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INTERNET BASED SUSTAINABLE ENERGY FOR THE ECOSYSTEM

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Abstract

The world has a wealth of renewable and conventional energies, but the lack of technological capabilities and capacities combined with the water-energy requirements limit their benefits to its citizens. Sustainable energy research and innovation will be revolutionized by IoT technologies and the latest IoT communications and sensing approaches. Internet of Things can also be used to address energy challenges for the community by leveraging existing infrastructure such as renewable energy, microgrids and P2G hydrogen systems. This chapter presents the IoT for sustainable energy system approaches, methods, scenarios and tools, along with a discussion on different sensing techniques and communication technologies. The IoT in Energy Systems is intended to improve the bidirectional exchange of network services by using Internet of Things on grid. This will lead to enhanced system resilience and reliable data flows, as well as connectivity optimization. The sustainable energy IoT challenges and opportunities for innovation are discussed in order to meet the energy needs and economic strength of the energy sector.

Introduction

Seventh Sustainable Development Goal (SDG), set by the United Nations, aims to eliminate energy poverty. To achieve global energy access, both the government and strategic levels must make continuous and sustained effort. The development of technology and systems is required, along with the implementation of policies, government practices and social change, to increase the affordability and speed of global, local and regional access to energy. Decentralized grid system approach will be necessary to ensure that energy is accessible at this level. Resources are distributed in the lower levels. (Gielen, 2019)

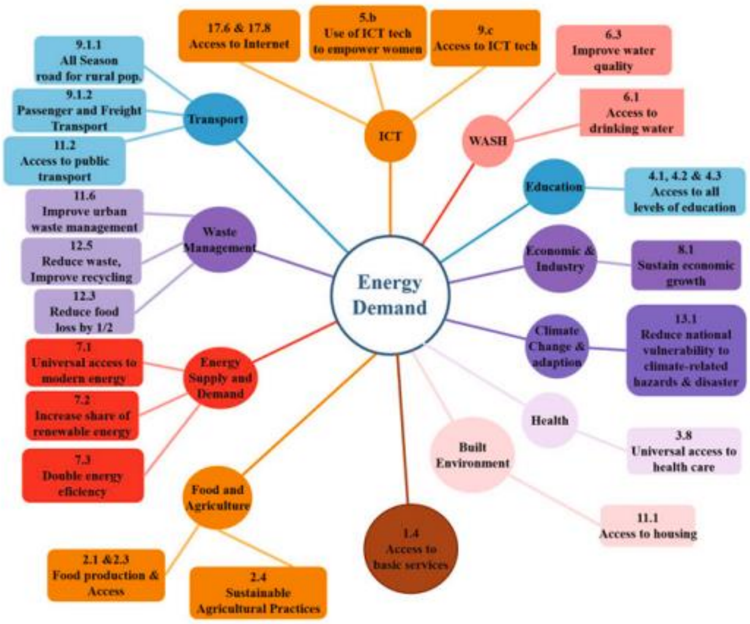


Figure 1: The SDGs related to the energy

One can observe that the energy demand is strongly related to almost all UN Sustainable Development Goals (SDGs). Energy access has a strong correlation with quality of life, and is vital in the following sectors.

- Energy infrastructure is vital to the health and educational sectors.
- Clean water requires energy
- The energy that drives agricultural irrigation systems
- Transport sector can't function without energy

- Electric lighting, heating, cooling and cooking in the home, as well as electric appliances, require energy.
- Energy is also vital for the industrial sector

Energy and sustainability

Energy access can reduce inequalities. Energy access is defined by the International Energy Agency as follows:

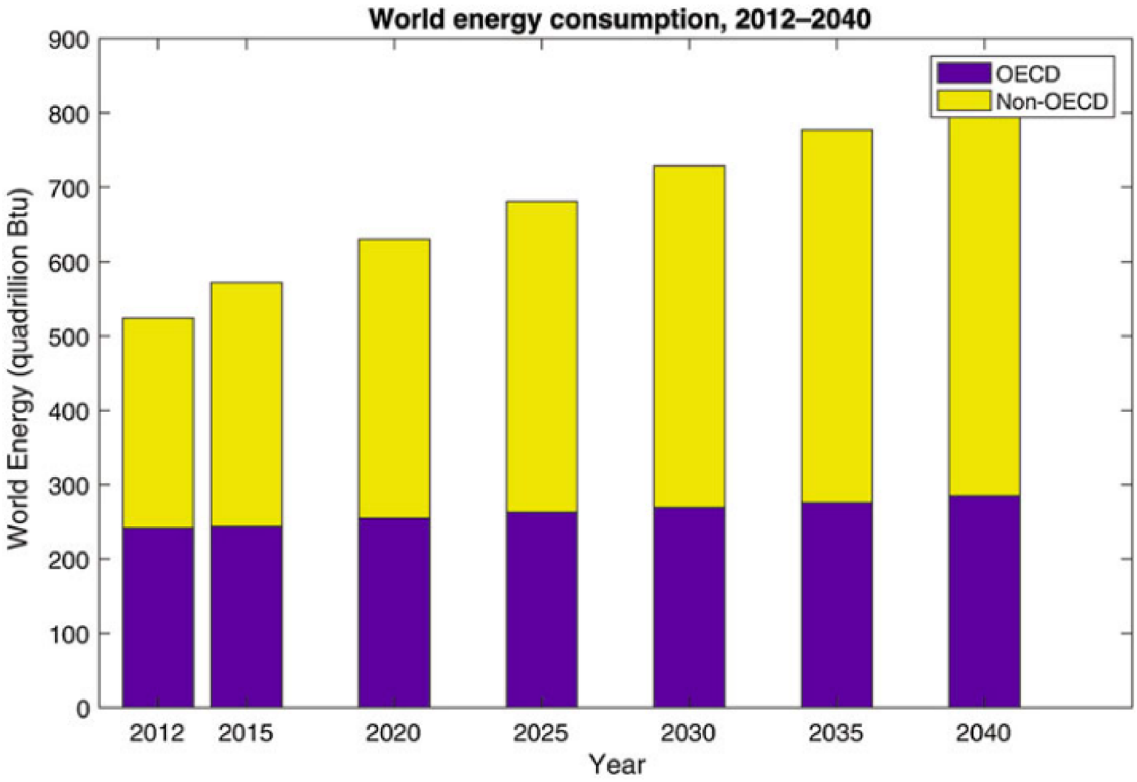


Figure: projected growth in energy demands of the world up to 2040

The average household has reliable, affordable, access to clean cooking equipment and electricity. This is sufficient to provide a package of energy services at first, but then increases over time until it reaches the average regional level. Around one billion people do not have access to electricity. Energy access has a greater impact on the poorest areas, such as Sub-Saharan Africa. It is expected that the increase in the world's population will outpace the current outlay for the new energy access. In Figure 1, the projected increase in global energy demand up until 2040 can be seen. This demand will be met by the current grid expansion, but there's a need for new energy sources. It is important to realize cheap techniques to produce clean energy to support economic growth and agriculture, to empower the poor with energy and to decrease the migration of people to developed countries due to lack of energy. Energy access can also be used to decrease gender inequality, as women in developing nations spend their energy during the day collecting firewood because of a lack of energy. This also leads to mental and physical stress among girls and women. In addition to meeting the basic requirement of sustainable energy, it also has tremendous benefits for the community, such as eradicating gender inequality and poverty. This vital issue is championed by the UN program Sustainable Energy for All. (Ahuja, 2009)

The advanced nations also need to be able to provide energy continuously. Energy is needed for businesses to function, as well as high-priority infrastructure, public security, healthcare and other industries. Energy access is also crucial for the treatment of potable water, wastewater, and other urban utilities. Failure in any one part can have cascading consequences in all areas. City planners and managers are now focusing on achieving energy resilience. (Majid, 2020)

Energy Related Challenges

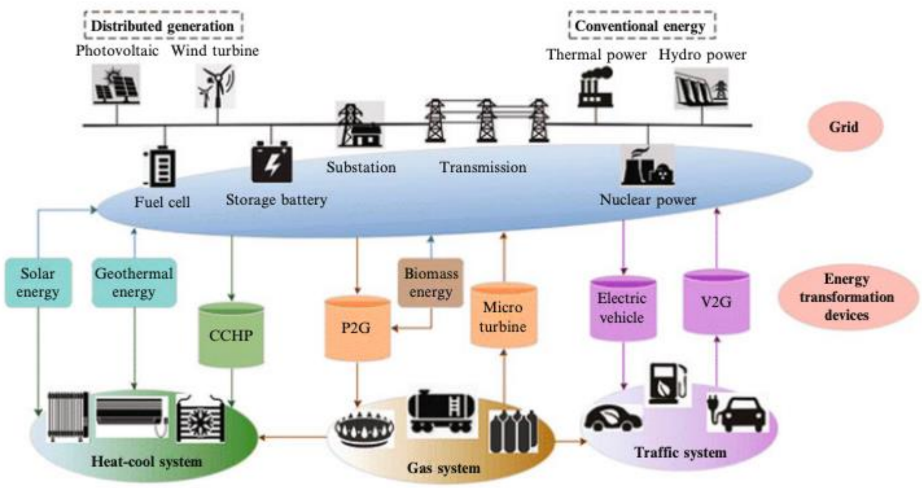
Modern advanced energy technologies will continue to develop, and with them new challenges. Future energy systems must address these by utilizing the latest advances. Below are some of the current and future challenges that our community faces in regards to energy. The challenges discussed below impact on the power generation capacity and result in disruptions to energy distribution.

- Water is a major component of the current energy system. Due to the variability in water availability (short term and droughts), new techniques are required for energy production.
- High-voltage transmission systems are not protected. They are overloaded and used for purposes other than their intended purpose. Transmission loss, which is a major problem that leads to blackouts and power outages, is another issue.

- Due to the high water availability, many energy facilities are situated in coastal areas. But rising sea levels, high tides and heavy rains and storm surges are affecting coastal infrastructure, energy infrastructure, and other infrastructure. Long-term energy interruptions in industrial and urban areas result in lost productivity and business losses. (Lambe, 2015)
- Extreme heat and high summer temperatures also cause a rise in energy demand and electricity consumption. The energy demand is expected to rise due to the peak load.
- Extreme weather conditions also have an impact on the energy and transportation infrastructure. The frequency, duration and intensity of extreme weather events can cause different energy disturbances. (Markolf, 2019)
- The increase of greenhouse gases is a challenge that comes with increasing energy consumption. Carbon dioxide (CO_2) and methane are among the gases that cause these emissions. The transportation sector is the largest source of emissions.
- Energy consumption of mobile, computing and information technologies is on the rise.
- As more and more electric cars (EVs) are manufactured, energy consumption to meet EV requirements is on the rise.
- Another challenge related to the energy infrastructure is the discrepancy in demand between energy systems and their capabilities, as well as the complexity of the energy requirements of industries and communities.

The Sustainable Energy IoT

It is clear from the discussion of energy and sustainability that without technology adoption, global access to energy cannot be achieved. Technology can help develop robust, low-cost solutions that will improve the efficiency and performance of current energy systems. The community can meet its need for affordable energy by utilizing the latest generation of sensing and communications technologies. This basic need for energy can only be met by IoT technologies that provide affordable energy. IoT is used to connect energy devices in a sustainable grid, service supply chains and the human capital. This technology can meet the future energy needs of this century and provide clean energy. The potential of this paradigm to create next-generation systems makes it useful for connecting various technologies in energy and innovative solutions on a global scale. Sustainable energy IoT can help achieve sustainability and resilience of existing energy infrastructure. (Majid, It is clear from the discussion of energy and sustainability that without technology adoption, global access to energy cannot be achieved. Technology can help develop robust, low-cost solutions that will improve the efficiency and performance of current e, 2020)



The IoT can also reduce future risks in energy through the development of innovative, secure and efficient technology and infrastructure. IoT-based sustainable energy systems enable a variety of methods to achieve global energy access by commissioning clean, renewable and low-cost sources of energy.

Sustainability Energy Things

IoT for sustainable energy is a valuable asset to the efficient value chain of energy. Smart grids are the most important part of sustainable energy IoT. They represent a major achievement in 21st-century technology. Sustainable IOT with IoT autonomy and efficient grid management has the potential to be a huge benefit in terms of consumption and production. Sustainable energy IoT, through real-time monitoring and environmental monitoring for renewable energy resources can improve the efficiency of solar power and wind energy. These can then be integrated to the grid in order to maximise the supply. By using distributed, low-loss smart microgrids, it will reduce the pressure and dependence on fossil fuel based, less efficient and high demand energy sources. Sustainability is reflected in:

- Green energy, smart meters, zero-energy homes and smart industry
- Wind, solar, water, natural gas and renewables are all sources of energy
- Transmission SCADA, transmission phasor measuring unit and transmission
- Smart distribution, microgrids, and voltage regulation
- Work order, billing, SAP CRM and SAP
- Retail energy providers, service providers, customer markets and wholesalers
- Distributed intelligence, plant control, electric cars, and other technologies
- Management of bulk and load

Sensors on Nuclear Power Reactors

Nuclear power is an important component of IoT-based sustainable energy systems. Because of the hazardous nature to human beings, sensors that are reliable and autonomous can help reduce the contamination risks.

Vibration Sensing

Vibration sensing is used in nuclear reactors to detect and prevent radiation leakage into the environment. Vibration sensing is also used to ensure the safety and health of employees and plant equipment for uninterrupted power production. Nuclear power plant failures have negative environmental and financial impacts. These sensors are based upon acceleration and give an electrostatic signal. Due to their high temperatures, these sensors don't contain any electronics-based signal processing components. In order to produce output, it is necessary to use external signal processing. Smart sensors, on the other hand can alleviate this issue if signal processing, communication, networking and analog-to digital conversions, are performed in-board. (Kabeyi, 2022)

Temperature Sensing

Temperature sensing is carried out in both control and safety systems. Chromel-alumel thermocouples and resistance based temperature meters are used for this. Surface sensors, pool sensors, and other types are available. There is a need for advancements in the high-temperature physical sensor technology, such as those used in nuclear reactors like pebble bed reactors where thermocouples show high drift at high temperatures. Some other approaches to temperature measurement include:

- Thermometry using ultrasonic waves. Ultrasonic guided wave propagation is not without challenges.
- Johnson Noise Thermometry This device is susceptible to electromagnetic interference (EM).
- Bragg thermometry. Photobleaching is possible at high radiation levels.
- Sensors with optical access ports. It is difficult to implement optical ports for these sensors.

Pressure sensor

These sensors are electronic instruments that measure pressure. They can also be used to measure differential pressure, flow, and level. The pressure sensor works by measuring its displacement mechanically, which is then converted to an electronic form. This conversion is also complicated due to high temperatures. They are prone to leaks. Salt contamination is a problem for the impulse-line techniques. Piezoelectric sensors can be used to measure pressure, such as chloride and fluoride liquids. Pressure sensors are made from ceramics derived from polymers, but their interface with external circuits, as is the case for temperature sensors, can be challenging. (Patel, 2019)

Oxygen Sensing

Oxygen sensing in fossil-fuel powered power plants is crucial for monitoring combustion and is an excellent indicator of incomplete burning. By analyzing how much air is being used in the combustion, the leftover oxygen can be used to regulate the process. In order to regulate the air intake and firing rate, they are adjusted. This process optimizes itself by reducing the oxygen set point while minimising incomplete combustion. In this application, two types of oxygen sensor are employed.

- These sensors are based on zirconia and utilize an air preheater/economizer. These sensors use solid catalytic platinum oxygen-ion conducting electrodes (at temperatures 300*C or higher), which can separate oxygen and convert it into electrons andions.
- The paramagnetic sensor can measure oxygen because the magnetic field is strong enough to attract oxygen. The method is based upon the use of two glasses filled with nitrogen in which oxygen can be displaced, resulting in a rotational suspension that is detected by photocells. The approach used is more sensitive to the other gases produced during combustion.

The Case Studies of Sustainable Energy IoT Technologies

Electric vehicle energy internet is a system that transmits energy to and from a destination. The EV stores and transmits renewable energy (e.g. solar and wind) from the source to places like charging stations or houses. The EV is equipped with batteries, and when combined, they can create a network of energy storage systems. For example, all the light cars in the USA would be EVs, so the power produced by the EVs will be up to 24 times greater than that generated by the electric grid. The EV Internet schematic is displayed. The EV is divided into two layers. It is divided into two layers. The lower layer is the transportation network of EV architecture. After charging the EV at a renewable energy source it travels to charging station, and then discharges. EVs then pick up energy at the substation to move on.

CCHP is a system of distributed generation that provides heating and cooling at the same time. Compared to the conventional alternative such as separate heating and cooling systems, CCHP has a higher fuel efficiency and system performance. The CCHP consists of three components: power generation, cooling, and heating. The CCHP system can be used to balance production of energy and the load requirements for heating and cooling, increasing overall efficiency by 40% up to 70%-90%. CCHP systems also have the added benefit of reducing emissions.

Power-to-Gas (P2G) Energy Internet

The energy markets around the globe are focusing on the shift to renewable energies from fossil fuels. The EU proposed a 20% target for renewable energy in the mix of their energy systems. Renewable sources are environmentally friendly and have a low emissions rate. As discussed in previous sections, renewable energy sources like wind and solar are unpredictable and vary. They can also lead to grid fluctuations, in addition to their unpredictable capacity. Renewable energy is still considered the future energy source, despite all its challenges. The above problem can be solved by storing a lot of energy during times when supply is lower than demand and then using this stored energy to meet the increased demand. Power-togas can achieve this flexibility. The P2G process is shown above as converting hydrogen from water via electrolysis, and then converting it to methane. It is an excellent option to store energy for a long time using renewable sources. The current system of energy-based storage gains flexibility. In terms of flexibility, the P2G provides three advantages: 1) time, 2) location and 3) end use. The P2G, in addition to being an energy storage system for long term use, is used as a way of balancing electric and gas grids.

Water Electrolysis

Water electrolysis is the key to P2G. Electric energy is transformed into chemical energy in water electrolysis. Electrolyzers are used to carry out the conversion. The electrolyzer consists of three parts: (1) electrodes (2) electrolyte and (3) diaphragm. The electrodes split water into oxygen and hydrogen when electricity is supplied. The diaphragm and electrolyte are used as isolators to stop gasses from emerging when a flammable mix is heated. The type of electrolyte used can help to classify the different types of Electrolyzers. The following sections discuss the various characteristics and technical aspects of electrolysis.

Challenges

P2G has just begun its development. P2G research is being conducted in two different directions. The first direction involves the development of electrolyzers and methanation modules. Second, is to improve P2G systems. There are two main areas to be explored:

Proper framework to use P2G technology as a balancer of systems

The lack of accurate data leads to uncertainty when modeling P2G, making it difficult to obtain reliable results

The lack of case studies for analyzing the social and economic impact of P2G technologies * Development of a smart management system to P2G

Conclusion

- Solar Roadmap.
- BioEnergy Atlas. This is an interactive map system for BioFuels BioPower.
- RETScreen. Clean energy software from Canada.
- A Planning Framework for Climate Resilient Economics Framework for identifying economic and climate vulnerability at the community level.
- Geothermal Prospector. Geothermal Prospector is a tool for mapping geothermal energy resources.
- The US Energy Information Administration Energy mapping system (EIA), is a database of U.S. infrastructure for energy.
- Bioenergy Research, Analysis, and Decision-Making Databases are available in the Bioenergy Knowledge Discover Framework (KDF).
- HydroSource. HydroSource is a data set that integrates water, energy and sustainability of ecosystems. Geospatial datasets are available for water and hydroelectricity management.
- U.S. Electric System Operating Data Tool for the visualization and analysis on hourly USA electricity demand.

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