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Internet of Things towards Energy Sustainability: A Critical Analysis

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"The ultimate test of man's conscience may be his willingness to sacrifice something today for future generations whose words of thanks will not be heard."

– Gaylord Nelson

As the quote suggests, the ultimate aim of this paper is to throw light on energy sustainability and it promotes the endeavors taken by our country for sustainable development. Therefore, this paper will highlight the integration of the Internet of Things (hereinafter referred to as "IoT") and the smart grid technology for better utilization of resources, energy consumption and sustainability. This paper will critically analyze the pros and cons of such integration. The rapid development and implementation of smart and IoT-based technologies have allowed for various possibilities in technological advancements for different aspects of life. The main goal of IoT technologies is to simplify processes in different fields, to ensure a better efficiency of systems (technologies or specific processes) and finally to improve life quality. Sustainability has become a key issue for population where the dynamic development of IoT technologies is bringing different useful benefits, but this fast development must be carefully monitored and evaluated from an environmental point of view to limit the presence of harmful impacts and ensure the smart utilization of limited global resources. The main agenda of this paper is to come to a better conclusion about such integration of the Internet of Things and the smart grid technology and will be an eye-opener for the promoters of energy sustainability.

Keywords: Internet of things, Energy, Technology, Sustainability, Integration

I. Prelude

Basically, the Internet of Things has emerged as an enabling technology for the smart gird, smart health, smart transport, smart environment and smart cities. Smart home appliances distributed renewable energy resources and power substations are the major smart grid devices.[i] By making use of the IoT technologies, smart grid technology has enhanced two-way communications between energy service providers and its users and empowered access to constant information that is being utilized to make financially efficient and environment friendlier choices. With the present reliable wireless applications, utilities can interconnect essentially the majority of their assets. For instance, meters and substations can be associated with one another, just as an interface with company vehicles and employee devices. Such connectivity will make never before acknowledged efficiencies.

From making energy supplies more efficient to the consumers and to sustaining the utilization of power by making use of renewable energy resources for the future needs, all these agendas require such kind of integration. However, this paper will also emphasize whether IoT has actually proved to be a milestone for achieving energy sustainability or not. There are certain studies which show that the electrical grids are not yet smart. They face difficulty when it comes to managing the intermittent of renewable energy resources such as solar and wind and rather rely heavily on fossil fuels. There are various policies of the government that have also worked in this particular direction which will be discussed in a separate chapter. Also, the paper will emphasize that there are challenges faced when it comes to the point of reliability because of serious security and privacy issues. However, the improvements to the environment as a whole cannot be ignored.

II. Role Of Internet of Things And Smart Grid Towrds Sustainanble Development

The Internet of Things (IoT) has recently emerged as enabling technology for the smart gird, smart health, smart transportation, and smart environment as well as for smart cities. The conceptual model of the seven domains of the existing smart grid has been developed without consideration of the IoT concept. As the smart grid evolved, there were many attempts to introduce the IoT to the grid as enabling technology. It is possible to consider each device in the grid as an object. Each device can use the IoT concept to have a unique IP address that can upload its status and download control commands over the Internet.

The IoT system consists of three layers: the layer of perception, the network layer and the layer of application.[ii] “The perception layer includes a group of Internet-enabled devices capable of perceiving, detecting objects, collecting information about systems, and exchanging information through Internet communication networks with other devices.” “Sensors, Global Positioning Systems (GPS), cameras, and RFID (Radio Frequency Identification Devices) are examples of devices at the perception layer. The network layer is responsible for transmitting data from the layer of perception to the application layer under the limitations of the capabilities of the devices, the limitation of the network and the constraints of the applications. IoT systems use a combination of Internet and short-range networks based on the communicated parties”[iii].

“Short-range communication technologies such as Bluetooth and ZigBee are used to transfer information from devices of perception to a nearby gateway. Other technologies like Wi Fi, 2G, 3G, 4G and Power Line Communication (PLC) carry the application-based information for long distances.” The upper layer is the application layer, where incoming information is processed to induce insights on which to design distribution and management strategies for better power. Applications are aimed at creating smart homes, smart cities, power system monitoring, demand-side energy management, distributed power storage coordination, and renewable energy generator integration.

i. Smart homes and smart cities

“The IoT technology is highly expected in smart grid applications to result in smart homes and appliances such as: smart refrigerators, smart TVs, home security system, lighting control, fire detection, temperature monitoring. These systems and appliances include sensors and actuators that monitor the environment and send data on monitoring to a home control unit.” The control unit allows householders to monitor and control the electrical appliances continuously and fully. It also uses monitoring data to predict future activities to prepare for a more convenient, comfortable, secure and efficient living environment in advance.

A group of neighborhood smart homes are connected to form a smart community through a Neighbor Area Network (NAN). Homes share the results of their outdoor surveillance cameras in a smart community to detect any accidents and may inform police stations. Other smart community concept applications are in health care, shared resource management, and social networking support. The smart community concept is expanded in order to develop a smart city in. A comprehensive monitoring system is developed in a smart city to monitor various activities within a city or country as a whole.

ii. Online monitoring of power lines

“As more buildings and areas are covered by power line systems, the number and severity of power outages increase, resulting in less reliability of the system. Reliability is important because it has serious adverse effects on public health and economic systems. The integration of IoT technology with the power grid aims to improve the reliability of power grids by continuously monitoring the status of transmission lines; in addition to environmental be3rhaviors and consumer activities to send regular reports to the grid control units.”

The control unit process and extract information from the reported data in order to detect faults, isolate the fault, and then resolve faults intellectually. Performing energy restoration in smart grid must consider the location of criticality of blackouts. For example, it is critical to guarantee high reliability for health and industrial systems. The restoration problem becomes a very complex problem when taking into the consideration the large number of combinations of switching operations which exponentially increases with the increase in system’s components[iv].

In a hierarchical model, designing the smart grid divides the problem into multiple control units responsible for restoring power within its region or scope. This increases the time required for data processing and speeds up the process of restoration. If some control units fail to restore energy within their scope in some regions, they will forward the issue to higher levels for better action and handling as higher levels are viewed by a larger system.

iii. Demand-side energy management

Demand-Side Energy Management (DSM) is the change in the energy consumption profiles of consumers according to varying electricity prices over time and incentives of other payments from utilities. Application response is used to minimize consumer electricity bills, shift peak load demand, minimize power grid operating costs and minimizes energy loss and greenhouse gas emissions[v].

IoT components collect energy requirements and send them to smart meters from different home appliances. In a strategy that minimizes the electricity bill, the control unit in smart grid schedules energy consumption of home appliances according to user preferences. At various levels of the hierarchical smart grid infrastructure, the DSM problem can be solved. It can be solved at home level to protect the privacy of consumers. It can also be resolved at higher levels to produce a more efficient scheduling plan that benefits not only consumers but also the utility company[vi].

iv. *Integration of distributed energy sources*

For environmental reasons, climate change and its low cost, renewable energy generators are being integrated into today's power grid. This reduces greenhouse gas emissions that raise the temperature of the Earth. Many governments, organizations, and individuals have begun installing solar cells and wind turbines in recent years to meet some of their power requirements. For example, Germany plans to fully meet its energy demands by 2050 using renewable energy sources. There is a shortage of renewable energy that has led to significant improvements in storage technology.

In order to help predict energy availability in the near future, IoT technology uses wireless sensors to collect real-time weather information. The accuracy of the projected power amounts is crucial for energy scheduling models during the next time intervals. In research to efficiently manage renewable energy sources within the smart grid, various strategies and optimization solutions have been developed.

v. *Integration of electric vehicles*

Electric vehicles (EVs) are used as devices for energy storage while idling. They also provide transport services that are efficient and clean. Developing effective scheduling techniques for charging and discharging electric vehicles can potentially reduce emissions, shave peak loads and increase the percentage used for generating renewable energy[vii].

In order to improve the efficiency of charging and discharging scheduling algorithms, perception devices collect information about the identity of electric vehicles, battery state, location, etc.Smart grid communication is based on technology for wireless and wired networks. These networks can be classified within the smart grid, regardless of the technology, based on their functionality. These classifications are: home area network, neighbourhood area network, network access, backhaul network, core and external networks, as reported in the literature.[viii] These networks connect many smart grid objects such as home appliances, smart meters, switches, re-closers, bank condensers, integrated electronic devices (IEDs), transformers, relays, actuators, points of access, concentrators, routers, computers, printers, scanners, cameras, field test devices, and other devices. All these appliances and devices are distributed geographically throughout the grid, starting from residential units to substations and up to utility data and control centres.

III. POLICY AND FRAMEWORK IN INDIA

In order to achieve the various objectives of energy sustainability with the help of IoT, the government has taken initiatives to improve the standards as well as keeping a check on the development and maintenance of integrating IoT with the energy sector in India. Following are the bullet points describing each one of the initiatives taken by the Government of India:

i. Initiatives:

Department of Electronics and Information Technology (DEIT) of the Ministry of Communications and IT:

In October 2014, it released a draft of IoT policy. The main objectives[ix] behind introducing this draft policy are as follows:

a) By 2020, there is a target to achieve a $15 billion IoT industry in India. It is also analysed that India will have 5-6% share in the IoT industry at the global level by the end of 2020 because of the increasing no. of connected devices from $200 million to $2.7 billion with the number of connected devices rising from about $200 million to over $2.7 billion.
b) Develop capacity for IoT-specific skill sets on both the human and technological fronts, focusing on international and domestic markets.
c) Enabling R&D of technology support.
d) To enhance products of IoT in multiple domains that are specific to Indian needs.

Ministry of Power with the inputs from India Smart Grid Forum (ISGF) and India Smart Grid Task Force (ISGTF):

Smart Grid Vision and Roadmap for India, 2013- Smart Grid Vision for India is to "*Transform the Indian power sector into a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of stakeholders*". With an aim to achieve this vision, stakeholders are advised to devise and formulate state/utility specific policies and programs in alignment with the following broad policies and targets which are in consonance with Ministry of Powers's overarching policy objective of "*Access, Availability and Affordability of Power for All.*"[x]

ISGTF- It is an inter-ministerial group which was formed to serve as a government focal point for activities related to the Smart Grid. The main functions of ISGTF are to ensure awareness, coordination and integration of diverse activities related to Smart Grid technologies, practices and services for Smart Grid research and development; co-ordinate and integrate other relevant inter-governmental activities; collaborate on interoperability framework and review and validate the recommendations from ISGFT.[xi]

ISGF- It is a public-private partnership initiative of Ministry of Power (MoP) for accelerated development of Smart Grid technologies in the Indian power sector. ISGF advises the government on policies and programs for promoting Smart Grids in India; working with national and international agencies in standards development and assisting utilities; regulators and the industry in technology selection as well as training and capacity building.[xii]

National Smart Grid Mission (NSGM), 2015-To further plan and undertake the smart grid developments in the country, there was a unanimous demand for launching a National Smart Grid Mission (NSGM) during the stakeholder consultations in 2013. Therefore, the Government in 2015 approved the framework of NSGM which was proposed by the Ministry of Power with inputs from ISGF and ISGTF. It is an institutional system for planning, monitoring and implementing policies and projects regarding Smart Grid operations. The NSGM offers help to Smart Grid Projects through assistance in formulation (prefeasibility analytical studies, cost-benefit strategies, financial modelling etc.); partial project funding; training and capacity building; customer commitment and project appraisal. The endorsement has been agreed for activities recorded above and costing INR 980 crore including a budgetary help of INR 338 crore from the Government of India amid the twelfth arrangement time frame.

The Department of Telecommunications (DoT)-The Union Minister of Communication and Information Technology has released the 'National Telecom M2M Roadmap' in April 2015. The main agenda for this roadmap was to act as a sole reference instrument for all stakeholders in India involved in machine-to-machine communication (M2 M). On 1 July 2015, in Bengaluru, Karnataka, India's first Center of Excellence (CoE) on IoT was launched. The National Association of Software and Service Company (NASSCOM), Department of Electronics and Information Technology (DEIT) and Education and Research Network (ERNET) has jointly set up the CoE which has allowed various start-ups to build their own prototypes and standards to test them. Though this initiative is not mainly focused on the energy sector but it helps the M2M/IoT stakeholders to test and conform with the various standards. It mainly focuses on creating alternatives for applications like agriculture, automotive, telecommunications etc. DoT's technical arm, officially known as The Telecommunication Engineering Center (TECI), has also begun its operation on Indian - specific IoT standards in line with evolving international standards.

National Telecom Policy (NTP) 2012-It acknowledges M2M / IoT's concept and potential. The main provisions for initiating such a policy are to facilitate the role of new technologies through affordable access and efficient service delivery in promoting public welfare and enhanced customer choices. Development of new service formats such as Machine-to-Machine (M2M) communications represents massive options, especially as their roll - out becomes more prevalent.[xiii]

The role of the Government of India in facilitating the participation of the private sector-The private sector has a very important role to play in realizing the vision for 100 smart cities. The Minister of Urban Development acknowledged this and stressed that private investment is the key to the construction of smart cities.[xiv] Besides attracting investment in aspects such as energy, infrastructure, socio - economic opportunities, etc., the Indian government contemplates that the country's plan to introduce 100 smart cities could lead to a significant and rapid integration of IoT in the country.[xv] Recognizing the need to allow private sector firms to support private sector organizations and firms, especially those operating in IoT and M2 M spaces, the DEIT has implemented a memorandum of IoT Policy, the objectives of which have been mentioned in the paper before.

ii. Projects and Challenges in India

The MoP, Government of India, has allocated 14 pilot programs in the country to kick - start smart grid technology demonstration projects to various distribution companies in different states. The joint expense of these undertakings is about $ 68 million, and in the subsequent stage they are likely to allow technology section guides and business case advances for larger projects. Most of these undertakings are supported by the MoP (50 percent of GoI's costs). A brief description of the major pilot projects that are in different phases of execution is shown in this segment.

One of the major projects is "Assam Power Distribution Company Limited (APDCL)) smart grid pilot project" which is located in Guwahati Distribution Region, Assam. It mainly works on various aspects such as AMI, Renewable Energy Integration, Peak Load Management, Outage Management, Power Quality. Nitin Bansal, head of networks at Ericsson India, also stated his views about this project and mentioned that "industry readiness is definitely there". "The opportunities here in India are immense, and India could potentially play a pivotal role in the development of global IoT ecosystem both as a market and as an innovation hub."[xvi]

"We have recently done a pilot with Assam Power Distribution Company for a smart meter project in which we will provide a comprehensive Advanced Metering Infrastructure (AMI) solution for operating 15,000 smart meters, along with systems integration and support services in Guwahati. The solution will offer outage management, reduction in aggregate technical and commercial losses, power quality management and net metering. The smart meter deployment is a key component in the transformation of power supply to significantly better the energy usage and distribution while reducing CO2 emission."[xvii] There are various other projects namely Chamundeshwari Electricity Supply Company (CESC), Mysore, Uttar Gujarat Vij Co. Ltd., (UGVCL), Gujarat etc. Some of the projects which came under the National Smart Grid Mission are Chandigarh Electricity Department Chandigarh mainly focusing on AMI, DT monitoring, S/S Automation, Rooftop Solar PV etc. and many other projects.

However, India faces significant challenges when enforcing projects such as IoT and M2 M technologies, by rationalizing resource consumption, are expected to decrease environmental issues. However, it is important to acknowledge that there is also a significant footprint for all parties concerned in the information and communication technology (ITC) sector with regard to manufacturing, power requirements and e-waste generation. It is estimated that by 2020, the global ICT sector will emit approximately 1,100 million tons of CO2, with its contribution estimated to rise from 1.3% in 2007 to approximately 2% in 2020. [xviii]

"A shift from the traditional approach to manufacturing smart city technologies with a green manufacturing approach is therefore important. This is important because resource stewardship will be an important prerequisite for companies to thrive in the decades to come".

IV. Challenges Under Internet Of Things: Security And Privacy

As IoT ends up being significant in our regular day to day activities, ranging from industrial controls to individual gadgets and infrastructure, for example, transport and power, the issues regarding security in these situations turn out to be extremely complex and have grave results. IoT offers abuse and critical security risks to more vulnerable hackers. Depending on the nature of the information and the devices it refers to, such risks may take different forms. A malfunction of the system or a dangerous attack could have dire consequences on such gadgets or devices.

Emphasizing energy grids and Smart Grids, IoT technology poses some of the key issues like grid security, distribution network failure, line losses, and overloading. Since energy resources are becoming exhaustive day by day, the global perspective has moved towards accomplishing energy conservation and green energy by employing IoT technologies in the energy sector. IoT applications have empowered power utilities to control resources from anyplace, and anywhere. For sustainable development with the help of the renewable energy resources, the IoT technologies bring answers for some of the key issues relating to renewable energy establishments, plant and performance monitoring, and fault management.

Hackers could target smart meters in the energy context to cause major blackouts, and it takes little imagination to consider the potential effects of a system failure or malicious attack in the home security context.[xix]

For instance, Google and Cisco, the mammoth companies are familiar with security problems and are trying to tackle the same. The most ideal approach for addressing security issues in devices at the design stage itself is to always upgrade gadgets from potentially possible risks. In addition, legislative and legal improvements should be made to deal more effectively with security issues. The following investigation to be considered is whether we require a separate law at national level or whether international law is a prerequisite. One proponent contended that, given the multiple factual scenarios that may arise, a homogeneous legal framework governing all facets seems to be hardly possible. In addition, while framing any legislation, "a heterogeneous and differentiated approach" would be needed. [xx]Because of the inclusion and intermingling of the electronic world, national legislation may not be the best way to deliver security issues, but any international mechanism would also face difficulties in terms of jurisdiction and applicability.

Some of the key security and privacy issues includes:

a) Impersonation or Identity Spoofing: An attacker can impersonate someone else to make him pay for that person's energy consumption. This is essentially communication in an unauthorized manner on behalf of a legitimate thing by impersonating the identity of someone.
b) Eavesdropping: Using public communication done through Smart Grid objects or devices and gaining access to their exchanged data. This will ultimately help the attacker clearly understand the households ' energy usage.
c) c)Data tampering: Modifying exchanged data and can mislead the consumers regarding the prices during the peak periods.
d) Privacy issue: The data exchanged between the service provider and the user tells more than the energy consumption. It also indicates their habits such as their wake-up time, sleeping time or could even tell when they left out of the house or when they entered, if they are on a vacation etc. Thus, these kinds of private information about a user can be easily identified in residential houses through their smart meters and smart appliances and thus a hacker can hamper a user's privacy.
e) Compromising and Malicious code: A hacker can target different kinds of software present in the objects and devices of the smart grid as they are computation and communication enabled, thereby creating software or malicious code infection.
f) Cyber-attack

Smart Grids are basically the largest Cyber Physical System (CPS) that includes physical processes representing smart grid tangible assets such as transformers, smart meters, cables, etc. The Internet and Communication technology actually controls or managed these physical entities, thereby making them vulnerable to cyber-attacks which could directly harm the physical assets.

There are also challenges when designing security algorithms or protocols and policies to address issues such as designing optimized security solutions such as data management and data encryption, as smart grids can span large areas and involve a large number of smart devices. Because of the above reason, protecting the physical perimeter where the smart grids are established is very difficult. A hacker can easily access the physical perimeter, so it is necessary that any attempt to tamper with the same should be detected by the security solutions. Also, resource restrictions are on smart devices and objects. Special care must be taken to ensure that the limited resources can accommodate the solutions. The classic example of applying such a security solution is based on either public-key cryptography or PKI, although it is a challenge due to resource constraints. Achieving secure end-to-end encryption is a challenging task due to the heterogeneity of smart grid device resources such as memory computation, bandwidth, time-sensitivity, and their protocols and communication stacks being implemented. Even some devices and objects that cannot support TCP / IP stack (e.g., Zigbee, HART, etc.) are unable to communicate with IP-based devices that make end-to-end encryption very difficult. All these challenges therefore needed to be overcome.

There are many such security and privacy issues but the main question which lies ahead is:

How can these issues be tackled?

Some of the recommendations that would be beneficial for implementing IoT in the energy sector may be implementing the authentication of each smart grid meter to associate a user with it in order to effectively identify him or her. It is very important to ensure that a user has to be associated with the identity of any device or object in the smart grid. The data exchange between a user and an energy supplier must be confidential, protected, encrypted and should not be altered in any unauthorized way. Smart meters should therefore ensure a software update's integrity as well as the source of origin. When entering into a contract with an energy provider, guarantees should be given that the data on energy consumption should only be used for billing purposes and not for any other purpose in order to maintain the privacy of the user. The on-field agent should also have the authorization, access control rights and the prerequisite for performing the manual configuration on a smart meter. To overcome these problems, it is an alarming need to make the legal framework robust. Therefore, these issues must be addressed as immediately as possible in order to effectively fulfill the main agenda with which such integration took place.

V. Conclusion

"In conjunction with the smart power grid, the Internet of Things (IoT) technology is being developed to make our daily lives smarter and easier. The author discusses IoT technology applications in the power grid as well as integrating renewable energy sources to achieve sustainable energy and climate change prevention. The author emphasizes the need to manage and store the big data collected in the IoT from various sensors and meters. In a highly distributed environment such as the smart grid, reliability and low latency are two goals." The application of stream processing on the architecture of fog computing supports a well-designed platform in the smart power grid for real-time applications. Over the past several decades, the Information System(IS) has played a key role in globalizing the global economy. For many organizations and industries as a whole, it has been a transformative force; enabling them to reduce costs, create new products and services, and interact more effectively with customers. Sustainability, however, is a relatively untouched information-intensive opportunity as businesses have become information-intensive. People's Internet (e-mail, social media, websites, etc.) has dramatically changed the nature of people-organizations communication.

The Internet of objects is created by the emergence of sensor networks, sensitized objects and their connection to universal networks. Information systems that connect people's Internet and objects ' Internet will lay the foundation for advancing sustainability in the environment. People will receive disaggregated information about their objects ' environmental impact and that deployed by others. *For example*, they will be alerted instantly when the energy consumption of their air-conditioning unit is beyond reasonable limits for the current weather and time conditions and can act remotely to solve the problem. *For example*, as they can now track a thunderstorm on their smartphone, they will also be able to visually follow the pollution plume of each coal-fired power station for their region. They will be able to deploy information systems that evaluate the impact on their health of current pollutants in their locality. The hidden effects of environmental damage will be revealed by sensor information. If C02 were purple, we would venture to claim that we would soon be very alarmed as the sky becomes violet every year.

On the demand side, increased use of social media will have transformative potential for green IS, promoting better practices in neighbourhood and cities, reducing the environmental burden. For example, emerging applications for carpooling and ridesharing can lead to reduced transportation environmental impact. Shared transportation can then be guided along the most efficient routes in conjunction with the Internet of Things. The emergence of self-driven cars is a transformational change in itself. Adding things to the Internet transportation can make them sensors.

These sensors can capture what we cannot perceive and transform it into information we can perceive and prompt transformative actions. This two-way, sensor-driven communication blurred the boundaries between the side of production and the side of demand, as is the case with the utility industry's "smart grid." Through emerging technologies such as 3D printing, wearable technologies, etc., similar macro-transformations are possible. Personally, the author believes that this should be the field's predominant research mission for the next few decades as sustainability is the most important issue in the world. It is truly

transformative for business and society, so IS research, both in its processes and outcomes, should also be a transformative opportunity.
Such transformation cannot be achieved through any one field's narrow lens. It is our hope that the IS field will be able to build collaborative bridges to attract researchers from various fields (environmental sciences, public policy, engineering, etc.) It is a critical core of sustainability-oriented trans-formations, and the affordance framework presented in this particular issue is the right start for thinking about green IS design, but only a beginning. The author provided an overview of the role played by smart grid in promoting sustainability of energy. On the power generation side, smart grid technologies can effectively improve the amount of intermittent clean energy generation in the power system, improve energy utilization; smart grid can also promote energy savings in power grid connections. The paper demonstrated that smart grids can make a significant and comprehensive contribution to sustainability of energy and the environment, save energy and reduce emissions, and mitigate environmental degradation and climate warming.

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