International Journal of
Energy and Environmental Engineering
a SpringerOpen Journal

ORIGINAL RESEARCH Open Access

Efficient energy utilization as a tool for sustainable development in Nigeria

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Abstract

This study takes a look at the national energy outlook of Nigeria. Energy utilization pattern of the country was investigated, and possible areas of energy conservation in the major economic sectors (industry, transportation, office and residential buildings) were considered. The study reveals that there is inefficient utilization of energy in the major economic sectors of the country. This study presented several energy conservation opportunities to cause energy savings and identified about six major areas through which energy conservation measures can effectively cause some savings in energy and allow for its stability. Such areas of focus for application of energy conservation measures include manufacturing/industrial setup, office and residential buildings, power generation and distribution, transportation, energy conservation through waste control etc. Various measures that need to be considered and appropriately addressed in moving towards energy sustainability in Nigeria have been recommended among which are energy use in ventilating equipment, lighting, electrically operated industrial machines and engines, design for energy-efficient buildings etc.

Keywords: Sustainable energy, Sustainable development, Energy, Efficient energy, Energy conservation

Background

Energy is the mainstay of Nigeria's economic growth and development. It plays a significant role in the nation's international diplomacy, and it serves as a tradable commodity for earning the national income, which is used to support government development programs. It also serves as an input into the production of goods and services in the nation's industry, transport, agriculture, health, and education sectors, as well as an instrument for politics, security, and diplomacy [1].

Some of the common energy carriers or sources are coal, petroleum, natural gas, nuclear fuels, biomass etc. Of all these, the most widely used energy sources are the hydrocarbon compounds or fossil fuels which account for more than 80% of global primary energy consumption [2].

Nigeria is richly blessed with primary energy resources. The country is endowed with the world's tenth largest reserves of crude oil currently estimated to be about 36 billion barrels (about 4.896 billion tonne of oil equivalent (toe)) in 2006. The country has also been described as more of a natural gas island than oil with an estimated endowment in 2006 put at about 166 trillion standard cubic feet (5,210 billion cubic meters). This includes associated and non-associated reserves, placing Nigeria among the top ten countries with the largest gas reserves in the world. Other significant primary energy resource endowment in Nigeria include tar sands - approximately 31 billion barrels oil equivalent (4.216 billion toe), coal and lignite - estimated to be 2.7 billion tonnes (1.882 billion toe), large hydropower potentials of approximately 10,000 MW, small hydropower potentials, provisionally estimated to be734 MW. Table 1 provides a brief summary of these endowments in Nigeria. The table contains recent estimates of other renewable potentials apart from hydropower [3].

Nigeria's coal reserves are large and estimated at 2 billion tonnes of which 650 million tonnes are proven reserves. About 95% of Nigeria's coal production has been consumed locally, mainly for railway transportation, electricity production, and industrial heating in cement production. Apart from the export potential of the Nigerian gas, local demand opportunities are power generation, cement industry, and iron and steel plants. The largest single consumer of natural gas in Nigeria is the Power Holding Company of Nigeria (PHCN), and it

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Table 1 Nigeria's energy reserves and potentials (2005)

Resources type	Reserves	Reserves (BTOE)[c]
Crude oil	36.0 billion barrels	4.896
Natural gas	166 trillion SCF[a]	4.465
Coal and lignite	2.7 billion tonne	1.882
Tar sands	31 billion barrel of Oil equivalent	4.216
Subtotal fossil		15.459
Hydropower, large scale	10,000 MW	
Hydropower, small scale	734 MW	
Fuelwood	13,071,464 ha[b]	
Animal waste	61 million tonnes/year	
Crop residue	8.3 million tonnes/year	
Solar radiation	3.5 to 7.0 KWh/m^2/day	
Wind	2 to 4 m/s (annual average)	

[a]SCF, standard cubic feet; [b]Forest land estimate for 1981; [c]BTOE, billion tonnes of oil equivalent. Adapted from Dayo [3].

accounts for about 70% which is used to operate electricity-generating gas plants in the country. The consumption rate of petroleum product in Nigeria has increased tremendously from 1990 to 2004 with motor gasoline and diesel oil taking a significant lead. The consumption of petroleum products stood between 80% and 90% of the total commercial energy consumption for over 35 years. The growth rate over the period averaged at about 22%, with gasoline at 28%, kerosene at 19%, and diesel at 18%. Gasoline and diesel are mainly used for transportation which accounts for 87% [4].

Although Nigeria is relatively endowed with abundant fossil fuels, the energy situation in the country is yet to be structured and managed in such a way as to ensure sustainable energy development. As a nation that has limited technological capacity but sees industrialization as constituting a crucial leverage and precondition for meaningful development, Nigeria should be wise enough to manage her scarce energy resources judiciously. As a matter of utmost importance, industrialists, civil servants, researchers, government officers, and students inclusive in Nigeria should take advantage of opportunities in low level, low risk but high worth energy-efficient measures that reduce the bottom line of any business enterprise [5].

In so doing, a lead time will be created to pursue high-tech-driven production processes that will find support at maturity in an already established energy-efficient culture. Researchers have shown that energy supply and end-use efficiency in the developing countries are still only two-thirds to one-half of what would be considered 'best practice' in the industrialized world [6].

Despite the ample coal, oil, and natural gas reserves, at the present rate of extraction, it has been estimated that these reserves, by the next 40 years, will be depleted to the point where it would be uneconomical to continue exploration. It becomes imperative, therefore, that we start implementing energy conservation and efficiency measures in conversion systems while looking for alternative sources of energy [7].

The increasing role of energy efficiency as a catalyst for sustainable development is realism in the industrialized countries of the world. In Nigeria, the story is different at the moment as the huge benefits derivable from adoption of energy efficiency and conservation measures by various economic sectors remain largely untapped due largely to lack of awareness of the economic and social benefits of energy efficiency measures [8].

A sustainable energy system may be regarded as a cost-efficient, reliable, and environment-friendly energy system that effectively utilizes local resources and networks. It is not 'slow and inert' like a conventional energy system, but it is flexible in terms of new techno-economic and political solutions. The introduction of new solutions is also actively promoted [9].

This study will thus take a look at the various energy requirements of the various sectors *vis-a-vis* the energy conservation opportunities therein and also the measures to maximize these opportunities and thus conserve energy. The study identified some major areas through which energy conservation measures can effectively cause some savings in energy and allow for energy stability. The main area of focus for application of energy conservation measures considered in this study include the manufacturing/industrial setup, office and residential buildings, transportation, and power generation and distribution. Each of these areas is being examined for possible energy savings and building a sustainable, long-term, energy future in the country.

Energy crises in Nigeria

Throughout the world, electricity is the most widely used and desirable form of energy. It is a basic requirement for economic development and for adequate standard of living. As a country's population grows and economy expands, its demand for electrical energy multiplies. If this demand is not met adequately, then a shortage in supply occurs. This shortage can assume crisis proportions. According to Chigbue [10], electric power as a major component in the requirements for effective industrialization and development is grossly inadequate in Nigeria.

For many years now, Nigeria has been facing an extreme electricity shortage. This deficiency is multifaceted, with causes that are financial, structural, and socio-political, none of which are mutually exclusive. At present, the power industry in Nigeria is beset by major

difficulties in the core areas of operation: generation, transmission, distribution, and marketing [11].

In spite of Nigeria's huge resource endowment in energy and enormous investment in the provision of energy infrastructure, the performance of the power sector has remained poor, in comparison with other developing economies. This assertion was confirmed by a World Bank [12] assessment study conducted on energy development in Nigeria, which compared the performance of Nigeria's power sector with those of 20 other developing countries. The study reveals that the sector had the highest percentage of system losses at 33% to 41%, with the lowest generating capacity factor at 20%, the lowest average revenue at US dollars of 1.56 kW h, the lowest rate of return at 8%, and the longest average accounts receivable period of 15 months.

There is no doubt that expensive and unreliable power remains a major concern to all sectors of the economy in Nigeria: the industrial, commercial, and domestic sectors especially. Multiple and unpredictable power cuts, which have become a daily occurrence in Nigeria, often result in equipment malfunctioning, which make it difficult to produce goods and provide service efficiently. As a result of this fundamental problem, industrial enterprises have been compelled to install their own electricity generation and transmission equipment, thereby adding considerably to their operating and capital costs [8].

Most businesses in Nigeria, large and small, end up relying on the generator for electricity to power their businesses. MTN - the South African mobile phone company and the largest mobile phone supplier in Nigeria - is estimated to have installed 6,000 generators to supply its base stations for up to 19 h/day. The company spends $5.5 million on diesel fuel to run the generators [8].

Energy consumption by sector in Nigeria

From the energy point of view, the Nigerian economy can be disaggregated into industry, transport, commercial, residential (household), and agricultural sectors. The household sector accounts for the largest share of energy use in the country - about 60%. This is largely due to the low level of development in all the other sectors [13]. Figure 1 shows the variation of energy consumption by sector in Nigeria from 1996 to 2005. It can be seen that the household sector has consistently accounted for over half of Nigeria's domestic energy consumption. Its shares varied from about 55% to about 61% [14].

The major energy-consuming activities in Nigerian households are cooking, lighting, and use of electrical appliances - in that order. Cooking accounts for a staggering 91% of household energy consumption; lighting uses up 6%, and the remaining 3% can be attributed to the use of basic electrical appliances such as televisions and pressing irons [7].

The predominant energy resources for domestic and commercial uses in Nigeria are fuel wood, charcoal, kerosene, cooking gas, and electricity [15]. Other sources, though less common, are sawdust and agricultural crop residues of corn stalk, cassava sticks, and in extreme cases, cow dung [16]. In Nigeria, kerosene and gas are the major cooking fuels especially for the urban dwellers. Majority of the people rely on kerosene stoves for domestic cooking while only a few use gas and electric cookers [17]. According to Enete and Alabi [18], distribution of household final energy consumption by type in Nigeria is electricity (4%), kerosene (13%), LPG (1%), and wood and others (82%).

Energy efficiency practice in Nigeria

Energy is an important production factor and therefore should be managed in parallel with land, labor, and capital. Energy-efficient production should be seen as a quick and cheaper source of new energy supply as the cost of providing energy can be several times the cost of saving it. Increasingly, energy efficiency is deemed to include not only the physical efficiency of the technical equipment and facilities, but also the overall economic efficiency of the energy system [5].

Energy efficiency means improvement in practices and products that reduce the energy necessary to provide services like lighting, cooling, heating, manufacturing, cooking, transport, entertainment etc. Energy efficiency products essentially help to do more work with less energy [19]. Energy efficiency is also defined as essentially using less energy to provide the same service [20]. In this sense, energy efficiency can also be thought of as a supply resource - often considered an important, cost effective near - to midterm supply option. Investment in energy efficiency can provide additional economic value by preserving the resource base (especially combined with pollution prevention technologies) mitigating environmental problems.

On the other hand, energy conservation defined as 'an attempt to reduce the amount of energy used for domestic and industrial purposes' is obviously synonymous with energy efficiency. It has been described as using energy more efficiently, whether through behavior, improved management, or the introduction of new technology [21]. Energy conservation is further defined as 'the strategy of adjusting and optimizing energy using systems and procedures so as to reduce energy requirements per unit of output (or well-being) while holding constant or reducing total costs of providing the output from these systems' [5]. It has sometimes been associated with efforts to curtail energy use at the cost of

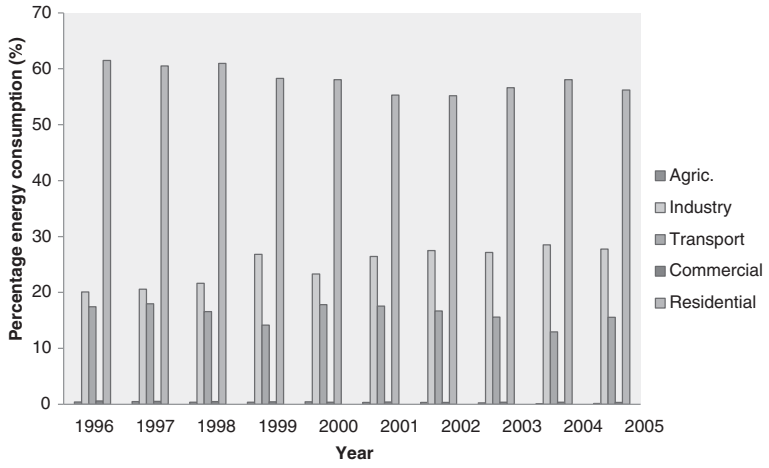

Figure 1 Sectoral energy consumption (PJ) from 1996 to 2005. Adapted from Dayo et al. [14].

economic activity and living standards, but it should be concerned exclusively with energy conservation as a means of increasing economic benefits. It can be seen from the various definitions and explanations that energy efficiency and energy conservation convey the same meaning and can be used interchangeably. The basic objective is the same - the reductions of energy costs or increase in energy supply.

Energy efficiency has become the key driver of sustainable development in many economies in the world [22]. If we use energy efficiently, it will help to reduce the building of more power stations. Thus, the money for building power stations will then be spent on other sectors of the economy. Moreover, more people will have access to energy; if we save energy in one part of the country, the energy saved can be made available in another part. In Nigeria, where the utility companies do not have enough energy to meet the needs of everybody at the same time, energy supply is alternated. With good energy management at the residential, public, and private sectors, there will be no need to alternate electricity supply.

Energy efficiency policy in Nigeria

The national energy policy and the draft energy master plan contain basic policies and strategies for energy efficiency and conservation in Nigeria. In specific terms the policy provides for the following:

- The promotion of energy efficiency and conservation in industrial, residential, and transport sectors,
- Designing a national program on industrial energy efficiency and conservation in collaboration with MAN and experts in higher institutions and research centers,
- Introduction of fuel efficiency labeling program in the transportation sector for various vehicle types,
- Establishing codes and standards for energy efficiency and conservation technologies, and
- Enforcing the codes and standards.

This policy is only on paper but never implemented so as to promote practice of energy efficiency and energy conservation principle in the country.

Inefficient utilization of energy in Nigeria

Energy efficiency does not mean that we should not use energy, but we should use energy in a manner that will minimize the amount of energy needed to provide services. This is possible if we improve in practices and products that we use. In Nigeria, a lot of energy is wasted because households, public and private offices, and industries use more energy than is actually necessary to fulfill their needs. One of the reasons is that they use old and inefficient equipment and production processes. The other reasons are unwholesome practices that lead to energy wastage. These are discussed in the following subsections.

Dominant use of incandescent light bulbs

The use of incandescent bulbs for lighting is energy intensive. Only about 5% of total energy used by an incandescent bulb is converted to light energy; the remaining 95% is converted to heat energy [23]. The energy rating of the incandescent bulbs found in the Nigerian market ranges from 40 to 200 W; thus, we have the ones for 40, 60, 100, and 200 W.

A major factor working against the shift from incandescent bulbs to energy-saving bulbs is the cost. Energy-saving bulbs are far more expensive than incandescent bulbs. The cost of energy-saving bulb in the Nigerian

market ranges between N800 and N1,000. However, some substandard energy-saving bulbs could be purchased for about N200. On the other hand, the prices of incandescent bulbs range from N30 to N100. Energy consumed in Nigeria can be drastically reduced if Nigerians replace their incandescent bulbs with energy efficiency bulbs.

Putting on light to advertise goods

Many people who sell certain goods such as snack and electrical materials switch on light during the day to draw the attention of people to buy their goods. In the same way, operators of fast-food centers do the similar thing; they use incandescent bulbs to heat their food and at the same time draw the attention of people to their products. This practice is energy intensive and should be discouraged. In some of the fast-food centers, several incandescent bulbs are put on at the same time for aesthetic purposes and to create illumination during the day. These houses could have been built in a way that they use the natural light during the day.

Switching on outdoor lighting during the day

Many Nigerians do not put off their outdoor lighting during the day. This is particularly very common in commercial and residential areas in many major cities in Nigeria. Even in public institutions such as universities and government ministries were also found to have their outdoor lighting switched on during the day. A lot of energy can be saved if Nigerians cultivate the habit of putting off their outdoor lighting in the daytime. Energy saved from using the natural light instead of light bulbs during the day can be made available for use in offices and for industrial activities.

Proliferation of private water boreholes

In many major cities in Nigeria, many people now have boreholes in their houses. This arises because of the inability of government to provide water in many parts of the country. The use of privately owned boreholes is on the increase. In many cases, you find two or more boreholes in one street. The machine for pumping water from the aquifer is an energy intensive machine and can consume up to 2,000 W of electricity. Apart from consuming a lot of energy, these machines exert a lot of stress on PHCN facilities. In many parts of the world, water is conveyed from a central system through a network of pipes to residential, public, and private buildings. With this method, the energy used to take water from the ground and make it available to the people is greatly minimized.

Industrial activities in residential areas

Many cities in Nigeria are not properly planned. The practice of building industries in residential areas is unhealthy for power supply for residential use. With this kind of practice, utilities providing electricity are not able to plan on how to allocate energy to the various sectors. In addition, because of the high energy consumption of the equipment used in the industries, the equipment exert so much stress on the PHCN facilities which were initially installed to serve residential areas. In this kind of system, it is difficult to allocate energy for the two sectors in a way to maximally satisfy everybody. It is also difficult for utilities to do load shifting.

Setting appliances on standby mode

Many Nigerians do not know that leaving appliances on standby mode, the appliances still consume energy. Putting an electrical appliance on standby mode is not the same thing as putting it off. Electrical equipment consumes energy when on standby mode. Although the energy they consume is not the same as when they are switched on, putting them off when not in use can save some measure of energy. Consumers should be appropriately informed by the manufacturers of the energy electrical appliances at standby mode. A good way to do this is to inscribe it on a label and stick them to the appliances.

Simultaneous use of multiple appliances in public buildings

This is a very common practice among public officers in Nigeria, especially the senior staff. In one department or building, you will find refrigerators and air-conditioners at the same time in all offices, even those of junior staff. It is a common practice to find out that in government offices, you will find a refrigerator, air-conditioner, television set, photocopy machine, desktop computers, fans, electric kettle, and incandescent bulbs, and in many cases, these appliances are switched on at the same time. You go to another office in the same department or building, and you find similar things. The reason for this practice could be that public officers do not pay individually for electricity, and thus, they are not conscious of the way they use energy. Also, it has been revealed that many government buildings are not metered; thus, government officers are not accountable to the energy they use during office hours. In university dormitories, occupants use all kinds of electrical materials, and they do not have restrictions on the kind of equipment they use. It is a common practice for students to use all kinds of electrical heating equipment for cooking in student dormitories. The use of a particular heating equipment popularly called *hot plate* in student dormitories is very energy intensive and should be discouraged. Individual rooms in student dormitories are not metered; this encourages wastage as they are not held accountable for the energy they use.

Leaving appliance on when not in use

Many Nigerians do not put off their appliances when they are not in use. This practice can lead to significant wastage of energy in residential, private, and public buildings. The reason for this could be that many Nigerians do not really pay for the electricity they consume. In many houses, the meters installed by PHCN are no longer functioning. What PHCN officials do is to place these houses on estimated bill. This practice encourages the wastage of electricity since they do not really account for what they consume.

Multiple use of inefficient heating equipment

The use of heating equipment for cooking and heating water should be discouraged in the residential and private buildings. The government should encourage the use of solar heaters. Heating equipment consume about 60% of the energy used in houses. In places like hotels where several water heating equipment are installed in several rooms, sometimes numbering up to 100 rooms or more, the use of solar heaters in these buildings will help to save a lot of energy.

Purchase of secondhand appliances

The Nigerian market is flooded with all kinds of secondhand appliances. Over 90% of Nigerians use one secondhand product or the other. They are cheaper compared to the new ones. Many Nigerians are on the opinion that secondhand products are more durable than the new ones. This assertion could be based on the fact that there are a lot of substandard goods in the market and that the secondhand goods tend to last longer than them. Many of the secondhand products come from European and North American countries, and they may have been manufactured a long time ago. The efficiency of these products is quite doubtful, and the possibility exists that they may have been rejected by the former users to purchase more recent and efficient appliances. The secondhand market needs to be further studied to direct policies that will address the situation.

Barriers to energy efficiency development in Nigeria

The following are barriers to the development of energy efficiency in Nigeria:

- Lack of policy and legislation. Lack of policy and legislation to address the inefficient use of energy is such a key barrier to the development of energy efficiency. Policy and legislation will help to change behavior towards an energy-efficient economy. From the survey carried out by Etiosa [22], about 79% of respondents are not aware of any policy on energy efficiency made by the government. Private and public institutions should also be encouraged to make their own policy to promote the efficient use of energy. The government can make it mandatory for public and large-and small-scale private organizations to establish an energy management department or unit.
- Lack of awareness. Many Nigerians are not familiar with the term energy efficiency, while those who claim they are familiar with the term could not really define it properly. Awareness creation will go a long way to help people understand the concept and change their behavior.
- Lack of trained personnel and energy efficiency professionals. Inadequately trained personnel and professionals is another factor inhibiting the development of energy efficiency. Nigeria as a country lacks adequate energy efficiency experts who will drive the development of the concept and policy that will promote energy efficiency.
- Importation of used machines. The proliferation of imported secondhand appliances may hinder the use of efficient appliances. The reason is that these secondhand equipment are cheap and easily available; the new and efficient ones may be unable to compete with them in the market.
- Lack of research materials on energy efficiency. There is lack of research materials and data that will guide the development of policy that will strengthen the efficient use of energy. Also, there is lack of material to conduct training on energy efficiency.
- Inefficient metering system and low electricity pricing. The metering system in Nigeria is very inefficient and does not encourage consumers to pay the correct amount for the energy they consume. Many people who still use the old meters are now on estimation since these meters are faulty. The use of prepaid meters which was recently introduced by the PHCN will help change the behavior of consumers to use energy efficiently.
- Proliferation of inefficient equipment and desire to minimize initial cost. The desire to minimize initial cost forces many consumers to purchase cheap and inefficient appliances. For example, the cost of energy-saving bulbs in the Nigerian market is about N800 compared to an incandescent bulb which cost about N40. Many consumers will prefer to go for the cheaper ones not minding the long-term benefit of using efficiency bulbs.
- Low income. About 70% of Nigerians leave below the poverty line of $2/day. Many are not able to afford the cost of efficient appliances which are sometimes more expensive than the less efficient ones.

Energy conservation in various sectors in Nigeria

The need for energy is increasing and outstripping its supply in Nigeria. Therefore, and in view of these

circumstances, primary energy conservation, rationalization, and efficient use are an immediate need. Getting all the possible energy from the fuel into the working fluid is the goal of efficient equipment operations. This not only saves money and produces higher productivity, but also influences the safety and life of the equipment and reduces pollution [24]. Steps taken to minimize energy consumption, or to use the energy more effectively, are steps in the right direction to preserve the global environment. Energy conservation measures or recommendations are often referred to more positively as opportunities. There are two primary criteria for energy conservation opportunities: that it should be easy to implement and that its payback be short. Ease of implementation and payback period have been used to classify energy conservation opportunities into three general categories: maintenance and operation measures, process improvement projects, and large capital projects [25].

Although energy conservation and efficiency are not resource *per se*, it is acknowledged that their adoption in the country can significantly mitigate the supply challenge. It is in recognition of this that the Federal Government of Nigeria recently approved the establishment of a National Centre for Energy Efficiency and Conservation [26]. The Center is charged with the responsibility for organizing and conducting research and development in energy efficiency and conservation. In this regard, the Center is to carry out the following functions:

1. Develop guidelines for energy-efficient end-use products and advise on their implementation;
2. Develop energy efficiency codes, standards, and specifications for domestic, industrial, and commercial facilities;
3. Gather, analyze, and manage energy supply and consumption data and information;
4. Serve as a Center for training of high-level manpower in energy efficiency and conservation;
5. Develop and execute pilot/demonstration project highlighting energy efficiency concepts;
6. Disseminate information on energy efficiency and conservation concepts through public awareness programs such as seminars, workshops, publications, etc.; and
7. Perform any other functions, as may be directed by the Federal Government in relation to energy efficiency and conservation in Nigeria.

Opportunities for energy conservation in buildings

If the building envelope and building materials were adequately taken care of to allow for a longer time period for daylighting, and maximum indoor space cooling, this would reduce the time of need of electrical energy for both lighting and cooling devices. Consequently, this will promote energy conservation. Apart from the building envelope, a lot of opportunities also exist for energy conservation in the lighting and cooling devices subsectors. For instance, due to the high first cost of fluorescent bulbs, incandescent bulbs (40- and 60-W rating) are still the predominant electric lighting device in the country. Hence, approximately 34.3% of total electricity use in urban households goes to lighting [27]. The tropical climate of Nigeria definitely makes space cooling an essential energy service. This is provided by electric fans and air-conditioners. Fans have a much higher market share than air-conditioners in Nigerian households because of their lower investment costs and lower electricity consumption. A study by Adegbulugbe and Akinbami [27] has revealed that electricity consumption by fan cooling ranges between 2% and 8% while the total average consumption is 7% of the total household electricity consumption in the various household income groups in the country. Similarly, the percentage share of electricity consumption by air-conditioners to the total household electricity consumption ranges between 0% and 2% with a total average of 1.5%. As a result of the downturn in economy in the past two decades, the Nigerian market has become a dumping ground for secondhand products from abroad. Definitely, due to overuse before shipment, the efficiencies of these products have dropped. These consequently promote energy inefficiency in our buildings. If better energy-efficient lighting devices such as compact fluorescent lamps (CFL) as well as better energy-efficient cooling devices such as fans and air-conditioners were promoted in the country, these would help in reducing both electric lighting and cooling energy. Putting altogether these energy-saving opportunities in the residential buildings alone, it is estimated that at least 10% of the total residential electrical energy use will be conserved. Similarly, about 10% of both the total industrial and commercial sectors' electricity demand could also be saved. Ultimately, these would lead to a reduction in greenhouse gas emissions in the country. Another means of energy conservation in buildings is to design the building with more consideration for its environment so that the need for active space heating or cooling by mechanical or electrical means is substantially reduced, if not, totally eliminated.

Opportunities for energy conservation in industries

In Nigeria, energy-saving opportunities in the industrial subsector of the economy have remained a matter for speculation over the years due to uncoordinated efforts at addressing issues relating to energy efficiency and management. It is in the bid to create necessary awareness on the huge potentials for energy savings in the sector that the Energy Commission of Nigeria in collaboration with UNIDO and other stakeholders have

for some time now engaged themselves in industrial energy efficiency programs in Nigeria [8].

Strictly speaking, two forms of energy carriers are commonly used in the industry: electricity and heat. However, among all the energy forms, electricity is the most widely deployed in the industry for the transformation of raw materials into the desired end products. Electricity consumption in the industry is usually for lighting and motor power-drives of various kinds of equipment, such as pumps, fans, compressors, blowers, conveyors, air-conditioners, and various machine tools. It is also used in electric furnaces and electrolysis. Improvement in the efficiency of electric motors in particular can result to large energy and cost savings. On the other hand, thermal energy is mostly used in boilers for processed steam generation and in kilns such as in cement production [5].

Investigation carried out in some industries in Nigeria reveals areas of energy conservation (savings) in Nigerian industries.

The following are highlights of walk-through energy audits of some industries in Nigeria.

- A foundry industry. Walk-through energy audit carried out in this industry by Unachukwu [5] shows that there are opportunities for energy saving in the industry. For instance, the total current measured is above the rated value for the main breaker, leading to unacceptable overheating and frequent tripping of the breaker which is now superficially overcome by the installation of a big standing fan to dissipate the generated heat. This is a source of energy waste, and can be avoided by the replacement of the main breaker, especially due to the fact that the contacts may melt completely and results into shutdown and loss of production man-hours. Furthermore, based on the measured total dissolved solid (TDS) value of the high frequency induction furnace cooling water system, it is inferred that the ion exchange resin has expired and is therefore due for recharging or replacement to avoid scale formation and rust along the piping network.
- Plastic industry. In this industry, it was observed that energy-saving potentials in the plastic company include repair of badly damaged insulation; elimination of fuel, gas, oil, and water leaks; reduction in excessive heating and cooling; cleaning of dirty surfaces of heat exchangers, motors, and lamps; prompt replacement of worn-out belts; greater use of diffused light; and replacement of the large number of incandescent light bulbs with energy-efficient CFLs.
- In the bottling company. In this industry, it was observed that the electricity supply is 100% from three 800-kV A diesel generators, while thermal energy for the boiler is from low pour fuel oil (LPFO). Two out of the three diesel generators are run at a time (24 h/day), and the other stays on standby. To say the least, this scenario is a replicate of most industries in Nigeria which is indeed a sad commentary of the electricity supply situation in the country. In terms of energy efficiency, the compounding wastes along the energy supply line are better imagined. The scenario in the bottling company in relation to energy efficiency is that a 10-bar, 2-tonnes/h capacity, LPFO-fired steam boiler produces steam at a pressure of 4 to 5 bars (about 140°C to 150°C) used in bottle washing that requires hot water at a temperature of about 80°C to 90°C. It was observed that the steam produced at a high temperature of about 140°C has to be throttled to reduce the temperature to the required level for bottle washing. Ironically, the runoff water from the final washing stage comes out at a temperature of 60°C to 70°C and is emptied into the drain. While this practice is considered proper from the point of view of avoidance of contamination, it is suggested that a low pressure steam boiler operated at 2 bars can meet the steam requirement and thus save thermal energy. Furthermore, in the compressed air unit, the water-cooled single-stage compressor delivers at a temperature of about 80°C, while the cooling water comes off at 60°C and is again let off the drain. Opportunity for energy efficiency here is that the heat of the air compression can be recovered to heat the boiler feed water, and this may result to about 5% energy savings.
- In the beer manufacturing company. The investigation reveals the following areas of energy-saving opportunities: copious amounts of steam loss from the deaerator by deliberate action of operators; steam line leakages from loose joints and holes along the piping network; the Wort Kettle where there is loss of latent heat in the evaporation of water from the kettle; exposed steam lines where there is radiation loss from uninsulated parts; boiler fuel not sufficiently atomized for efficient combustion; oversized boiler that operates on part load most of the time; cooling tower where treated water is allowed to overflow, and there is thick ice formation along the NH_3 pipeline; brine motor pump where there is use of constant speed motor drive which runs continuously even at no load; large quantity of water waste at the bottle cleaning section; boiler TDS not monitored, feed water make up not measured, and condensate not recovered; low generator frequency at 47 Hz and low power factor at times.

Opportunities for energy conservation in transport

The transport sector is the third largest consumer of energy after the industrial sector. The share of energy consumption from transport sector varied from about 13% to about 18% from 1996 to 2005 [28]. In terms of consumption of petroleum products, it is by far the largest consumer sector and is therefore the sector with the highest impact in terms of foreign exchange costs. Thus, energy saving in this sector is of high priority particularly in financial and economic terms.

In Nigeria, many factors are responsible for high consumption of energy (fuel) in the transport sector. Some of these factors are as follows: owing of fleet of vehicles by the rich people and government officers (political leaders), purchasing of secondhand ('Tokunbo') vehicles, use of inefficient and uneconomic vehicles, use of vehicle with old engine, bad road network etc. To reduce energy consumption and greenhouse gas emissions, the government has to implement the following recommendations:

- Introduce mass transport services as operating in some cities (Lagos, Port Harcourt etc.) in the country: shift road freight to rail and from small vehicles to large vehicles.
- Promote the use of non-motorized transport (bicycles and pedestrian) for short distance.
- Promote availability of spare parts for maintaining efficient operation.
- Continuing improvement of road network. Continued efforts should be made to upgrade the road network particularly between the secondary towns, as this not only improves socioeconomic activity, but also reduces energy demand.
- Decentralize industrial development. Industrial investment should be encouraged by fiscal measures and should be following the pattern of secondary town development to avoid creating centralized industrial conurbation far from the location of the labor force, with resultant high transport requirements.
- Facilitate for railway rehabilitation. Given the generally favorable economics of rail transport when the capital outlay is no longer a significant part of cost, high priority should continue to be given to the restoration of the railway and the use of its terminal as an inland port for urban areas in Nigeria.
- Shift freight transport from road to rail and from using small vehicles to large ones.
- Standardize imported vehicles with respect to energy efficiency and environmental safety.

Energy conservation measures in Nigeria economic sectors

Possible energy conservation measures in six different Nigerian economic sectors considered in this study are given as follows.

Energy conservation measure in office and residential buildings

Possible energy conservation measures in office and residential buildings include the following:

1. Proper building orientation and symmetry. Building design should permit most of the spaces to be daylighted. Using daylighting reduces energy consumption by replacing electric lights with natural light. Buildings designed for daylighting typically use 40% to 60% less electricity for lighting needs than do conventional buildings.
2. Provision of enough windows for cross ventilation. In very hot climate, ventilation is very important. This will go a long way in reducing the use of air-conditioners at homes and offices. Although sunlight and daylight are free and readily accessible, their use without causing glare and overheating can be difficult. Glare can be avoided by using window sills, louvers, reflective blinds, and other devices to reflect light deep into the buildings. Thus, windows, with selective glazing that transmits the most visible light while reducing solar heat, should be favored. Considerable saving potentials for energy in Nigerian office and residential buildings are possible through cost-effective building design.

Lighting

Possible energy conservation measures through lighting in offices, homes, commercial centers, and industries in Nigeria include the following:

1. Relamping. It means substituting one lamp for another to save energy. New fixtures are available which produces superior energy savings, reliability, and longevity compared with incandescent lamps. CFLs are generally considered best for replacement of lower incandescent lamps at homes, offices, and commercial and industrial outfits. These lamps have efficacy ranging from 55 to 65 lm/W. The average rated lamp life is 10,000 h, which is ten times longer than that of a normal incandescent. They offer excellent color-rendering properties in addition to the very high luminous efficiency. Also, they offer energy-saving potential.
2. Installing lighting control systems in bathrooms, stores, and bedrooms. Lighting controls are devices for turning lights on and off or for dimming them. There is the need to install lighting control systems

such as photocells, timers, occupancy sensors, and dimmers in bathrooms, stores, bedrooms, and other areas not frequently used. This is to avoid wastage of energy in these areas.
3. Street light control. Street lighting accounts for more than 50% of all electricity consumed in Nigeria. Of this value, about 50% or more of the energy is wasted by obsolete equipment, inadequate maintenance, or inefficient use. Saving lighting energy requires either reducing electricity consumed by the light source or reducing the length of time.

Energy conservation measures in manufacturing and industrial processes

Three prominent broad areas had been identified for energy conservation measures in manufacturing and industrial processes in Nigeria. These include the following:

1. Improved housekeeping. Improved housekeeping with such factors as furnace maintenance, adjustment of lighting system operations, use of daylight, improving space conditions for lighting, and improving lamp and fixture efficiency are quantifiable measures of energy conservation.
2. Recovery of waste. This forms a significant savings in energy through recovery of waste heat - flue gas, exhaust steam, cogeneration of electricity etc. Heat reclamation is the recovery and utilization of energy that is otherwise wasted, which can be a substitute for a portion of the new energy that would normally be required for heating, cooling, and domestic hot water system. Heat recovery conserves fuels, reduces operating costs, and reduces peak loads.
3. Technological innovation. This border on major redesign of processes and products to yield greater efficiency of cycle operations.

Energy conservation measures in transportation

Possible energy conservation measures in transportation in Nigeria include the following:

1. Increasing the efficiency of the vehicle system through proper vehicle maintenance for better engine performance.
2. Rationing. Techniques used in rationing include restricting the uses of an item, for example, forbidding the use of gasoline to power pleasure boats, limiting the number of vehicles to be owned by every citizen to one, setting a maximum amount a person can spend for fuel (petrol or diesel) etc.
3. Improved technology through electric cars. These are automobiles propelled by one or more electric motors, drawing power from an onboard source of electricity. Electric cars are mechanically simpler and more durable than gasoline-powered cars, which store their energy on board typically in batteries but alternatively with capacitors or flywheel storage devices. It may also generate energy using a fuel cell or generator; they produce less pollution than do gasoline-powered cars. Energy conservation in electric cars, however, is so important that engineers found a way to recover the heat and use it for other heating purposes.
4. Encouraging people to use mass transport system and use of alternative energy source, e.g., fuel cells.

Energy conservation measures in household appliances

Possible energy conservation measures commonly used in household appliances in Nigeria include the following:

1. Air-conditioners. Check and clean the air-conditioner filter once a month, and make sure the air-conditioning unit is the proper size for the room it is cooling. Locate the air-conditioner on the north or east side of a house in a shady area, ventilate the house's attic to reduce heat buildup, and install ceiling fans to improve air circulation.
2. Refrigerators. Check door seals to make sure there are no air leaks, and clean condenser coils on the back of the refrigerator. Keep refrigerator away from the oven or dishwasher, and give the unit breathing room; turn the thermostat down to 2.8°C, and turn on the energy saver switch.
3. Water heater. Lower the heater setting in the range of 49°C and 54°C, insulate the water heater and any exposed hot water pipes, and use low-flow shower heads.
4. Computers. Turn off computers when not in use or set the computer to energy-saving mode.
5. Cloth washers and dryers. Use only with a full load; use warm or cold water, reserving hot water use only for heavily soiled clothes. Use only full loads for the dryer, and if a second load is necessary, dry that load immediately after the first to retain as much heat as possible. Clean lint filter before each load.
6. Ovens and stoves. Use microwave instead of oven where possible; food in glass dishes can be cooked at lower temperature. Preheating oven is usually unnecessary; on the stove top, cook with covered pans and match pan size to the size of the burner.

Energy conservation measures in power generation and distribution

This involves improvement in energy conversion technology for better efficiency, use of thermionic, thermoelectric in magnetohydrodynamic generators for better fuel saving.

Energy conservation measure through research and development

The Department of Energy (DOE) has responsibility for energy research. These programs, now distributed among a number of departments within the DOE, are concerned mainly with scientific and engineering research. They aim to develop better and cleaner methods for extracting and burning traditional fuels, such as coal and oil, and also to develop new sources of energy, such as solar power, liquid fuels from biomass, and nuclear fusion.

In Nigeria, demonstration plants have been funded for technologies such as coal liquefaction and coal gasification, fluidized bed combustion of coal [29], and improvement of methods for extracting oil from shale. Other concepts being explored are the conversion of solid waste into methane gas, the extraction of natural gas from coal seams, the use of fuel cells, magnetohydrodynamics, wind energy, and ocean thermal energy. Solar power research is being pursued in connection with efforts to design residential and commercial buildings that will use energy more efficiently. Some of the most promising devices are solar collectors (which employ water heated by the sun), solar mirrors, and photovoltaic cells capable of directly converting the energy of sunlight into electricity [29]. Improvement can be done through government assistance in releasing funds regularly for the energy research institutes in the country.

Conclusions

Energy is an important production factor and therefore should be managed in parallel with land, labor, and capital. Energy-efficient production process should be seen as a quick and cheaper source of new energy supply as the cost of providing energy can be several times the cost of saving it. Increasingly, energy efficiency is considered to include not only the physical efficiency of the technical equipment and facilities, but also the overall economic efficiency of the energy system. Hence, the adoption of energy efficiency measures in the major economic sectors (household, industrial, and transport) in Nigeria will enhance profitability, reduce greenhouse gas emissions, promote sustainable development, and improve corporate social responsibility. The time to begin aggressive campaigns for energy efficiency measures in the Nigerian economy chain is long overdue.

Presentation on the opportunities that are available in conserving energy in the various sectors - office building and residential areas, manufacturing industries, transportation, and electricity generation and distribution has been made in this work. The various areas where energy saving can be made have been identified in this study; these include energy use in the cooling system of office, residential, and industrial buildings, lighting, cooking, transport, household and office appliances, electrically operated industrial machines and heat engines such as pumps, motors, fans, boiler etc. Several guidelines and measures have been suggested to conserve energy in these areas, and if the guidelines and measures are strictly adhered to, substantive savings in energy will be made.

In order to ensure the sustainability of energy supply and subsequently of the country's sustainable economic development, the government has to intensify further the implementation of energy efficiency programs.

Competing interests

The author declares that there is no competing interest.

Received: 5 December 2011 Accepted: 7 March 2012
Published: 11 July 2012

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doi:10.1186/2251-6832-3-11
Cite this article as: Oyedepo: **Efficient energy utilization as a tool for sustainable development in Nigeria.** *International Journal of Energy and Environmental Engineering* 2012 **3**:11.