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Challenges and Opportunities in Implementation and Utilization of IoT in the Energy Sector: An Empirical Evidence

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The feeling that this master’s degree is coming to an end gives me immense relief and joy. This is my graduation thesis in the master’s Programme in Industrial Management, Vaasa of University

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ABSTRACT:

A plethora of academic studies and industry projects indicates a steep transition of the third industrial revolution into the fourth industrial revolution is in progress during the last decade. Similar to other disruptive technologies, the Internet of Things technologies seeks to accelerate the pace of transition by providing advanced centralised automation solutions for various industrial applications. Meanwhile, industrial systems consume a larger share of global energy supply, therefore, it is imperative to build smart solutions for the energy sector to enhance energy efficiency in transmission, distribution, and consumption phases.

In this perspective, IoT has shown the potential to revolutionize the entire energy sector. However, as emerging technologies, major challenges and benefits related to IoT implementation are not clear, both in academia and industry. Thus, the current thesis aims to answer the basic research question of the study - "What are the major application areas, benefits and barriers of IoT implementation in the energy sector"?

Current study empirically evaluates challenges, benefits, and key strategies to successfully implement and utilize IoT in different areas of the organizations operating in the industrial ecosystem of the energy sector. In addition, the study seeks to find out the practitioner's perspective on utilization level and future of Artificial Intelligence and Blockchain technologies in energy sector.

Semi-structured interviews with top managers from Finland were conducted to answer the research question. Data has been analysed through content analysis and it was found out that Information Technology, Transportation & Logistics, Manufacturing and Product Development are major application areas, whereas Return on Investment, Privacy, Security, lack of industry best practices and high level of resistance to change are major barriers in IoT implementation.

Moreover, results revealed that Artificial Intelligence has a greater role in the industry and its applications are predicted to grow considerably, whereas studies are needed to design business cases with Blockchain technologies. At the end of the thesis, strategies to successfully implement IoT, managerial implications and future research directions are also discussed.

KEYWORDS: Internet of Things, industry 4.0, product development, manufacturing, energy efficiency, challenges, Implementation strategies

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List of Abbreviations

AC	Alternate Current
AI	Artificial Intelligence
ANNS	Artificial Neural network
BC	Blockchain
BLE	Bluetooth Low Energy
CAI	Conventional Artificial Intelligence
CC	Cloud computing
Co2	Carbon dioxide
CPS	Creative problem Solving
DC	Direct Current
EIA	Energy Information Administration
EU	European Union
GPS	Global Positioning System
HAVC	Heating, Ventilation and Colling
ICT	Information Communication Technologies
IoT	Internet of Things
IT	Information Technology
LoRa	Long Range
LPWAN	Low Power Wide Area Network
LTE	Long Term Evolution
ML	Machine Learning
NB-IoT	Narrow Band-IoT
NGCCPP	Natural Gas Combined Cycled Power Plants
PIR	Passive Infrared
PLM	Product Life Cycle Management
POC	Proof of Concept
RBF	Radial Base Functions
REE	Renewable energy sources

RFID	Radio Frequency Identification
ROI	Return on Investment
SCADA	Supervisory Control and Data Acquisition
T&D	Transmission and Distribution
VRE	Variable Renewable Energies
Wi-Fi	Wireless Fidelity
XR	Extended Reality

1. Introduction

1.1 Background of the study

In the year 1998, Kevin Ashton introduced wireless communication and networking base novel paradigm called as Internet of Things (IoT) (Bandyopadhyay & Sen, 2011). Over time industrial systems have evolved due to rapid technological advancements, and it has reached the current level called industry 4.0. industry 4.0 is also called a fourth industrial revolution. In his book, Schwab (2017) explains the fourth industrial revolution having greater impacts on the economy and businesses, as compared to the first three revolutions. Schwab (2017) also explains fourth industrial revolution is restructuring the world economy, and emerging technologies such as the Internet of things (IoT), big data, Artificial intelligence (AI), robotics, autonomous vehicles, 3D printing, nanotechnology, biotechnology, material sciences, energy storage & production and quantum computing are major driving forces of industry 4.0.

Among these technologies, interest in IoT has increased exponentially both in industry and academia. It is believed that IoT has more potential to disrupt the businesses as compared to other competing technologies such as AI and robotics (*The Internet of Things Is Far Bigger than Anyone Realizes, 2014*, 2016). With the billions of devices connected through the Internet, 20% compound annual growth rate for IoT market has been observed (International Data Corporation), making it more than 7.1 trillion dollars market at the end of the year 2020 (Lund et al., 2014). Adoption and usage of IoT are expanding across the industries due to wide breath IoT ecosystem, which includes intelligent and embedded system shipments, connectivity services, IoT platforms, applications, analytics, security, infrastructure, and other professional services.

IoT are changing competing grounds for organizations, in the current business era, products are not only limited to the combination of mechanical and electrical parts, instead, the product is also a complex system that can include hardware, different sensors, communication protocols, data storage, microprocessors, and software (Porter & Heppelmann, 2014). Thus, IoT providing baseline for smart connected products, which ultimately altering the competing grounds, restructuring industries, and compelling businesses to develop new strategies to survive and thrive in the market. IoT based applications are being used in different areas such as business, manufacturing, agriculture, energy, logistics, safety, home, health care and knowledge management. Data collected through IoT provides valuable insights for the businesses. In this perspective, significant growth in implementation and utilization of IoT have been observed in different areas of organizations operating in energy, manufacturing, and digital services business.

In the energy sector, with the advancements in technology and industrialization, worldwide energy demand has increased by 2.3% in 2018 (*Global Energy & CO2 Status Report 2019 – Analysis*, n.d.). Consequently, with the massive increase in energy demand, energy sector CO_2 emissions simultaneously also reached a new peak. Co_2 emissions, natural resources depletion, water scarcity for thermal power production and air pollution caused by higher energy demand, poses urgency to not only shift energy production from fossil fuels to renewable energy but also need for efficient use of energy throughout the energy sector. The energy sector can be further divided into three main phases i.e. energy production, energy supply & distribution and energy demand (Hossein Motlagh et al., 2020). Real time data analysis can play important role in both efficient energy management and optimizing energy supply chain (Tan et al., 2017). To monitor real time data monitoring and analysis, IoT are believed to have the best-suited framework, which consists of sensors and transmitting wireless technologies to sense and transmit real time data. Implementation of IoT in the energy sector also has the potential to further revolutionize the entire energy sector by transforming it into a distributed, smart, and integrated system from the centralised system. Thus, providing a framework for the development of locally deployed and redistributed renewable energy systems such as Wind and Solar energy.

Furthermore, implementation and utilization of IoT are not only limited to the energy sector, as they are also restructuring the other sectors such as industrial engineering and digital services. Real time data sharing and equipment connectivity changing the concept of traditional factories into smart connected factories. As compared to the traditional factory, all the operations and processes in the smart connected factory are interconnected through centralised IoT ecosystem, which facilitates factory management to overview the performance of each process and operations in a real time

(Hozdić, n.d.). Moreover, through sensors and other technologies, the IoT ecosystem enables real time monitoring of the equipment and assets by sharing real time data on the condition of the equipment, thus plays a key role in predictive maintenance. In addition to equipment predictive maintenance, within industrial engineering, the IoT role is going to be crucial in efficient manufacturing. Interconnection of assets and equipment through the IoT system can depict the comprehensive picture of a manufacturing process in the one frame, making it easier to monitor production line, production flow and identifying bottlenecks.

One of the essences of implementing IoT in the organization is data-driven digital transformation. Companies are realizing the significance of digitalization in all major areas of the organization such as product development, information technology, manufacturing, marketing & sales, customer experience, inventory management, supply chain and after-sale services. Agile teams are formed to identify potential areas and cases to understand the technical and economic feasibility of going digital roadmap. However, internal teams and the IT department of the organization often do not have a profound understanding of digital technologies and innovative creative problem solving (CPS) based solution (Pflaum & Golzer, 2018). Moreover, they also explained data scientist and other experts in emerging technologies are difficult to hire due to intense competition in such a talent hunt. Another challenge internal IT department faces while going digital is to understand the maturity level of emerging technologies, and also to find out which emerging technology is best suited to their business case. in this context, digital services providing companies can play a key role to help organizations in devising techno-strategical fit. Abovementioned and other challenges related to the implementation and utilization of emerging technologies in different areas of the organization has created a big opportunity for digital services providing companies, particularly in the domain of IoT based platforms. The market for IoT based solutions has become a multi-billion dollars industry which is expected to reach $ 7.1 trillion marks by the end of 2020 (Lund et al., 2014).

1.2 Research gap, problem, and objectives

There have been a growing number of studies conducted on the domain of IoT from both technical and economic perspectives. Recently, efforts have been made to develop a theoretical framework in the domain of IoT, (Nord et al., 2019) made a summary of prominent literature and presented a theoretical framework related to IoT. Furthermore, literature review studies have been conducted to identify key application areas, opportunities and challenges in implementation and utilization of IoT in different sectors such as energy (Hossein Motlagh et al., 2020) and industrial manufacturing (Tan et al., 2017).

In addition to the literature review, survey-based studies have been conducted to highlight key technologies used in the domain of IoT (Al-Fuqaha et al., 2015; Samie et al., 2016; Shah & Yaqoob, 2016). Several other studies have explored IoT application and utility areas in different industries, however pertinent literature on IoT priority application areas in the energy sector is scattered and lacks empirical evidence. Even though efforts have been made to identify key application areas and benefits of IoT implementation, but a wide range of studies focused on technical aspects of IoT in the energy sector and little attention have been paid to empirically evaluate technical and non-technical challenges, main benefits, and framework to overcome such challenges while implementing and utilizing IoT. There is a clear need for roadmaps which have managerial implications for IoT implementation in terms of their benefits, applications, and challenges. Therefore, this study will try to answer the basic research question: “what are the key application areas, barriers and benefits of using IoT in the energy sector?”.

Purpose of the current thesis is to empirically evaluate challenges and opportunities in the implementation and utilization of the IoT in different areas of the organizations operating in the energy business. Besides, the study will also try to find out experts’ insights on the future of other disruptive technologies such as Blockchain and Artificial Intelligence in the energy sector.

Objectives of the study are:

- To identify priority areas of IoT implementation in the energy sector.
- To evaluate key barriers and opportunities of implementing IoT in the Energy Sector.
- Identify key strategies to overcome challenges related to IoT implementation and utilization in energy organizations.
- Also, to evaluate the role of other disruptive technologies i.e., Artificial intelligence and Blockchain in the energy sector.

1.3 Definitions and limitations.

Despite the fact there is no single agreed definition of the IoT (Wortmann & Flüchter, 2015), authors agree upon the broad objective and architecture of these technologies. Internet of things (IoT) are smart connected devices, the combination of mechanical and electrical components, connected to the server through various information communication technologies. In comparison to traditional Internet, IoT connects machines, equipment and facilities through embedded sensors and actuators, sensors monitor the condition of physical objects, fetch data and share it real time with the backend server through various telecom and short distance communication protocols. This amount of big data is used to creates meaningful insights for organization management for decision making in their internal and external processes. Despite multiple definitions of IoT, experts agreed on common three layers (physical object e.g. sensors & actuators, connectivity e.g. Bluetooth, Zigbee, RFID & GPS etc and applications) framework of IoT (Nord et al., 2019).

Furthermore, the energy sector can be divided into three distinct phases, energy supply, transformation and consumption (Hossein Motlagh et al., 2020). Energy supply consists of activities related to energy production, extraction, treatment, import and exchange; whereas activities such as energy conversion, transmission & distribution fall under energy transformation phase. The final phase is energy consumption also known as demand phase, which includes end user's energy utilization, end-use appliances, and energy efficiency. As the limitation of the research, this study focuses on IoT implementation and utilization in industrial ecosystem of the energy sector which includes transformation and consumption phases.

1.4 Structure of the thesis

This study starts with *chapter one - introduction*, which includes research background, the research gap, central research questions, objectives and limitation and definition used in the thesis. Also, this chapter indicates central concepts of the study, an overview of the three sectors of economy and IoT role, significance, and relevance to the selected areas of study.

The second chapter includes conceptual and theoretical details of the IoT, their technologies and literature review. Moreover, a conceptual framework regarding the utilization and implementation of

IoT in energy transformation & consumption, marine technology, and surface finishing technologies is presented.

The third chapter precisely explains the research methods, process, design, and strategy used in the study. It also presents the research instrument, the population of the study, the sampling technique, and demographical details of the respondents.

The fourth chapter deals with the outcome of the interviews with experts in the domain of IoT. In this chapter interview analysis technique, analysis outcome and results are presented.

Fifth chapter, which is the concluding part of the study discuss the results of the study, answer to the basic research question is discussed in this chapter. Moreover, results about objectives of the study are also discussed along with key research findings and future research directions of the study.

Figure 1. Structure of the thesis

2. Literature review

2.1 A brief overview of the energy sector

Ever since the technological advancements in mechanical systems and industrialization energy has remained one of the most integral parts of industrial systems. Utilization of energy can be directly linked to developments in Industrial systems and tracing energy usage explains energy in many forms have been used widely in industrial systems such as in production, transportation & logistics, inventory, and warehouse to name a few. To meet the immense amount of demand over the globe, the energy sector has grown exponentially which ultimately formed a sophisticated supply chain in the energy sector. The contemporary supply chain of the energy sector can be divided into three distinct phases i.e., energy supply, transformation, and consumption (Bhattacharyya, 2011).

Energy supply phase includes resource extraction and refinery. Bhattacharyya (2007) explains in the first transition, the main source of energy generation was coal as the technology enables energy conversion from fossil fuels to run steam engines. In the second phase, oil emerged as a major source of energy production, as technological developments made it possible to convert oil into electricity. Electricity and invention of combustion engines are believed as a ground-breaking innovation in the second transit phase of fossil fuels based energy resources (Bhattacharyya, 2007). Currently, the major share of energy demands over the globe still depends heavily on fossil fuels-based resources, particularly coal and oil. Although, efforts are being made to shift the dependent from fossil fuels to renewable energies, such as Solar, Wind, Biofuels, and Thermal energy, etc. There is an ongoing debate in the literature on the issue of when renewable energies can replace fossil fuels as the main source of energy. Some studies such as Guo (2019) illustrate that it is not possible to eliminate the share of fossil fuels-based energies as there are various economic and technological limitations. While some researchers such as (Bhattacharyya, 2007) believe that transition in energy systems is highly likely by overcoming certain challenges.

The second main phase of the energy supply chain is energy transformation and distribution which includes conversion technologies, transmission and distribution systems and energy losses (Hossein Motlagh et al., 2020). In this stage energy is converted from one form to another and example of energy conversion are power plants, such as pulverized and fluidized coal power plants, natural gas combined cycled power plants (NGCCPP) and nuclear power plants etc (*Energy Conversion Technologies* - n.d.). Similarly, energy transmission and distribution consist of a series of connected microgrids, smart grids, load management and energy storage system (Wang et al., 2015). To summarise, this phase includes all stages and processes which enable energy transmission from energy generation to the final user. It is estimated that a large portion of the energy is lost during transmission and distribution phase due to inefficient energy storage and transmission technologies.

Energy demand is another important part of the energy supply chain which mainly related to using energy in industry and personal usages such as manufacturing, logistics, transportation, industrial appliances, home appliances, building lighting, heating, and cooling system, etc. (Bhattacharyya, 2011; Hossein Motlagh et al., 2020). Industrial systems and transportation consume a larger share of total energy consumption globally, for instance only in USA 60% of total energy consumed by industry (manufacturing, mining, agriculture and construction) and transportation (includes material and goods logistics, and people transportation) (*Use of Energy in Explained - U.S. Energy Information Administration (EIA)*, n.d.). Similarly, data illustrates that Finnish industrial energy consumption remained 45% in 2019 and transportation accounts for 17% (*Final Consumption of Energy - Motiva*, n.d.). Moreover, a large portion of the energy is wasted during energy consumption, and experts believe that efficient energy monitoring and smart energy solutions can reduce energy demand. Smart energy systems not only reduce demand but also increase energy efficiency, thus smart solutions based on emerging technologies are imperative to decrease energy demand and increase efficient energy management system.

2.2 Motivation to innovate the energy sector

Emerging technologies such as the Internet of Things, Artificial intelligence and Blockchain are seen as major enablers of Industry 4.0. With the advancements in industrial systems, the energy consumption of the industrial activities is also posed to go up, and to date, a larger portion of current energy demand is met by using fossil fuels. Combustion and extraction process of fossil fuels have adverse effects on the environment, as well as on the health and safety of the people. It is estimated that reserves of fossil fuels such as oil, coal and natural gas are not indefinite and their consumption with current rate would deplete them soon. Ahmed (2017) predicts that major oil-producing countries have already crossed their peak production level, which indicates in coming few decades availability of cheap fossil fuels would be rare. It is need of the hour to develop sufficient alternatives to meet the future energy demands before running out of fossil fuels resources. Furthermore, extensive use of fossil has resulted in the as polluting factor which ultimately led to climate change and air pollution to name a few.

Other than environmental cost, (Kreps, 2020) emphasises on the fact that fossil fuels extraction cost is increasing and in future, it would not be economically feasible to extract such resources. In this context (Guo, 2019) draw a comparison between the pros and cons of fossil and biofuels in the environmental perspective. It is not possible to fully depend upon biofuels for energy demands, however, consumption of fossil fuels can be minimized by developing biofuels. Biofuels as compared to fossil fuels are more environmentally friendly and energy generated through biofuels is more environmentally sustainable than fossil fuels such as coal and oil. In this perspective, development of Renewable energy sources (RES) and efficient energy management system based on emerging technologies is indispensable to slow down the catastrophic effects of fossil fuels (Connolly et al., 2016). Similarly, Grubler et al. (2018) stressed upon the importance of developing renewable energy sources, such as Solar energy, Wind energy and Bioenergy to decrease world dependence on fossils fuels, which eventually diminish the adverse impacts of fossil fuels-based energy.

In addition, other than the development of Renewable energy sources (RES) and biofuels, achieving efficiency in energy distribution, transmission and consumption process is also essential. Shakeel et al. (2016) discus share of renewable energy sources in power generation is increasing all over the world. Only in the United States of America (USA) about 6-2 % and 4% of energy lost in transmission and distribution processes subsequently (*Lost In Transmission*, n.d.). Although compared to past, Finland able to increase the share of RES in their energy mix (Shakeel et al., 2017), yet fossil fuels makes larger share of total energy. Country also imports a substantial part of their energy needs, thus increasing energy efficiency is crucial for Finland. Moreover, EU 2030 target for Finland compels the country to emphasise on development of RES and increase the share of renewable energy sources to 51% while limiting the energy consumption to 290 WTH through the efficient energy management system.

However, achieving the aforementioned objectives are challenging and require collaborative efforts from industry and public sector to follow the roadmap, especially when the industry is transiting towards industry 4.0. Industry 4.0 is more about automation and a greater role of machines and applications of digital technologies in the industry, which potentially can lead to an increase in energy demand. Likewise, Finland is already considered among top countries in energy consumption and it is imperative to develop RES and efficient energy management system.

Research studies such as Hossein (Motlagh et al., 2020) show that disruptive technologies have a greater role in the development of RES and efficient energy management system. Among disruptive technologies, IoT has revealed the potential to assist the development of RES and efficient energy management system. Tan et al. (2017) suggest that IoT can prove as the backbone of current and future energy management system, and at any level of the supply chain it can monitor and increase the awareness about energy performance and real-time energy consumption. Based on the discussion, the current chapter presents key literature on IoT and related technologies, their applications in energy generation, intelligent transport, smart factories, smart buildings, smart grids, and major industrial application areas.

At first, Conceptual and technical overview of IoT and related technologies is explained, then application of IoT in different stages of the energy sector are discussed. A brief overview of IoT role in intelligent transportation, smart factories, smart buildings, smart grids, and major other application areas are presented. At last, a literature review on major challenges related to IoT application in the industry is presented.

2.3 Brief introduction of the Internet of Things and other related technologies

IoT is termed as arising innovation which utilizes the Internet and plans to provide a linkage among actual devices or "things" (Haseeb et al., 2019). Through proper utilization of these sensors and correspondence systems, these devices provide meaningful information and facilities to people. For example, controlling the energy utilization of buildings in a keen design empowers dropping the energy costs (Zouinkhi et al., 2020). IoT has an extensive scope of uses, for example, in the assembling, service, and building industry (Holler et al., 2015).

IoT is likewise generally applied in ecological management, medical care frameworks and administrations, proficient administration of energy in structures, and robot-based management (Atzori et al., 2010; Hui et al., 2017; Hossein-Motlagh et., 2020; Motlagh et al., 2019). Mechanism of IoT can be divided into three categories, the initial phase also known as the development of IoT Platform, and the second phase includes devices which connect IoT gateways and third include communication protocols. At first IoT development phase mainly concerned with planning the framework of IoT application. It is essential to carefully determine IoT segments needs so that they must match all requirements of IoT application. These segments include sensors, correspondence procedures, data storing and processing, and reckoning should be aligned with the proposed application (Hossein Motlagh et al., 2020).

Then, the second stage consists of devices which include sensors, actuators, IoT gateways and any other devices which enable data collection, processing, and analysing. Similarly selecting the appropriate communication protocols is crucial, this phase empowers the various devices to convey and impart their information to the regulators. IoT stages offer the adaptability to choose the sort of correspondence technology, as indicated by the necessities of the IoT platform. The samples of these innovations incorporate "Wi-Fi, Bluetooth, ZigBee" (Karunarathne et al., 2018), and cell innovation, for example, LTE-4G and 5G systems (Jin et al., 2020). Combing all three phases allows IoT to sense, share, store, and process data for the user.

Since IoT devices generate an enormous amount of data, and to store and utilize this huge amount of data a proficient data storage system is necessary. For such purpose, a different type of data storage mechanism can be used such as a cloud server or storing at the corner of an IoT network. Data collected through IoT devices plays important role in providing insightful information through data analytics. In light of need, the data can be analysed either in the offline mechanism by putting the data or it can be real time data analysis. The offline analysis first gathered data and, afterwards visualized on-premises utilizing required apparatuses. On the other side, the real-time analysis required a cloud or server for visualization or stream analytics (Hossein-Motlagh et al., 2020).

2.3.1 Overview of technologies used in IoT

Atzori & Morabito (2017) defined IoT as “a paradigm in which items and components of a framework that are prepared with sensors, actuators, and processors can link with one another to offer significant types of service”. The IoT systems at first collect a huge amount of data through sensors and other technologies, then by using different analytics technique, it transforms raw data into meaningful information. After analysis, the information is sent back to the actuator. At that point, the numbers of the actuator, information, and computing devices are present. In the subsequent subchapters, different enabling IoT technologies utilized in the energy sector are briefly explained. Moreover, previous research work in the field will be also discussed. Fig 2 shows the conceptual framework of IoT and their technologies based on the reviewed literature.

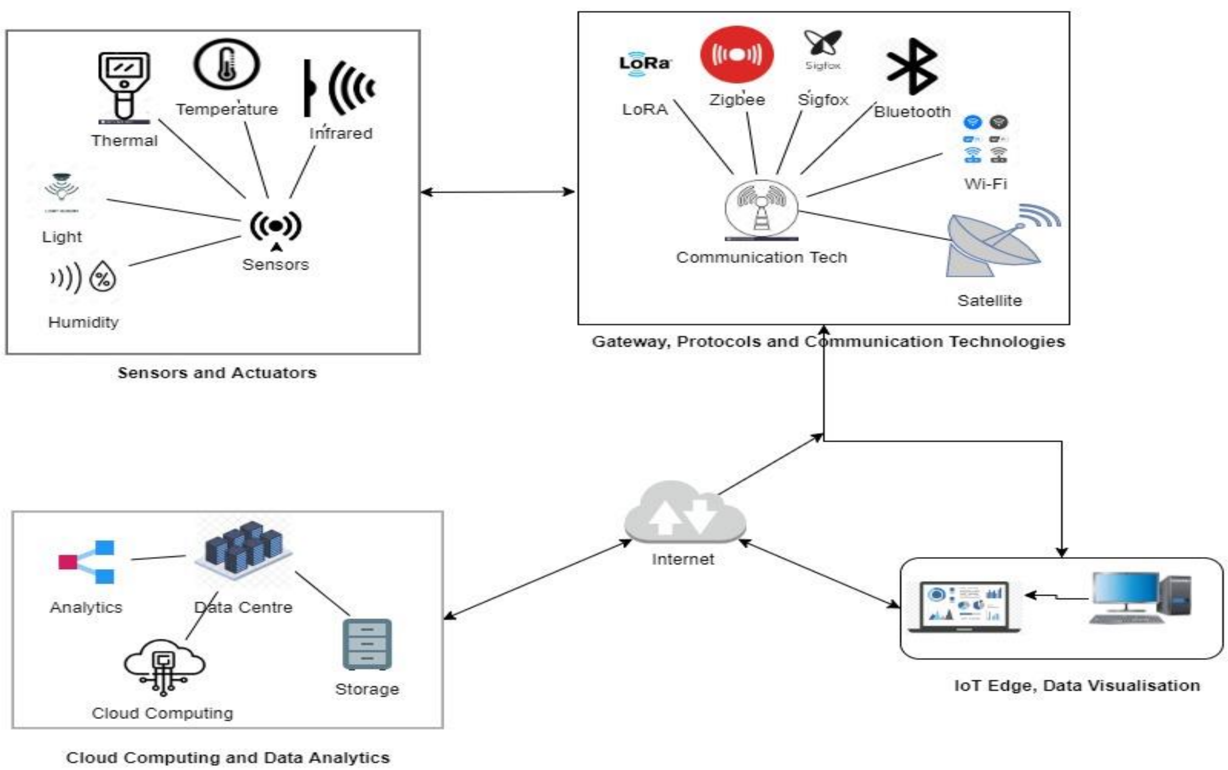

Figure 2. Conceptual framework of IoT

Sensors

Due to their capability to collect and transfer data in real time, it is widely believed that sensors play a key role in IoT technologies (Kelly et al., 2013). Utilization of sensors can result in as enhanced viability, effectiveness, and plays a fundamental role in IoT systems (Hossein-Motlagh et al., 2020). Different types of sensors are used based on their purpose to deserve. Application of these sensors includes but not limited to agribusiness, ecological checking, medical care frameworks, administrations, and public security (Rault et al., 2014). As a fundamental technology in IoT, sensors in the energy area are sensors are utilized to in cost savings as well as energy savings. By utilizing sensors in the energy sector, the share of Renewable energy sources (REE) can be increased and the goal to achieve optimal energy consumption is more achievable. Hereafter, most widely used sensors are discussed below. Among all sensor's temperature, humidity, light, passive infrared, and proximity sensors are most commonly used.

Temperature sensors have a key role in both phases' energy generation and consumption. They are utilized to sense the variations in temperatures in different environments such as in cooling and heating systems in energy generation and conversion plants (*8 Types of Sensors That Coalesce Perfectly with an IoT App - IT Firms*, n.d.). Mechanism of energy conversion is one of the basic principles in the energy sector. Different kind of energies such as energy obtained through wind, thermal and solar resources is converted to mechanical energy and then mechanical energy turns into electrical energy through temperature variations mechanism (Hossein Motlagh et al., 2020). Furthermore, in the energy consumption perspective, temperature sensors are used to detect the temperature so that cooling and heating system on the end customer side should be managed accordingly (Kelly et al., 2013).

The second type of sensors are humidity sensors, and those are utilized to detect the humidity and moistness in the environment. Humidity sensors are utilized extensively in the energy area, such as they are commonly utilized in the generation of wind energy. Their utilization on offshore wind turbines is imperative because of the noticeable high level of humidity all around. In the nacelle and lower part of wind turbines, these sensors can be installed to constantly monitor humidity level there (Hossain 2020). This empowers the administrators to make moves to changes in the turbine activity conditions, prompting more predictable tasks, streamlined working, and lower expenses of energy.

Similarly, light sensors are utilized in both industrial and home appliances to gauge light glow of light. As a principle means of energy utilization in construction linked to lighting, which, separately, represent almost 15% of total energy consumption (Pérez-Lombard et al., 2008). Globally, roughly 20% of the electricity is utilized for lighting (Hossei-Motlagh et al., 2020). Light sensors work according to the darkness in light level. They automatically switch on and off the lights to save energy. The level of the lights automatically changes corresponding to change in the ambient of the light. Through this mechanism, energy consumption can be optimized and the required amount of energy to keep the indoors bright can be minimized (Motlagh et al., 2018).

Another type of sensors are Passive Infrared (PIR) sensors, they are also known as movement sensors. As their name depicts, they are used to detect the movements of the objects based on infrared light radiation discharged by the objects in a certain environment. These sensors have various uses in different industries, in the energy sector, these sensors have proven vital in diminishing the energy utilization of the buildings. For example, PIR sensors can detect movements of the people inside spaces, so that to switch the lights on and off automatically. Furthermore, this can be used in the air conditioning system which uses approximately 40% of the building light (Pérez-Lombard et al., 2008). Another type of sensors is proximity sensors which are used to notice the existence of close objects with no actual contact (Kim et al., 2005). Their utilization proves cornerstone in wind energy generation. “In wind turbines, the applications of proximity sensors include blade pitch control, yaw position, rotor, and yaw brake position; brake wear monitoring; and rotor speed monitoring” (Hossein-Motlagh et al., 2020).

Actuators

Mechanism and functionality of actuators is converse to sensors, as they take electrical input and convert this input into certain type of motion to perform actions in automation systems (Hossein-Motlagh et al., 2020). Actuators produce diverse movement types, for example, straight, oscillatory, or rotational movements. Actuators can be classified in various types such as Pneumatic, Hydraulic, Thermal and Electric actuators (Nesbitt, 2011).

Pneumatic actuators utilize compressed air for creating movement. They utilize a piston or cylinder to put force. These actuators are utilized to control activities that require a speedy and exact reaction. Whereas Hydraulic actuators use the fluid for moving. Hydraulic actuators comprise of fluids which provide chamber or liquid engine that utilizes water-driven capacity to give mechanical operations.

The mechanical movement gives an output regarding direct and oscillatory movement. Utilization of these devices is mainly in high power based industrial processes (Hossain et al., 2020). Among these actuators, one of the most widely used are thermal actuators which depends on heat to produce movements. Thermal actuators transform thermal energy into kinetic energy. The thermostat actuators are made through a material that senses the temperature and pushes the cylinder. The material through which thermostat actuators are made can be of any type. The basic function of the material is to change volume according to the temperature. Whereas, compared to other actuators electric actuators depends on external energy sources to create motion. These actuators are mechanical devices equipped for changing electricity into kinetic energy in either a straight or rotary motion.

In the energy area, various types of actuators are used at different phases, for instance, Pneumatic actuators are regularly utilized as the last control component in power plants operations (Hossein-Motlagh et al., 2020). They are also utilized in limiting the energy waste in opening portals, securing brakes of wind turbines, and creating movements in solar tracking panels. In the past literature, there are numerous researchers investigates the actuators inside IoT. For example, the study in Blanco et al. (2018) illustrates how remote sensors and actuators contributes to IoT based automatic intelligent process. The proposed system reduces energy utilization during the activities of devices in IoT systems.

Communication technologies

Wireless communication framework is an integral part of IoT functional mechanism, it links the sensor device to IoT gateways and executes end to end communication between these devices of IoT. Development of wireless frameworks depends on various wireless standards and the utilization of each of them relies upon the needs of the application such as communication reach, data transfer capacity, and power utilization prerequisites. For instance, mostly renewable sources including wind and sun-oriented power plants are generally situated in exceptionally far-off territories. Consequently, guaranteeing trustworthy IoT communication in those areas is a big challenge. Utilizing IoT frameworks on these destinations requires the choice of reasonable communication technology that can ensure a consistent link and provide real time data transfer efficiently. There are various communication technologies such as Wi-Fi, Bluetooth, Zigbee, Lora, Sigfox, LTE-M and Bluetooth low energy to name a few.

Literature studies such (Eugenio, 2014; Rodriguez-Diaz et al., 2015; Karthika et al., 2019; Lee et al., 2017; Lee et al., 2016) discuss the application of small range wireless communication technologies, e.g., Wi-Fi, narrowband IoT (NB-IoT); ZigBee; Bluetooth low energy (BLE) technologies; as well as the emerging LPWAN technologies such as LoRa, Sigfox, and LTE-M operating in the unlicensed band" (Hossain et al., 2020). However, Wi-Fi technologies are not deemed efficient as their energy consumption is much higher than the other similar technologies (Hossain et al., 2020). Compared to Wi-Fi technologies, LPWAN technologies provide more energy-efficient solutions and utilization of such technologies in future can see a considerable growth (Kabalci et al., 2019). Similarly, (Jain et al., 2018) explained arising LPWAN technologies empower setting up a consistent, ease, low-power, long-term, last-mile innovation for efficient energy management solution. Below, key IoT empowering technologies will be discussed.

One of the most commonly used technology is Bluetooth Low Energy (BLE), which is mainly utilized to transfer data over the IoT network. The basic mechanism of the technology is it enables wireless communication through radio frequencies "(https://www.bluetooth.com/)". These technologies consume a fewer amount of energy and their installation and operation cost in less than competing technologies. However, their scope of range limits only to the maximum of 30 M (Lee et al., 2007) and can be used only for sharing of the lower amount of data communication such as for smart office energy management (Choi et al., 2015) and communication within the office and home buildings to minimize the utilization of energy in smart homes (Collotta & Pau., 2015a).

The other key technology is known as Zigbee, which is used as communication development for private network communication "(https://zigbee.org/)". Similar to BLE, Zigbee is easy to install, requires minimal cost, low -data rate sharing and provides consistent networks for low-power devices (Craig, 2004; Froiz-Míguez, et al., 2018). Zigbee uses in the complex network where devices are connected in interconnection ways. The use of Zigbee in complex networks and compared to BLE it can cover a range of up to 100 m. The use of Zigbee in IoT devices is mostly incorporate lighting frameworks (structures and road lighting), smart grids, home automation frameworks, and industrial robotization. These applications give ways to deal with proficiently using energy. Studies Erol-Kantarci and Mouftah (2011), Lim (2010) Han et al. (2014) shows Zigbee implementation effectiveness in smart homes to minimize energy usage and increase energy efficiency. Additionally, the research by Batista et al. (2013) illustrates how ZigBee technology can enhance the efficiency of observing photovoltaic and wind energy frameworks.

Other long-range communication technologies include Long Range (LoRa), Sigfox, Narrowband IoT (NB-IoT) and Long-Term Evolution for Machine-Type Communications (LTE-M). LoRa is communication device intended for IoT (https://loraalliance.org/). LoRa provides low power and cost-effective solutions for IoT communications and their range covers up to an area of almost 50 Km (Augustin et al., 2016). Several such as Mataloto et al. (2019), Javed et al. (2018), Ferreira et al. (2018) explore their applications in smart home and industrial HVAC. In their application, energy usage, installation cost and coverage area Sigfox is near to LoRa, however, data transfer speed in Sigfox is much lower in than LoRa.

NB-IoT is a cheap solution which has long battery life and along with the possibility to upgrade the battery. Furthermore, the research in Pennacchioni et al. (2017) shows the NB-IoT innovation for smart metering. In their research, Li et al. (2017) provided a comparison between NB-IoT and other prevailing communication technologies and they found out that NB devices are best in terms of their application in smart grid communication about data rate, range, and battery life.

Similar to other devices LTE-M is highly secure, but it provides more area coverage of almost 200 KM along with high-speed data sharing, and high structure ability. Likewise, this innovation offers energy proficiency and resources allotment for power distribution devices, thus it has the potential to be an integral part of future smart meters (Deshpande & Rajesh, 2017) and smart system communication (Emmanuel & Rayudu, 2016).

Another emerging communication technology is “Satellite which is communication technology innovation that has a wide-territory inclusion and can uphold low data rate applications in machine-to-machine (M2M)” style (Wei et al., 2019). Satellite technology is appropriate for the backup of IoT devices in far off spots. Studies such as (Sohraby et al.,2018; De-Sanctis et al.,2015) presents a mechanism of satellite communication technologies integration into smart grid, solar system, and wind turbine power generation.

Figure. 3 presents the comparison between various wireless communication technologies adopted from (Hossain et al., 2020).

Technology \ Parameter	Range	Data Rate	Power Usage (Battery Life)	Security	Installation Cost	Example Application
LoRA	⩽50 km	0.3–38.4 kbps	Very low (8–10 years)	High	Low	Smart buildings (smart lighting)
NB-IoT	⩽50 km	⩽100 kbps	High (1–2 years)	High	Low	Smart grid communication
LTE-M	⩽200 km	0.2–1 Mbps	Low (7–8 years)	High	Moderate	Smart meter
Sigfox	⩽50 km	100 bps	Low (7–8 years)	High	Moderate	Smart buildings (electric plugs)
Weightless	<5 km	100 kbps	Low (Very Long)	High	Low	Smart meter
Bluetooth	⩽50 m	1 Mbps	Low (Few months)	High	Low	Smart home appliances
Zigbee	⩽100 m	250 Kbps	Very Low (5–10 years)	Low	Low	Smart metering in renewable energies
Satellite	Very Long >1500 km	100 kbps	High	High	Costly	Solar & wind power plants

Figure 3. Comparison between different communication technologies used in IoT (Hossain et al., 2020).

2.3.2 Cloud and Fog computing

The basic purpose of implementing IoT is to monitor and control objects through real time data collection and analysing the data. IoT technologies collect a huge amount of data often termed as Big data, big data can be utilized in making key decisions related to business operations and processes. Similarly, in the energy sector, this huge amount of data can be used to enhance the energy efficiency, reduce consumption and development of REE (Jaribion et al., 2018). However, data is collected from various sources and it includes a huge amount of raw data, therefore certain kind of sophisticated computing techniques are required to classify highly useful and irrelevant data sets from big data (Stojmenovic, 2014). Cloud and Fog computing are two major known computing mechanism available to handle and process big data (Hossain et al., 2020).

“Cloud Computing (CC) is TCP/IP based high development and integrations of computer technologies such as a fast microprocessor, huge memory, high-speed network and reliable system architecture” (Gong et al., 2010). The infrastructure of CC consists of 5 layers i.e., “clients, applications, platform, infrastructure and servers” (Gong et al., 2010). As their definitions indicate it is a combination of hardware, software, and services layers. Furthermore, Internet and communication protocols also make an important contribution to the CC functioning. Cloud computing is highly sophisticated techniques which have the potential to process and analyse IoT based big data (Stojmenovic, 2014). In cloud computing, user interact with service layer through the Internet and secure access is provided to the user to access the services, however, the hardware of cloud servers is present in big data centres at a different location than user location (Armbrust et al., 2010). Greater number of organizations are utilizing cloud services because of its advantages such as minimize the hardware expenses, providing huge amount of data storage, secure and multilayers architecture and ease of accessibility from multiple geographical locations (Foster et al., 2008).

Despite the popularity and providing many opportunities in data computation and analytics, cloud computing has certain limitations such as delay in accessing the server and bandwidth issues (Gong et al., 2010; Hossein Motlagh et al., 2020). These issues limit the efficiency of the system; therefore, it requires a decentralised computing method to overcame delays and bandwidth issues. In this context, a complementing way of cloud computing can be utilize named as fog computing. Fog computing is decentralized and extension of cloud computing, it functions as a mediator between a cloud server and client hardware. In the perspective of IoT, collected data is computed locally instead of sending it to the server, thus providing more reliable and faster data response by reducing network traffic (Atlam et al., 2018).

2.3.3 Artificial Intelligence

Artificial intelligence (AI) believed as one of the most impactful disruptive technology in the current era. AI convert mechanical machines into intelligent devices based on the technology which implies human brain simulation along with understanding and utilizing of cognitive patterns. Advancements in AI are aiming to imitate and develop human-like cognitive capabilities through different techniques and innovations which leads to the development of machine intelligence (Shi, 2011). Ultimately AI enables machines to function like a human brain (Abduljabbar et al., 2019). Availability of big amount of data provides many opportunities for the businesses to achieve efficiency in their decision making, However, often data is in big amount and complicated which creates challenges for simple computational techniques to process and retrieve useful information for decision-makers. In such a situation, AI can process, classify and generate key information from big data through two main computational mechanisms.

Gharbi & Mansoori, (2005) discuss that the paradigm of AI can be divided into two fundamental categories, "Artificial Neural Networks (ANNs) and Conventional Artificial Intelligence (CAI)". Compared to ANNs, CAI is known basic level computational mechanism as it operates and responds in more general computing style by observing the predetermined rules and knowledge provided by human brains (Abduljabbar et al., 2019). Whereas ANNs has a sophisticated framework which uses a system of neuron connections and mimics the functioning of the human brain. Structure of ANNs is designed in a which enable technology to remember and connect with previous events based on its quality to distinguish certain characteristics, identifying patterns in a huge amount of data.

Learning, complex problem solving and linking certain characterises to specific events, objects or entity are core attributes of the human brain, similarly AI specifically through Machine Learning tries to mimic the human brain through different algorithms. In AI, machine learning is considered as one of the main categories and enhance computational powers of a system through learning algorithms, (Jain et al., 1996) explains there are three main ways of learning algorithms i.e., supervised, unsupervised and hybrid learning algorithms. Each algorithm has its conditions and application based on the requirements and purpose of using AI, for example, linear discriminant analysis using multilayer feedforward structure to analyse the data and pattern classification, whereas, RBF (Radial base function) learning algorithm use RBF structure to classify patterns, function approximation, prediction and controlling purposes (Jain et al., 1996). Despite the availability of multiple models and algorithms related to machine learning, studies and implementation of ML are in their initial stages.

2. 4 Overview of major IoT applications in industrial ecosystem of the energy sector

Compared to several studies on challenges, studies are limited which highlights and prioritizes key application areas of IoT, especially in the energy sector. Porkodi & Bhuvaneswari, (2014) provided an overview of application and communication technologies in IoT, and they categorized IoT applications in three major domains, i.e., society, environment, and industry. Similarly, Bandyopadhyay & Sen, (2011); S. Chen et al., (2014) stress upon the importance of IoT applications capabilities in asset management, fleet monitoring, environment monitoring, medical monitoring, remote controlling and location-sensing etc. Furthermore, Maple (2017) presents a comprehensive review on IoT applications and found out IoT provides opportunities in various sectors of the economy such as connected autonomous vehicles, health and wellbeing, industry 4.0, logistics, smart grid, smart buildings, retails, agriculture and entertainment & media. Another study by Shaikh et al., (2017) proposes a spectrum of IoT applications is widespread from industry to final consumer end, however, it argues there is an urgent need for deploying green IoT which are more energy and environment friendly. In their research, Li et al. (2017) discussed possibilities to build smart shopping centres using IoT based on RFID technology. Similarly, Nord et al. (2019) presented literature review and theoretical framework related to challenges, application areas and opportunities in implementation and utilization areas of IoT.

Narrowing down the studies on IoT applications in the energy industry only a handful of studies can be found, yet they rarely present practitioners viewpoint on application areas and challenges faced by organizations in the energy sector. Lahti et al. (2017) emphasize the possible use case of IoT throughout the energy supply chain i.e., energy generation, transmission, distribution, consumer, and device level. They also discuss IoT can be very useful in managing energy demand and supply model through real time data provision. Few numbers of studies (Al-Turjman & Abujubbeh,2019; X. Chen et al., 2011; Engineering et al., 2015; Zhukovskiy et al., 2019) explore IoT use cases, technologies, security issues, challenges and protocols in smart grids and energy sector. While other (Miao Yun & Bu Yuxin, 2010; Shafique et al., 2018) propose key application areas of IoT in the energy sector. Main application and utilization areas of IoT in the industrial ecosystem and energy sector are highlighted below, based on the published scientific research and conference papers. Fig 4 shows Major IoT applications in the industrial ecosystem of the energy sector.

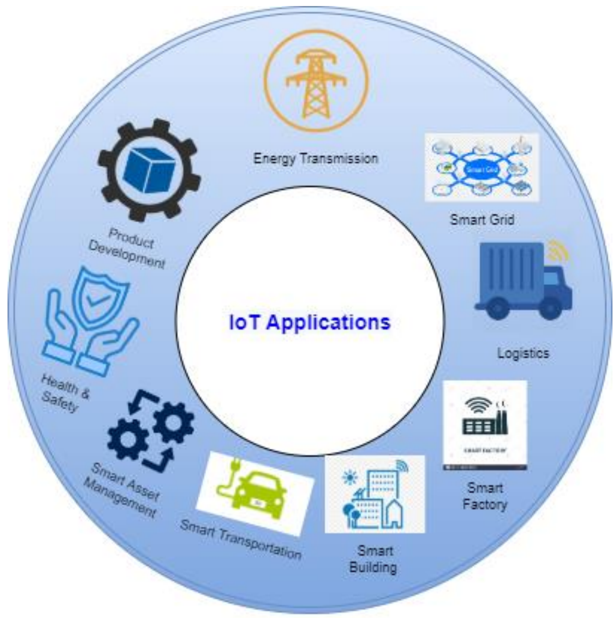

Figure 4. IoT applications in industrial ecosystem of the energy sector

2.4.1 Energy generation

In 1960s industry leaders started thinking to automate the industrial processes in different sectors such as energy sector, and in 1990s significance progress was made to automate the power sector industrial processes and supervisory control in energy systems (Ramamurthy & Jain, 2017). In the early stages of automation, IoT started to remotely monitor and control equipment and processes, which ultimately alleviated the risk of production loss or blackout (Hossein Motlagh et al., 2020). Challenges in power generation remain somewhat similar when it comes to new and old power plants. Major challenges of old power plants remain to be reliability, efficiency, environmental impacts, and maintenance. Another problem with old power plants is their equipment obsolescence which leads to higher maintenance cost and higher energy losses. Moreover, these old assets cannot be replaced due to higher replacement cost and they are expensive. Ramamurthy & Jain (2017) explains implementing sensor and Internet-based connected devices (IoT) can predict and analyse any failure or discrepancy in energy operations or transmission, thus alarms the management for timely maintenance of the system. In such a way, implementing IoT has threefold benefits i.e., increased reliability, the efficiency of the system and reduced maintenance cost (*SIGFOX.COM*, n.d.).

Furthermore, the role of IoT in power generation is not only limited to traditional power plants, but it also has a vital role in renewable energies. As discussed earlier, development of Renewable energy sources can diminish the adverse impact of fossil fuels, therefore, many countries are promoting REE to produce energy locally than relying heavily on fossil fuels to meet their energy demands. Variable renewable energy (VRE) and weather dependent sources particularly solar and wind energy have emerged as major energy sources in REE. Their technologies are emerging and being implemented at large scale in different parts of the world. Energy generated through VRE technologies is much cleaner, environmentally friendly and emit fewer greenhouse gases (Al-Ali, 2016). However, there are certain technical and financial challenges related to REE technologies, especially with solar and wind energy resources. One of the major technical challenges with VRE technologies is known as the intermittency challenge. As solar and wind energy generation depends heavily on sunshine and wind subsequently, and availability of wind and sunshine varies a lot at times, it makes it very challenging to meet the energy production and demand. (Ramamurthy & Jain, 2017) argue that IoT based solutions can provide a balance in the generation of energy, optimizing energy usage through machine learning algorithms and enhance energy efficiency.

2.4.2 Smart grids

Term smart grid is associated with electricity grids which utilize advanced information communication technologies to optimize the processes of energy generation, transmission & distribution and its final consumption through interconnection of smart meters and multidirectional information flow (Hossain et al., 2016). Smart grid application can be further divided into subsectors of the energy system such as in energy generation, buildings, transportation, or smart buildings. There are various functions which differentiate smart grids over conventional grids, for example, batteries in conventional grids were charge through adapters and cables with AC/DC converter, whereas in smart grid those are charged wirelessly through inductive charging technology (Hossain et al., 2016; Hossein Motlagh et al., 2020). Another aspect of smart gird is to enable efficient energy management by analysing the energy demand pattern using IoT platform-based data. Analysing the energy demand pattern can be beneficial in many ways, for instance, using IoT in the smart grid can bring better results in terms of enhanced control and monitoring of the battery-equipped devices, ultimately energy distribution can be adjusted.

Furthermore, IoT can be implemented in microgrid and isolated cases for organizations where the persistent supply of energy is required without interruption. Such systems can utilize IoT for integrated interconnectivity of all assets, as well as the availability of data on the energy usage of each unit in the system. IoT can also play important role in asset management in the smart grid. Constant monitoring through IoT can detect if the demand for energy at a particular time is exceeding the capacity of the grid. Real time data gathered from monitoring process can be used to identify demand peak hours and demand patterns, thus enabling management to develop different strategies (real time pricing, dynamic pricing tariffs) to optimize the energy consumption and supply.

2.4.3 Smart buildings

Smart building is one of the prominent parts of smart city concept, from energy consumption perspective smart buildings in the city can be distinguished into two categories, commercial and domestic buildings, later also known as residential buildings. Energy consumption of domestic buildings includes appliances, lighting, domestic hot water, refrigerating, cooking, and heating & air conditioning (HAVC). Vakiloroaya et al. (2014) report that about 50% consumption of the domestic energy accounts for heating and air conditioning. Similarly, (District Heating Statistics, n.d.) shows in Finland district heating system used 36, 600 GWH energy during the year 2019, which cost more than 3 billion Euros. High operating and generating energy cost and environmental impacts related to HAVC system compel organizations to provide innovative solutions to decrease energy consumption in the HAVC system. In the era of disruptive technologies, IoT has shown promising results to control and reduce energy losses, increase energy efficiency by optimizing the energy usage from the customer end. For example, wireless devices with sensors can realize the unoccupied places and reduce energy consumption by holding the heating process or reduce the intensity of the operation. Such optimization enabled through IoT can reduce energy consumption and increase energy efficiency. Furthermore, the same mechanism with the help of IoT can be applied to reduce the energy losses in the lighting system (Arasteh et al., 2016; Ejaz et al., 2017).

2.4.4 Smart manufacturing

Manufacturing area accounts for almost 30-40% of world energy consumption, therefore it is essential to increase energy efficiency in the manufacturing area to reduce the burden on energy resources without compromising on the production levels. Emerging technologies can play their role in energy efficiency and studies such as (Tao et al., 2016) asserts that IoT can turn manufacturing into smart manufacturing, which ultimately leads enhanced energy efficiency and improved manufacturing process quality. Experts believe that its common practise in the industry to ignore the energy consumption of the manufacturing facilities as well as industry lack mechanism collect real time data on energy consumption in the manufacturing process (Tao et al., 2016). Besides the fact that IoT is in their stage of infancy, yet both academia and industry believe this emerging technology has the potential to shift the industry from traditional and conventional manufacturing to smart manufacturing. In smart manufacturing, all the components, assets, machines, facilities products can be interconnected through smart embedded sensors and other technologies to communicate and share real time data autonomously, which resultantly can enhance manufacturing quality, automation, and real time energy consumption throughout the manufacturing facility. In such a way applying IoT in the manufacturing process can have multifaceted advantages in terms of improved manufacturing quality, assets condition monitoring and improved energy efficiency (Tao et al., 2016).

2.4.5 Supply chain & logistics, environment

IoT can play an integral role in enhancing the effectiveness and efficiency of marine technology, particularly engines through the interconnection of sensors and actuators installed on the engine and other equipment. Embedded sensors and actuators monitor condition of the environment and equipment in real time, share live data through different communication protocols and highlight the exact location of the fault, thus enabling management to conduct predictive maintenance before any breakdown (Xu et al., 2019). Moreover, a big amount of acquired data also increases the monitoring and analysis of engine energy consumption pattern, which in turn increases energy efficiency and reduces carbon dioxide emissions. Real time acquired data also enable an organization to improve product development in future by analysing the past data, thus IoT also enables smart manufacturing. Talking of industrial systems, Successful and integrated supply chains are deemed as an essential requirement for industry 4.0. Contemporary supply chains are becoming a more complex and sophisticated buyer and suppliers' framework due to globalized logistics system (Tazhiyeva, 2018). In this perspective, importance of IoT cannot be neglected as IoT can ensure the availability of real time data, as a result, actual-time visibility in the supply chain networks increases. Enhanced visibility among the supply chain network in turn improves the accuracy in demand and supply. Therefore, it makes the supply chain cost-effective, efficient, and sustainable (Wang and Li, 2006).

Transportation and logistics account for a major share of energy consumption in the contemporary business world. Current industrial logistics of production input, output and products depend heavily on sea and roadways transportation methods. Ship transport also known as water transport of industrial goods is deemed as the most efficient and cost-effective way to transport industrial goods. However, despite being cost-effective both rail and marine transportation require a higher amount of energy to function the logistics system. Despite some progress in RES, fossil fuels remain the main source of industrial goods transportation in marine vessels, rails, and road vehicles. Which in turn results in as increased air pollution, climate change and energy losses all over the globe. To achieve sustainable development goals especially in terms of environmental impacts of energy consumption in transportation and logistics, it is integral to develop RES and integrate RES in transportation system along with cutting the energy consumption of existing fleets and vessels (Hossein Motlagh et al., 2020). Studies such (Hossein Motlagh et al., 2020) shows applying IoT technologies can provide a global management system to develop an energy-efficient solution to the marine and road transportation systems. Importance of such technologies in smart transportation and logistics have been admired both in academia and industry (*The Top 10 IoT Application Areas – Based on Real IoT Projects*, n.d.) they rank 1st IoT technology integration in the logistics industry as a top trend in 2020 followed by AI and BC. By connecting fleets through the Internet and other communication technologies, IoT in logistics and transportation can play a significant role in reducing CO2 emissions, hazardous environmental impacts and increase real time monitoring of whole logistics process (Ejaz et al., 2017). Fleets and products real time monitoring through smart interconnectivity can produce a large amount of data. Applying different data analysis techniques, collected big data can be translated into meaningful business decision-making tools such as optimizing logistics process, increasing information visibility, stakeholder's engagement, increased buyer suppliers trust, efficient inventory management, smart space management, balanced supply, and demand to name a few.

2.4.6 Asset management and safety

Real time data sharing and equipment connectivity changing the concept of traditional factories into smart connected factories. As compared to the traditional factory, all the operations and processes in the smart connected factory are interconnected through centralised IoT ecosystem, which facilitates factory management to overview the performance of each process and operations in a real time (Hozdić, n.d.). Through the Internet of Things, assets in the production sites and factories are interconnected through an integrated digital IoT ecosystem. This interconnectivity of devices, equipment and components facilitates management to achieve a higher level of operational efficiency by utilizing real time data providing live monitoring on assets condition. Furthermore, the interconnectivity of assets and equipment can report and analyse the condition of assets through vibration and other sensors, thus helps an organization to pinpoint the exact location of the fault and enables them to do predictive maintenance (Zonta et al., 2020). Sensing the fault before it happened or even highlighting the exact areas of fault is not only helpful in preventing the disaster but also reduces the cost of doing maintenance. Haarman et al., (2017); Mobley, (2002) says almost half of total operating cost could go into maintenance cost in most of the cases. (Zonta et al., 2020) stresses upon the fact that most of the organization even do not measure properly how much they are spending on maintenance of the assets: therefore, it is important to have key data from all process of manufacturing plants and assets (Kiangala & Wang, 2018), and IoT have game changing capabilities to collect and provide real time data on each component installed in manufacturing and other processes. This way IoT can help organization to decrease maintenance cost, equipment breakout time and to keep assets in efficient condition. In addition to equipment predictive maintenance, within industrial engineering, IoT role going to be crucial in efficient manufacturing. Interconnection of assets and equipment through the IoT system can depict the comprehensive picture of a manufacturing process in the one frame, making it easier to monitor production line, production flow and identifying bottlenecks.

2.4.7 Product development and customer experience

In recent times, efforts have been made to tap the potential benefits and opportunities of IoT in product development. Studies (Porter & Heppelmann, 2014; Prasad, 2020) show that IoT can play a significant role in product development, product life cycle management (PLM) and enhanced user experience. Integrating IoT in product development and PLM in the manufacturing process can enhance product quality and provide new insight into businesses. Besides their all-important role in product development process within the company, it also offers many opportunities and benefits to the customer, and data collected through smart connected products provide a baseline to product developers, engineers and sales force (Golovatchev et al., 2016). Acquiring credible and enough amount of data in PLM from customer end has always been important since it provides insightful information product usage, consumption pattern and risk associated in PLM. Availability of data even becomes important in the context of industrial products or business to business (B2B) products because they are used in heavy processes and often requires careful monitoring and timely maintenance. Moreover, any disturbance in the industrial assets can result in break out which can ultimately lead to huge business losses. From the final customer perspective, due to globalization competition among the businesses is very high, and in scenario retaining the customer is indispensable to thrive and survive in the industry. Smart connected products on one hand, provide useful data on the product usage and their energy consumption, while on other side it can highlight what improvements in the existing solutions need to be done in order to retain the customer. Moreover, in some cases smart connected devices with the help of data connectivity can guide end user to achieve higher product utility and create new values. All in all, smart connected products can influence customers greatly, which in turn can increase customer loyalty as well as generate new business revenues and efficient product development.

2.4.8 Information technology

At its essence, IoT technologies provide innovative solutions in terms of new product development enabling novel business models by combining physical components with digital technologies. Yoo et al. (2010) argue due to advancements in power management systems, communication technologies, reliable memory and powerful microprocessors, digitalizing industrial products is a reality in the contemporary world. The core structure of IoT technologies depends heavily on information technology, integrating software application and hardware devices through centralised or decentralised IoT ecosystem. Applying IoT essentially adds value to the core purpose of the primary physical things, for example in a traditional lighting system, lights turn on and off either through switching it manually or there is specific timer applied to turn the light off/on, while in smart lighting system enabled through IoT bases sensors, the additional value would be to turn the light on/off by detecting the human presence in that particular location. Moreover, connected sensors can also present analysis on times with the most and least present of humans in the building. Consequently, less energy would be used also it can provide a low-cost security system to the building owners by sending intrusion alerts to them on their mobile phone.

Moreover, as discussed earlier in the chapter there are various communication and hardware technologies related to IoT, however, their integration in the existing organizational information systems depends heavily on their alignment with internal information technology structure. In contemporary industrial systems, there are two main practices when it comes to implementing IoT based solutions in the organizations (Pflaum & Golzer, 2018). First is an internal IT department consisting of organization own experts of hardware and software implement IoT solutions by configuring their existing IT structure concerning IoT. Otherwise, nowadays certain organizations also known as digital platforms or IoT solution-based platforms are operating which provides customized and standardized software and hardware IoT based solutions to various industries (Pflaum & Golzer, 2018). So, in a nutshell, IT and IoT technologies are interrelated and go hand by hand, and it is indispensable for organizations to deeply know their information technology system before implementing IoT based solutions either made internally or provided by the digital platform companies.

2.5 Overview of barriers in IoT implementation and utilization

There are certain barriers which hinder the selection of certain technology and IoT is no special case (Insights Team, 2017c, p. 9). The solutions provided by IoT are ordinarily made up of some technological advancements, developing an environment which is unpredictable and quickly evolving. Summary of key studies on major challenges identified in literature are presented in table 1, and it can be seen that security, privacy, trust, networking, financial factors, and standardization are the major barriers in IoT implementation.

Table 1. Key studies on challenges in IoT implementation

Researchers	***Challenges***	***Paper classification***
Younan et al. (2020)	Integration among technologies, scalability, network, communication, data analytics	Literature review
Nord et al. (2019)	Security, trust, networking, investment, cross-department cooperation, skilled people, network challenges, too few best practices,	Literature review
Kumar & Mallick (2018)	Security, privacy, interoperability, standardization, legal regulatory, economic / investment.	Survey research
AlEnezi et al. (2018)	Security, privacy, investment.	Survey research
Farhan et al. (2017)	Scalability, energy requirement, security, fault tolerance.	Survey research
Ouaddah et al. (2017)	Privacy, networking, communication, access control, Social constraints, economic issues.	Survey research
Lennvall et al. (2017)	Installing & retrofitting, security, reliability, availability, scalability, interoperability, sustainable business model.	Survey research
Hsu and Lin (2016), Lund et al. (2014).	Authenticity, access control, communication, privacy, mobile security.	Survey research

2.5.1 Privacy and security

IoT has been predicted as an essential part of every industry from medical care to monetary administrations to transportation. As every technological advancement is reliant on technical components that increase the risk of privacy and security likewise IoT is also relied upon wireless networks, sensors, clouds storage and so forth. Insights Team, (2017c) that raises the worries of protection of personal data and security and trust. In this IoT connected world, some concerns of privacy and security have not been identified and settled (Lund et al.,2014). Table 1 illustrates and many other studies argue that IoT security and privacy are major concerns in IoT development and implementations.

Hsu and Lin (2016) additionally found that the protection and security concerns affect expected utilization of IoT, as without privacy and security users of IoT programs will not disclose their personal information as they are concerned about information leakage. Sicari et al. (2015) in their research recorded some fundamental security difficulties in IoT which are: access control, protection, strategy enforcement, trust, secure middleware, confidentiality, and verification.

Several other studies in the literature were found on the protection and security of IoT. Lee and Lee (2015) organized a study of IoT applications and numerous difficulties of IoT adoption including managing information, information mining, protection, and security. With the view to support this discussion, demonstrates that security is a critical concern, as IoT devices are all the more now and again turning into an objective for hackers. When comes the monetary domain, privacy and security is a huge responsibility for the IoT developers, they should maintain aspects of privacy and security in all phases of IoT technological advancements.

Furthermore, a study by (Jay, 2018) underlines that the CFO should work intimately with the CIO to guarantee all devices are fit for withstanding attacks that could inconveniently affect their company's dealings and maintain continuous surveillance. Several authors have discussed the IoT related privacy, three kinds of agreements should be provided by the IoT service providers; according to (Ziegeldorf et al., 2014) awareness of security risks among the users of smart technology, individual supervision on gathering and processing the personal information by the users of smart technology, awareness of use and circulation of personal information by third parties that are outside the personal control. To make sure that IoT services are accepted and majorly used, the service providers should develop a privacy strategy that would allow preserve the privacy of the users and protect their personal information (Miorandi et al., 2012).

Peppet (2014) argues that the privacy and security concern of IoT is very arduous, hence making protection issues. There is an overall consent that exists around this conflict and the issues regarding protection and security are basic factors in IoT adaption and development deployment (Ransbotham et al., 2016, Miorandi, & Coen-Porisini, 2016) some researchers come up with some contributions on controlling the IoT including rules, best practices, and arrangements.

2.5.2 Trust

The term trust is employed in various circumstances and with different implications. Trust is a term which has complex meaning, to certainty, beliefs, and desires (Yan et al., 2014). Miorandi et al. (2012) in their study acknowledged that the term trust has various meanings in different contexts. In this perspective, (Paliszkiewicz, 2019) suggested trust in information security compliance can be divided into three main dimensions: trust competence, benevolence, and integrity. Study also suggest that all three dimensions of trust impacts the organizational leadership towards information security policy. Moreover, it was also found out that trust is important factor in predicting employees information security compliance (Koohang et al., 2020), therefore trust is integral part of organizational information security and privacy compliance.

Sicari et al. (2016) depict the idea of trust as being associated with positive influence and repute of party and credibility. If the person or party has a positive influence and good repute it is considered as trustable as it shows its credibility. So, in different contexts the meaning of the term trust is dissimilar. When the term trust is used in smart technology it means the level of comparability that is the conduct expected by the client and actual performance of the application Mišura and Žagar (2016).

In similar circumstances when the concept of trust is used in IoT, the term consists of two aspects; firstly, it means the credibility when both the parties i.e., service provider and the user of service are interconnecting with each other and secondly from the point of view of a user, the reliability in the systems of a service provider (Roman et al., 2013). Trust is the major component in IoT when it comes to the personal information provided by the user of service. While using and following IoT services trust is the essential element, without credibility the adoption of IoT is not possible in the industry. It envelops how clients feel while communicating in the IoT if the users feel that the interaction is safe and there is no risk of leakage of their personal information then the services of IoT can widely be adopted.

Fernandez-Gago, Moyano, and Lopez (2017) set up a structure for engineers to incorporate trust worries in IoT frameworks, as it is one of the foremost concerns in the adoption of IoT services. Thus, following a proactive methodology, the structure should include the aspects of trust in all the phases of IoT technological advancements. The edgework recommends that trust should be remembered for all periods of the improvement of IoT frameworks following a proactive methodology.

Trust in IoT service is an important issue but it comes after the two major concerns of privacy and security. To attain trust, (Guo et al., 2017) reported a review of trust calculation models for IoT, after doing the survey the author ended with future directions regarding trust calculation research. While protection, security, and trust are on the whole basic to the achievement of IoT, without these factors the adoption of IoT is very challenging as IoT has been viewed as an essential part of every industry.

Privacy and security are antecedents to trust and should be considered perpetually. Despite these difficulties, the research by Insights Team (2017c) uncovered that 42% of the respondents were satisfied with IoT programs and claimed that these programs have been doing the exact things they should do in setting some cash aside as savings, working of the company has become more effective and efficient and their firms are making profits.

2.5.3 Standardization

In our era, the efforts of standardization seem much difficult even tough for the advancement and growth of IoT standardization plays a vital role. As there is competition in the service providers nowadays, so IoT plans it to bring down the hindrances for the new suppliers and clients, to make better the interconnection of various systems and to permit the services so that they can work better at higher levels. To make better the interconnection of various systems, these are being created, affirmed, and kept up by a synergistic agreement-based process of decision making. These facts suggest that unique standards are one of the critical components for the growth of IoT. This kind of standards is a significant facilitator for advancement due to their accessibility to the general public (Lennvall et al., 2017).

Additionally, by utilizing these standards there is less possibility of being restricted to a particular vendor or innovation which is a significant factor for IoT advancement. There are many standardization activities with the extent to come up with open standards, consistent availability, and interconnections of various systems. Despite these fundamental standardization bodies, there is no standard reference for IoT advancements. To empower consistent availability and interconnection among different IoT empowering advancements, these issues and difficulties require to be considered in future.

2.5.4 Scalability

The speedy advancement of smart technologies is bringing on to the huge development of mini devices such as sensors. The rapid growth of embedded technologies is leading to an enormous deployment of miniaturized devices (sensors, actuators, etc.). As the quantity of devices develops, the information delivered by these devices develops immensely. Consequently, controlling the development of several devices and data they produce is a huge test in IoT (Čolaković & Hadžialić, 2018). Besides, future IoT frameworks should be versatile and adaptable through programming, tending to plan that manage and scale with a huge number of devices. The one solution to the problem of scalability is to use the huge scalable platform in IoT applications that can store an immense amount of data being gathered and processed. This is such an arising issue in today's IoT systems and very attractive for further research.

2.5.5 Accessibility and reliability

Accessibility of services is one of the main questions to be addressed to appropriately deal with the elements of IoT frameworks. Accessibility implies that IoT applications should be accessible where the client or user of IoT service may, it should be accessible to them. Some items are mobile and continuously moving, so IoT applications should be versatile and astute to help consistent network and accessibility. Accessibility of connection and its inclusion territory should maintain the connectivity of services without considering the mobility of the object. Some technological advancements experience the ill effects of discontinuous accessibility which can cause a disturbance in connection.

There are some new difficulties as depicted like Mobility is another significant challenge in IoT frameworks when services are rendered to portable clients. IoT devices might be moved and regular geography changes can happen.

Despite the advance changes with the changing environment the objective of IoT applications is to make a robust framework. Hence, there is a prerequisite for such a mechanism that can handle proficient portability. Likewise, a few arrangements of IoT systems suggest that IoT systems need to know the location of the devices and their environmental conditions (Lennvall et al., 2017). This is another significant challenge for further investigation, particularly when creating some ongoing applications that require identification of that area. Nonetheless, this issue needs to be improved in future.

2.5.6 Environmental issues

There are pros and cons of every application on the Internet. IoT system affects the environment in both positive and negative ways. Consistently there is an ever-increasing number of devices that are being sent subsequently "ecological friendliness" is a point that should be given more consideration in future investigation. More and more microdevices are being developed such as mobile phones, sensors and metal chips that can harm the health of human beings and can be found destructive for the environment as they consume energy.

Environment sustainability is one of the core issues in today’s world as there is more and more demand for energy due to these increasing number of devices and their electronic wastage. The solution lies in the further research on the topics of reduction of energy consumption, identification of renewable energy sources, make such devices that are small in sizes so that no decay materials should be less, different impacts on human wellbeing etc. The 5% of our total energy resources is spent on Internet applications, as there is a more increasing demand of energy being used on the Internet by different devices and this is another issue to be considered in the future technological advancement of IoT-based frameworks (Čolaković & Hadžialić, 2018).

3. Methodology

3.1 Research process and research design

Research process and design in academic studies are deemed an integral part of the whole research study. An appropriate research design is indispensable for academic study so that results can be found through a systematic and rigorous process. Moreover, it also requires a researcher to be unbiased during the whole process and observe objectivity so that he/she should not influence on findings of the study. The research method of the current study is qualitative since respondents were asked to fill out an online consent form for the interview, then online semi-structured interviews were conducted to deeply comprehend the concepts. As compared to the quantitative approach, qualitative studies emphasis on understanding a research question as a humanistic or idealistic approach (Pathak et al., 2013). Qualitative methods are most suitable when study aims to understand people beliefs, experience or attitudes towards certain concepts, phenomenon and topic (Pathak et al., 2013).

Since the basic purpose of the study is to highlight major benefits, barriers and key strategies related to IoT implementation by exploring professional experience on the topic, this study is designed in as exploratory study design. In the current study scenario, the exploratory design is suitable as there are few research studies on the topic, and research studies in the domain are in their state of infancy. Thus, applying exploratory research design will provide a deeper understanding of the concept, explain current ideas in the subject and elaborate more accurately research problems (DeJonckheere & Vaughn, 2019). Furthermore, the exploratory study design is used where multiple set of outcomes can be anticipated on the subject being evaluated (Yin,2003). The research process can be seen in Fig. 5 below.

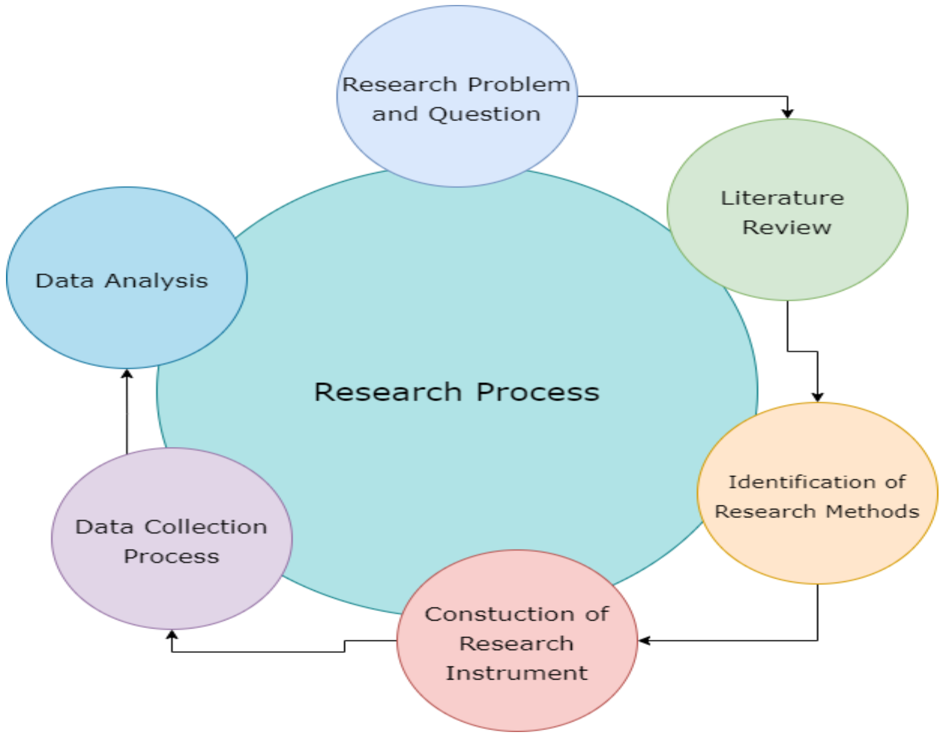

Figure 5. Research process

3.2 Qualitative research methods

As discussed earlier qualitative research studies best fit when the aim is to understand people's experience, beliefs, or attitude towards specific subjects. However, within a qualitative study, there are certain categories and research designs which are applied according to the research questions and problem of the study. Baxter & Jack (2008) argue there are seven distinct research designs such as explanatory, exploratory, descriptive, multiple case study, intrinsic, instrumental, and collective to conduct qualitative research. There are three basic types of a data collection method in qualitative studies observational studies, interview-based studies and document or textual analysis (Gill et al., 2008; Pathak et al., 2013), and among that most widely used method is conducting interviews (Gill et al., 2008). In qualitative studies, researchers put questions to the given interviewee about the topic and try to collect comprehensive subjective information about the subject based on interviewee's beliefs and experience.

The most distinguishing feature of a qualitative study is that the participant of the study feels more involved in the study as compared to quantitative studies (Pathak et al., 2013). Moreover, the interaction between the researcher and participants remains more informal in the qualitative study as compared to a quantitative study, thus helps the researcher to tap the untapped aspects of the topic of the study. Besides, to pursue research objectives in the qualitative study, the researcher carefully and purposefully selects the interviewees based on their experience and relevancy to the topic of the research.

3.3 Interviews approach

It has been discussed there are three basic kinds of interviews I.e. structured, semi-structured and unstructured (Gill et al., 2008). In structured interviews content of the interview is written in the form of questions and respondents answer cannot vary from the listed questions, also there is no possibility to ask follow-up questions. Structured interviews are usable where little clarification on the topic is required and no in-depth information is needed. Contrary to structured interviews, in unstructured interviews, open-ended questions are asked, and researcher starts with a very basic question and then follow-up the questions based on the interviewee initial answer and so on (Gill et al., 2008). Main limitations with such form of the interview are, they require much more time, sometimes lack agenda and guidance where to lead and maybe confusing for participants. However, this form of interview is very helpful when deep investigation about the topic is required and existing information about the topic is very little. The third main type of interview method is to conduct a research study in semi-structured design, this method facilitates researcher to set key questions and then ask follow-up questions if required based on the answers from the interviewee (Gill et al., 2008). It allows the researcher to get more detailed information about the phenomenon while keeping the interview more focused on the objectives of the study. This research approach provides flexibility and possibility to tap the untapped aspects of the relevant topic. Semi-structured interview qualitative research is the best-suited research approach which serves the purpose of the study. Contemporary literature on IoT in business cases is still in their early stages and little information is available to develop framework for successful strategies to implement IoT in energy organizations. Therefore, this research utilizes semi-structured interviews approach since it allows researcher to get deeper insights on the topic by asking key questions followed by contextual questions.

3.4 Research instrument reliability and validity

Designing a reliable and consistence research instrument is very important for survey data collection. Term reliability and validity are more often deemed prevalent in quantitative research and some researcher such as (Stenbacka, 2001). Golafshani (2003) argues reliability in qualitative research is misleading in its core because the criterion used in evaluating reliability in quantitative research used in qualitative research would lead to the conclusion that the study is not good. However, conversely (Healy & Perry, 2000) argue that reliability also related to the quality of the study and quality of research paradigm should be evaluated through terms of relevant research paradigms. In quantitative studies quality of the study is judged by reliability and validity while in qualitative paradigms terms such credibility, neutrality, confirmability, consistency, dependability, applicability, and transferability can be considered an integral criterion for good quality of a qualitative study (Lincoln & Guba, 1985).

Foregoing discussion leads the researcher to develop the research instrument more consistently. Research questions were developed by doing an extensive review in the domain of IoT and their capabilities to apply in different industries, the scope of the review was narrowed down to the energy sector. Conducting a literature review helped the researcher to cover a range of concepts related to IoT in the energy sector. Moreover, it also provided a baseline to develop reliable, relevant, and dependable research questionnaire. Furthermore, it was reviewed by Professor and one PhD researcher, minor changes were suggested, and the questionnaire was modified as per their suggestions.

Validity in the context of research methods refers to the notion that the construct of the study measures what it is meant to measure (Magarey et al., 2009). It also relates to the accuracy and precision of the research instrument to the concept under considerations. Practically, validity is measured into two different kinds named as internal and external validity. Internal validity specifies how the instrument is constructed and has not been affected by any other factor, whereas external validity is more linked to examine results applicability to other similar situations and determine for other possible outcomes (Shuttleworth, 2008). To ensure internal validity, research instrument was sent to the test group for common understandings of the items. Based on the feedback further clarity among the questions was established.

3.5 Data collection methods implied in the current study

As discussed above, online semi-structured interviews were the main source of data collection for the study. To collect the data top-level managers working in the domain of IoT and data analytics were contacted through LinkedIn, organizational websites, email address and on some key forums related to IoT such as Nordic IoT week event. Online semi-structured interviews serve four key objectives, 1) they were best-suited method during the exceptional times in Covid- 19 pandemic, 2) they allow to record the meetings online so that content of the discussion can be retrieved anytime, 3) it saved time and travelling cost, therefore allow the researcher to conduct more interviews in less time and cost-effective way, 4) most of the online meeting software such as Zoom, Skype, MS Teams allow participants to have video calls, so respondent expressions can be noted too. However, the major drawback is network connectivity, and it was ensured to use high-speed Internet with at least one back up source of Internet.

Overall, during the interviews, there were no Internet connectivity issues and all the data was saved. Furthermore, to ensure the credibility of the study researcher ensured all interviewees have relevant experience in the domain of IoT and they are in top-level management of their organization in Finland. Furthermore, professionals working in digital services companies were also contacted since digital services providing companies can play a key role to help organizations in devising techno-strategical fit. Experts working in digital platform companies have immense and diverse experience and most of the time they are involved in multiple projects related to IoT implementation in various industries. However, it was made sure respondents have experience in working on IoT related project in energy organizations. I believe their diverse experience can provide a valuable contribution to the study. Besides digital platform companies, the financial impact cannot be ignored as they are expected to reach $ 7.1 trillion marks by the end of 2020 (Lund et al., 2014).

A preliminary online survey was sent to experts which evaluates IoT application, utilization areas and major challenges their organizations faced while implementing IoT. If the organization utilizes IoT in their application areas, then request for an online interview was sent and a total of 7 experts agreed to reserve their time for an online interview. Interviews were conducted in a semi-structured manner and researcher neutrality was ensured to get reliable results. To tackle the ethical issues, Interviewee consent and permission was acquired to use the data for academic purpose and to record the online interview. The notion behind selecting managers for interviews is the novelty of the topic and only experienced professionals can answer questions like, “What are major challenges your organization faced while implementing IoT?”, similarly “How do you think implementing IoT helped your organization? And what was the framework to overcome the challenges that your organization faced?”. About such questions, managers’ opinions matter and they are in a better position to answer the questions from a technical and strategical point of view.

3.6 Participants background information

All interviewed participants are working in different organizations and deals with a different type of products in the energy sector. Their experience ranges from 3 to 30 years and all of them are involved in dealing directly with IoT in their organizations. Moreover, they were well aware of the implementation process and strategical level aspects of emerging technologies implementation in their organizations. To serve the research purpose it was decided to cover a wide range of organizations operating at different phases in the energy sector such as energy transmission and distribution, energy demand and efficiency and organizations providing IoT based industrial solutions to the energy sector in Finland. Having different types of organization in sample enrich the study results and provide a comprehensive view of overall energy sector organizations in Finland.

Interviewed participants include but not limited to experts from organizations operating in marine and power engines, electric power systems, energy solutions for smart buildings, smart grid, industrial IoT for energy sector, pioneer digital solutions company with more than 25 industrial partners and covers range of industries and deals with especially in providing IoT and AI-based solutions to partner organizations. Researchers believe that the versatile experience of participants is very useful to understand key barriers, applications, and benefits of implementing IoT in the energy sector. Moreover, one of the key objectives of the study is to develop a framework to overcome challenges and successfully implement emerging technologies, therefore participants with a different professional background also helpful to develop a framework to overcame challenges in the implementation of emerging technologies I.e., IoT, AI and BC. Details of the participants are presented in the following table 2.

Table 2. Background information of the participants.

Company	*Interviewee (Position)*	*Organization products/Services*	*Experience*	*Country*
A	Director of Innovation, Global product line manager	IoT system configurator, customized solutions & professional services	30 years	Finland
B	IoT systems developer	Marine Power, Diesel engines	5 years	Finland
C	PhD Researcher, IoT architecture specialist	Smart building, smart heating solutions	3 years	Finland
D	Master builder, emerging technologies	IoT solutions for the energy sector	7 years	Finland
E	Business Development Manager	Industrial IoT	3 years	Finland
F	Systems architect	Cutting tools Tech for the energy industry	10 years	Finland
G	Application Engineer	Drive technology, variable speed generator technology, energy storage system, Dedicated Power Management System.	5 years	Finland

3.7 Data analysis technique in current study

Current study use content analysis to formulate conclusive results by interpreting and classifying textual data obtain through transcribing the interviews. Content analysis can help evaluate the qualitative data and turn into meaningful quantitative data. Furthermore, this study based on inductive approach, (Burnard et al., 2008) they suggest in qualitative research inductive approach is applied when a researcher has little or no predetermined theoretical framework or structure, therefore the structure of the study depends heavily on analysing the data. Although this approach is time taking still it is very useful when there is little, or no information is known about the phenomenon in the study. Also, inductive content analysis allows a researcher to derive categories directly from raw data, so that researcher should avoid predetermined categories, hence it reduces the researcher biases and focuses more on objective results (Moretti et al., 2011). It was decided to implement inductive content analysis for the current study based on the novelty of the research topic, literature has little theoretical framework/ structure to provide information about the study topic, and to minimize the researcher biases about the predetermined categories and let the data decide on results and highly new insights about IoT implementation in the energy sector. Based on the above discussion it is evident that inductive content analysis is the best-suited approach to analyse the qualitative data in the current study, and so current study uses inductive content analysis to induct the results.

4. Results

Two-step method was adopted to answer the research question and accomplish study objectives: first, an online survey has been sent, followed by semi-structured interviews asking respondents to highlight key application areas, utilities and challenges related to IoT implementation in their organization.

4.1 Priority application areas

When respondents were asked to answer, “what are major IoT application areas in their organization?”, all of 8 respondents answered in an online survey, however one respondent did not appear in the interview due to his busy schedule. Figure 6 shows the application areas of IoT in the sample organizations.

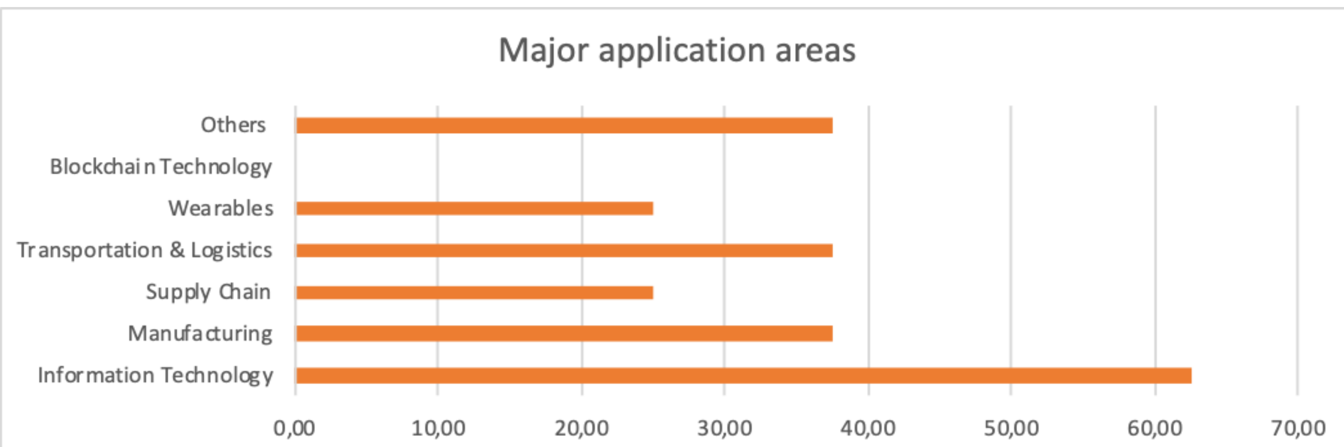

Figure 6. Priority IoT application areas in industrial ecosystem of the energy sector

As can be seen from fig 6 Information technology leading IoT implementation in the energy sector, followed by manufacturing and smart grid. Furthermore, transportation and logistics along with supply chain remain key application areas in participants organizations. Moreover, respondents also identified key other IoT application areas such as smart city, smart spacing, wireless hardware, warehouse, and inventory management.

Participants were also asked “to elaborate on how IoT technologies are being implemented in specific application areas of their organization that they have mentioned” such as manufacturing, information technology, smart grid, transportation & logistics. Majority of participants were able to explain their process in detail, while few were not sure how to explain briefly.

For example, in the manufacturing process they explained:

> "*We have in our factory thousands of sensors, measure pressure applying and measuring rolling and lot of other things, these sensors have been mainly used inside the machine, and we are now live streaming sensors values to the cloud, storing it to the data lakes and we do visualization and next step is to start optimizing through data analysis to see what dimensions effect quality the most."* – IoT System Developer.

> *"We did actually created the manufacturing execution system a kind of having smart connected assets in the field to monitor the performance of all components in the manufacturing process, especially in the service area perform preventive maintenance but then also they are using it for fault Finding."* – Business Development Manager.

IoT provides multiple smart solutions in the energy industry, it enables renewable energy technologies for environmentally friendly power generation, efficient energy storage and distribution system as well as energy optimizing demand. Organizations Implementing IoT in smart grid and energy sector explained their usage in such a way:

> "*We have kind of horizontal solutions for the network is used for power quality monitoring but then also so for example like H**** use that for solar factories for connecting different types of assets to realize demand response elasticity scenario, stabilize the grid frequency of 50 hertz automatically to all the big power plants…… [….] hydropower plants are controlled from that energy storage solution."* – Director of Innovation.

When asked about IoT and Information Technology, respondents shared IoT and IT are two central concepts and IT is one of the most important application areas. For instance,

> *"I think IT is the core of IoT implementation, we have to complement our system with IoT*." – IoT Systems Developer.

"Our organization provides digital solutions and professional services in the domain of IoT and AI, and we use IT in combination with our customized solutions to provide sustainable digital solutions to our partner companies." – Master Builder Emerging Technologies.

"Obviously, the aim of our IT is to provide information in decision making, and implementing IoT enabled us to collect data, the large amount of data and now we see in our manufacturing and product development it is helping a lot by reporting discrepancies and enabling process automation. So, the combination of IT and IoT is working well for us." – System Architect.

Similarly, participants explained how IoT is applied in logistics, transportation, and user experience:

*"We have ***** (organization name) self-built marine engines and we have IoT devices in the field which actually collect data from engines and then publish data to the cloud where we have MQTT brokers and collect the data and then finally data is consumed by analytics downstream customer to provide valuable user experience to the end customer."* – IoT systems Developer.

"*Main application of IoT is in basically in logistics because of Marin power or shipment industry basically customer of our organization, and also the energy sector independent power plant."* – IoT Systems Developer.

"Our organization use IoT in multiple projects related to smart grid and Marin power solutions. However, we have just started implementing IoT related projects and utilization is at its basic level." – Application Engineer.

Moreover, participants were also asked to choose all major utilization areas of IoT in their organization, results illustrate interesting aspects with major alignment to the literature studies. It was found out that around 8 out of 9 organizations use IoT in their product development, thus in product development, IoT are being implement greatly. Sample organizations utilize IoT for improvement in existing products by monitoring their usage patterns, opening up new product lines, and innovative product development. Besides product development, asset management remained second top priority which followed by customer experience, safety, and environment.

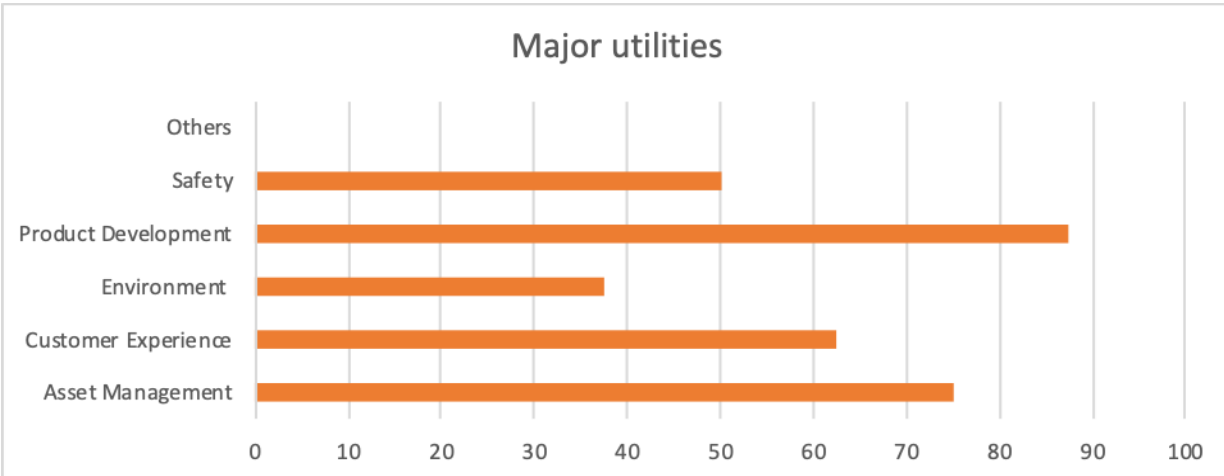

Figure 7. Major utilities of IoT in industrial ecosystem of the energy sector

While answering question "how they utilize IoT in the specific area which they have mentioned in the online survey"? about product development participants have detailed information, for instance:

> *"This is where we use IoT to monitor sensors data to our production plan, but using it locally for decision making, then the other thing is that is in our sanding and polishing machines we have Bluetooth and Wi-Fi connectivity with sensors, measuring how much they vibrate and how fast they rotate and battery level. It can be controlled through the cell phone or other industrial solutions. New sanders will be controlled through Digital twin, so every machine will have a digital twin. when you go to our system as a customer and you change the settings, those settings are changed in the DT and changes will show up in the machine. then we are also streaking data directly to the cloud. In this way, we are utilizing IoT to develop our products based on the huge amount of data collected through the Internet of things". – Systems Architect.*

> *"With IoT, you connect a lot of things and the next step after Big Data the connecting with AI, but eventually I mean it's is solving a problem that is out there making things efficient making new types of products." – Business Development Manager.*

"*We have a start-up company of which we have developed some products with the help of IoT…. like Building an automation system for heating and cooling off of any house…., it can detect if the people are at home or if the people are outside and turning the heating on/off, ultimately cutting the heating energy by 40%, and it's a huge contribution in energy efficiency." – IoT Architect Specialist.*

"For our organization emerging technologies especially IoT and AI are new business opportunities, they contribute to new product development and new service offerings." – Master Builder Emerging Technologies.

While on Asset Management and other utilization of IoT, study participants shared their thoughts in these words:

"We use IoT to monitor sensors data to our production plan using it locally for decision making, then the other thing is that is in our sanding and polishing machines, we have Bluetooth and Wi-Fi connectivity with sensors, measuring how much they vibrate and how fast they rotate and battery level." – Systems Architect.

"Enabled (organization) to benefit from the IoT is that they were finally able to monitor the thousands or ten thousand of machinery operating plants without necessarily manually walking through each equipment to get the data … […]… what is essentially allows for them is to very cost-efficiently capture some of the vibration measurement and make a preliminary analysis the scalable and cost-efficient condition monitoring." Director of Innovation.

"*Our solutions range from a kind of having smart connected assets in the field to monitor the performance over them especially in the service area to implement preventive maintenance." – Business Development Manager.*

"Mainly IoT collect data from field marine engines and send it to cloud services……. data is used for customer experience and predictive maintenance." – IoT Systems Developer.

4.2 Major barriers in IoT implementation

When participants were asked to *"identify key challenges related to IoT implementation in their organization"*, it was observed that return on investment is the major challenge, companies are more concerned with IoT implementation cost and most often it is hard for them to invest on heavy cost related to replacing existing technologies such as SCADA with IoT. While privacy, network challenges and integration among technologies are second-most challenging aspects of implementing IoT in the energy sector. It was also observed during the interview's cooperation among the departments, too few best practices, organizational culture related barriers and lack of strategical vision is also hampering the growth in adoption of emerging technologies in different organizations. Contrary to literature the majority of the organizations shown a high level of trust in IoT technologies.

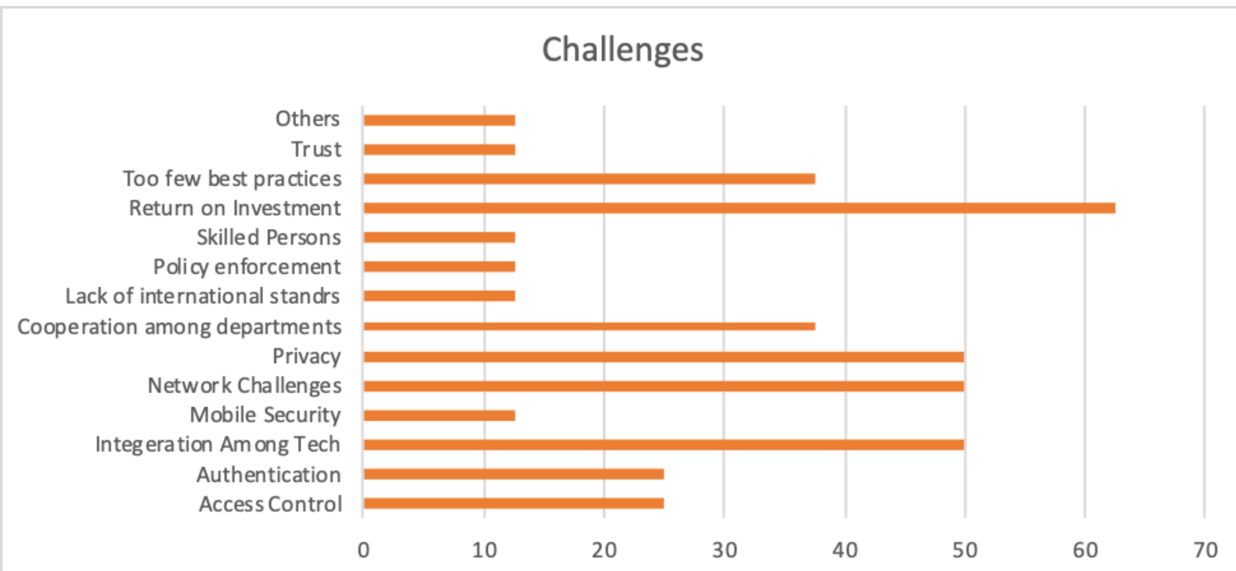

Figure 8. Key barriers in IoT implementation and utilization in industrial ecosystem of the energy sector

Participants were also asked to briefly explain the challenges which they have mentioned in an online survey. Discussing Return-on-investment issue, respondents revealed that

> *"Matter on return-on-investment is very tricky because from my personal experience the way how it is being calculated in our industry is tricky, a lot of IoT related projects around 70-80% fails in their POC stage and in my experience, it happens because the objectives of the POC are not clearly pretty define………. it's much more challenging for them to start implementing new*

technology which might not bring return-on-investment immediately." – Business Development Manager.

"About return on investment the project is still in initial phases and gradual changes are happening, implementing IoT requires high investments, it is a challenge indeed." – IoT Systems Developer.

However, some experts believe perspective on return on investment is short-sighted and in the long run, this challenge can be overcome as the technology develops in terms of their business opportunities, such as

"Although it's a challenge, but the implementation of IoT technologies is efficient and might bring revenue for large industrial players but over a long run which they also understand on the short term at the moment." – Business Development Manager.

From the perspective of technical challenges, network, privacy, and integration among the technologies are the most challenging one. Participants shared their experience in such a way:

"I think for our organization network is the most challenging especially if we talk about sites and fields where Marine operates, … […] … changing their IP'S and it makes quite challenging." – IoT Systems Developer.

"We have kind of edge device which is batching and buffering data and if the Internet connectivity will go down, so we have to buffer the data, so the connection restored, … […] … MQQT protocols authenticate and how we orchestrate and manage from an operational perspective, these are kind of challenges we have looked at that." – Systems Architect.

"Challenge of interoperability, in our technologies we are utilizing a proprietary connectivity platform…. it is ideal for our applications for our devices essential … […] … we have developed our whole product around that connectivity protocol, one of the biggest problems is with industrial customers clients s they have very closed systems." – Business Development Manager.

Besides, interviewees were also asked “what was the response of employees to this change, how was the acceptability of IoT in your organization?” got valuable answers from the participants. It was revealed by the participants that organizational culture, leadership, and employee’s commitment can play deciding role in success and failure of all emerging technologies. Participants revealed that strategic approach towards emerging technologies is indispensable to reap the real benefits out of technology also to stay competitive in the industry.

> *“Major challenge was organization going though transformational phase …[...]…, taking on board and coordination among all stakeholders was big challenge … […] … transformation is always painful and human nature tend to resist to come out of comfort zone, and it was driven well by the management, by having more and more information sessions and discussing why transformation is necessary.”* – IoT Systems Developer.

> *“I think it's always about people about decision-makers people are always an issue and when it comes down to implementing new technologies because of course it's much easier to try to mitigate the risk rather than trying to catch opportunities…[…]… it's much more challenging for them to start implementing new technology which might not bring return-on-investment immediately but will bring in the next 2 to 3 years or this might not apply to everyone but especially for talking about decision-makers.”* – Business Development Manager.

> *“Generally, you could say you know people might feel threaten in an organization actually by an IoT in some degree for privacy issues when the external solution is provided.”* – Director Innovation.

> *“People might feel threaten in an organization actually by an IoT in some degree kind of start boycotting the external solutions, spread misinformation starts working against it … […] … it becomes real distractor that is very hazardous.”* – Director of Innovation.

> *“When it comes to change and implementing new things there is always resistant especially in terms of large organizations, it was challenging to take all stakeholders on board, however, all*

stakeholders were involved from the beginning, employees had training sessions and discussed benefits and shared the value of new technology. We did well at the end." – Systems Architect.

Respondents also explained how change management is important in successful technology implementation. In their opinion organizations embracing change and their employee's behaviour in embracing new technologies solutions can lead them to a win-win position.

"When an organization's embracing it … […] …, with IoT applications that organization had within the shortest time they created over a hundred applications and they were able to know because they looked at data and things in a different way that they actually created to the invention, so they applied for two patents and I think that is kind of like an incredible story." – Director Innovation.

4.3 Benefits of IoT implementation

IoT has the capabilities to revolutionize the entire industry. Study results revealed that IoT utilization level in the energy sector of Finland is in their early stages and organizations have started realising how imperative is to apply IoT. Despite at their early stages of implementation, IoT has shown key benefits i.e., energy efficiency, enhanced user experience, financial savings by cutting the cost, improved product quality, supply chain efficiency, new value streams, and health & safety.

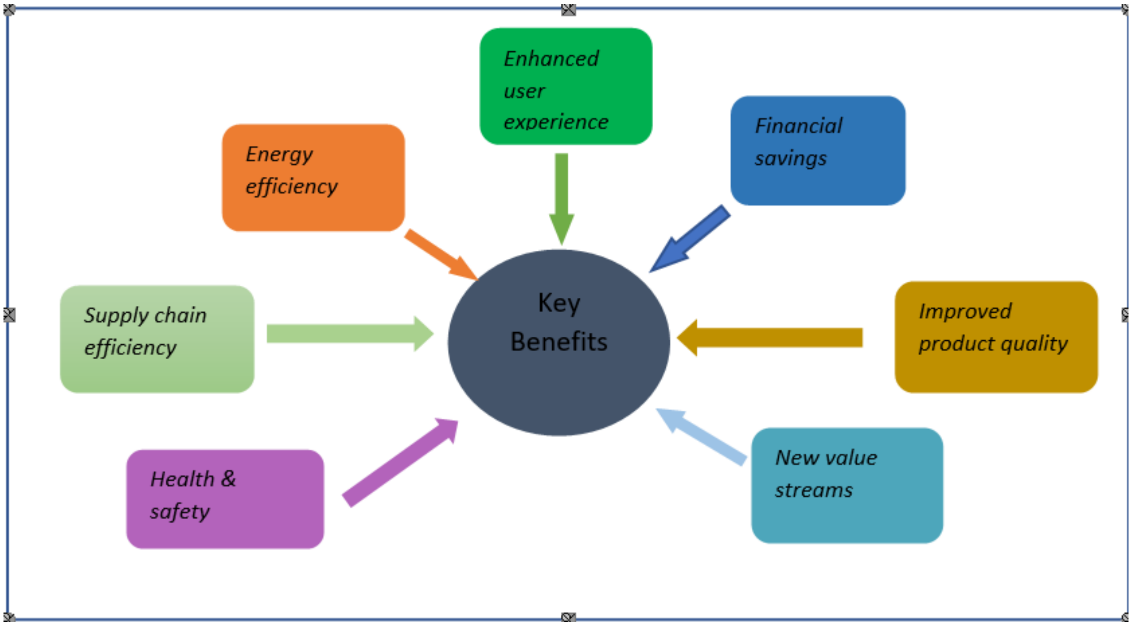

Figure 9. Benefits of implementing IoT in industrial ecosystem of the energy sector

Question about "How do you think implementing IoT helped your organization?" received a mix response from participants. Some participants explained they have got few benefits in terms of energy efficiency, making the organization more efficient, increasing health and safety, and cut the cost of assets conditions monitoring. However, most participants argued that they are yet to realize real benefits of implementing IoT as projects related IoT are in their early stages and it takes time to reap the benefits. Respondents views on IoT benefits were:

> *"I would say it's still quite a niche market and it's not being utilized as heavily as expected and in the area of IoT, I would say that maybe the benefits are not so clear but over a long run I believe that if an organization or company is going to fail to adapt to this environment and Implement such technologies is eventually going to fail."* – Business Development Manager.

> *"In my opinion is always comes down to these three points, of course, you have a lot of subcategories to you everything but the main things more about new revenue streams and health and safety, cutting cost."* – Director of Innovation.

> *"For our organization its new business opportunity, making company more efficient and enhancing supply chain efficiency by real time monitoring of logistic and information transparency."* – Master Builder Emerging Technologies.

"Well, we haven't seen the benefits yet, we know there are few, but the project takes time because we want to do the foundations right. we have several tracks, we have machines, sanding machines, productions plants, so from the sanding machines I mean there we fairly believe having this data is probably interesting for the end-user of the machine, so yeah. I don't know until now I don't know much." – System Architect.

"yes, implementing IoT has been beneficial in terms of energy efficiency, enhancing user experience, customer services by providing real time data on engines energy consumptions, but the matter of fact about return on investment and financial benefits, the project is in initial phases and we haven't realized financial benefits." – IoT Systems Developer.

Furthermore, it is worth to mention all participants unanimously agreed upon the fact that they are highly satisfied with IoT implementation and none of them had intentions to revert to traditional business practices than IoT.

4.4 Roadmap for successful IoT implementation

As discussed, organizations face technical and non-technical challenges while implementing IoT. Implementation of emerging technologies such as IoT, AI and BC require systematic changes and, in the organization replacing, updating, or complementing existing technologies with emerging technologies expose organisations to certain types of risks e.g., risk of failure. Consequences of failure could be huge for the organization in terms of losing a huge amount of investments and losing potential market share that emerging technologies can capture for the organization. In this perspective, the identification of a clear roadmap to IoT implementation is imperative to mitigate the risk of failure. Through experts' discussions, key success factor and steps in IoT and AI implementation were identified. Moreover, since a majority of factors are of strategical importance, therefore the scope of their applicability can be also generalized to other emerging technologies such as Robotics, BC, XR. Based upon the expert discussions it was found out to successfully implement emerging technologies combination of strategical and operational level initiatives are required. Strategical initiatives include stakeholder's engagement, defining clear objectives, leadership commitment and cooperation among the industry.

Participants stressed that stakeholder's engagement is the most important factor while implementing emerging technologies. All stakeholders must be taken on board throughout the journey as their involvement contributes greatly to the success and failure of the technology. Stakeholders engagement especially leadership and employee's commitment are important, as leadership or employees can feel threatened by new technology at the beginning which leads to spread of misinformation and implemented technology fails to meet the required objectives. Therefore, it is crucial to engage and onboard all key stakeholder. Leadership plays important role in the success or failure of the technology as they are in decision making position. Since they have decision making authorities, top management commitment is a key deciding factor for technology implementation. If they have a higher level of commitment, they can motivate employees and facilitate project teams.

Furthermore, setting ambiguous objectives is another reason of why technology-related projects fail, one of the cornerstones of successful technology implementation is to define clear and measurable objectives. The organization must know what they want to achieve by implementing new technologies and what kind of business value they will achieve through emerging technologies. Inventing business cases especially in terms of IoT, organizational management can pick specific areas to implement and find out whether they want organizational efficiency, energy efficiency, insights on product consumption, product value addition, condition monitoring or improving the customer experience. Last but not least, emerging technologies carries new frameworks and structures and in their phase of infancy there is always a need for learning from their implementation best cases, in this regard learning from other and cooperation among the industry can help organizations to successfully implement emerging technologies.

Beside strategical factors, operational level key initiatives are also of greater importance. Mapping user journey, employees' training and intra organization communication were identified as key factors for successful emerging technologies implementation. Mapping the user journey in physical space before real implementation helps the project team to reduce risk. It is always recommended to conduct training sessions with employees to train them to give the required technical skills and share the value of using new technology. Sharing the value of new technology is crucial to motivate employees and acceptability of new technology.

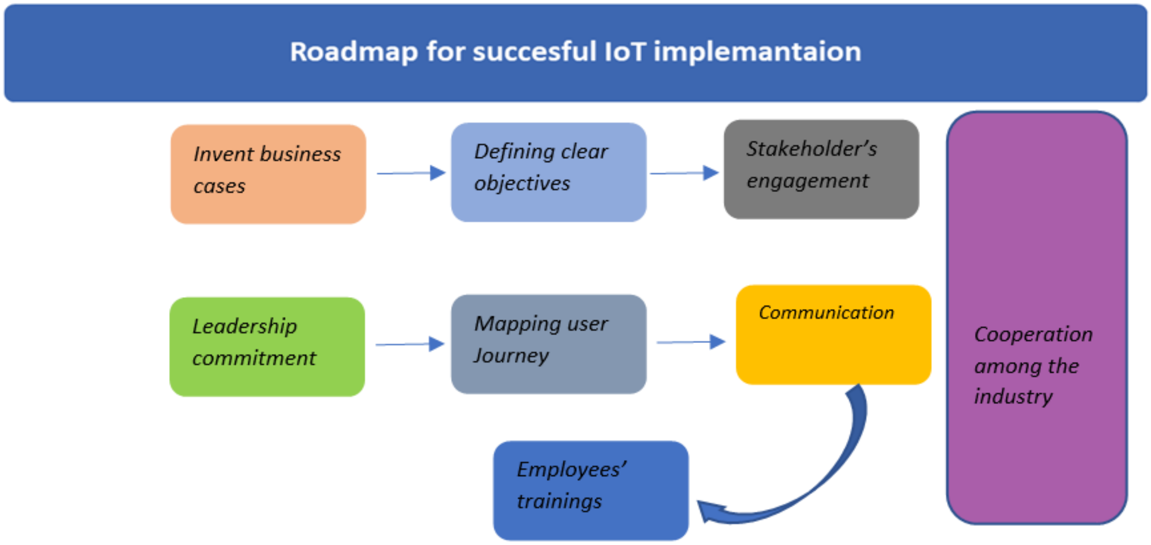

Figure 10. Roadmap for successful IoT implementation

When participants were asked their opinion about the role of IoT in sustainable business practices, most of the participants agreed these technologies have the potential to contribute to sustainable business practices in many ways. Implementation of IoT result in energy efficiency, operations efficiency, and product utilization. Most of the participants explained since these technologies are in their initial phases their role in sustainable practices is still illusional. However, certain examples were given by participants how these technologies are contributing to sustainable business practices. Such as

> *"Well, one of the main things with connected sanding machines we could inform the user of the sanding machines when the sandpaper is fully used because today we saw operator replacing sanding paper to the sanding machine early so that they don't use it to the full potential of the paper. there is one thing that could be the benefit of reducing waste, and sustainable business practises to use the product at full potential."* – Systems Architect.

> *"IoT such a diverse concept and I think the idea is pretty much Clear of course in it will eventually lead to a point where to lead to sustainable business."* – Business Development Manager.

“It does contribute to sustainable business practices in terms of saving energy consumption and distribution.” – IoT Systems Developer.

4.5 Role of other disruptive technologies

Last important objective of the study was to evaluate the role of other disruptive technologies i.e., AI and BC technologies. Role of AI and BC technologies in contemporary business processes and operations in the energy sector was discussed with participants along with industry future based on these technologies. Participants shed light on different aspects related to AI and BC, and it revealed that compared to BC, AI has enormous potential to revolutionize business models. AI has the potential to drive new business opportunities, change business models, competitive grounds, and change sales tactics. Similar in the energy sector, majority of organizations are implementing a combination of IoT and AI-based solutions, and more and more organizations are using IoT and AI combination to derive insightful information from data collected through IoT. Majority of participants termed AI is the technology of the future, and it will help businesses to achieve optimal efficiency in different operations and processes of the organization through machine learning-based algorithms. For instance,

“Yes, we are using it (AI) more and more, we have already done some proof of concept… […] … for example, using different machine learning algorithms to analyse and camera on the top and we take a picture and analyse picture and ML algorithm to find quality inspect in our products.” – Systems Architect.

“AI again like it's is making life easier by automating a lot of things and belongs to this sustainable business practice….” – Business Development Manager.

“Future of AI is more in industry and this technology has the potential to change current business practices.” – Master Builder Emerging Technologies.

“Central system of our IoT based data in power solutions is integrated with AI-based server and we are expecting a great amount of efficiency.” – Application Engineer.

However, it was found the potential of implementing BC in the energy sector in Finland is still limited. Certain limitations are associated with BC technologies were discovered, such as technical challenges related to their mechanism, incapability to derive business value through BC implementation, and it was worth noticing that most of participants organizations have a higher degree of trust in their information technology systems which also rules out utilization of BC in their businesses. Few respondents also added that organizations have started tapping the potential of all disruptive technologies, despite their slow pace in future organizations can implement BC-based solutions, but currently their utilization level is rare in energy organizations.

5. Discussion and conclusion

The current chapter includes discussion, conclusion, and summary of results. Also, in the light of expert's interviews, managerial implications and future research suggestions are presented. The aim of the study was to addresses the primary research question: "What are the major application areas, benefits and barriers of IoT implementation in the energy sector?". The design of the study was divided into the following four main objectives:

- To identify priority areas of IoT implementation in the energy sector.
- To evaluate key barriers and opportunities of implementing IoT in the energy Sector.
- Identify key strategies to overcome challenges related to IoT implementation and utilization in energy organizations.
- Also, to evaluate the role of other disruptive technologies i.e. Artificial intelligence and Blockchain in the energy sector.

To address the primary research question and accomplish study objectives a systematic rigorous research process was followed. Basic idea was to identify key application areas, barriers, opportunities of utilizing IoT in the energy sector based on semi-structured interviews with experts in the field. An effort has also been made to identify key strategies and roadmap to overcome challenges related to IoT and other disruptive technologies, so to reduce failure risk of related technologies. In the end, the role of Blockchain and Artificial Intelligence was also evaluated.

5.1 Research key findings

The current research examined what are priority applications of IoT and how IoT are being utilized in those specific areas of organizations. It has also been found out what are the main benefits of using IoT and major technical and non-technical barriers in their implementation and utilization. Discussion with experience mangers from IoT and business domain also revealed different strategies for successful implementation of IoT in different organisations. Based on the retrieved results, it is evident that IoT is being utilized in almost all major application areas of organizations in the industrial ecosystem of the energy sector. However, their utilization level is still in their phase of infancy as it is a phenomenon widely related to the implementation of all emerging technologies. Majority of organizations are utilizing IoT to improve their Information Technology system efficiency and effectiveness. Integrating IoT in IT system enhance organization capability to collect a huge amount of data and use it for decision making. In most cases integrating IoT enable organizations to real time monitor data and this real time, data availability led them to improve their manufacturing and logistics processes. In factory settings, implementing IoT enable an organization to enhance their capability to improve production quality by highlighting the discrepancies and errors in the form of data, efficient asset management through predictive maintenance, and increased awareness about health and safety.

On other hand, it was found out implementing IoT plays important role in product development, customer experience and marine engines energy performance optimization. By monitoring sensors-based movement and conditions, IoT collects insightful information for the end consumer as well as for the manufacturer to look for product improvement and monitor the consumption pattern of the product. Integrating IoT opened many new product lines for organizations as well as added business value to existing solutions. For example, in marine power engines IoT enables management to monitor engine energy consumption and other performance indicators data even when they are offshore, provides useful insights for management to optimize engines performance and report actual performance offshores, along with improved user experience.

As discussed in literature studies shows there are various challenges linked to IoT implementation in the industry which potentially halt or slow down the growth of technology utilization. From interviews results, it can be observed that organizations face three kinds of main challenges, financial, technical, and non-technical challenges.

Among financial challenges, Return on Investment (ROI) is major challenge organizations are facing. For most organizations, transforming from traditional technologies such as SCADA to IoT requires a huge amount of investment, and organizations need to see clear financial benefits to transform their technologies. However, most participants believe organizations have started realizing the importance of implementing emerging technologies such as IoT and AI, and some have already realised clear benefits of utilizing these technologies. It is believed that matter on ROI is short-sighted and upon realization of benefits of introducing IoT, their application in the industry expected to grow in years to come.

From the perspective of technical barriers, integration among the technologies, network and privacy remained prevalent challenges. It was found out that each organization use their own IT and communication systems, which is most of the time customised and hard to complement IoT solutions in their existing systems. Providing an accessible network for streaming real time data is a big challenge for organizations, especially connecting products which are outside organization factory premises. Moreover, several technologies use dynamic IPS and firewall block them to integrate occasionally.

Finally, non-technical barriers such as employees’ behaviour, management commitment, organizational culture and leadership style impact greatly on success or failure of technology implementation. Interviews’ results reflect that most of the organization lacks a strategical approach towards emerging technologies implementation. It was also found out that major cause for IoT related projects failure was ambiguous objectives, lack of scalability, and employees’ resistance to change. To add, in literature studies are scarce which tap organizational culture, leadership style and employee behaviour towards IoT and other emerging technologies.

Furthermore, implementing IoT have several benefits for organizations as compared to traditional technologies. Despite that IoT, utilization is in their early phases as mentioned by all participants, yet organizations started realizing clear benefits such as new value streams, improved product quality, cutting the cost which ultimately gives financial benefits, enhanced user experience, energy efficiency (distribution and reduce consumption), supply chain efficiency and health and safety measures. Moreover, it was also found out that integrating AI can yield much greater benefits while AI and IoT are termed as technologies of the future. Both of these technologies can disrupt contemporary business models and change competitive grounds.

5.2 Managerial implications

The research presents key guidelines for companies on use cases, potential barriers, benefits, and roadmap to successfully implement IoT in different areas of the industrial ecosystem of the energy sector. The essence of the study results is that it expands the applicability of results in different industries also, such as manufacturing companies, logistics and supply chain-based organizations, building heating and lighting solutions-based companies and product development in various industry settings.

To successfully implement IoT, organizations need to follow the systematic roadmap and develop a strategic approach towards emerging technologies. It is recommended for practitioners to invent business cases, clearly define objectives, and try to scale them up, engage stakeholders throughout the journey, and communicate the need for transforming to the new technologies. While on operational level, employees should be trained to acquire the technical and operational skills to utilize the technology as well as to decrease their resistance to change. Also, it is important to map the user journey and take considerations of interoperability, network, privacy, and issue of integration among technologies.

5.3 Future research recommendations

The study suggests three main avenues for future research work:

First is the development of improved IoT framework to tackle networking issue especially in offshore IoT implementation such as in Marine logistics and offshore wind power plants. Further technical development is required to improve privacy and integration among the technologies in IoT framework. A study can be conducted to explore the role of 5G data communication to overcame networking and communication challenges. Resolving such issues in IoT implementation can result in an increase in their application-level on a wider scope in the industry.

Secondly, studies which empirically explore the role of Leadership styles, organizational culture, and change management in the adoption of IoT and other emerging technologies are limited. Thus, this study suggests future researchers explore more on what motivates employees to act positively towards the adoption of IoT and other emerging technologies. Studies can also be taken to investigate which type of leadership style plays an encouraging role towards implementation of IoT and other technologies.

Last but not least, researchers are recommended to conduct a study to evaluate and present business cases for Blockchain technologies, as there is lack of understanding about blockchain technologies business cases and value streams both in academia and industry.

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Appendices

Appendix 1. Interview invitation email sent to participants

I am writing to you to seek your 10-20 minutes online interview based on your experience and expertise in energy industry.

Being one of the leading organizations in (organization speciality), a response from Organization name) on IoTs could be vital in a wider understanding of IoT in academic settings.

I am working on a master's thesis under Prof. Josu Takala, University of Vaasa. The project aims to evaluate challenges and opportunities in the implementation and utilization of the Internet of Things (IoT) applications in different areas of the organization.

Your response in this regard is highly valuable for the project. If you have any questions, regarding this research study in general please contact Prof. Josu Takala at josu.takala@uwasa.fi or you can contact by replying to the same email.

Br,
Shahid Hafeez

Note: In this study, informants will be invited to join semi-structured interviews and interviews are designed in a way which asks more generalized information about the maturity level of IoT in different industries and only the generalized results will be published. There is no risk associated with the research and informants can withdraw anytime.

Appendix 2. Online questionnaire and consent form

IoT interview consent form

1. Your organization name ________________________

2. Please select all major applications of IoT in your organization.

- Financial Services Information technology Manufacturing
- Smart grid Supply chain Transportation & logistics
- Wearables Blockchain technology
- Other (please specify) ______________________

3. Please select all major IoT utilization in different areas of your organization.

- Asset Management Customer Experience Environment Finance
- Product Development Safety Other (please specify) __________

4. Please select all major challenges your organization faced in the implementation of IoT.

- Access control Authentication Integration among technologies Mobile security
- Network challenges Privacy Cooperation among departments Policy enforcement
- Skilled persons Lack of international norms and security Return on investment Trust
- Too few best practices Other (please specify) _____________

5. Confidentiality Disclosure:

The interview will be recorded and the researcher in discussion and the supervisor will have the exclusive access. However, you may use a pseudonym for your introduction and your anonymity will be ensured.

You have the right to withdraw at any moment and you may request to destroy your information.

Agree

Disagree

Appendix 3. Interview questions list

1- Please introduce yourself, your organization, your title in the organization and how long you have been in this organization?
2- Can you explain your organization business and main products?
(Is your organization an SME or a large enterprise?)
3- What kind of IoT technologies are used by your organization / clients?
(What kind of IoT related projects you have been involved?)
4- How did you overcome major challenges related to implementation and utilization of IoT in your organization / while implementing in client's organizations? (challenges mentioned in the short survey)
5- What was the response of employees to this change, how was the acceptability of IoT in your organization?
6- How do you think implementing IoT helped your organization /clients?
7- In your opinion, to what extent IoT proved beneficial to your organization in terms of convenience, earning new revenues, making company more efficient, saving money, and increasing energy efficiency?
8- Has your organization / client ever felt that it should revert to the traditional business practices rather than using IoT?
9- In your opinion how does IoT contributes to sustainable business practices?
10- Do you use blockchain technology in your organization? what are the main benefits and limitations - in your perspective?
11- What do you think is the future of your organization and industry based on advancements in AI and other similar technologies?

Note* Interviews were conducted in semi structured settings, additional questions were also asked from participants based on the ongoing discussion.