Energy Efficiency and Conservation

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Abstract. Energy efficiency and energy conservation (EEAEC) is the forerunner to an ideal energy solution for sustainable development. Both EE and EC join forces to achieve and maintain optimum energy procurement and utilization in any household or organization. They help also to minimize energy costs, wastes as well as environmental ill-effects without affecting quality of work done in production process. Energy efficiency (EE) means saving energy while keeping the same level of service. It is the ability to capitalize on new technologies and equipment to do same work with less energy. On the other hand energy conservation (EC) is achieved when you adopt better ways of doing things using the same amount of available energy to perform more useful work. EC reduces the need for non-renewable sources of energy. The spin-offs can result in increased environmental quality, national and personal security together with higher cost saving which places EC at the top of the sustainable energy portfolio hierarchy in ranking. This paper therefore should be seen as stimulus to ginger us to adopt every acclaimed energy thrift procedures uniquely in our daily activities, anthropogenic lifestyles and processes in industries. The paper has tried to examine and demonstrate the technical differences between EE and EC, thus enabling us to develop an energy audit checklist relevant for home, commercial and industrial applications.

Keywords: energy management, energy efficiency, energy conservation, sustainable development, energy audit, energy-thrift schemes
1. Introduction

In the past our economy and our over-all lifestyles have been naturally modeled by very low energy costs. This was occasioned by the shear availability of abundant energy resources and naturally occurring potentially cheap energy sources globally. However, the price of oil, natural gas, coal and human labor as part of energy source have increased markedly this past decade. As a result, this has compelled energy consumers, commercial, industrial and service sectors to clamor and search for modalities to reduce energy need. Such modalities entail to look for alternatives aimed at achieving more efficient energy solutions which will save energy and reduce costs while services to be rendered remain constant and protection of the environment assured for the benefit of future generations(1).

Hence, to actualize the aim above, which is to achieve higher energy efficiencies, there is the need to adopt sustainable technologies, articulation of policies that will encourage application of energy thrifts by consumers, the use of eco-friendly products, the application of known viable investments in more energy–efficient industrial processes(2). Same for households, communities and in the transport sector of the economy. The resourceful deployment of EE and EC is the best practice answer. For instance the energy consumption in the transport sector takes up to seventy percent [70% as at 2007 in Nigeria] as opposed to other sectors, Residential 3%, Industry 7%, Others 8%, Comm./Public services 12% (3). Transportation taking 70% of energy demand in that sector is an indication of the attendant environmental ill-effects associated with energy production and utilization from raw fuels [GHG, acid-rains and global warming, oil-spills, air and water-pollution, loss of wilderness-areas, construction of new plants] adverse effects/environmental and social impacts to the population, today the above figure has not changed. Transportation involves the use of vehicles, cars, ships-marine and air transport, rail all of which use fuels of all sorts with the attendant pollutants [CO₂, SO₂, NOₓ, PM₂.₅, PM₁₀]. Case studies have shown that it is possible to reduce the energy consumption by adopting EE, cause a change in the energy demand by practicing EC [like avoidance of the need to use the normal transportation infrastructures]. The use of alternatives that can provide the same work to be done or even better services- internet of things [IoT], information communication technology[ ICT], drone technologies-Ghana used drones to transport COVID-19 test
samples - this is an excellent example of highest energy-efficiency service rating, emails or telephoning gives about 68% energy saving as at 2009 using the cost of making a call as an option to physical contact or travelling (4), WhatsApp, the novel ZOOM platform for remote contacting (5,8), and most recently is the power or ability to do work remotely. With the above we can begin to see that remote work is the new oil and gas, and it is growing at geometric progression (6, 28).

Energy conservation practice reduces the demand for non-renewable energy sources such as coal, oil and natural gas. Such practice calls for alternatives to augment for the proxies[use of sustainable transport system, use of buses or riding bicycles for short distances and the likes ] of energy usage, it further looks to the need to encourage utilization of waste to energy action plans and implementation (7). EC is also a behavioral effort which calls for actions that encourages reduction of commercial, industrial and household energy use. It advocates for the use and application of alternative energy modes, better ways of doing things that save cost of rendering energy services. These are energy conservation options; recycling of materials save energy which means saving costs during productions/reproduction if such materials were to be created anew, converting waste to energy either through direct conversion or using waste to generate it- saves an equivalent of the energy which would have been thrown into the environment nay as pollutants. Bio- waste is another option. There are elements of energy thrift applications involved in innovative ways of collection and handling of wastes which conserve and save energy. The purposeful use of solar water heaters , especially in temperate elimes instead of electric water heaters in a combined heat and power (CHP) practice. This is another option. All boils down to the fact that EC is an effective way to lower energy consumption, that is ‘cutting back’ on energy use and demand(8). Examples include building designs that do not require fans, electric water heaters and the likes. The same can be said for improved energy efficiency like the use of newer appliances, kitchen equipments, the use of LED bulbs in place of incandescent bulbs. However, the terms do not mean the same thing.

The term Energy efficiency (EE) implies using energy more effectively (9). It uses advances in science and technology as catalysts to provide services and products which will require the use of less and less energy inputs to achieve same or even higher services delivery.
Examples include replacing older model appliances such as refrigerator or washing machine, with newer, energy-efficient models. Modern appliances use significantly less energy than older models yet produce more work done and even better quality service delivery. Thus EE is defined as saving energy, but keeps the same level of service. Other examples abound using colder climate regions for instance like adding insulation materials with correct “U” values to the attic and walls of a home (www.buildsustainably.com). Such added insulations would enable the home owner to reduce heating or cooling energy supply while maintaining a comfortable temperature within the living room/house. Energy efficiency in such a home can also be improved by replacing drafty windows with new energy-efficient ones. Examples are found in recent energy efficient building designs, green buildings and green architecture (10, 13, 20). EE is also achieved via the use of correct building codes and standards, the use of ducts (piping/ducting designs which will save energy when such provisions will be required in future) in high rise buildings, crossing of roads or rivers- to effect electric power or water supply and those actions that save energy and therefore reduce costs in the long run.

In any industry, the three top operating costs are often found to be energy [both electrical and thermal], labor and materials. Among the three, energy has the highest potential for cost reduction. Energy efficiency standard practice will cut the energy use of most new appliances by up to 25 percent (25%) which will help save consumers money, create jobs- new products bring in new manufacturing outfits, reduce pollution and spur innovation and investment according to industry experts, energy auditors’ reports, environment and other energy efficiency groups. In particular, refrigerator standards have been quietly saving consumer’s money while protecting our environment, reducing CO₂ emissions. Most refrigerators nowadays for instance are made of eco friendly materials notably- compressors with compact florescent bulbs (CFL’s), refrigerants: hydrofluorocarbon and hydrocarbon replacing chlorofluorocarbons(24).Other standards for energy efficiencies, sustainable and passive solar designs which include green buildings proper. The important factors that should be considered include the following: a) site planning and orientation; b) day-lighting; c) facade design; d) natural ventilation; e) thermal insulation; f) strategic landscaping; and g) advocacy for renewable energy- Renewable brings together climate protection, poverty reduction, technology development and the securing of jobs (11,29).
I. METHODOLOGY

One question is how do we achieve the aims and objectives of energy conservation which is a behavioral change. Even though much attention is given to the nature and types of processes to be followed in a particular procedure, the following are considered as crucial: Method one would include to lower energy consumption or ‘cutting back’ on activities which will involve energy usage without stopping the capacity to do the same things or get usual things done. Another aspect pertains to saving energy, actions to follow in that regard! These objectives are subtle means on how to improve EC. A best practice in any related specific case is the unique analysis, evaluation of efficacy and eventual adoption of the items in the energy audit list (12,15), those that meet the criteria. Energy audit is an inspection and analysis of energy use and flows for EC in a building construction, manufacturing process or systems to reduce the amount of energy input into the system without negatively affecting outputs (13). Continuing, using the list includes a critical utilization of the Conservation Pyramid Tenets [CPT] (12, 14) and finally adoption of the six perspectives of energy conservation activities [PECA]. It is crystal clear that adopting sustainable energy conservation methods would ensure a drastic cut in energy usage, demand and expenses. The overall gimmick is anchored in reducing energy consumption while energy services are effectively constant, this is energy efficiency: Below are some of the actions to consider.

DESCRIPTION OF METHODS USED TO ACHIEVE EE AND EC:

*The use of energy efficient equipment- example is the “Hydrogen-on-tap-device-turns-trucks-into-fuel-efficient-vehicles”(35);another example is the use of solar-electric vehicles/machines to traverse difficult terrains and do dexterous work efficiently [Electric 4 Wheel Drive] (27)

*Equipment maintenance

*Reduction of Water Consumption

*Efficient Lighting

*Decrease heat usage

*Reduce ambient temperature—used in EEDBs, codes and standards[Whole Building Design Guide-WBDA.org]
Shutting down idle equipment

Efficient kitchen layout

Training of staff- to increase their work place-efficiency to save costs due to their inefficiencies - by following energy efficient protocols: Standards and procedures, the use of standard operations procedure [SOP].

Contact your utility company: To learn how smart grid can help give optimum energy resource utilization.

Use of Battery Storage in generator supported locations-Fuel Saving, increases grid efficiency in power /generator utilization:

Batteries and Benefits

Battery storage can be used at almost all generator-supported locations that require a significant amount of system services – especially remote communities and industrial operations. The result of this pairing is a range of tangible end-user benefits that include fuel and cost savings; improved generator utilization; reduced operating time and maintenance; and lower emissions. Such an approach is field-tested, environmentally friendly, and provides a high level of stability and performance (13, 19).

Fig. 1: Spinning Reserve Displacement With Batteries: Saving Fuel, Mitigating Emissions And Costs - Source: Engineersforum: April 9, 2020 Chemical, Power0
EE - The production, demand and utilization of energy is a concern to all nations. Production cost is on the increase due to inefficient use of energy. Thus the question is how can we use EE to reduce the production cost of goods and services. Considering the fact that to use available energy (electricity-via improving the efficiency of electric motors ~ electric vehicles [EVs], Robotics-the application of mechatronics technology and artificial intelligence [AI], etc in the industries, manufacturing as well as in production to increased efficiency lies more on enhancing the performance of the individual electrical/mechanical/structural component parts. That means to undertake the production of better and efficient machines/equipments itself. One example in practical use is to reduce induction motor losses which practice increases motor efficiency thus saving energy which is a cost reduction achievement. Here success is achieved through reduction of energy consumed during the induction motor production—[innovations in induction motor parts production] (14,21). A second method which achieved efficiency of ninety one percent [91%] of distribution network using technical losses in Electrical Power System by U. O. Orji et al was Modeling Distribution Power Losses and Voltage Profile with Fuzzy Controller (33). Modeling and Assessment of Power System Reliability using a Wind–Solar Power Plant is a smart grid energy efficiency solution (34). Other examples found in induction motor manufacturing are evident in modeling and design of split phase induction machines using MATLAB/SIMULINK® as a modeling tool/technique or software (15,32). In all these, each method or process used was aimed at increasing manufacturing efficiency which is to stop energy wastes via; making use of more efficient industrial equipments, spare parts[tooling, jigs and fixtures] using a 25% industry saving potential standards [ISO, air and emission Acts] and good house-keeping which translates to effective and efficient maintenance system and tooling efficiency for jigs and fixtures, equipments, machineries, plants [Boiler plants- elaborate/ efficient instrumentation and control, energy generating plants-gas/steam turbines ]. Some companies have achieved up to 35% through retrofitting-better design and redesign of component parts/equipments. For the process industries, consideration has been on the common practice of embarking on efficient/economic operation of an oil fired boiler plant [Same can be done for other types of fuel-gas, coal/lignite]:
Economical/efficient operation of an oil fired boiler plant

For fuel and energy savings, consideration is given on (16):

∞Fuel cost reduction – achieved when there is higher efficiency of the boiler plant.

∞Altering of flue gas temperature - the higher the flue gas temperature the more losses is involved. If the flue gas temperature is high, a waste heat recovery system can be employed to recover the heat/energy. In like manner, heat recovery, from the flue gases of natural gas or fuel oil boilers, can increase the efficiency of boilers by preheating the feed-water before it goes into the boiler. This heat can be recovered by heat exchangers in the exhaust stack of the boiler, and are referred to as economizers. In general, economizers usually can reduce fuel requirements by 5–10% (10).

∞Effect of altering flue gas composition – Apart from flue gas temperature losses, analysis of the flue gas composition can be used to reduce heat loss by examining the potential heat carriers in the gas. Parameters of interest include (i) volume of flue gas and their species composition , (ii) Excess air content –if no excess air is needed. A gas analyzer is used to measure these parameters including exhaust gas temperature, ambient air temperature, and oxygen content to calculate combustion efficiency of the boiler (5, 20).

∞Effect of Materials Heat losses-This is not easy to measure so we use this in the heat balance. Low load condition radiation losses represent amount of fuel used. Since this is an oil fired boiler, radiative-heat transfer [heating] is most significant when energy balance is undertaken, this is used in the heat balance calculations.

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Q = \text{AeO}(T_1^4 - T_2^4)
\] - The symbols have their usual definitions. Q gives the heat loss, which percentage may look small but translates to a huge amount per annum.
Blow Down in a Boiler - This process is used to remove sludge/scales; salts are prevented from entering the main steam-line. To recover some of the heat, a heat exchanger is installed to absorb the heat during blow down. This will be used in space heating or drying of materials. All these will reduce the cost of operating the boiler.

Boiler Design - The design of the boiler will dictate the mode of operation. A boiler with enough monitoring instruments can be useful if handled by competent and well trained operators in achieving the most efficient economic operating conditions. These analysis using oil and gas which we rely on for heavy industrial power generation is still relevant today since we still must rely on fossil fuels [non-renewable] until and when the world would achieve one hundred percent [100%] alternative energy sources. Thus we assume this relevance pending that utopian time.

Energy Efficiency in the Transport Sector
In the transport sector, which takes about seventy percent of energy demand in the economy, a sustainable transport system (STS) as an improvement concept is required to checkmate the economic and social need to travel to places where to eke out a living. The introduction of EE takes the method aimed at achieving this sustainable transportation idea. Apart from the objective inherent as a means to minimize energy costs – the use of alternatives comes to better consideration. Small business geniuses are few mobile vendors of goods and services who take their wares to buyers using vehicles, vans thus avoiding shoppers trooping to the market place.

Some of these alternatives include adopting renewable energy sources (RES) are laid hereunder: Considering the enormous energy consumption in the transport sector (which takes 70% of energy) of the economy, a sustainable transport as an efficient energy improvement concept ensures a drastic reduction of this figure. The concept include as methods:

1. Planning objectives in communities, localities through limiting the need to travel plus offering a genuine choice of transport modes which offers and also highlights the importance of creating an up-to-date baseline data for developmental plans, in decision making taking cognizance of land use and climate change (17, 36).

2. To use a transport and planning solution for the urban areas which incorporates a potential means of combating traffic congestion and improving air quality by a systematic traffic reduction strategy that limits car parking and gives priority to public transportation, in such cities like Abuja, Lagos, Onitsha, Port-Harcourt, Aba, Kano, Kaduna or other high density cities elsewhere in the world. Improving air quality requires the use of baseline data generated for the towns/metropolis which will provide statistical data for the system to use in controlling, CO₂ emissions, particulate matters, NOₓ, SO₂, UHC, CO, and other pollutants generated during vehicular movements in the cities.

3. Another method which will reduce the energy demand in the transport sector is the most recent concept created by the COVID-19 pandemic-tagged remote working best practices and resources to help employees work remotely and effectively. The ability to do work remotely, which also is energy efficient discourages migration, thus avoiding the need to travel and solving its attendant social, environmental and economic impacts such travelling will inflict on urban dwellings (18, 28).
II. Results
The results of critical evaluations, assessment of the actions and processes, activities, procedures, approaches together with the scientific method used to ensure improved EC abound. These include: energy savings, cost reductions, and energy efficiency (EE) adaptations which all contribute to mirror the observed benefits inherent in an ideal energy solution for sustainable development (SD). They are hereunder briefly discussed. From field measurements, analysis and evaluation of Energy-Efficient Building Designs (EEBDs) for architects, here a pilot design systems using the Whole-House Approach (H-HA) showed that in a 360° circumference scale, the application of EEBDs made a contribution of about sixty per cent [60%] savings in energy demand, passive solar was twenty percent [20%], equipment-eight per cent [8%] that is innovations that emanate (accrued) as a result of installing very efficient– newer equipments in the house (21). The remaining, twelve percent [12%] becomes the energy needed which can then be sourced from the national grid or direct from smart grid installations which is part of conventional solar. It is pertinent to note that the energy conserved is calculated to be eighty eight percent [88%] (23, 39).

Fig. 3: The Outcome of A Whole-House Approach SOURCE: Lechner Norbert (2015)
Benefits Of Energy Efficiency (EE)- Technology Based Activities

While we see overall profitability as the main inducement and reason d’etre for organizations that employ EE as best practice approach in ideal energy solution, it is on record that energy efficiency endeavors has resulted in the following:

• Increased efficiencies come in many forms: equipment maintenance, in efficient running of generating plants - Spinning Reserve Displacement With Batteries results in Saving Fuel, Mitigating Emissions And Costs (29). Thermal Energy Recovery [TER] practice also increase efficiencies in industries [18], manufacturing concerns, restaurants-home kitchens and house holds.

• The introduction of electric vehicles [EVs] is a spin-off on the gains accruing from the use of more efficient and improved induction motors. These motors utilize s the technology of electric-vehicle battery [EVB- also known as a traction battery]. EVB is a battery used to power the electric motors of a battery electric vehicle[BEV] or hybrid electric vehicle [HEV]. In terms of operating costs, the price of electricity to run a BEV is a small fraction of the cost of fuel for equivalent internal combustion engines [ICE], reflecting higher energy efficiency(43).

• IoT, ICT-Online and internet marketing, online Businesses, GoTo Barbing- GoTo Selling, GoTo Hairdressing, you create a "niche" and hang it out onto the web. Let the web get access to your good skills which translates to taking your goods/merchandise/services to a selected group/community where such is needed (30), Robotics Companies and Laboratories: COVID-19 pandemics showcased the use of robots to attend to corona virus patients in isolation centers. Robots are now widely used for spraying chemicals in contaminated areas. Rwanda uses robots to manage patients. Likewise the now novel king- kong – drones have been used in Ghana to deliver urgently needed medical supplies, blood samples and COVID-19 test samples (38). In Zimbabwe where they are used to deliver urgently needed blood samples for accident victims in remote villages (29).

• Energy efficient buildings, home designs, redesigning and remodeling of houses to introduce green architecture in the built environment. It includes the generation of heavily prioritized environmental performance net-zero buildings through the use of natural light and ventilation together with the incorporation of winter gardens for their socio-environmental benefits (16, 20).

• Remote Sensing Jensen,2007 (41) – the use of ArcGIS [a geographic information system for working with maps] - to locate in real-time geo-referenced points to undertake maintenance in remote and inaccessible places. Drones which are enhanced by artificial intelligence [AI] are now used to effect maintenance in such remote and inaccessible areas by humans (42).
All these are evidences when looking at the cost saving implications of achieving above improved services by not using old and inefficient tools/equipment to compare the costs of achieving the same level of services using modern or more energy efficient ones.

- Results also in better trainings of staff/operators, the use of elaborate procedures in labour management, efficient office human relations [HR]-the use of standard operation procedures [SOP] to achieve efficient running of complicated systems[in plants like water treatment systems[WTS], sewage and effluent management plants and their maintenance.

- Good house-keeping, better and controlled environment--utilization of appropriate landscaping for homes to achieve proper energy saving functions, efficient waste management of all sorts recycle-reuse-repair-remodel-reclamation[5Rs]. These also reduce costs in production, maintenance, manufacturing in industries and commercial concerns.

- Now the generalized energy audit checklist is also an outcome of the EC and EE ideal solution game plan since it provides a good platform for energy accounting. The accounting matrix when well-arranged will give an all-round energy balance sheet that will clearly show which areas to further reduce wastes, where costs can be saved and areas where and how the environment can be protected more sustainably.

- Energy efficiency in transport sector gains hinge on the use of less and less of oil and gas resources which consumes more than seventy percent[70%] of energy resources (15). Reduction of this figure would be made possible through the use of alternatives like avoiding transportations, where alternatives exist using ICT, IoT, emails and the likes to transact, achieve the same services or provide that capacity to do things and get things done(18,30). That energy [cost of using energy] which would have been expended in transport can be invested in providing integrated community oriented recreational facilities. This will further encourage the establishment of ‘parks and ride’, designation of paid parking lots in the metropolis, provision of pedestrian foot paths, leisure spots,[ as required by Town Planning Acts of Nigeria as an example for Aba Metropolis-Nigeria which was my case study and by development authorities globally] (31). The new found COVID-19 method of delivering test samples using drones. Remote work idea will be a knock out for EE implementation result as well. Evaluation of the energy saving results speak volumes of the inherent benefits as an ultimate list of Remote Work Statistics show reduction of CO₂ emissions, PMs, NOₓ, SO₂, environmental health improvements, population stability and modification of the area’s carrying capacity.(22,26).
III. Conclusion
This paper has endeavored to throw light on ways and means of enhancing energy efficiency and conservation in households, communities in rural areas, in the industries, manufacturing and other places as well as in the transport sector. The context will give guidelines which industry leaders can use to improve on their energy solutions, investors would be able to tap viable gimmicks to sell to their portfolio managers to invest in green and eco-friendly buildings while environmentalists would be able to utilize natural landscapes to execute green architectural structures. It concludes with efficient and action-packed recommendations, advocacy for increased use of alternative energy sources: solar, modern-biomass, wind, small-scale hydro, geothermal, and marine energy (24, 26), government’s energy thrift policies which hopefully will culminate in the right energy mix code in line with the tenets of EC and EE practices for any country and in particular Nigeria. The inclusion of sustainable transport system as a means of achieving EE and EC in our development planning will lunch our cities to enviable positions that would attract tourists from other countries (31).

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and Research in Engineering Education .The advent of modern computers has tremendously
changed the mode of research in engineering and sciences. Engineering problems which have
traditionally taken months or years to solve can now readily be solved in a few hours by the use
of commercial engineering software packages such as MATLAB/SIMULINK ® , ANSOFT ® ,
SIMPLER ® , WORKBENCH ® , etc. This paper highlights the immense capability of
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