Investigating Energy End-Use Efficiency in Small and Medium Scale Enterprises for Sustainable Industrialization

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Abstract: - Industrial policies in Africa seem silent on energy efficiency measures for small and medium scale enterprises (SMEs) in the continent. Existing literature indicates that SMEs in Nigeria are unaware of energy end-use efficiency. Towards identifying policies for achieving the Sustainable Development Goals (SDGs) 7, 9, and 13, energy end-use efficiency issues within one hundred (100) manufacturing SMEs were empirically analyzed. Probability Proportional to Size (PPS) technique was used to select the firms based on recent framing of enterprises by the Small and Medium Enterprises Development Agency of Nigeria (SMEDAN).
The study utilized structured questionnaires and interviews to capture cross-sectional data. The research identified some enablers of energy end-use efficiency in the companies. Factors identified equipment/appliance selection, capital and financial incentives, information, and technical capacity, management commitment, smart manufacturing, and government policy or legislation. Contrary to the view in existing studies, the outcome of the study shows a strong awareness of energy end-use efficiency among 93.81% of the sampled firms. We recommend the roles of relevant stakeholders and some strategic measures essential for the improvement of energy end-use efficiency in SMEs towards decarbonizing the industrial sector and achieving sustainable development.

Key-Words: - Energy, End-Use Efficiency, Decarbonization, SMEs, Manufacturing, Industrialization, Sustainability

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1 Introduction

Energy utilization has remained a critical factor in human society development based on its pivotal role in most economic activities (Ugwoke et al., 2020). Energy is required for the production of goods and the creation of services, transportation, communication and information technology, agriculture, sports and recreation, and many other aspects of a functional society (Gershon & Mbajekwe, 2020). The rising demand for energy and increased greenhouse gas emissions underscores the need for energy efficiency, especially in the era of rising energy shocks with great impacts on households, firms and economies (Gershon et al., 2019). An important aspect of energy management is the focus on energy end-use efficiency, as well as the elimination of energy losses and wastages at the point of final consumption. The energy utilized by the final consumer in the energy value chain is termed “end-use energy”. Energy end-use efficiency therefore describes the efficient utilization of energy by the end user - in the context of this paper, small and medium scale enterprises are the energy end-users.

Engineers and economists often hold different views on the concept of energy end-use efficiency. On the one hand, an economist would typically approach the concept from a monetary input-output ratio perspective purely considering the economic optimization of energy transactions. On the other hand, from the engineering perspective, efficient utilization of energy entails a physical input-output ratio that emphasizes achieving more with less energy (Lovins, 2005). However, both perspectives are not mutually exclusive from a sustainability perspective - value optimization - in the use of energy.

Small and medium scale enterprises (SMEs) make up about ninety percent of Nigeria’s industrial sector

(NIPC 2002) and many of the SMEs are located within the industrial areas at Ota, Agbara, and Igbesa in Ogun State, southwest Nigeria. SMEs typically stimulate indigenous entrepreneurship, drive industrialization, provide jobs, trigger the emergence of larger indigenous enterprises, and contribute to sustainable economic growth and development (Umoidem, 2018; Gunasekaran, Forker, & Kobu, 2000). Furthermore, SMEs constitute a major block of energy consumers with their demand for energy increasing proportionately (Ugwoke, Gershon, Becchio, Corgnati, & Leone, 2020) and emissions (Gershon, Azubuike, & Asekomeh, 2022).

Most SMEs seldom invest in measures or technologies that enhance energy end-use efficiency (Cagno, Trucco, Trianni, & Sala, 2010). The energy end-use efficiency discourse is therefore particularly compelling given the prospects it holds for small and medium scale enterprises that are keen on saving costs, improving their competitiveness, boosting productivity and output, and improving their environmental aspect performance.

2 Literature Review

The barriers to energy efficiency in industries are researched - focused largely on energy efficiency from the supply side. However, not much work has been done in the area of energy end-use efficiency improvement in industrial settings. As such limited literature exists on the subject and this paper seeks to the gap. End-use efficiency started receiving some attention in the mid-1970s when its cost-saving potential became well established (Jochem, Adegbulugbe, Aebischer, Bhattacharjee, Gritsevich, Jannuzzi, Jaszay, Baran-Saha, Worrell, & Fengqi, 2000).

Considering the extraction of energy from fossil fuels, IEA estimate indicates a 5 percent energy utilization in the extraction phase and a staggering 65 percent loss in the form of combustion heat in the process of generating electricity (IEA, 2014). This estimate is fast changing with the gains in energy efficiency across industrialized and transition economies. Jochem et al. (2000), attributed much of this gain in energy efficiency to the reduction in energy use intensity occasioned by recycling and dematerialization; reaffirming the notion that energy efficiency supports sustainable development globally. There is growing consensus that the adoption of energy end-use efficiency measures which are cost effective and practicable in industries is very necessary in the face of increasing globalization and diminishing trade barriers which opens up local markets (Asekomeh et al., 2022; Gershon & Agbene, 2021; Rohdin & Thollander 2006).

Researchers have argued that an energy efficiency gap exists because industries do not always implement energy efficiency measures since many of these industries (especially the SMEs) are held back by various barriers (SPRU, 2000). There is good evidence that industrial SMEs focus more on production and give little or no attention to energy use issues. This explains why such firms consider "lack of time" as a factor that hinders them from finding and implementing energy use efficiency measures in their operations (Rohdin, & Thollander, 2006).

While some researchers maintain that the size of an organization can aid or enhance the organization's ability to adopt energy efficiency improvement strategies; implying that larger enterprises have a better capacity to implement energy end-use efficiency improvement measures (Aramyan, et al. 2007) (Schleich. 2009), others argue against the impact of company size on energy end-use efficiency performance (Anderson & Newell, 2004; Fleitera, et al., 2012). The potential of an enterprise to adopt energy efficiency measures may depend on the availability of capital, technical know-how and the transaction cost for each energy efficiency measure to be adopted (De Groot, Verhoef, & Nijkamp, 2001). Conversely, other researchers hold the view that larger enterprises may struggle with energy efficiency measures implementation because of bureaucratic bottlenecks typical of large-sized organizations which delay decision-making (Velthijsen. 1995).

Although this research work focused mainly on small and medium scale enterprises thus fully excluding larger firms, a review of existing literature indicates that the impact of company size as a barrier or an enabler for energy end-use efficiency can be more clearly seen in studies that involve larger enterprises and allow ample variation in company size to highlight effects with statistical significance (Anderson & Newell. 2004).

Authors of previous work related to this research have identified production rates (material throughput) and the type of equipment or conversion devices used in the production process as having a significant impact on energy utilization and efficiency (Gutowski, Dahmus, & Thiriez, 2009).

Closely related to this position is the submission that auxiliary equipment and systems such as pumps, air compression systems, blowers and fans consume enormous amounts of energy and are also

responsible for energy losses and inefficiencies arising from their wrongful selection and poor design (Diarra, 2010).

Information is an important factor for energy efficiency improvement in industries and relevant information for energy efficiency improvement strategies are readily available (Fleitera, Schleich, & Ravivanpong, 2012; Trianni, Cagno, Worrell, & Pugliese, 2014). However, some studies maintain that the available information are sometimes fragmented or very complicated and therefore not useful to some firms, especially the smaller enterprises (Trianni & Cagno, 2012). The integrity of the sources of such information also plays a role in how well the information is utilized by firms. A review of existing literature also shows that the competency and expertise of the personnel working in a firm can aid the adoption of energy efficiency measures irrespective of the sector. Identification, planning, and maturation of energy efficiency improvement opportunities require expertise that SMEs lack. Shortage of personnel and the obvious competency gap in smaller enterprises therefore limits the ability of these smaller enterprises to readily identify and implement energy end-use efficiency measures in their operations, this underscores the impact and relevance of training including vocational and technology-specific training (Cagno, & Trucco, 2008). Other authors who support this view also highlight the need for external support and expert training which in their view is often not prioritized or readily available and may be difficult to access by the smaller enterprises operating informally without registration and formal recognition (Etea & Obodoechi, 2019).

Previous studies related to industrial energy efficiency carried out on the SMEs operating in Nigeria shows that the Nigerian government is fully aware of the relevance of energy efficiency to the growth of SMEs and by extension, the nation's economy. In this regard, Gershon, et al, (2020) emphasized the linkage of energy intensity and economic growth. Gershon & Agbene, (2021) considered hybrid options for telecommunication industry, while Etea & Obodoechi (2019) argued that the Nigerian government's ambition for energy efficiency and industrial growth will require private sector participation and strategic engagement for actualization.

3 Method and Methodology

3.1 Data Collection and Analysis

In this paper, the concept of energy end-use efficiency is investigated within the domain of small and medium scale enterprises. To achieve the research objective of empirically identifying the enablers of energy end-use efficiency in the SMEs operating in southwest Nigeria, a case study approach was adopted. The approach is based on the need for authenticity of findings and avoidance of bias and generic variable manipulation. The firms selected for the study were investigated in their natural setting or environment to capture their specific experiences and issues.

The probability proportional to size technique was used to select one hundred (100) small and medium scale enterprises based on the framing of enterprises by the Small and Medium Enterprises Development Agency of Nigeria (SMEDAN, 2021). These companies were formally invited to participate in the study, but ninety-seven firms responded and took part in the survey. It is important to note that based on SMEDAN's categorization of enterprises, nano and micro enterprises were not included in this study. The chosen sample size therefore provided sufficient representation for the SMEs in the southwest region. Primary data was obtained from these ninety-seven firms using structured questionnaires and on-site interviews of key personnel. The questionnaires were strategically designed to capture the specific characteristics of individual enterprises, their energy consumption patterns and devices (equipment) used, operations scope, current energy efficiency practices and behaviours, specific challenges and experiences about energy use, and opportunities for energy end-use efficiency improvement. The empirical investigation followed an inductive approach focused on extracting respondent-specific data, creating in the data meaningful themes and patterns, highlighting resemblances and relationships to establish hypotheses, and drawing conclusions typically within the actual environment (natural context) of the subject of the empirical investigation (Umoidem, 2018; Creswell, 2005). The cross-sectional data from the survey formed the basis for the qualitative analysis which produced robust findings that support the suitability of this work as reference material for future research on the subject.

3.2 Results and Discussion

Analysis of the research data showed that all the companies that participated in the survey were SMEs based on their company size and limited number of employees. Although the ninety-seven firms surveyed are connected to the public power supply system (Ibadan Electricity Distribution

Company - IBEDC) data analysis shows that all the companies have diesel generators installed in their plants and these power generating sets are the most used power sources (see Table 1). This finding corroborates the claim by SMEDAN that a large proportion of businesses utilize alternative power sources daily (SMEDAN, 2021). 58 companies representing 59.79% of the sampled population utilize natural gas for power generation while 7 firms representing 7.22% utilize natural gas as feedstock in their manufacturing process as shown in Table 2. Thirteen (13) companies representing 13.40% also use natural gas for other purposes including for raising steam in boilers, and furnace operations.

Power Source	% of SMEs	Most used Source
National Grid (IBEDC)	100%	0.00%
Generators (diesel driven)	100%	64.50%
Solar	0.00%	0.00%
Natural Gas	59.79%	35.50%

Table 1., Analysis of power source

Natural Gas Utilization by SME	% of SMEs
Feedstock	7.22%
Power Generation	59.79%
Heating/Furnace Operations	13.40%
Raising Steam in Boilers	13.40%

Table 2., Natural Gas Utilization by SMEs

Thematic analysis of the research data revealed that contrary to the popular view canvassed by several authors of existing literature that there is a gross lack of awareness amongst small and medium scale enterprises in Nigeria with regards to energy end-use efficiency, there seems to be adequate awareness as expressed by 91 firms representing 93.81% of the sampled population (see fig.1).
Natural Gas Utilization by SMEs % of SMEs
Feedstock 7.22%
Power Generation 59.79%
Heating/Furnace Operations 13.40%
Raising Steam in Boilers 13.40%
However, these firms are held back from pursuing energy end-use efficiency initiatives because of several reasons s- as highlighted in the literature review - but the focus of this work is on identifying the enablers energy end-use efficiency in these organizations. Therefore, the findings and results of the study are discussed below:

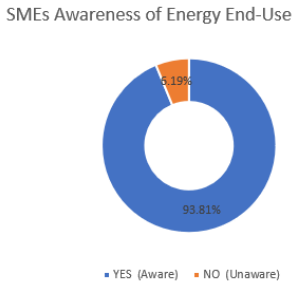

Fig. 1:, SMEs Awareness of Energy End-Use Efficiency

3.2.1 Equipment Selection Criteria and Production Rates Optimization

Analysis of the research data highlights a correlation between the overall efficiency of a manufacturing facility, the production rate (material throughput), and the equipment selection including the type of conversion devices and systems used in the factory. Data analysis revealed that significant energy use optimization occurs during periods of high production when critical machinery is optimally utilized thereby curbing loss of energy arising from equipment requirements (idle devices). Besides optimizing the production rate to enhance energy end-use efficiency, 67% of the small and medium scale enterprises surveyed noted that a careful evaluation of equipment selection criteria e.g. during procurement can help to improve energy end-use efficiency. This extends to the very critical and highly energy-consuming auxiliary equipment and systems - such as pumps and pumping systems, heating systems, air compression systems, motors and drivers which require careful selection to optimize energy utilization and enhance efficiency.
SMEs Awareness of Energy End-Use Efficiency
YES (Aware) NO (Unaware)
Selecting hydraulic equipment and systems will certainly translate to higher energy intensity than that of a process which utilizes electric or electronic equipment with reduced energy consumption.
Motors and drives, as well as heating systems consume enormous amounts of energy and play critical roles in the manufacturing process. Respondents maintain that motor speed and size greatly affect the efficiency of motors while heating systems (especially those using steam) can become inefficient due to steam leakages, insufficient piping, clogged surfaces, poor insulation, excess air in the system, and heat losses via the exhaust. Ensuring accurate sizing of motors and incorporating motor speed control mechanisms can improve energy efficiency, and reduce energy-related costs, while

also improving the reliability of the system. Similarly, adequate insulation or lagging, periodic monitoring and cleaning of boiler surfaces, as well as prompt arrest of steam leakages will enhance the energy efficiency of the system. This finding further corroborates the results of Gutowski, et al (2009) and Diarra (2010) on the impact of equipment type and selection as well as production rates on energy end-use efficiency.

3.2.2 Availability of Capital, Subsidies, and Other Financial Incentives

The ease of access to capital and provision of funding opportunities ranked high among the key enablers of energy end-use efficiency in small and medium scale enterprises in western Nigeria as seen in the analysis of research data. The respondents were almost unanimous in their submission that the availability of capital would greatly enhance the adoption of energy end-use efficiency measures and practices in their factories (see Table 3). From the analysis of research data, it is evident that the smaller enterprises seem to face great difficulty in accessing capital even for the expansion of their operations and even greater difficulty in getting financial support whether as loans, grants, or subsidies to fund energy efficiency improvement initiatives.

A few SMEs (8.2% of the sampled population) indicated in their responses that they have received funding (loans) for business expansion from the Bank of Industry (Nigeria's foremost industrial development finance institution). The SMEs, however, confirmed that getting funding or subsidies for energy efficiency improvement programs is very difficult in Nigeria, largely due to the apparent absence of dedicated financial structures and mechanisms for investments targeted at energy enduse efficiency. Respondents also decried the near-zero level of awareness and lack of technical (energy efficiency-related) expertise in the domain of the financial institutions which invariably hinders their appreciation of the gains and huge benefits of investing in energy efficiency improvement ventures. Even the banks that give loans to small and medium scale enterprises, for business expansion purposes are seemingly unable to understand, the correlation between energy end-use efficiency improvement initiatives and the ability of such enterprises, to pay back bank loans and as such they are less motivated to invest in or fund energy efficiency improvement projects. This finding also explains why the support funding provided by the Nigerian government for small and medium scale enterprises is often applied to areas other than energy efficiency improvement projects. This corroborates the findings of previous studies as seen in the literature review (Etea & Obodoechi, 2019).

3.2.3 Information and Technical Capacity

The thematic analysis of research data shows that many small and medium scale enterprises consider the availability of accurate and useable information as an important factor that can enhance the adoption of energy end-use efficiency measures in their organizations. Although several of these firms are aware of the energy efficiency issues in their domain, there seems to be no structured and formal system of providing information about energy efficiency issues either by the government or energy suppliers. This scarcity of information and enlightenment explains the seeming lack of awareness and apparent skepticism on the part of key business stakeholders (including banks and other investors) regarding the huge economic and environmental benefits of energy end-use efficiency, and their reluctance to invest in or fund energy efficiency improvement projects.

The importance of technical capacity also ranked high among the factors identified from data analysis as enhancers of energy end-use efficiency in small and medium scale enterprises. Smaller firms lack the capacity and expertise to research, identify, plan, and implement energy efficiency measures in their operations. Although the level of expertise required for the Identification, planning, and maturation of energy efficiency improvement opportunities seems to be beyond the reach of many small and medium scale enterprises, strategic training and awareness creation can help bridge the competency gap and empower these firms to implement even the most basic energy efficiency measures as well as simple behavioral adjustments and practices that can enhance efficiency in terms of energy utilization in their factories. This finding underscores the impact and relevance of training including vocational and technology-specific training.

3.2.4 Organizational Commitment

Data analysis shows that many small and medium scale enterprises do close to nothing in terms of improving energy efficiency in their daily operations even the basic practices and affordable measures that can yield energy savings concerning lighting and ventilation systems. For example, just

about 5.7% of the companies surveyed use energy-efficient conversion devices in their factories' lighting and cooling systems incorporating sensor-controlled lighting and standard energy-saving practices and behaviours. Several other firms still use light fittings and cooling devices that are not energy efficient and pay little or no attention to conservation and sustainability issues; it is commonplace to see outdoor lighting (mostly energy-intensive incandescent light bulbs with high levels of energy losses via heat) kept continuously on even when not needed. Many of the firms surveyed cite cost as a reason for their continuous use of incandescent light bulbs and other inefficient energy conversion devices. A lot can be done internally by these companies in terms of policy, process modification, facility upgrade, employee engagement and sensitization on energy efficiency improvement, behavioral adjustments, and a clear management commitment to energy efficiency improvement documented as a policy and implemented in the organization. Firms that are committed to energy efficiency improvement will not cite "lack of time" as an excuse for not pursuing energy use efficiency improvement goals. Rather, such firms would understand that while production is a priority, putting a premium on energy efficiency will enhance sustainability and profitability.

3.2.5 Smart Manufacturing

The energy conversion devices, equipment and systems used in small and medium scale manufacturing enterprises have large energy footprints and the same can be said about their production process set-up and overall factory layout. The continuous use of old and outdated equipment and production methods supports the inefficiency and losses in terms of energy end-use.

100% of the survey population agree that smart manufacturing which implies the use of modern manufacturing technologies that incorporate instrumentation and control, advanced sensing, and process optimization can deliver significant energy savings and improved productivity for their companies.

Besides unlocking enormous gains in energy savings from the level of equipment and conversion devices and across the entire manufacturing spectrum, smart manufacturing can also make information regarding equipment and systems performance, energy conversion and utilization available in real-time thereby aiding strategic decision-making and energy management. Despite the significant economic and environmental benefits of smart manufacturing, it can be seen from the analysis of research data that several small and medium scale enterprises are not implementing smart manufacturing in their factories for reasons largely tied to a lack of capital and technical capacity as already discussed in this paper. Strategic intervention and synergy by the government, corporate development finance agencies, and the manufacturing enterprises themselves are necessary to collaboratively create enabling conditions and policy frameworks for investment in energy end-use efficiency and integration of energy efficiency-enhancing technology and methodologies in the Nigerian manufacturing sector.

3.2.6 Government Policy and Legislation

The current low level of awareness and adoption of energy end-use efficiency measures in Nigeria's industrial sector especially among small and medium scale manufacturing enterprises, is largely due to the apparent lack of legislation and enforceable policy on energy use efficiency by the government, a situation that creates room for unethical and wasteful utilization of energy by individual and corporate end users. Data analysis shows that although many of the firms surveyed claim to be aware of the concept of energy end-use efficiency, they do not know about any government policy or existing legislation on energy efficiency, and certainly do not have any internal policy or guidelines on energy use. An urgent and strategic closure of the policy gap will provide clear and mandatory guidelines that will help change the behavior of energy end-users towards energy efficiency as well as encourage targeted investment in energy efficiency projects.

Factors that support Energy End-Use Efficiency in SMEs	% of SMEs
Equipment Selection	67.00%
Capital and Financial Incentives	91.80%
Information and Technical Capacity	56.70%
Organization (Management) Commitment	69.07%
Smart Manufacturing	100.00%
Government Policy and Legislation	67.00%

Table 3., Enablers of Energy End-Use Efficiency

4 Recommendations and Conclusion

This research work has shown that the small and medium scale manufacturing enterprises in Nigeria can achieve energy efficiency and reap the economic, environmental and reputational gains thereof, with a commitment on their part and support from the government and other key stakeholders such as industrial development finance

institutions and energy companies. The relevance of this research
work lies in the quantum of credible data it presents on the subject which can greatly aid policy development efforts concerning energy end-use efficiency in the context of small and medium scale enterprises.
This study which was focused on identifying the enablers for enhancing energy end-use efficiency in small and medium scale enterprises operating in western Nigeria has uncovered key factors some of which are beyond the control of the small and medium scale enterprises. Therefore, the recommendations are structured to highlight both the roles of key stakeholders and the strategic actions necessary for the enhancement of energy end-use efficiency.

4.1 The Role of Small and Medium Scale Enterprises

Implementing energy end-use efficiency measures in a company requires commitment by the management and employees, the management sets the goal and drives the implementation with effective communication to get the buy-in and participation of everybody in the company. This commitment may be demonstrated through strategic planning and prioritization of energy efficiency pursuits, staff training and capacity building, acquisition of energy efficient equipment and conversion devices, deployment of advanced manufacturing technologies for smart manufacturing,
personnel sensitization programs targeted at creating awareness about energy efficiency improvement practices and behaviours, targeted investment in energy efficiency improvement projects, production process modifications and facility upgrade.
These companies must ready themselves (by satisfying all statutory requirements for their existence
as corporate entities including full registration and tax compliance) to be able to leverage available opportunities for funding, Information, and technical support.

4.2 The Role of Government and other Stakeholders

Aligned to existing literature (Etea & Obodoechi, 2019), the findings in this study point to an interplay of economic and political factors that re-echoes the need for collaboration between the government and private sector towards driving energy efficiency improvement in the industrial sector. The government has the responsibility of setting up the policy and legal framework that regulates energy suppliers and industrial energy end-users regarding energy efficiency. Such policy and government action should also encourage development finance institutions to fund energy efficiency improvement ventures and improve their support for SMEs. Furthermore, it will cause the companies to domesticate energy efficiency improvement initiatives - including the setting up of dedicated units - and motivate energy suppliers to provide credible information on energy efficiency solutions.
The government's regulatory efforts must be well harnessed to create an enabling environment (including stabilization of energy pricing) that attracts investment in energy efficiency projects by the private sector. Furthermore, the government should assist in providing strategic information and technical capacity building through the Industrial Training Fund (ITF).

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