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Smart Energy

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INTRODUCTION

Energy is indispensable in our modern society. It is necessary for economic growth and development. It is crucial to tackling the most important issues such as climate change, sustainable development, health, global food security, and environmental protection. The ever-increasing cost and ever-growing demand of energy have led governments around the world to seek smart ways for generating, controlling, supplying, and saving energy. For example, using energy efficiently in smart homes saves money and reduces carbon footprint.

Traditional renewable energy sources such as photovoltaics, hydroelectricity, wind power, tidal energy, and geothermal energy have greatly advanced recently. However, they cannot respond to environmental changes. Developing smart and economical generators is crucial to meet energy needs of the modern world [1].

We are in an era where everything is expected to be smart. Common examples include smart cities, smart factory, smart farming, smart healthcare, smart university, smart medication, smart water, smart materials, smart devices, smart phones, smart grid, smart homes, smart buildings, smart metering, smart watch, smart economy, smart mobility, smart environment, smart people, smart living, and smart governance, and smart energy. Smart energy refers to an approach in which smart electricity, thermal and gas grids are combined. It is a radical, holistic, and universal approach as opposed to a single sector approach. Smart energy supply is essential for our industrial growth. It addresses the environmental impacts of the energy and transport sectors.

Recently, the terms "smart energy" and "smart energy systems" have been used to expand the concept of "smart grid." While smart grids focuses mainly on the electricity sector, smart energy systems (or smart energy grids) include other sectors such heating, cooling, industry, buildings, and transportation [2]. Smart energy regions refer to regions that offer maximal quality of living to their inhabitants with a minimal consumption of energy by combining infrastructures (energy, mobility, transport, communication, etc.). Realizing this may require a robust communications infrastructure for ubiquitous and reliable information exchange among sensors and actuators.

This chapter presents a brief introduction to smart energy. It begins by introducing smart energy portfolio and smart energy management. It covers some applications of smart energy. It presents some benefits and challenges of smart energy. The last section concludes with comments.

SMART ENERGY PORTFOLIO

The smart energy portfolio is tailored under eight new options, shown in Figure 1 [3]:

(1) *Exergization:* This is the art of using exergy analysis and its tools for better design and analysis.
(2) *Greenization:* This is the process of converting traditional systems into more efficient, more cost effective, and more environmental-friendly ones.
(3) *Renewabilization:* This is the process of switching to renewable energy (solar, wind, geothermal, etc.) based options from conventional fossil fuels based ones.
(4) *Hydrogenization:* This is the process where hydrogen is used for systems to achieve hydrogen-based economy for better sustainability.
(5) *Integration:* This is a process where energy systems are combined to achieve better efficiency.
(6) *Multigeneration:* This is process of modifying the systems where one can obtain at least four useful outputs by utilizing the same input.
(7) *Storagization:* This is the process of implementing energy storage options to offset the mismatch between demand and supply.
(8) *Intelligization:* This is the process where artificial intelligence tools are utilized to better simulate, model, and optimize smart energy applications.

SMART ENERGY MANAGEMENT

Smart energy entails an efficient utilization of energy through improved design, high efficiency technologies, and conservation, along with the use of clean renewable resources to create electricity, heat, and transportation fuels. The smart energy network is part of the electrical energy system, which is a critical infrastructure underlying many other critical and non-critical infrastructure. It would be a system resilient in the face of troubles, capable of rapid recovery from disasters.

Smart energy management has two major components: the smart energy system and smart meters:

1. *Smart Energy System:* A smart energy system is affordable, 100% renewable energy, and consumes a sustainable level of bioenergy. It encompass new technologies and infrastructures, which create new forms of flexibility, primarily in the conversion stage of the energy system. The smart energy system has the following four characteristics [4]:

- *More than a power system:* It supplements the electric power grid with natural gas, district heating, and district cooling. This enables certain energy-efficient solutions for the use of renewable energy.
- *Enabling grid synergies:* The smart energy promotes synergistic effects between different renewable energy sources through the use of conversion and storage technologies. This also makes the smart energy system highly energy efficient.
- *Use of ICTs:* The smart energy system uses Information and Communication Technologies (ICTs) to promote cohesion between energy supply and demand.
  This enables intelligent energy management, ongoing monitoring, control, and regulation.
- *Empowering the consumer:* The smart energy system is able to empower consumers and give them the opportunity to have a positive impact on the overall energy system.

The smart energy system is based on three grid infrastructures [5,6]:

- *Smart Electricity Grids*: These grids connect flexible electricity demands such as heat pumps and electric vehicles to the intermittent renewable resources such as wind and solar power. These are connected to flexible electricity demands such as heat pumps and electric vehicles to the intermittent renewable resources such as wind and solar power. All smart grids are major contributors to future renewable energy systems.
- *Smart Thermal Grids:* These grids connect the electricity and heating sectors. They enable thermal storage to be utilized for creating additional flexibility and heat losses in the energy system.
- *Smart Gas Grids:* These grids to connect the electricity, heating, and transport sectors. They enable gas storage to be utilized for creating additional flexibility. If the gas is refined to a liquid fuel, then liquid fuel storages can also be utilized.

Smart energy grids can provide efficient bidirectional energy supply and enhance the operational efficiency of energy supply with reduced greenhouse gas emissions. They allow for intelligent monitoring and distributed energy generation capabilities within the multienergy systems (thermal, electricity, and gas, water). They facilitate the integration of diverse technologies such as renewable energy, electrical vehicles, and smart homes.

The major expectations from smart energy systems are presented in Figure 2 [7]. An energy system is considered smart if it uses technologies and resources that are adequate, affordable, clean, and reliable. Therefore, smart energy systems are evaluated based on their efficiencies and environmental performance. The successful functioning of smart energy systems necessitates strong minded and direct action.

The future energy system will rely on renewable energy resources such as wind and solar power. Use of renewable energy (such as solar power and wind power) is one of the pillars for attaining smart building and smart cities infrastructure. Renewable energy is not just limited to the sun or wind. The combination of electricity and gas infrastructures may be important in the design of future renewable energy systems. Electricity storage is an important component of the renewable energy system. It has a more direct effect on the ability of the energy system to integrate fluctuating renewable electricity sources. Energy storage can revolutionize how we use energy, just as the invention of refrigeration changed how food is consumed. Energy storage allows us produce clean energy when it is cheapest, store it, and put it back into the electricity grid when needed.

2. *Smart Meters:* These are electronic devices that are used in a home or business to measure how much energy is consumed. They are the most basic components in the intelligent energy networks. Although smart metering technologies have so far been mainly used in electric smart grids, recent development has enabled auto reading and two-way communications of heat and gas meters [7]. Smart meters are wireless, high-tech, digital communication devices that will replace the old, analog electricity meters and allow remote electricity readings of utility consumption (energy, gas or water). Using smart meters provides us with some environmental benefits as well as eliminating the need for manual meter reading. A smart meter creates a mechanism for interaction between electricity producers and consumers [8]. Smart meters provide real-time information necessary to prevent malfunctions and damages to utilities. They are a key technology to enable consumers (using computers, smart phones or tablets) to track their energy use in real time [9]. The smart meter acts like a gateway for the smart building to communicate with the rest of the grid.

Other technologies involved in smart energy management include Internet of things (IoT) and RFID. The key to smart energy is information technology's ability to optimize grid operations.

APPLICATIONS

Smart energy is used in smart homes, smart cities, smart lights, commercial buildings, electric vehicles, smart irrigation, and wherever energy is used.

- *Smart Home*: The smart home is one of the emerging infrastructures. It is an application of ubiquitous computing that provides services to users in form of remote home control or home automation. Smart homes should be regarded as the building blocks of smart cities and intelligent communities. A smart home is usually a new building that is equipped with smart features and technology to enable occupants to remotely control devices in the home [10]. For example, Smart Home's home assistant collects data from sensors, uses AI algorithms to make suggestions, and automatically makes home temperature more comfortable and convenient. A ZigBee smart energy can be implemented to monitor energy consumption of household appliances in order to control them in an energy efficient way.
- *Smart Building:* Buildings consume a lot of energy and are responsible for the largest carbon dioxide (CO2) producers. They require energy for cooling, heating, hot water, and lighting. Technologies like smart metering, smart lighting, smart grid, ICT, energy Internet, and smart HVAC systems are the major technologies being used to achieve a smart building [11]. ICT enables smart buildings to communicate both with its inside devices and appliances. New buildings can be built smart and apply new standards and regulations that can assure the consumption of much less energy.
- *Smart Cities:* Cities are the fastest growing form of settlement worldwide and they need energy to sustain them. The concept of smart city emerges as a major response to the rapid urbanization and socio-economic challenges faced by cities worldwide. The concept embraces the following six functions [12],

- Smart economy (competitiveness)
- Smart people (social and human capital)
- Smart governance (participation)
- Smart mobility (transport and ICT)
- Smart environment (natural resources)
- Smart living (quality of life)

Some of these functions are illustrated in Figure 3 [13]. Smart cities are essentially tech-savvy towns that utilize digital technologies to do their business and create efficient and livable environment. The intelligent city has a wide range of electronic and digital technologies that enable its devices to communicate. Two closely related technologies, the Internet of Things (IoT) and big data, enable the transformation of traditional cities into smart cities [14]. Making efficient use of energy at smart homes, smart cities, and smart buildings is crucial for conservation and reduction in greenhouse effects. Cites can promote smart energy by constructing of green and energy efficient homes, businesses, and civic buildings. They can also reduce fossil fuel consumption and air pollution from transportation through fuel-efficient fleet policies, bicycling, and walking.

- *Transportation:* Transportation is an important factor that affects the quality of life. It is one of the hardest issues to solve as far as energy is concerned. Modern transportation sector accounts for more than 43% of energy used in the U.S. It is responsible for a large fraction of global energy consumption and depends very heavily on fuels derived from oil. Cities can provide leadership for encouraging alternative modes of transportation. Public transportation is a good way to ensure mobility in a city. Smart transportation (and its cousin, intelligent transportation system) offers a means of providing innovative services on different modes of transportation and traffic management. It is an important area in the smart grid and an extension of smart cities. Its components include infrastructure, vehicles, and users [15].
- *Electric vehicle:* The conventional gasoline cars are no longer the only options consumers have in selecting a car. To achieve a sustainable road transport system, electric vehicles (EVs) are preferred. EVs are emerging as sustainable solution to environmental and transportation challenges in urban areas. They use electricity rather than petroleum. An electric vehicle (EV) is any vehicle that uses electric motors for propulsion. Electric vehicles include electric cars, electric bicycles, electric trucks, electric trains, surface and underwater vessels, electric aircraft, and electric spacecraft [16]. The foremost goal of an EV charging system is to ensure that an EV has enough charge to meet its travel requirements. EV chargers are produced by such companies such General Electric, Leviton, Schneider Electric, and Delta Group. The companies offer a simple user interface, provide the ability to delay charging to make use of off-peak energy, and have RFID interfaces for billing purposes [17].

BENEFITS

Smart energy has the potential to reduce energy bills of households and businesses. It also reduces the demand for oil and gas and creates new green jobs. It will open new niches for distributed zero-emissions power sources such as solar and wind. Electricity providers increasingly use smart energy technologies to shift electricity consumption outside peak times. Efficient use of energy is crucial to the achievement of smart energy goals (as well as land protection, water quality, and other environmental objectives) because reduced energy use results in long-term cost savings and enhances odds of meeting our future energy needs through renewable sources. Sustainable energy can be achieved by transforming conventional building into smart buildings through application of smart energy technologies. A smart energy system would involve incorporating new forms of flexibility in combining energy storage, demand side response, smart networks, and interconnection.

Other benefits of smart energy include [18].

- *Energy Efficiency:* Energy efficiency is a basic, effective strategy for reducing the demand for heating, cooling, and electricity. Buildings are a major user of energy. Smart building can save water, and energy. Energy efficiency is also the most direct way for businesses to control and cut their production costs. The importance of energy efficiency is shown in the energy pyramid.in Figure 4 [19].

- *Environment:* Smart energy system, as one of typical sustainable energy systems, addresses the environmental impacts on the energy and transport sectors.
- *Reducing Fossil Fuels and Pollution***:** Reducing fossil fuel use and the associated environmental impacts through enhanced technologies and use of alternate fuels in the transportation sector.
- *Economics:* Promoting smart energy has strong economic development benefits. And can create an opportunity for the economy.

CHALLENGES

While smart energy technology has positive impacts on global warming, health, and cost, it has negative effects on security and privacy [20]. Data security and privacy become important when IoT technologies are employed for smart energy applications. Smart meter invites intended or unintended privacy breaching activities such as in-house activity detection. Careful planning is required to ensure that all possible measures are taken to prevent compromise. Energy security is also important for the advancement and improvement of all societies [7].

Smart energy grids present huge technical challenges in their design, operation, and maintenance. They also present challenges for communication networks and information technologies. Electricity section is just a part of the energy sector. The heating/cooling sector poses some challenges as well.

Energy efficiency is a primary concern for modern society. It can be done without compromising standard of living. Technology can improve energy efficiency. Government authorities can use laws, standards, regulations, and taxation to encourage the use of energy-efficient solutions. And consumers can learn to minimize energy consumption [21]. In view of these challenges, the government and non-government agencies are already taking action to support smart, flexible solution.

CONCLUSION

The modern economy depends heavily on energy. Governments all over the world are investing in smart energy grids to ensure optimum energy supply and use. This will facilitate the integration of heterogeneous technologies, such as renewable energy systems, electrical vehicle networks, and smart homes. Smart energy focuses more on residential and industrial issues and less on transportation and commercial [22].

With the introduction of smart grids, smart meters, and related technologies, energy systems are going through an ICT transformation. Implementing smart technology to help consumers make well informed energy choices is vital to a smart energy future. In the smart energy future, consumers will have a clearer picture of their energy usage and will be able to monitor, manage, and conserve energy [23]. As nations become more conscious of reducing their carbon footprint, solar energy and wind energy are given more priority. Smart energy will eventually transform the existing supply and use of energy [24].

More information about smart energy can be found in [4, 25-32] and other books on the subject available in Amazon.com. One may also consult journals devoted exclusively on energy issues. These include *Joule, Energy, Applied Energy*, and *Energy Technology & Policy*.

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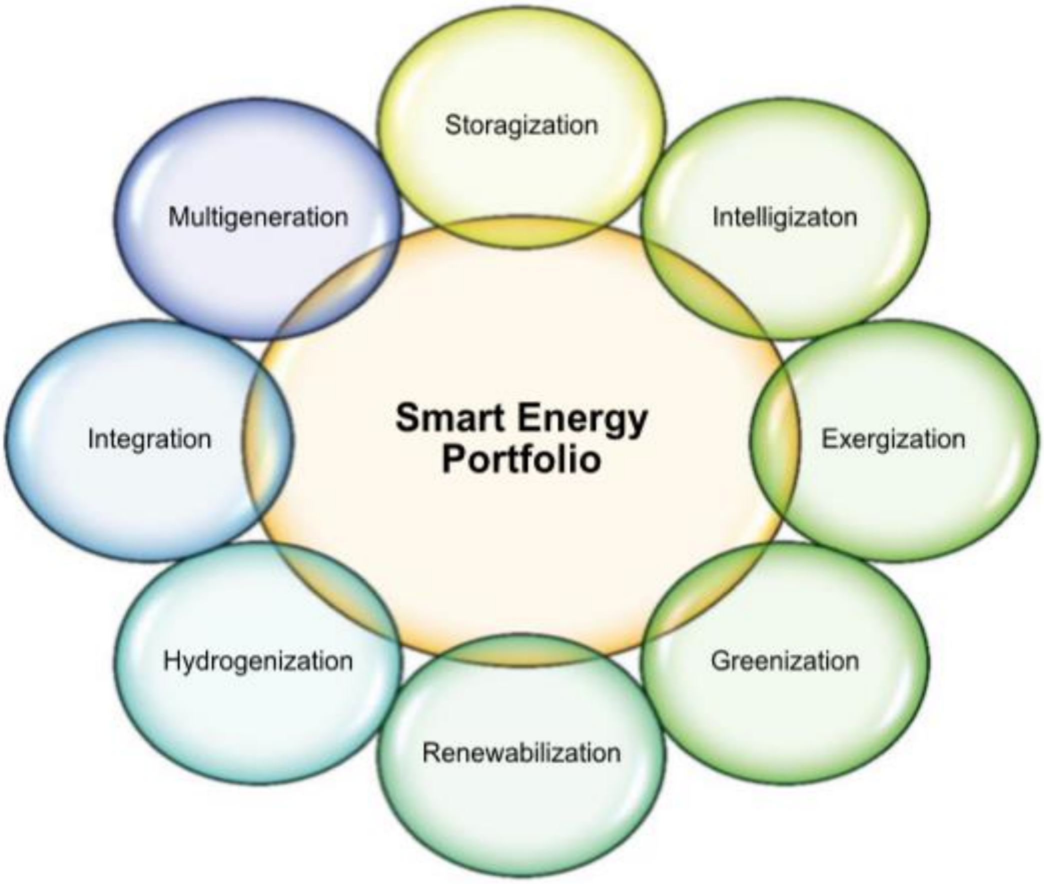

Figure 1 Eight branches of smart energy portfolio [3].

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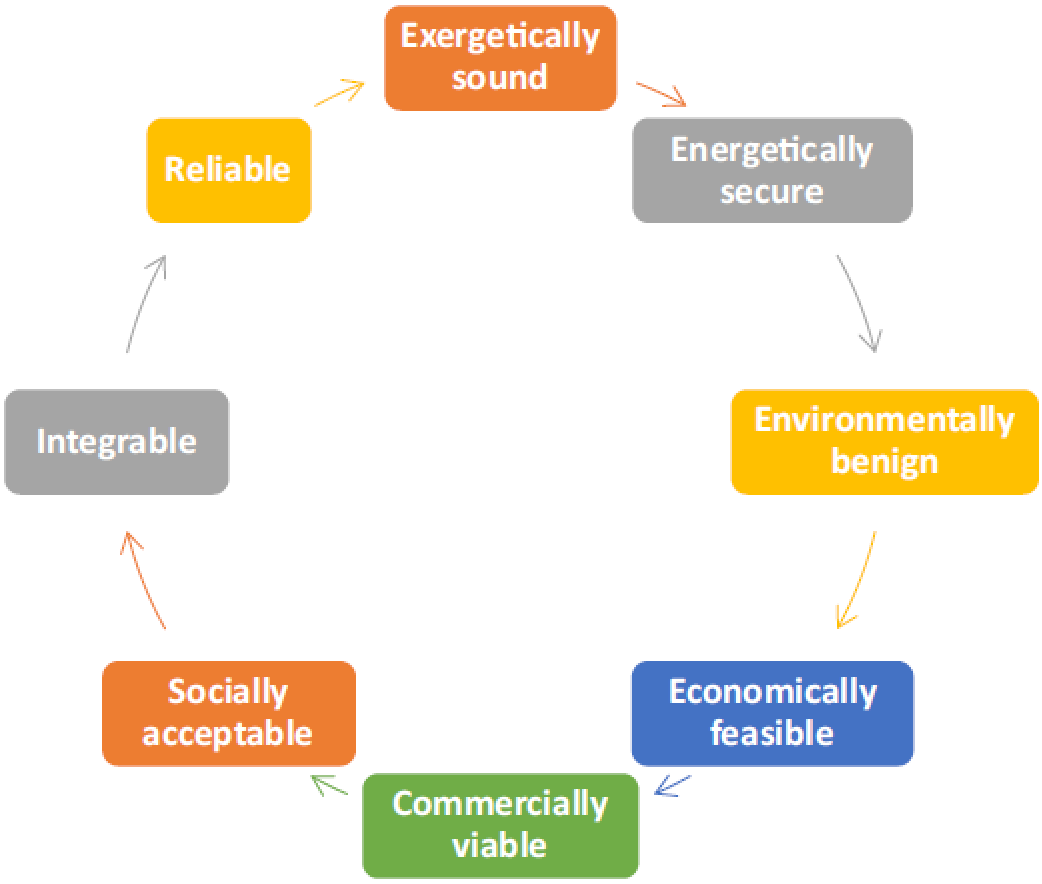

Figure 2 Major expectations from smart energy systems [7].

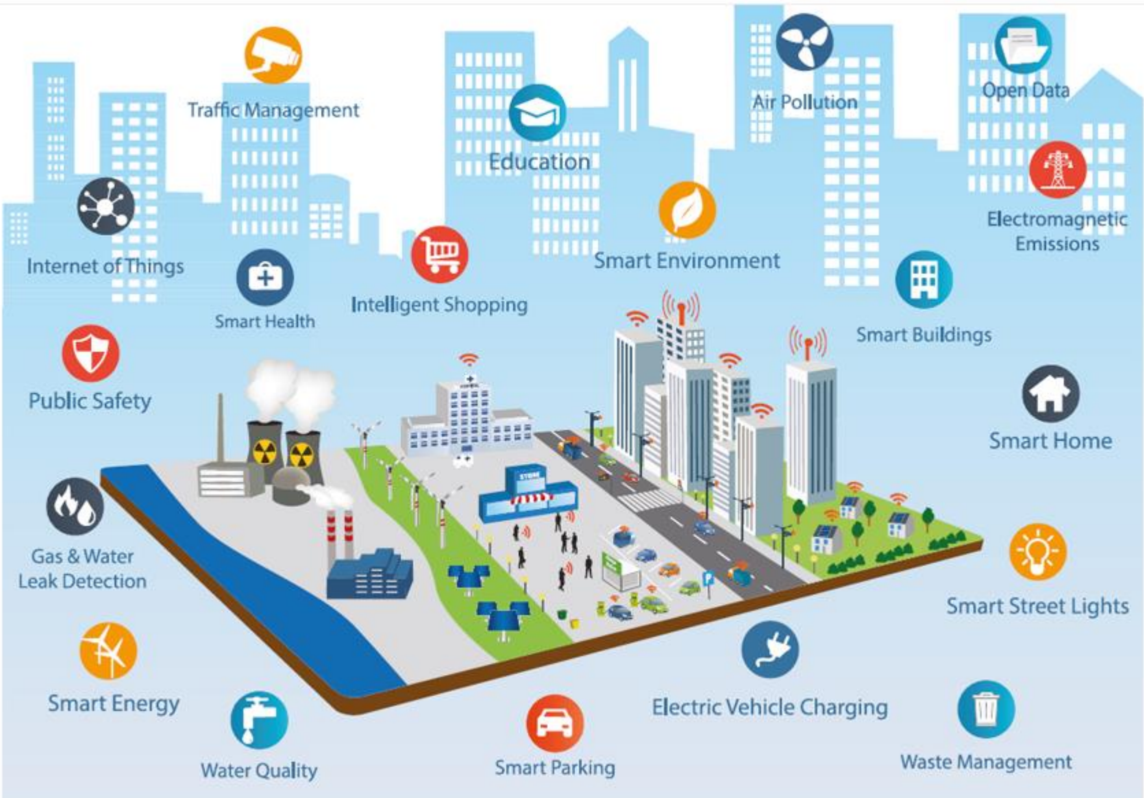

Figure 3 Smart city components [13].

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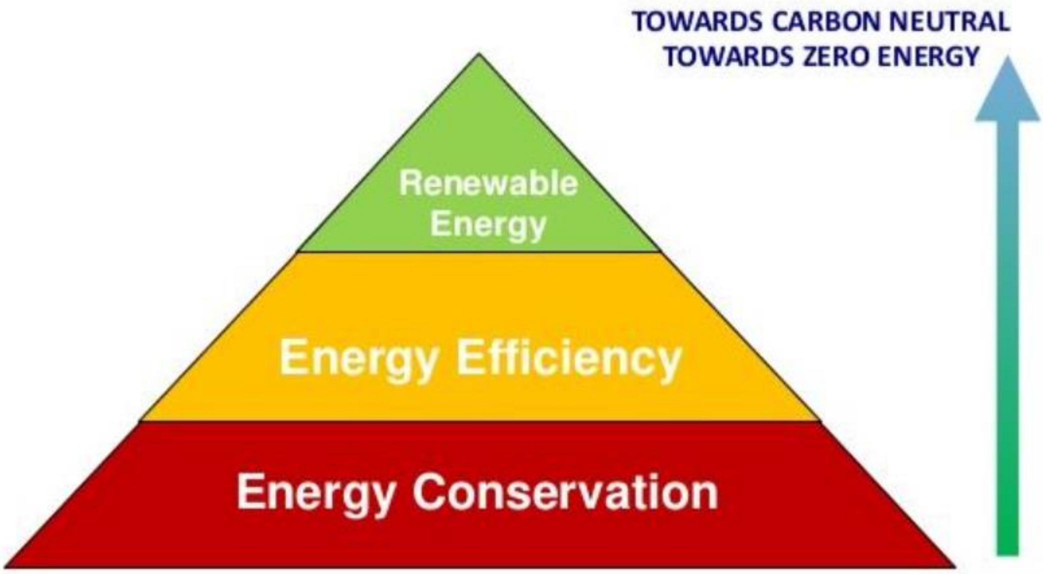

Figure 4 The energy pyramid [12].