy efficiency for the Economic Community of West African States (ECOWAS) region (ECREEE 2022).

8.3. Data collection framework for industrial data in Ghana

Ghana lacks proper data collection framework for industrial energy use and emissions. While conducting this study, we face severe challenges regarding data and information related to energy use in industry sector in Ghana. Even basic information on how much energy use by industry subsector and energy type is not available in Ghana. This highlights an immediate need in Ghana to establish a proper data collection framework for collecting industrial data.

Having an effective data collection framework is necessary to track industrial energy efficiency progress and disentangle the different drivers of energy demand and GHG emissions. Data collection framework for industrial energy efficiency improvement and decarbonization should include energy demand side data as well as data related to the assessment of industrial energy efficiency improvement. Along with sub-sectoral energy demand data, it's necessary to include the activity data (value-added or physical output) representing similar boundaries in the data collection framework in order to track the energy intensities at the level of industry sector and sub-sectors.

The first step in the data collection framework that could be suggested for the government of Ghana is taking inventory of already available data required to track the industrial energy efficiency. This data may already have been collected by the subsector related trade organizations. This step is followed by identifying the data gaps, deciding the methods of data collection, frequency of data collection and sample sizes. There are various ways of collecting the bottom-up data required for the implementation of a successful industrial energy efficiency program. Data collection for both energy demand and energy efficiency at the subsector level could be performed with the combination of surveys, modeling and metering. Surveys can be conducted either by industry census (applicable to more homogenous subsectors with bulk products such as iron and steel, cement, pulp and paper etc.) or by a stratified sample approach (practical for heterogenous subsectors). In order to effectively capture the development of energy efficiency trends, the surveys should be carried out annually.

The Government can either mandate the responses or provide financial or non-financial incentives to the respondents. Metering is typically done in the context of holistic energy audits of individual establishments. Metering can be an important method for tracking energy efficiency at the level of industry processes and benchmarking exercises. Collection and publication of metered data however can be inhibited by confidentiality issues. Which can be overcome by anonymizing the data wherever possible. Modeling can be used to complement the surveys and measured data. Models are useful in developing more detailed indicators such as process efficiencies and technology diffusion as well as for generating future scenarios. Detailed energy benchmarking exercises as well as the energy efficiency measures already implemented within the industry sector can also be made part of data collection framework to evaluate the energy performance of industrial processes in relation to industry best practices (International Energy Agency (IEA), 2014).

8.4. Awareness strategy to engage industrial companies in Ghana

Information campaigns to raise awareness and engage industrial companies should be at the core of energy efficiency program (United Nations Industrial Development Organization (UNIDO), 2007). Industry engagement strategies are typically set with the goal of addressing the communication gaps, lack of collaboration between the government and the private sector and reducing asymmetric information related to industrial energy efficiency programs. The outreach to the private sector right from the initial stages of the industrial energy efficiency policies and programs will result in the private sector being active partners in the process of setting up the programs and governments will benefit from developing a strong understanding of drivers and barriers for the industrial energy efficiency within the private sector. For an effective industrial energy efficiency program, the government needs to form partnerships with companies from the private sector.

The first step for the Government of Ghana in order to engage the private sector could be to analyze the context of engagement. This can be done by setting up a committee composed of government officials responsible for industrial energy efficiency programs and key market enablers from the private sector. Once the contexts are analyzed, the government can then set up an outreach program to communicate the energy efficiency program with the private sector, identify the vulnerabilities and revise and appraise the program if necessary. During the implementation stages, the government can provide support for the implementation of energy efficiency measures within the companies. Development of reporting and monitoring mechanisms should also be part of the private sector engagement strategy. The private sector engagement can be further enhanced by sharing knowledge and success stories (Crawford, 2020).

These partnerships can result in changing existing practices and behaviors in favor of greater industrial energy efficiency, dissemination of energy efficiency messages further down the supply chain or to trade associations, developing credibility within the industry sector, ensuring the proposed policies are practical, identifying the right talent pool for further building capacity programs and dissemination of financial benefits of industrial energy efficiency (UNIDO,2018).

8.5. Monitoring and evaluation framework

Having clear goals and clear metrics can greatly help the effectiveness of industrial energy efficiency program. Monitoring and evaluation of energy efficiency programs can help ensure the accountability and effectiveness of the program. Establishing the goals and metrics at the beginning of the program can help to identify which data should be collected, and the process of data collection. Monitoring is a process of collecting the data related to effects of energy efficiency measures and evaluation entails analysis of collected data. The government of Ghana can set up the monitoring task using several different ways (USAID):

- Computer-based modelling to predict energy performance.
- Measurement of the energy use on the whole before and after implementation of the industrial energy efficiency program.
- Conducting field measurements for the energy savings by individual upgrades.
- Monitoring the market compliance through product testing based on prescribed protocols, accreditation of testing facilities and proper reporting.
- Top-down monitoring of energy efficiency gains at sectoral and sub-sectoral levels.
- Monitoring of market trends of energy efficient technologies.

The evaluation of the energy efficiency program helps governments gauge the success or a failure of the program. In case of failure the monitoring and evaluation framework can help identify the pitfalls of the program. Evaluation of the energy efficiency program typically takes place at three levels. Process level evaluation addresses the stages like design and implementation of the program, capacity building activities to support the program and financial mechanisms. Impact evaluation focuses on the energy savings achieved through the program whereas market evaluation assesses the market growth and energy efficient technology penetration.

8.6. Recommendations for institutional arrangements and responsibilities

Based on the recommendations of the different policy options for industrial energy efficiency and decarbonization in Ghana, it is suggested that a "National Energy Efficiency Committee (NEEC)" be constituted to undertake activities related to policy formulation, monitoring, reporting and verification for industrial energy efficiency. It is suggested that the chairman of the NEEC or taskforce should be from the Ministry of Energy. Members of the NEEC from other ministries and agencies will be the Ministry of Finance, Energy Commission, Ministry of Trade and Industry, Environmental Protection Agency and Council for Scientific & Industrial Research. Additionally, other members of the NEEC shall be from academia, industry, professional bodies, private sector, research and energy consultancies, etc. These entities should have coordinated responsibilities to play across the whole spectrum for industrial energy efficiency in Ghana, bringing on board local knowledge and international best practices as may be relevant. The table below suggests some of the proposed entities and their respective responsibilities under the NEEC.

Table 14. Roles and responsibilities of members of the NEEC

Institution	Recommendation/ Roles & Responsibilities
Ministry of Energy (MoEn)	• To be the sector lead in preparing industrial energy efficiency policies and Legislative Instruments. • In collaboration with Energy Commission (EC) and other agencies to prepare proposals to secure grants to undertake national industrial energy efficiency projects.
Ministry of Finance (MoF)	• Support in subsidizing loans for industrial energy efficiency projects using public funding (i.e., soft loans which are offered at an interest rate lower than the market interest rate). • Providing other fiscal incentives like tax exemptions on the purchase of equipment for industrial energy efficiency projects.
Energy Commission (EC)	• To lead in the preparation and enforcement of standards and labels (S&L) for high energy consuming industrial equipment. • To lead in the preparation of national industrial energy efficiency programs and timelines. • To prepare national communications (NCs) and reports on industrial energy savings from industrial energy efficiency projects. • To lead awareness creation and information sharing on industrial energy efficiency. • To provide registration and licensing of energy auditors for industrial energy efficiency projects. • Develop and implement a system for Measurement, Reporting and Verification (MRV) of industrial energy efficiency in Ghana.
Ministry of Trade and Industries (MOTI)	• In collaboration with Energy Commission, undertake preparation of national industrial energy efficiency programs and timelines. • Support development of standards for promoting industrial energy efficiency • Provide support to industries to implement industrial energy efficiency projects
Environmental Protection Agency (EPA)	• Prepare national inventory of GHG emissions from large industrial faculties. • Prepare reports on GHG emissions reduction potential from industrial energy efficiency programs.
Council for Scientific and Industrial Research (CSIR)	• Support research on industrial energy efficiency opportunities across different industries in Ghana. • Develop guidebooks and tools for industrial energy efficiency

Institution	Recommendation/ Roles & Responsibilities
Academia *Kwame Nkrumah University of Science & Technology (KNUST), Kumasi* *University of Energy and Natural Resources (UENR), Sunyani*	• Through their certified centers for Sustainable Energy Services, deliver training and certification for energy auditors and energy management professionals • Support Energy Commission to conduct industrial energy audit. • Support research on industrial energy efficiency.
Energy Foundation (EF)	Support Energy Commission to undertake industrial energy audit
Energy Consultants and ESCOs *Enercom Africa Limited*	• Advice on policy development of industrial energy efficiency based on international best practices. • Conduct market research, capacity building and training on industrial energy efficiency based on international expertise and best practices. • Advice on development of policy on data collection and analysis framework for industrial energy efficiency. • Advice on policy aimed at financial & investment evaluations for industrial energy efficiency based on local and international expertise. • Advice on policy development and incentives to leverage private sector investors' support for industrial energy efficiency.
Association of Ghana Industries (AGI)	• Support in collecting energy consumption data collection from the member industries. • In collaboration with EC and ESCOs, implement mandatory energy management systems (ISO 50001 & ISO 50002) in member organizations/industries. • To lead in signing target agreements between large energy-intensive industries and the Government of Ghana to improve industrial energy efficiency and reduce GHG emissions.
ECG/NEDCO/GRIDCO/IPP	Support in data collection from industrial facilities.
Ghana Association of Bankers	Support in preparing loans "**special interest rates**" that are lower than market rates for industrial energy efficiency projects.

8.7. Policy Proposal: Top-100 Energy-Consuming Enterprise Program in Ghana

This proposed Top-100 Energy-Consuming Enterprise Program in Ghana is modeled on international target-setting programs (also called voluntary or negotiated agreement programs). These types of target-setting programs that focus on energy efficiency improvement and reduction of GHG emissions by industry have been implemented in both developed and developing countries since the 1990s. For example, the Netherlands implemented a successful voluntary agreement program on industrial energy efficiency and China's Top-1,000 and Top-10,000 program has been among the most successful energy efficiency programs in China.

These programs are essentially a contract between the government and industry, or negotiated targets with commitments and time schedules on the part of all participating parties. Such agreement programs typically have a long-term outlook, covering a period of five to ten years, so that strategic energy-efficiency investments can be planned and implemented. A key element is that they focus the attention of all actors on energy efficiency or emission reduction goals. The essential elements of such programs include the assessment of the energy efficiency potential of the industrial facility as well as target-setting through a negotiated process. Participation by industries is motivated through the use of both incentives and disincentives. Supporting programs and policies, such as facility audits, assessments, benchmarking, monitoring, information dissemination, and financial incentives all play an important role in assisting the participants in understanding and managing their energy use and GHG emissions in order to meet the target goals. Some of the more successful voluntary agreement programs are based on the use of a mechanism to reduce environmental regulations or taxes for participants (Price et al. 2008). We are proposing a similar program in Ghana initially focused on Top-100 energy consuming enterprises.

Characterization of the Top-100 Industries in Ghana

The industrial plants to be included in Ghana's Top-100 Energy-Consuming Enterprise program are large-scale enterprises that are ranked as the top 100 in terms of total energy consumption.

Target-Setting for the Top-100 Energy-Consuming Enterprises in Ghana

The major targets of the Top-100 Energy-Consuming Enterprise program are to significantly improve the Top-100 enterprises' energy efficiency; reduce unit energy consumption to domestic best practice level for all major products; have some enterprises attain either international best practice levels or sector best practice levels. All participating enterprises will sign energy efficiency agreements with the government and will promise to reach the energy savings target in five years from the start of the agreement. The targets will be modified every five years to ensure continuous improvement over time.

Expectations of the Top-100 Energy-Consuming Enterprises in Ghana

The Top-100 enterprises will be expected to do the followings:

- establishment of energy conservation working groups in enterprises,
- implementation of the target responsibility and accounting system,
- conducting detailed energy audits and developing energy efficiency plans, based on the guidelines provided by the government,
- conducting energy efficiency benchmarking,
- establishment of energy management systems (EnMS) either based on the national standards or international ISO 50001 standard for energy management systems,
- have dedicated energy manager in each facility and conduct trainings for energy managers,
- implementation of energy utilization reporting system and report their energy consumption by fuel quarterly to government,
- continuation of phasing-out of backward technologies,
- acceleration of energy efficiency retrofits,
- improvement of energy measurement and measuring instruments.

Energy Managers and Energy Management System Requirement in Top-100 Program

Under the Top-100 program, industrial facilities must have a dedicated energy manager or energy management team. Government should provide free trainings and guidelines for energy managers in these facilities. In addition, facilities in Top-100 program must implement energy management systems (EnMS) like ISO 50001. The EnMS is a system of standards that provide a set of protocols and procedures for the management of energy consumption. Such energy management systems can be used to identify the opportunities, set and track internal goals for industrial energy efficiency improvement and GHG emission abatement.

Role of the National, Regional, and Local Governments in Top-100 Program

A number of national government departments and entities will be involved in the Top-100 Program in Ghana, including the Ministry of Energy, Ministry of Finance, Energy Commission, Ministry of Trade and Industries, Environmental Protection Agency, and Council for Scientific and Industrial Research (CSIR).

The national government should establish and publicize the guiding principles and goals of the program and publish a list of the Top-100 enterprises by name. The energy saving authorities of the region, district, or city should be directed to collaborate with related organizations to lead and implement the Top-100 program, including the tracking, supervision, and management of the energy-saving activities of the enterprises. The local authorities should support the enterprises in their energy management, energy auditing, and energy reporting requirements.

Ministry of Energy should conduct a series of training sessions for the Top-100 enterprises staff members and others covering variety of topics related to energy efficiency in industry under the Top-100 program. The government should establish a package of effective supporting policies designed explicitly for the Top-100 program in order to provide enterprises with appropriate incentives and support for achieving their targets.

The government should also evaluate establishment of a system of awards for enterprises that meet their targets – and possibly a system of penalties for those that fail to meet their targets – in terms of how the award funding would be generated and whether such awards could be offered at a level that would provide motivation to enterprises (Price et al. 2008).

Finally, the government should coordinate with international programs that can contribute to key Top-100 program elements such as UNIDO, the United Nations Development Program/Global Environmental Facility (GEF), United States Agency for International Development (USAID), The World Bank, German International Cooperation (GIZ), and others.

Energy Efficiency Funding and Financial Incentives for Top-100 Program

Different financing schemes as explained in section 7.2.2 of this report can be used to provide financial support for energy efficiency improvement under the Top-100 program. The energy efficiency investment incentives such as subsidies, grants, loans, tax reliefs, and others should be directed towards high energy-saving investments that may be otherwise disregarded by enterprises due to the high initial investment costs. In addition to these domestic funding resources, international energy efficiency funding such as the grants provided by United Nations Development Program/Global Environment Facility (GEF) should be considered to support Top-100 program.

Information Dissemination and Capacity Building for Top-100 Program

Information dissemination is an important component of target-setting and other industrial energy efficiency programs. Technical information sources such as energy efficiency guidebooks, databases, software tools, and industry- or technology specific energy efficiency reports are produced in many countries. Ghana can tap into these available resources and provide them to its industrial companies.

Government of Ghana can also conduct the following activities in order to develop and disseminate information and build capacity for industrial energy efficiency in Ghana under the Top-100 program:

- Have industry sector associations or other sector-specific experts develop energy efficiency information sources for identifying energy-savings technologies and measures for the Top-100 enterprise sectors.
- Develop benchmarking tools in conjunction with sector associations or other sector-specific experts to assist with evaluation of each enterprise's energy efficiency potential, to provide a simplified energy auditing tool, and to assist in development of each enterprise's energy action plan.
- Develop detailed energy management guidance documentation based on international best practice, including a framework to standardize, measure and recognize industrial system optimization efforts.
- Review a sample of the enterprise audit reports to determine whether they are comprehensive and high-quality and to identify areas where further training related to specific elements of energy auditing could improve audit quality.
- Establish a database or directory of energy auditing entities and ESCOs, identifying their areas of expertise.
- Review a sample of the enterprise energy action plans to determine whether they are comprehensive and high-quality and to identify areas where further training related to specific elements of development and use of energy action plans could improve their quality.
- Engage key sector-focused industrial associations and research institutions to develop and deliver sector-specific information for energy audits, energy benchmarking, and identification of energy-efficient technologies and measures, working with provincial-level entities and technical universities to build their sector-specific capabilities.
- Establish the National Energy Conservation Center and/or another national level energy information dissemination and training center as soon as possible to play a coordination role for many elements of the Top-100 program.
- Conduct a limited number of study tours to U.S., EU, and Asia with strong target-setting programs for enterprise representatives from enterprises that are playing a leading role within the Top-100 program.

Monitoring and Evaluation of Top-100 Program

It is extremely important to establish effective monitoring guidelines at the beginning of an energy-efficiency or target-setting program. Clear and transparent monitoring guidelines should be outlined that give enterprises an overview of what needs to be reported, when it should be reported, how it should be reported and to whom. Enough detail should be provided at the beginning of the project about how the project's savings will be documented and what level of accuracy is desired. Ideally, monitoring also includes verification by an independent third party that will validate the submitted information and oversee the monitoring procedures. It is important to clearly define the monitoring process, outline the format and requirements of monitoring reports, and provide clear definitions regarding energy use and energy saving measures (Price et al. 2008).

Top-100 program should develop enterprise-level monitoring and reporting guidelines that include not only reporting on annual energy use, but also information on annual production levels, enterprise organisational changes, and on progress on the specific energy-saving activities outlined in the enterprise action plan be developed.

Top-100 Program Timeline and Expansion

Figure 28 shows the suggested timeline for design, implementation and expansion of the Top-100 program in Ghana. After its phase 1, the Top-100 program should be expanded to Top-500 and Top-1000 over time. As the government and industry gains experience and refine the program in its initial years, the expansion should be a natural next step. In addition, the energy efficiency improvement targets should be reevaluated every 5 years and new targets should be set.

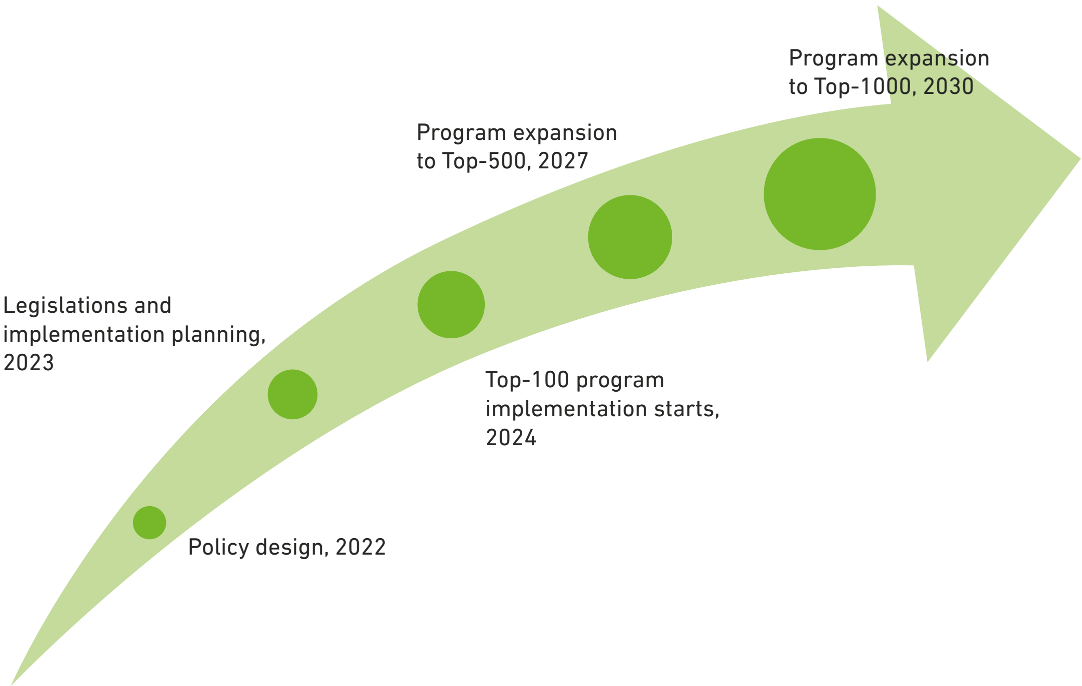


Figure 28. The suggested timeline for design, implementation and expansion of Top-100 Energy-Consuming Enterprise Program in Ghana

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Appendices

Appendix 1. Methodology for motor systems energy efficiency cost curve

We analyzed the industrial motor systems energy-efficiency potential in Ghana.

The base year for our analysis is 2020, the latest year for which energy-use data were available at the time of the study.

Country-specific data were collected from various sources. Electricity use for industrial subsectors in Ghana was from IEA's World Energy Statistics (IEA 2021). For this study, we built on the information collected and the method developed during our study for the United Nations Industrial Development Organization (McKane and Hasanbeigi 2010). We refined the methodology from that study and used more recent data, applying it to Ghana.

To conduct these studies, we also developed a framework to obtain expert input to supplement existing data. We consulted 13 motor system experts during our previous UNIDO study on the percentage of system energy use by industrial sector, energy efficiency of systems in a market with a defined set of characteristics, creation of a list of common energy-efficiency measures, and the energy savings and implementation costs associated with these measures. A Delphi-type approach was taken in which several cycles of input, analysis, and review were performed to refine the expert input.

Estimation of Electricity Use by Industrial Motor Systems in Ghana, by Manufacturing Subsector

Because no database reports manufacturing subsector electricity use in Ghana, we estimated these values. The international energy agency (IEA) publishes national data on energy consumption for different countries including Ghana. In these data set, they report electricity use by different economy subsector (residential, commercial, industrial, and transport) and fuel (IEA 2021). This source does not report electricity use by manufacturing subsector for Ghana. Once we estimated the electricity use for industry in Ghana, we used the 70% ratio from IEA (2016) and U.S. DOE (2022) to estimate industrial motor systems electricity use in Ghana.

Base-Case System Efficiency Scenario Definition

We established three base-case efficiency scenarios (LOW-MEDIUM-HIGH) for industrial motor systems based on previous research and expert input. There was a remarkable degree of agreement among the experts concerning the range of efficiency for each system type that could be expected in these base-case scenarios. After defining the base cases, we assigned base case values to Ghana, to establish a reference point for current motor system performance in the country.

The first step in establishing a base case was to create a unique list of system energy-efficiency practices representative of each of the three efficiency scenarios for motor systems. Tables A.1-A.3 in Appendix lists the practices assigned to each base-case efficiency level for industrial pump systems, fan systems, and compressed air systems, respectively.

Table A.1. Characteristics of LOW-MEDIUM-HIGH efficiency base-case scenarios for pump systems

No.	LOW Efficiency Base-Case Scenario
1	Less than 10% of pump systems have been assessed for system energy efficiency.
2	Maintenance is limited to what is required to support operations.
3	Flow is typically controlled by throttling or bypass.
4	Flow regularly exceeds actual system needs.
5	Variable-speed drives are not commonly used
6	Motors of all sizes are routinely rewound multiple times instead of replaced.
7	~10% of the installed motors are high efficiency--either EPAct or EFF1 equivalent.
No.	**MEDIUM Efficiency Base-Case Scenario**
1	~20% of pump systems have been assessed for system energy efficiency.
2	Maintenance is a routine part of operations and includes some preventative actions.
3	System operators take steps to avoid controlling flow via throttling or bypass.
4	Efforts are made to efficiently match supply with demand.
5	Variable-speed drives are frequently proposed as a solution for flow control.
6	Motors ≥ 37 kW are typically rewound multiple times, and smaller motors may be replaced.
7	~25% of the installed motors are high efficiency--either EPAct or EFF1 equivalent.
No.	**HIGH Efficiency Base-Case Scenario**
1	30% or more of pump systems have been assessed for system energy efficiency.
2	Both routine and predictive maintenance are commonly practiced.
3	Flow is not controlled by throttling or bypass except in emergencies.
4	Fluid is only pumped where and when needed to meet demand.
5	Variable-speed drives are one of several flow-control strategies commonly applied to increase system efficiency.
6	Most facilities have a written rewind/replace policy that prohibits rewinding smaller motors (typ <37 kW).
7	50% or more of the installed motors are high efficiency--either EPAct or EFF1 equivalent.

Table A.2. Characteristics of LOW-MEDIUM-HIGH efficiency base-case scenarios for fan systems

No.	LOW Efficiency Base Case Scenario
1	Less than 10% fan systems representing 40% of the connected fan load have been assessed for system energy efficiency
2	Maintenance is limited to what is required to support operations
3	Flow is usually controlled by dampers or bypass
4	Low cost fans types, like radial, are often used even in clean air applications
5	Fans are sometimes located on the dirty side of the process
6	Fans are sometimes oversized for the present load
7	Variable speed drives or variable inlet vanes are sometimes proposed as a solution for flow control
8	Motors of all sizes are routinely rewound multiple times instead of replaced
9	10% or less of the installed motors are high efficiency--either EPAct or EFF1 equivalent
No.	**MEDIUM Efficiency Base Case Scenario**
1	~30% fan systems representing 60% of the connected fan load have been assessed for system energy efficiency
2	Maintenance is a routine part of operations and includes some preventative actions
3	System operators take steps to avoid controlling flow via dampers or bypass
4	Airfoil or backward curved impellers are used in clean air handling applications

5	Fans are located on the clean side of the process whenever possible
6	Fans are chosen to efficiently serve a given condition
7	Variable speed drives or variable inlet vanes are frequently proposed as a solution for flow control
8	Motors ≥ 37 kW are typically rewound multiple times, while smaller motors may be replaced
9	~25% of the installed motors are high efficiency--either EPAct or EFF1 equivalent
No.	**HIGH Efficiency Base Case Scenario**
1	~50% fan systems representing 80% of the connected fan load have been assessed for system efficiency
2	Both routine and predictive maintenance are commonly practiced
3	Flow is not controlled by dampers or bypass except in emergencies
4	Fans are located on the clean side of the process whenever possible
5	Variable speed drives are one of several flow control strategies commonly applied to increase efficiency
6	Fans types are chosen based on the highest efficient type to serve a given condition
7	Fans are selected and procured so that typical process flow and pressure requirements are at or near Best Efficiency Point
8	Most facilities have a written rewind/replace policy that prohibits rewinding smaller motors (typ <45 kW)
9	50% or more of the installed motors are high efficiency--either EPAct or EFF1 equivalent

Table A.3. Characteristics of LOW-MEDIUM-HIGH efficiency base-case scenarios for compressed air systems

No.	LOW Efficiency Base Case Scenario
1	Less than 10% of compressed air systems have been assessed for system energy efficiency (both supply and demand side assessment)
2	Maintenance is limited to what is required to support operations
3	Compressor control is coordinated but poorly and a single trim compressor operates inefficiently
4	System pressure profile, supply / demand balance, and storage partially optimized
5	Leaks are ≥ 25%, but < 35% and are fixed irregularly
6	There is widespread inappropriate use of compressed air
7	Motors of all sizes are routinely rewound multiple times instead of replaced
No.	**MEDIUM Efficiency Base Case Scenario**
1	~20% of compressed air systems have been assessed for system energy efficiency (both supply and demand side assessment)
2	Maintenance is a routine part of operations and includes some preventative actions
3	Compressor control is coordinated and a single trim compressor operates efficiently
4	Variable speed drives are frequently proposed as a solution for flow control
5	Leaks are ≥ 15%, but < 25% and are fixed periodically
6	Inappropriate end use of compressed air has been reduced
7	Motors ≥ 37 kW are typically rewound multiple times, while smaller motors may be replaced
No.	**HIGH Efficiency Base Case Scenario**
1	~30% or more of compressed air systems have been assessed for system energy efficiency (both supply and demand side assessment)
2	Both routine and predictive maintenance are commonly practiced
3	Compressor controls and storage are used to efficiently match supply to demand
4	System pressure profile from supply to end use has been optimized
5	Leaks < 15%; Leaks management is ongoing
6	Inappropriate end use of compressed air has been minimized
7	Most facilities have a written rewind/replace policy that prohibits rewinding smaller motors (typ <37 kW)

We asked motor systems experts to estimate the range of system energy efficiency they would expect to see when auditing a system in an industrial facility with the characteristics given for each efficiency base-case scenario (LOW-MEDIUM-HIGH).

Table A.4-A.6 in Appendix shows the consolidated results, including the base-case values used in calculating the efficiency cost curves. There was a high degree of agreement among experts regarding the range of system energy efficiency that would be expected based on the list of characteristics assigned to the base cases. We used the average of low and high values for the LOW-MED-HIGH efficiency base cases in our analysis.

Table A.4. Consolidated system efficiency for LOW-MED-HIGH efficiency baselines

	Pump System Efficiency		
	low end (%)	high end (%)	Average (%) - used in the analyses
Low level of efficiency	20%	40%	30%
Medium level of efficiency	40%	60%	50%
High level of efficiency	60%	75%	68%

Table A.5. Consolidated system efficiency for LOW-MED-HIGH efficiency baselines

	Fan System Efficiency		
	low end (%)	high end (%)	Average (%) - used in the analyses
Low level of efficiency	15%	30%	23%
Medium level of efficiency	30%	50%	40%
High level of efficiency	50%	65%	58%

Table A.6. Consolidated system efficiency for LOW-MED-HIGH efficiency baselines

	Compressed Air System Efficiency		
	low end (%)	high end (%)	Average (%) - used in the analyses
Low level of efficiency	2.0%	5.0%	3.5%
Medium level of efficiency	4.8%	8.0%	6.4%
High level of efficiency	8.0%	13.0%	10.5%

After defining the base-case efficiencies for each motor system, we assigned a base case to Ghana as a reference point for current industrial motor system performance in Ghana based on available information. Table A.7 shows the base-case efficiencies assigned for each industrial motor systems in Ghana

Table A.7. Base-case motor systems efficiencies assigned to Ghana

Base Case Efficiency Level	Motor System
LOW	Pump systems
LOW	Fan systems
LOW	Compressed air systems

Energy-Efficiency Measures and Their Savings and Costs

We developed a list of motor system energy-efficiency measures and asked motor system experts their opinion on energy savings likely to result from each measure implemented independent of the others, expressed as a percentage improvement over each of our base cases (LOW-MED-HIGH).

The experts were also asked to provide cost information for each measure, disaggregated by motor size range. The size ranges were selected based on categories developed for the most detailed motor system study available. In this study, "motor system size" refers to a motor system's aggregate hp or kW. The costs provided are for when efficiency measures are implemented in systems with LOW base case efficiency level. However, for systems that have Medium or High efficiency base case, the cost of efficiency measures where reduced using an adjustment factor.

In addition to the energy-efficiency improvement cost, we asked experts to provide the useful lifetime of the measures, disaggregated into two categories of operating hours (1,000 - 4,500 hours per year and more than 4,500 hours per year). In some instances, the initial list of measures included several measures that would be unlikely to be implemented together (i.e., it is more likely that one would be selected). In those cases, we chose the most common measure based on experts' judgment.

Tables A.8, A.9 show example of typical percentage improvements in efficiency over each base case as well as an estimated typical capital cost of one motor system energy-efficiency measure, differentiated by system size. The actual installed cost of some system measures can be highly variable and dependent on-site conditions, including the number and types of end uses. The need to add or modify physical space to accommodate new equipment can also be a factor in installed cost.

Table A.8. Example energy-efficiency measure and typical % efficiency improvement impact on pump systems in Ghana

Energy-Efficiency Measure	Typical % improvement in energy efficiency practice		
	% Improvement over LOW eff. base case	% Improvement over MED eff. base case	% Improvement over HIGH eff. base case
Replace pump with more energy efficient type	20%	15%	5%

Table A.9. Example of capital cost of a typical pump system energy-efficiency measure in Ghana

Energy-Efficiency Measure	Typical Capital Cost (US$)				
	≤50 hp	>50 hp ≤100 hp	>100 hp ≤200 hp	>200 hp ≤500 hp	>500 hp≤1000 hp
	≤37 kW	>37kW ≤75kW	>75kW ≤150kW	>150kW ≤375kW	>375kW ≤745kW
Replace pump with more energy efficient type	$8,000	$ 16,200	$ 19,900	$ 23,000	$ 53,200

Systems larger than 1,000 hp (745kW) are usually custom designed, and their cost is highly variable. The cost data from experts for this size system varied so much that it injected significant uncertainty into the final results, so we excluded systems larger than 1,000 hp (745kW) from the final analysis. Excluding these systems from the analysis resulted in a proportional decrease in total system energy use and a corresponding decrease in the energy savings resulting from the energy-efficiency measures analyzed. This limitation should be considered when reviewing the results presented in this report.

This report uses the estimated full cost of the energy-efficiency measures analyzed rather than the incremental cost. This choice was based on the goal of our analysis, which was to assess the total potential for energy efficiency in industrial motor systems in the base year (2020) assuming a 100% adoption rate. Therefore, we assumed that all the measures are installed in the base year, so the full cost of the measures should be used because the existing systems are not all at the end of their lifetimes.

Development of Energy-Efficiency Cost Curves

The energy-efficiency cost curve (also known as the energy conservation supply curve) is an analytical tool that captures both the engineering and economic perspectives of energy efficiency. The curve shows energy-efficiency potential as a function of the marginal cost of conserved energy (CCE). CCE can be calculated from Equation A.1.

$$\textbf{Cost of Conserved Energy (CCE)} = \frac{\textbf{(Annualized capital cost + Annual change in O\&M costs)}}{\textbf{Annual energy savings}} \quad \textbf{(Eq. A.1)}$$

The annualized capital cost can be calculated from Equation A.2.

$$\textbf{Annualized capital cost} = \textbf{Capital Cost}*(d/\,(1-(1+d)^{-n})\quad \textbf{(Eq. A.2)}$$

d: discount rate, n: lifetime of the energy efficiency measure

In this study, because only one type of cost (capital cost) was available for each measure, the capital cost was used to calculate the CCE without regard for any change in operations and maintenance cost (given in Eq. A.1). Some of the measures themselves are improvements in maintenance practices.

After calculating the CCE for all energy-efficiency measures, the measures are ranked in ascending order of CCE. Also, on an efficiency cost curve, an energy price line is determined. All measures that fall below the energy price line are identified as "cost-effective." That is, saving a unit of energy by means of the cost-effective measures is cheaper than buying a unit of energy. On the curves, the width of each measure (plotted on the x-axis) represents the annual energy saved by that measure. The height (plotted on the y-axis) shows the measure's CCE. Figure A.1 shows an illustrative example of an energy-efficiency cost curve for measures A and B.

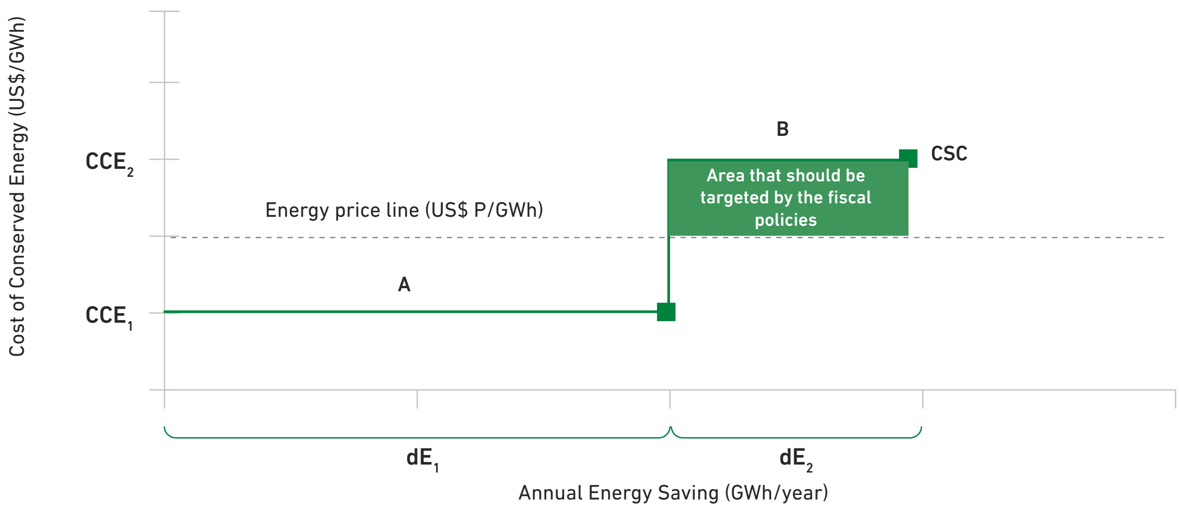

Figure A.1. Illustrative example of an energy-efficiency cost curve

In our analysis, a real discount rate of 15% was assumed. This choice seems to be reasonable since the commercial banks interest rates in Ghana are quite high and it was over 15% in 2020. The choice of the discount rate also depends on the purpose of the analyses and the approach (prescriptive versus descriptive) used. A prescriptive approach (also called social perspective) uses lower discount rates (4% to 10%), especially for long-term issues like climate change or public-sector projects. Low discount rates have the advantage of treating future generations equal to our own, but they also may cause relatively certain, near-term effects to be ignored in favor of more uncertain, long-term effects.

Figure A.2 is a schematic of the process of calculating motor system energy-efficiency cost curves. The details of each step are explained in the following sections.

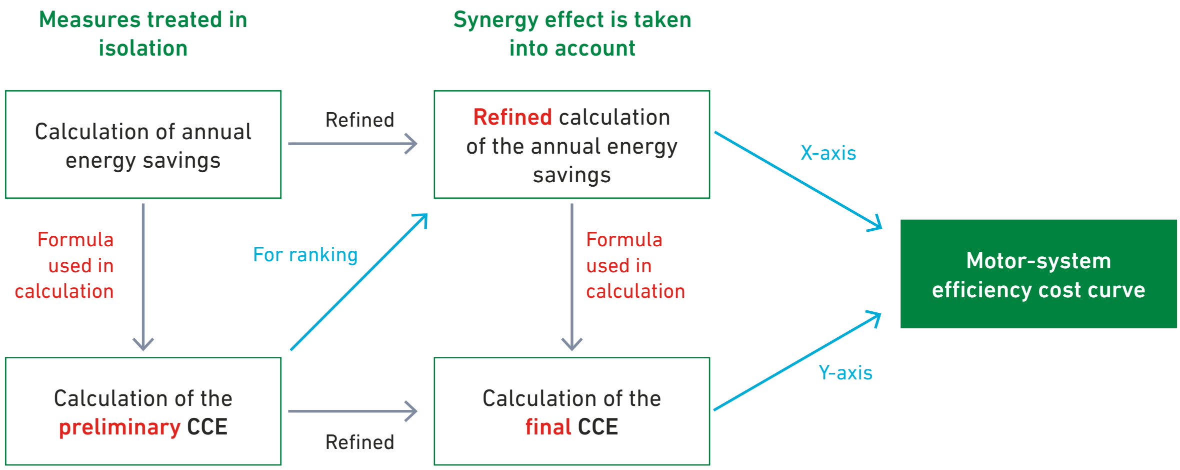

Figure A.2. Calculation process for constructing motor system energy-efficiency cost curves

For calculating energy savings from each motor system efficiency measure, the following inputs were available:

- The efficiency base-case scenarios for motor systems (low, medium, high), developed as described above. As explained earlier, Ghana was assigned a LOW base-case motor system efficiency.
- For each motor system efficiency measure, experts provided a typical percentage improvement in energy efficiency over each base-case efficiency.
- Electricity use in the industry in Ghana.
- From the above information, the annual electricity savings can be calculated for each individual industrial motor system efficiency measure when measures are treated individually and can be implemented regardless of the implementation of other measures.

However, implementation of one measure can influence the efficiency gain from the next efficiency measure implemented. When the first measure is implemented, the base-case efficiency is improved. Therefore, the efficiency improvement of the second measure will be less than if the second measure was implemented first or considered alone. Because of this, in our analysis, the measures were treated in relation to each other (as a group). In other words, the efficiency improvement from implementation of one measure depends on the efficiency improvement achieved by the previous measures implemented. We call this the *synergy effect*.

In this method, the *cumulative* electricity savings are calculated by taking into account the synergy effect of the measures rather than by treating the measures in isolation from one another. For instance, the cumulative annual electricity savings from measure #3 include the efficiency gains from the previous measures implemented (measures #1 and #2).

Calculation of the cumulative savings rather than individual savings is also desirable because the cumulative electricity savings will be used to construct the motor system efficiency supply curves. At the same time, the ranking of the measures significantly influences the energy savings attributed to each measure. That is, given a fixed percentage improvement of efficiency from each individual measure, the higher the rank of the measure, the larger the contribution of that measure to the cumulative savings. To define the ranking of the efficiency measures before calculating the cumulative energy savings using the method described above, we calculated a preliminary CCE for each measure, treating each in isolation from the others, i.e., without taking any synergy effect into account. The measures were ranked based on their preliminary CCEs, and this ranking was used to calculate the final cumulative annual energy savings as well as the final CCE. Table A.10 shows some of the assumptions used in the analyses.

Table A.10. Average unit price of electricity for industry and emissions factor for grid electricity in Ghana in 2020

	Ghana
Average unit price of electricity for industry in 2020 (US$/kWh)	0.13
Emission factor for grid electricity in 2020 (kgCO_2/MWh)	500

It should also be noted that the purpose of our analysis is to determine the cost-effectiveness of efficiency measures and estimate the total electricity savings potential for industrial motor systems. This study does not analyzed scenarios based on the assumption of different penetration rates of the measures in the future; instead, we aimed to identify the magnitude of the total savings potential in 2020 and associated costs.

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