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Using ICT for Mongolia's sustainable development in energy industry

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Abstract

Nowadays every technology is becoming smarter. Consequently, intensive use of ICT in the whole industries and cities enables a sustainable approach to meet enormous productivity, efficiency, transparency and conservation of natural recourses. Likewise, the role of ICT in terms of controlling, monitoring in the energy industry allows integrating potential renewables, bulk energy conservation and reliable optimized operation in the entire system. In this paper outlines challenging issues in renewable energy integration in Mongolia and proposes potential recommendations and conclusions. The author investigated the main technologies used in energy industry mainly smart grid, challenges and policy aspect in Mongolian energy sector by using the primary and secondary approach with case studies and literature based methodologies. Based on the policy aspect and current implementation of smart grid, the paper tries to address the readiness for the main application and future potential ICT driven applications. Furthermore, it concluded that ICT convergence is demanded to overcome the current vulnerabilities and significant momentum to leave behind by using its potential energy recourses and favorable geographical state. Policymakers may find this study useful, as it answers the question of whether ICT investment can ultimately reduce energy consumption and may aid in future planning. Even tough, in order to develop a smart grid and integrating renewables firstly set an appropriate market structure, ICT will key enabler to make energy system more profitable and sustainable. Regarding the result of this study, ICT deployment contribution is a huge demand for future opportunities energy in Mongolia.

Keywords Mongolia, ICT, smart grid, sustainable development

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1. INTRODUCTION

The energy is a fundamental driving force for economic development and environmental sustainability for the entire world. In order to reach sustainable development goal, access to affordable, reliable and sustainable energy is vital through cutting poverty, encouraging infrastructure and promoting shared prosperity. In this modern era, sustainable energy production and decarbonization are playing a key role to establish wellbeing society and inclusive cities. Therefore, energy systems must approach sustainable production, provide reliable energy, meet environmental and social objectives, recover operating costs as well as invest for the future in order to embody sustainable world. In the context of global warming, decarbonisation, energy production is a critical part of this agenda. However, there are still big challenging issues remained in terms of primary needs of physical and infrastructure for mankind. Disputes associated with critical air pollution, climate changing, global warming, water crisis and growth of population have required the world to unite. Hence, colligating agreements what pledge to reach significant consequence in terms of sustainable future. Paris summit was a significant symposium to strengthen the global response to the threat of climate change to keep the temperature by giving joint effort representatives among 196 countries. With this in mind, whatever we can do is, every unit should be responsible on their own. It seems that we can make more environmentally through upgrading existing condition. Importantly, the energy industry has a commitment to decrease operations, impact to the environment. In terms of primary energy, coal has been the second dominating recourse followed by oil since the 1970s. Especially, China, US, and India which are in charge of 70 percent of total coal consumption have more responsibility for the commitments with coal production. Besides, many developing countries have been using old technologies where need outside investment.

As declared in the 7^{th} global sustainable development goal, the energy industry needs to ensure access to affordable, reliable, sustainable and modern energy for the citizens in order to reach sustainable development goal through installation and integration of renewables (United Nations, 2015). The climate has been changing increasingly due to the production of energy linked to economic growth, population growth, and human activities in the 21st century. The energy sector considered as the largest contributor to the GHG emissions. In 2010, it revealed that 35 percent of global GHG direct emission came from energy industry (World Energy Council (WEC) and Cambridge University, 2014). Besides, world cities represent 65% of global energy demand and produce 70% of CO-2 emissions. For this reason, global renewable electricity capacity has overtaken coal to become the world's largest installed power source for the first time. According to IRENA (International Renewable energy agency), half a million solar panel is being installed these days. A total of 153 GW of renewable power capacity was installed during 2015 which is more than the entire generating capacity of Canada (WEC, 2016). For example, in our neighbor the biggest nation, China half a million solar power panels were installed every day and two wind turbines were set up every hour in 2015. The IEA forecasts that rapid renewable expansion will continue, with 825 gigawatts of capacity expected to be built by 2021. These great numbers can illustrate that renewable energy has a significant role in the sustainable energy industry.

In the recent decades, Information Communication Technology (ICT) is addressing the key issues all the aspects above. In this digital era, optimized energy production, smart grid, and smart home are changing the traditional lifestyle and old road maps. The implementation of smart grid has started systematically in Mongolia by ensuring the flexibility. The existing grid was developed as a central approach with relatively few large-scale power plants operating at 50 Hz interconnected by high voltage AC transmission systems, a large number of distribution lines supplying the loads after voltage reduction. Recently, renewable energy system which produces a few kilowatts in the case of photovoltaics up to some megawatts in the case of large wind turbine and solar, are rapidly deploying throughout the world, are transforming the traditional system into a large distributed system which comprises thousands of generators, designed by different technologies, voltage, current, and power levels as well as topologies. When the two system and renewable integration itself meets among them, intelligent approach which called as a smart grid enables grid managements and energy storage which enhances load balancing and needed for for overcoming energy fluctuations owing to the unpredictable nature of renewable energy system (RES), preventing widespread power grid cascading failures and enabling the plug-in hybrid and electric vehicles while increasing the energy efficiency. So that providing the back up to meet the demand and reducing the emissions from transportation (V. Cagri Gungor,D.S, Taskin Kocak, S.E, Concettina Buccella, C,..Gerhard P. Hancke, February 2013), (IEA, 2011).

In order to realize the current state of ICT deployment among smart grid in Mongolia and to foresee the further challenges, the theoretical framework of implementation stage of smart grid needed to take into account. It has been assumed that the smartening the energy system is an evolutionary process, not a one-time event. For instance, while The Republic of Korea initiated roadmap comprised three phases with the investment of 24 billion USD by 2020, Europian Union and China planned 56 billion USD by 2020, 101 billion USD by 2030 respectively (Vincenzo Giordano, Flavia Gangale, Gianluca Full, Manuel Sánchez Jiménez, 2011), (Ministry of Knowledge Economy and Korea Smart Grid Institute, 2010).

The smart grid contribution to policy goals explained by different aspects. Although, sustainability, competitive and efficient market, reliability and quality of supply, consumer services and benefits, as well as data analysis and security, are the common highlights linked to ICT-enabled smart grid (Vincenzo Giordano, Flavia Gangale, Gianluca Full, Manuel Sánchez Jiménez, 2011), (G. M. Shafiullah, Amanullah M. T. Oo, A. B. M. Shawkat Ali, Peter Wolfs , 2013).

Meanwhile, Mongolia is the 9th big coal exporters in the world. However, Nevertheless, when looking into the coal production or total installed capacity of energy production, it's instantly 100 times less than China. Although there is a huge potential of renewables, the country still has been a capacity shortage and pays for the importation. Air pollution and its effects are appalling due unplanned urbanization and obsolete energy production. Nonetheless, strengthening installed capacity and intensifying the integration of renewables absolutely can be one of the solutions for the challenging issues. On the other hand, Mongolia has an abundant energy resource including coal, the wind, and solar which can reach 15000 TWh per year using solar and the wind according to the IRENA (Ministry of Energy of Mongolia, IRENA, March 2016). At present, smart grid initiative started deploying throughout the country involving entire 5 distribution networks (Mongolia M. o., 2017). Considering the challenging issues, several technical and non-technical barriers have to be addressed in order to deploy effective smart grid roadmaps.

Firstly, The paper aims to give a comprehensive understanding of effective deployment of the ICT-enabled energy system to the policy makers and young researchers through introducing pilot smart grid initiatives and demonstrations as well as addressing smart grid contributions to the sustainable energy industry. Secondly, tends to evaluate the current state of ICT convergence in Mongolian energy sector and barriers conducting SWOT analysis in the aspect of information communication technologies in smart grid as well as a comparative analysis with the leading countries in ICT convergence in terms of smart grid implementation phases. Thirdly, the paper aims to give recommendations and conclusions considering potential barriers and readiness for future smart grid deployment. Therefore, to explore common smart grid issues and potential barriers addressed by the international researcher, research on Mongolia's energy policy and potential opportunities, investigates future smart technologies and trends.

2. BACKGROUND

The biggest energy distribution network namely “Ulaanbaatar electricity distribution network” state-owned joint stock company, provides energy distribution and supply services for the capital city of Ulaanbaatar and 17 more administrative units in the central region with 260000 targeted customers (UBEDN, 2017). Ulaanbaatar electricity distribution network implemented smart grid technologies in the 2010s. Currently, a reformation project replaced electro-mechanical and impulse type meters with electronic and smart meters has been implemented in several phases. So far, 57 % of our customers have been provided with electronic and smart meters. Furthermore, the aims to complete the installation and acceptance of Distribution control and management SCADA-based system and system information and planning "Titem" system (UBEDN, 2017).

Mongolia is generating 77 percent of its total primary energy supply (TPES) from coal. Mongolian integrated energy system consists of 1139,75 MW installed capacity with electricity, 2818 Giga calorie MW with thermal energy (D.Enkhbolor, T.Azjargal, B.Suvd, 2015). However, the country recognized as the 9th big exporter of coal, low access to electricity in suburban areas and isolated regions highlighted as a shortcoming. In addition, the importation from neighboring countries is constantly increasing, which is leading the country to be highly dependent on importation (MoE, 2016). The annual growth of energy consumption will be at least 3.5 percent to 6 percent according to the energy master plan (LLC, 2014). According to energy master plan, it will need to have extra demand for 438 MW of electricity by 2020, 993 MW by 2025 (ERC, 2016). Although feasibility studies and power plant projects have been discussing beyond this a few projects have been discussing out of 67 special licenses (Parliament of Mongolia, 2016). The first problem associated with ICT refers to the smart grid can be addressed in the aspect of renewable energy integration. That is to say, small and medium scale renewable energy producers participate in the same market with a traditional system which is dominated by middle-scale conventional power plants encounters regulation issues. Secondly, old and obsolete infrastructure and lack of investment for it and poor awareness in this matter has been addressed. Thirdly, Mongolia vulnerable understanding about smart grid among public and inadequate consumer engagement considered as a problem in the aspect of effective smart grid implementation.

3. LITERATURE REVIEW

Information and communication technology (ICT) consumes energy, but also it has an important role in energy conservation (Friedemann Mattern, Thorsten Staake and Markus Weiss, 2011). Likewise, the current trend on energy industry determined as economically, environmentally and socially (IEA, 2011). The use of ICT in energy industry enables an intelligent system so-called smart grid by using millions of sensors, activators, powerful hardware and software and IoT devices. In today's digital era, the role of ICT in the all aspect of industry, manufacturing, logistics, healthcare, enterprises, energy and governance are explained as an improved productivity, effective, efficient and smarter way to reach the goals, sustainable and resource saving attributes. Therefore, attention to the ICT roadmap, ICT-based initiatives has been constructive policy accelerator for nations and unions to overcome the challenges and vulnerabilities of climate changing and recourse saving issues. For instance, The European Commission noted that Europe will meet 20 percent reduction of greenhouse gas through deploying ICT for energy efficiency by 2020 (Lorenz M. Hilty, Vlad

Constantin Coroama, Thomas F. Ruddy, Esther Thiébaud Müller, 2009). It is estimated that 70 billion of the 400 billion kWh on annual electricity consumption in private homes across the EU could be saved without any restriction in their daily lives (EICTA, 2009). Similarly, The Global Information Infrastructure Commission (GIIC) stated that the change of the behavior of business and consumers are given by ICT can help the environment without economic sacrifice (GIIC, 2008). The relationship between ICT and its economic, social and environmental importance have been becoming an increasingly interesting topic in the last decade as well as tend to stand attractive in the future (Youngsan Cho, Jongsu Lee, and Tai-Yoo Kim, March 2007), (Accenture and The Global e-Sustainability Initiative, 2015).

3.1 Information communication technologies in smart grid

The definition of smart grid assumes that the smart grid is the electricity grid that integrates information technology with communication that supports two-way communication across the energy system. In other words, smart grid briefly understood as a convergence of ICT into energy system in order to ensure enable informed participation by customers, accommodate all the generation and storage options, enable market and new product, provide power quality, optimize asset utilization and operating efficiency, sustain flexible and environmental energy production (IEA, 2011). The variety of technologies used in the smart grid together refers the significance of the smart grid. Below Figure 3.1 (Technology categories and descriptions adapted from NETL, 2010) shows the technology area in the smart grid. The technologies comprise different systems, hardware, and software.

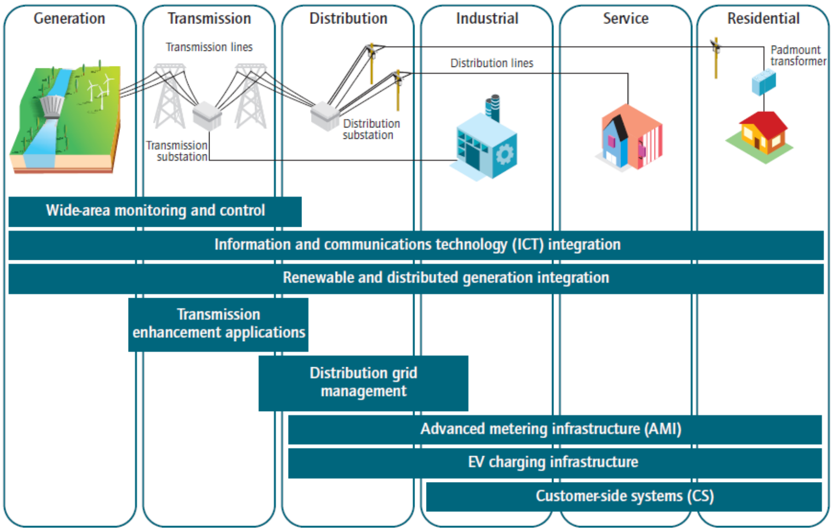

Figure 3.1 Smart grid technology area

As shown in Figure 3.1 wide area monitoring and controlling applications usually used in generation and transmission systems through phasor measurement units (PMU), sensor equipment in power plants and transmission lines as well as widely used in transformers. Numerous systems and software in wide-area monitoring and controlling such as SCADA, WAMS, wide-area adaptive protection, control and automation (WAAPCA) and wide-area situational awareness (WASA) used for reliability, controlling and monitoring proposes. In particularly, superconductors, FACTs, HVDC technologies, and network stability analysis as well as automatic recovery systems changing the traditional transmission lines into modern, effective long-distance transmission systems. In the view of distribution grid, wide range of hardware including automated reclosers, switches, capacitors, remote controllers, storages, transformer sensors, as well as wire and cable sensors used for reliability, detection and back-up proposes. The majority of systems and software namely Geographic information system (GIS), distribution management system (DMS), outage management system (OMS), workforce management system (WMS) increasing the efficiency of distribution networks. In the recent decade, advanced metering infrastructure (AMI) has been deploying widely within the distribution networks in order to arrange the favorable infrastructure. Interestingly, electric vehicles also integrated in the distribution networks in order to enhance the transportation sector aiming to reduce CO2. In the recent five years, many vendors introducing smart home applications including smart appliances, routers, in-home display, building automation systems, thermal accumulators, smart thermostat where consumers able to engage using energy dashboards, energy management systems, energy applications for smartphones and tablets. Overall, renewables able to integrate in all the levels under the appropriate application of ICT.

3.2 Smart grid implementation stages

International Energy Agency proposed a general roadmap for smart grid deployment in the distribution network. In simply, the roadmap is a strategy a plan that describes the steps to be taken to achieve the stated and agreed goals on a defined schedule (Figure 3.2). Afterward, barriers in the aspect of the technical, policy, legal, financial, market and organizational levels are able to be defined. As well clearly defined goals, the range of solutions have to be provided to overcome the barriers. Roadmaps can be developed for various levels such as global, national, regional barriers as well as can be a sector or specific technology.

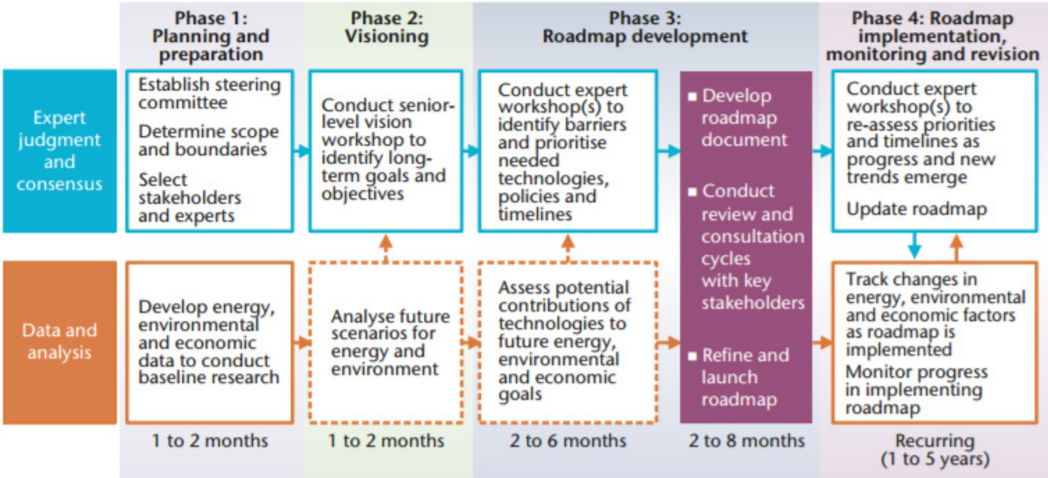

Figure 3.2 Smart grid roadmap

According to the suggested framework, four main phases namely planning and preparation, visioning, roadmap development and implementation, monitoring and revision included in the elaborated roadmap. Well defined roadmap must be the appropriate foundation of technical implementation of the smart grid deployment for any national, regional and specific initiatives.

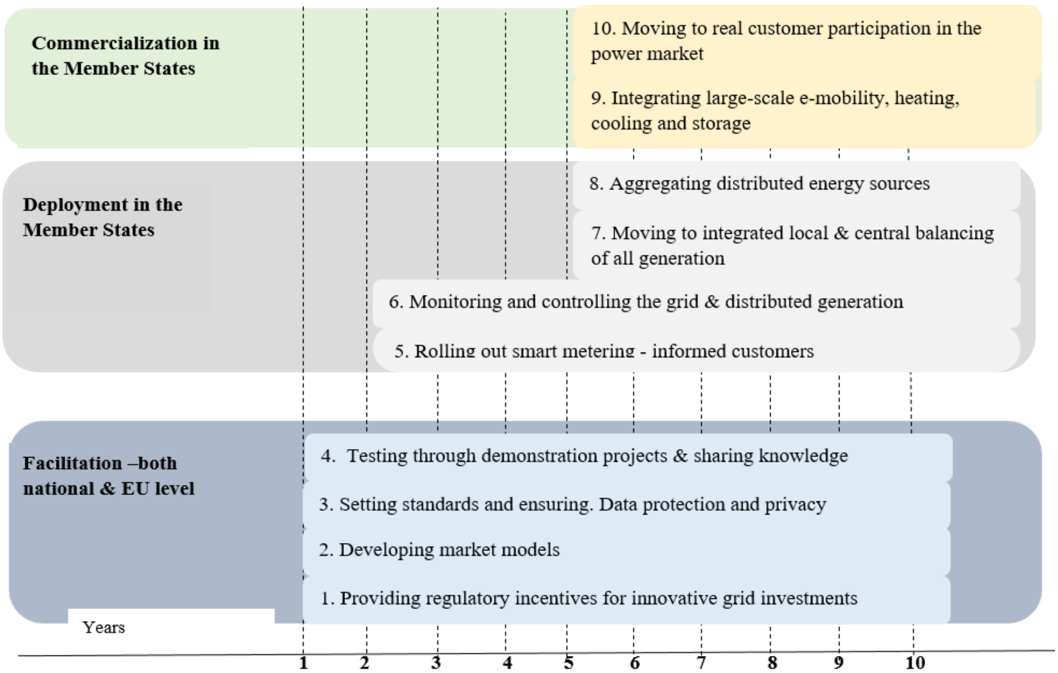

Figure 3.3 Smart grid implementation stages described by EU

Similarly, European Union described smart grid implementation stages with three phases comprises 10 year steps as an evolution of the grid (Euroelectric, 2015). As illustrated in the figure based on the elaborated roadmap regulation and market models should be well founded in order to launch the projects. Significantly, implementing smart grid projects across the union or nation-wide, prior to test demonstration project. Consequently, project may expand with rolling out smart metering, distributed generations prior to integrate large scale application such as e-mobility, heating, cooling and storage systems (Figure 3.3).

3.3 ICT enabled power grid and pilot projects in Northeast Asia and beyond as a demonstration.

Basically, the smart grid is generally understood as an ICT-enabled energy system which comprises all the producers, transmission and distribution networks, renewables and storage as well as consumers at the time. IEA provided a definition of the smart grid, in which a smart grid is an electricity network that utilizes digital and other advanced technologies to monitor and manage the transmission and distribution of electricity from all generation sources to meet demands of end-users by integrating wide communication network simultaneously (Figure 3.5). Smart grids coordinate the needs and capabilities of all generators, grid operators, end-users, and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimizing costs and environmental impacts while maximizing system reliability, resilience (flexibility) and stability (IEA, 2011).

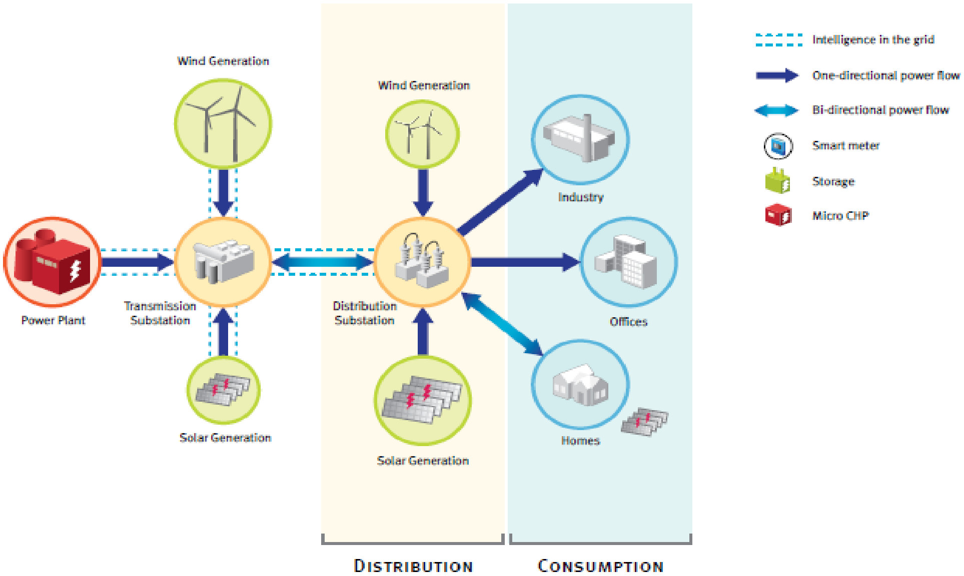

Figure 3.4 Today's smart grid

As seen in the Figure 3.4, today's smart grid integrates wind and solar producers with the transmission and distribution network in while managing the customers including industrial, offices, homes. Significantly, smart grid allows customers to supply its exceeded generation to the grid. In future, energy service providers, electric vehicles and energy storage systems integrated to the distribution grids.

Smart grid initiative and its investment action started rapidly since around 2009 and 2010s over the world in the foundation of low-carbon development. Recently, the projects focus on grid enhancement such as smart metering, demand-side management, and distributed generation. Data related issues and low consumer participation such as data gathering, real-time analysis, processing and forecasting are likely to be the prior issue in the first stage of implementation. The ICT convergence in the smart grid brings more independence on IT and management (IEA, 2011).

Table 3.1 Demonstrative smart grid projects in NorthEast Asia and EU

Country	National initiatives	Planned smart grid investments
China	State Grid Corporation launched China's pilot smart grid plan in 2010 which invests water system, rural development, power grids, renewables integration in order to increase the overall efficiency of the system and to reduce the energy consumption. Smart grid investment expected to reach minimum 96 million USD by 2020.	101 billion USD by 2030.
Japan	The Federation of Electric Power Companies of Japan is developing a smart grid, embraces solar energy intensification. As well as the government has announced the smart metering initiative and the large utilities have announced smart grid programs.	Solar energy incentive 100 million USD by 2020.
South Korea	Korea has announced plans to implement smart grids nationwide by 2030 in order to complete the world's first national unit smart grid. The Korean government has launched a USD 66 million pilot program on Jeju Island in partnership with industry. The pilot consists of a fully integrated smart grid system for 6 000 households, wind farms, and four distribution lines.	24 billion USD by 2030
Russia	Russia is pursuing the State policy of innovation activity in the electricity sector. This applies to energy efficiency, renewable energy, and smart grids. It is stated in the Energy Strategy of Russia for the period up to 2030.	
Europian Union	ADDRESS (Active Distribution network with full integration of Demand and distributed energy RESourceS). The project adopts a "demand approach" (rather than "generation approach") in an attempt to draw small and commercial consumer participation in the power system through innovative commercial arrangements. As well as big projects including Green for Europe, Green eMotion, Ecogrid are the wide projects among 27 countries.	1.5 trillion euro by 2030

Generally, countries in North East Asia considered in researched demonstrative projects is leading in Asia. As well as, European Union has the best experience implementing smart grids through several demonstrative projects. Japan and South Korea has ranked in the highest list in terms of distribution network and consumer engagement technologies in the world. China were installing half million solar panels per day was surprising news in worldwide last year (Myllyvirta, 2016). Japan has been taking significant attention to the solar, PV technologies. According to Japan's Renewable Energy Institute, Solar photovoltaics rose from 2.7% in 2015 to a whopping 4.3% in 2016 (Pentland, 2017). Moreover, Japan is planning to install 8000 MW solar panels in 2017 (Pentland, 2017). Korea has been testing smart city and smart grid initiatives throughout the country including Incheon free economic zone and Jeju testbed projects. Furthermore, electric vehicle, energy storage systems launched successfully, are planning to integrate into the grid. As can seen in the Table 3.1, countries have planned huge investment, are emphasizing collaboration between government and private sectors.

3.4 ICT contribution to sustainable electricity grid

3.4.1 ICT contribution to environmental aspect of the energy system

With the ICT enabled electricity network, energy system sustains societal, regulatory, economic and technological aspects to the public, system itself and government policy at the same time compared with a traditional network. Sustainability is defined as how biological systems endure and remain diverse and productive (LLC, 2017). The policy on sustainability can be divided into three areas of policy including environmental protection, social responsibility, and economic practice. The agenda usually embraces energy conservation, sustainable social development, support on sustainable business, advances in sustainable technology and development and investigation of climate change on sustainability (LLC, 2017).

3.4.1.1 Reduction of CO2 emissions

The climate has been changing increasingly due to the production of energy linked to economic growth, population growth, and human activities in the 21st century. The energy sector considered as the largest contributor to the GHG emissions. In 2010, it revealed that 35 percent of global GHG direct emission came from energy industry (World Energy Council (WEC) and Cambridge University, 2014). In the context of the smart grid, demand response is the potential tool which influences peak load saving, energy saving and reduction of total energy consuming (Vincenzo Giordano, Flavia Gangale, Gianluca Full, Manuel Sánchez Jiménez, 2011).

Demand response- technology is often described as technologies using real-time information to better much supply and demand (load management), incentives to shift demand (Accenture and

The Global e-Sustainability Initiative, 2015). Demand response program usually merged with energy efficiency ideas of alignment, with a pricing strategy to reduce load shedding, energy efficiency programs designed to reduce overall energy in order to save a certain amount of production (S.Gander and D.Lauf. , 2016).

Smart grid and reduction of system losses- Smart Grid solutions can make a significant contribution to the reduction of transmission and distribution losses and therefore to the reduction of the amount of generation (and related emissions) needed to serve a given load. Through the deployment of smart metering, faulty meters (which were not detected before), and another technical metering can enhance the metering system and to detect the fault and losses where does it happen (Vincenzo Giordano, Flavia Gangale, Gianluca Full, Manuel Sánchez Jiménez, 2011).

Transportation sector can have a better approach to reducing the emissions from vehicle in light of the integration of electric vehicle. Notably, in the case of renewable energy utilization and off-peak charging (Kim, December 2014). Electric vehicle market has been booming since 2010. According to International Energy Agency (IEA), The year 2015 saw the global threshold of 1 million electric cars on the road exceeded, closing at 1.26 million. The electric vehicle industry 20 by 20 target calls for an electric car fleet of 20 million by 2020 globally. The Paris Declaration on Electro-Mobility and Climate Change and Call to Action sets a global deployment target of 100 million electric cars and 400 million electric2- and 3-wheelers in 2030 (IEA, 2016). In order to fulfill this ambitious target, the biggest market of EV, United States is defining that the Regional transmission organizations (RTOs) and Independent system operators (ISOs) need to adopt specific ICT technology to integrate EVs into the RTO/ISO markets and manage transmission and distribution (TS&D) functions (council, 2015). The United States and China are dominating in the electric vehicle market in order to meet their obligation to reduce CO2 emission.

3.4.1.2 Renewable energy integration

Variable energy producers, small-scale distributed energy recourses, energy harvesting, and energy storage systems considerably enhanced the system to meet increasing energy demand and reduction of CO2 emission. **Distributed renewable energy recourses (DER)** typically defined as a renewable energy generation technology which occurs many small size and capacity producers where connected to the distribution network able to supply produced energy. The technology potentially reduces the centralized generation, high voltage transmission lines and transmission and distribution costs (IRENA, Renewable energy integration in power grids, April 2015). Many countries have an ambitious target to integrate renewable energy into the overall system. Hence, the share of renewables is rapidly increasing in both developing and developed countries in the last five years. A transition towards to renewable and especially distributed recourse integration requires re-thinking of the design, system preparation and future planning both of realistic economic and technical point of view. Distributed renewable energy resource with a smart inverter can be integrated into current distribution automation (DA) (IRENA, SMART GRIDS AND RENEWABLES: A Guide for Effective Deployment, November 2013).

Variable energy integration- Depending on the mix of the installed capacity energy system meet many dispatching challenges to meet the consumer demand. Renewable energy fluctuations due to meteorological condition, inflexible conventional recourses lead difficulties on forecasting and real-time forecasting. With this, we can do much to integrate diverse energy recourses. For instance, imagine a PV system, wind and industrial electricity consumers on an interruptible rate, all tied together with smart grid communication and control technologies. If one of the systems drops due to the metrological event, the system will resume after the event. When the system integrates electric vehicles, wind energy can be energy supplier for EVs (IRENA, Renewable energy integration in power grids, April 2015).

Energy storage system- is an energy storing technology to meet changing power consumption and appropriate amounts of electricity (IEC, 2011). Renewable generation, notably, the wind and solar energy production, can lead to major fluctuations in the energy supplied to the power grid due to weather conditions. Such fluctuations sometimes even lead to negative energy prices. This phenomenon can be mitigated by smart devices that consume or store energy when excess power is available, leading to an improved balancing of supply and. This not only requires an ICT infrastructure in which smart appliances can cooperate, but also measures such as smart meters, real-time pricing, and real-time forecasting and planning models that take account of various parameters such as the weather, the time of day and consumption habits.

3.4.2 ICT contribution to economic aspect of the energy system

3.4.2.1 Direct financial benefit

Operational costs are reduced or avoided in light of communication network. Smart metering and communication tools system allows customers have pricing choices and access to energy information. In the recent years, entrepreneurs accelerate technology introduced into the generation, distribution, storage, and coordination of energy in order to decrease the cost (Shahram Javadi and Shariar Javadi).

As illustrated in the following table, the direct economic benefit comes in each difference compared to the traditional grid system.

Table 3.2 Comparison between Traditional Grids and Smart Grids

	Current Grid	Smart Grid
Communications	None or one-way typically not real-time	Two-way, real-time
Customer Interaction	Limited	Extensive
Metering	Electromechanical	Digital
Operation & Maintenance	Manual equipment checks time-based maintenance	Remote monitoring Predictive condition-based maintenance
Generation	Centralized	Centralized and distributed
Power Flow Control	Limited	Comprehensive
Reliability	Prone to failures and cascading outages	Pro-active real-time protection and islanding
Restoration	Manual	Self-healing
Topology	Radial	Network

3.4.2.2 Electricity system benefits

The use of information communication technology changes the paradigm from centralized to the decentralized market structure. Economic benefits of smart grid usually explained by following aspects. 1). Opportunities to leverage its recourses and enter new marked created by smart grid opportunities such as microgrid and demand response; 2). Increased revenues due to smart metering which enabled accurate billing; 3) Economic dispatching could enable by optimizing different recourses and energy storages; 4) As well as it has been recognized that smart grid can save investments need for massive infrastructure (Keith Dodrill, 2010), (Electricity Committee, 2008). The integration of microgrid and grid-tie system decreases the huge centralized power plants by a small amount as well as reduce the high transmission line and towers from centralized power plants. According to Global e-sustainability Initiative, ICT-enabled Smart Grids are expected to make energy generation and distribution more cost-effective by saving 700,000 km grids, as well as total 810 billion USD of additional revenues from the evolution of Smart Grids could create $2.1 billion in additional revenues for the ICT sector and $811.3 billion in revenues for renewable energy companies (Accenture and The Global e-Sustainability Initiative, 2015). According to US Energy advisory committee, smart grid technologies expected reduce power disturbance costs to the U.S. economy by $4 billion per year. As well as huge infrastructure investments by between $46 billion and $117 billion over the next two decades (Electricity Committee, 2008). 5). Anticipating huge outage or reduction of outage frequency. By monitoring the equipment in the system such as a transformer, high transmission towers and other high-cost equipment abled to anticipate and foresee the expected damage and outage. Having an awareness about outage allows the system to prepare back up and actions to take. Blow up of one transformer or when fall one high transmission tower leads high financial loss in the entire system. Nowadays, controlling and monitoring system helps the system to work efficiently and reliably. 6) Improved market transparency. Increased market participation, the set-up of open market platform increases the transparency of the market and contribute move towards liberalized market. In that sense, it requires active access among costumers that is to say willing to access to the provided platform (Vincenzo Giordano, Flavia Gangale, Gianluca Full, Manuel Sánchez Jiménez, 2011). 7) Enables interconnection among regions and cross-border trade (Accenture and The Global e-Sustainability Initiative, 2015).

3.4.2.3 Residential Consumer benefits

Smart grid offers to potential savings to the consumers through managing their consumption habits. As well as gives them knowledge about understanding about energy conservation and its impacts (Electricity Committee, 2008). The use of consumer-based enabling technologies including in-premise customer displays or "energy dashboards", controllers which have the ability to programmable and price-responsive and home domotics (IEA I. E., 2015). The integrated utilization of above technologies with advanced metering allows users to get transparent and frequent billing information (IEA, 2011).

3.4.3 ICT contribution to socially responsible energy industry

3.4.3.1 Consumer engagement

ICT convergence enables two- way communication in the energy industry to engage the customers. The two-way communication described as a form of transmission in which both parties involved transmit information (Two-way communication, 2017). The convergence of ICT made significant interoperability for large infrastructure systems (IEA, 2011). The wide use of copper wiring, optical fiber, power line carrier, wireless technologies and broadband over power line technologies are making the grid as interactive and dynamic. The consumer engagements considered as a key part in order to evaluate and take further actions in the smart energy system. In order to engage the consumers, the consumer has to be a) enabled and b) motivated (Global Smart grid federation, 2012). Consumer motivation is relatively common and sophisticated to engage consumers and to have results. Especially, in newly adopted system consumer response does not get early. Therefore, some external stimulus is crucial such as introduction of time-of-use (TOU) pricing, smart metering and in-home display units (IHDs). Some of the implemented projects among smart grid federation countries have seen 2.5-15 percent energy savings by motivating consumers with this stimulus (Global Smart grid federation, 2012). To enabling consumers, both advanced metering infrastructure (AMI) and in-home display units allows consumers to customize their consumption. The way motivating and enabling consumers has been revealed greater advantage than financial incentives for real.

3.4.3.2 Reliable and quality service

Advanced analytics for used to forecast demand strengthening the system capability to meet consumer demand. The integration of energy storage and harvesting technology, a detecting system, and compensation techniques cultivates the quality and reliable service when the primary source is lost. The use of cohesive grid-wide information technologies enhances the system to address the common issues with renewable as well as technical issues such as fluctuation, uncertainty, forecasting and failure (Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang, 2012). According to Xi Fang, protection that supports the reliability is one of the advanced features out of three characteristics. The following Figure 3.6 shows the different perspective of the smart grid. The detectors and sensors used in distribution network help to sustain voltage level and prevent outages.

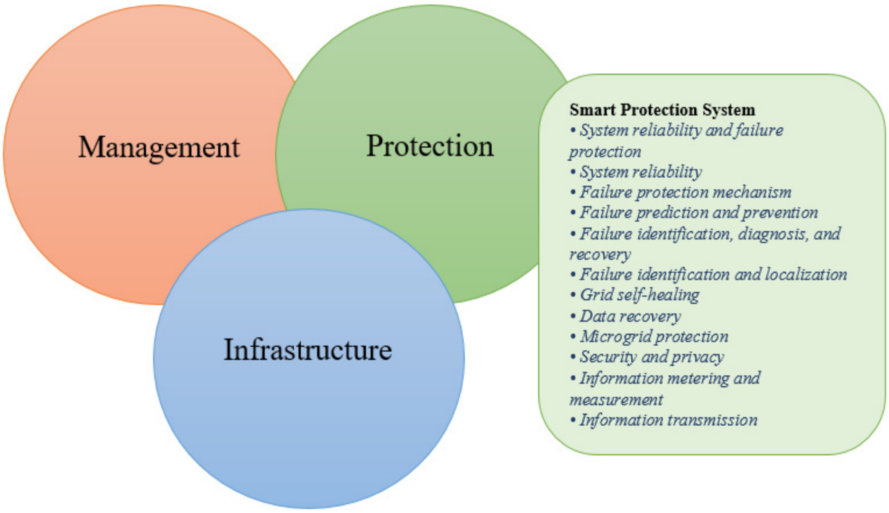

Figure 3.6 Smart grid reliability

As seen in above Figure 3.6,grid management, protection and infrastructure together offers reliable and quality services to the consumers through improving technical reliability, decreasing outages, voltage drop by using fault detection, FACTS and other related technologies. Available data, smart metering systems, dashboards enable consumers to participate actively and having monitoring.

4. RESEARCH METHODOLOGY

In this paper, qualitative research methodology with primary data and secondary data with literature-based approach will be used in order to achieve the purpose of the paper.

The primary data underlies observations collected from researchers, articles, and reports in common issues on ICT deployment, challenges and opportunities in Mongolian energy sector as well as expected trends in North East Asia and beyond.

The secondary data is based on the data collected by other countries where the smart grid initiatives successfully implemented. Notably, case study and literature documents used in order to understand the significance and consideration of smart grid. Especially, ICT role in electricity system and smart grid contribution to the smart grid to understand the meaning of sustainable development and the significance of ICT convergence.

Using the secondary data from intergovernmental projects, different regions comparative analysis based on the evaluation of ICT deployment rate in Mongolia and demonstrative projects in other regions to fulfill the objective. Meaning to say, the theoretical basis and key considerations cover to give awareness and recommendations to Mongolian energy sector. The evaluation of ICT deployment rate in Mongolian energy industry focused on SWOT analysis and related research documents mainly toward smart grid projects as well as distribution network projects. It is vital to understand the current state and to show the level of implementation stage. So that in light of the comparative analysis and key recommendations will be meaningful.

Finally, discussion and conclusion part provided based on the primary and secondary analysis. The methodological framework of the study shows below (Figure 4.1).

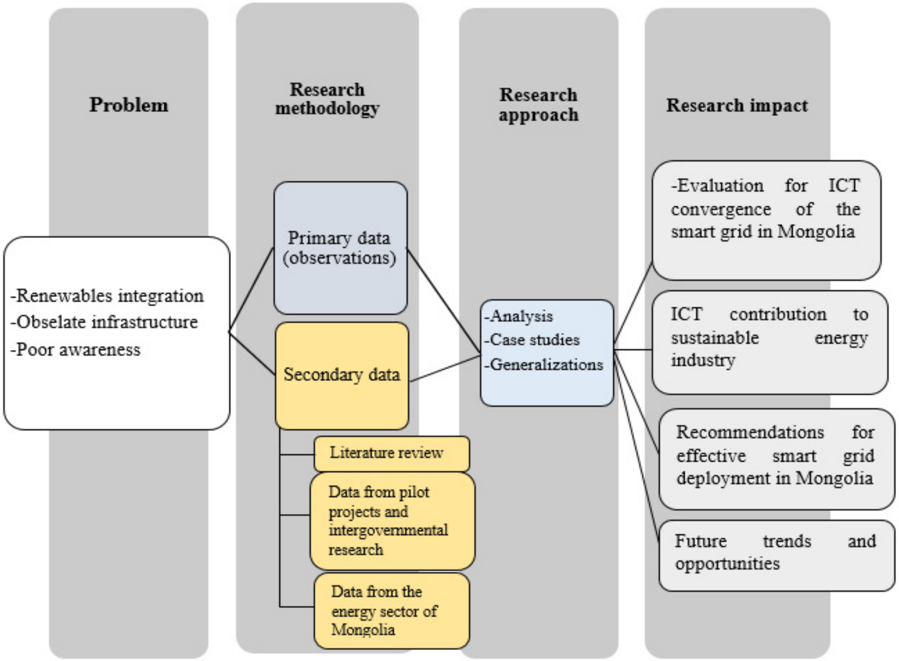

Figure 4.1 Research methodological framework

In figure 4.1, the scheme for the study used methodology with its approach and impact is shown.

4.1 Research approach

The detailed methodology covers the actions to reach all the objectives of the research. For the first objective, investigation in sustainable development, ICT deployment in smart grid, pilot demonstrative smart grid have done to define ICT convergence with energy industry contribution to sustainable development and to introduce pilot and demonstrative projects through generalization and findings from intergovernmental project reports and policy documents. For the second objective, policy documents implemented projects and policy directions used in order to define the level of the ICT penetration in an implemented smart grid project in Mongolia. As well as, the comparative analysis provided for successful smart grid implementation projects by benchmarking the skills from particular countries. For the third objective, through considering the basic stages of smart grid implementation and successful project phases in overseas by coordinating with policies and the current state of Mongolian energy sector the paper tries to give an evaluation and recommendations. Additionally, future trends and opportunities in the area of ICT convergence to the sustainable energy industry have done in order to give a comprehensive approach to the paper. Research area is limited by electricity grid.

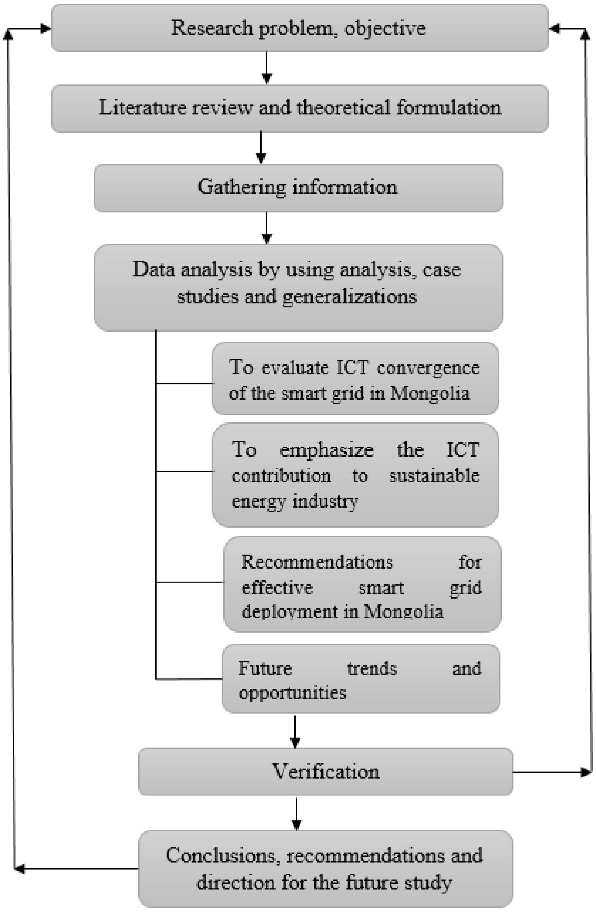

Figure 4.2 Research approach design

Figure 4.2 shows the design of research approach with the objectives.

5. ANALYSIS AND FINDINGS

5.1 Case study: South Korea's greening strategy

5.1.1 Key point

Korea has ranked 6th place overall in the world in terms of top smart grid market, according to the U.S Department of Commerce in 2017 (ITA, January 2017). As illustrated before, Korea has announced plans to implement smart grids nationwide by 2030 in order to complete the world's first national unit smart grid. The Korean government has launched a USD 65 million test bed project on Jeju Island in partnership with industry. The pilot consists of a fully integrated smart grid system for 6 000 households, wind farms and four distribution lines where emphasizes on grid IT-enabling and resilience via microgrids (IEA, 2011), (Sung-Young Kim and John A. Mathews, 15 December 2016). There has been a number of government initiatives such as the creation of particular institutions such as Korea Smart Grid Institute (KSGI), a new industry association, the Korea Smart Grid Association as well as the formulation of industrial roadmaps. A special feature of the Korean smart grid initiative was based on urban -based grids namely Smart Grid Station (SGS) and island-based grid. In the context od the international role on smart grid, the primary goal is examined as an economic boost from exporting technology (Sung-Young Kim and John A. Mathews, 15 December 2016), (Jacob Cottingham, Robert Langston and Stefan Trifonov, 2011).

5.1.2 Power grid as a ubiquitous platform

Korea determined its smart grid concept as a ubiquitous based platform including Low carbon deregulation of the source, increased intelligence and reliability and energy efficiency. Figure5.1 shows the general feature of the platform.

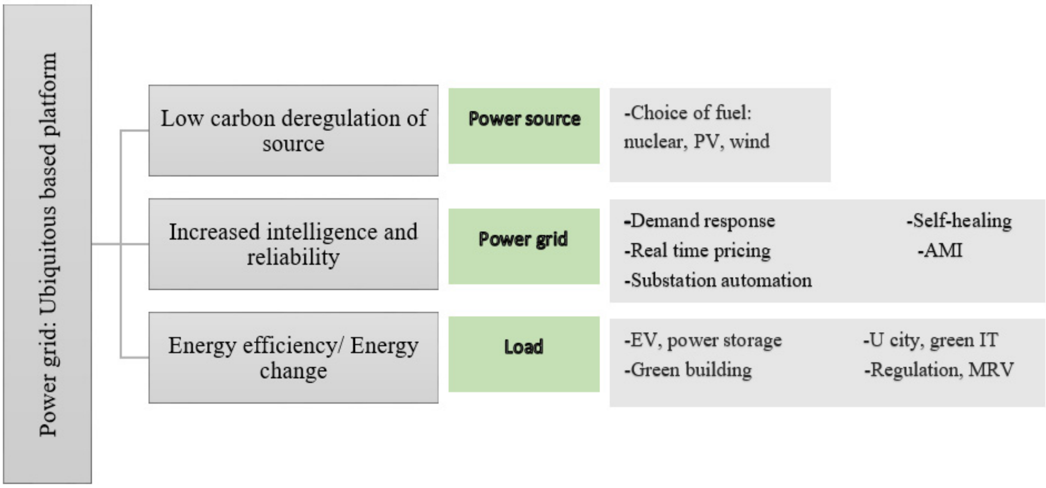

Figure 5.1 Korea's smart grid platform design

Korea emphasized low carbon deregulation, increased intelligence and reliability and energy efficiency with the innovative technologies. Great application of ICT deployment to the power source, power grid and load are making unique advantage to the country to take far develop.

5.1.3 Korea's smart grid roadmap

As illustrated in above Figure 5.1, basic Korea planned basic three phases in order to achieve nation-wide smart grid implementation (Jung, 2012). Within the framework of the first stage, Jeju test bed project which consists of five domains including smart electricity market, place, transportation, renewable, and power grid initiated in 2010 in Jeju island. The project has officially started from 2012, commercialized 58.9 MW offshore wind turbines consists of different sites and 506 kW photovoltaic capacities successfully today. So far, the wind farm is supplying 11 percent of the total electricity consumption of Jeju island by producing around average 45 MW electricity. At present, Second Dongok- Bukchon wind farm project which has total 24 MW capacity is ongoing. This project is going to finish by Dec 2017. By the end of 2022, the capacity of the onshore wind farm projected to reach 151 MW and for the offshore will have the capacity with 302 MW. The annual electricity generation will reach 2485 GW. The planned investment for this big project is total 3560 USD dollars 320 million USD, 3240 USD per onshore and offshore respectively. In the second stage, the country has planned to expand smart grids by deploying in different cities up to 2021. Finally, the country is planning to implement nation-wide smart grid by 2030.

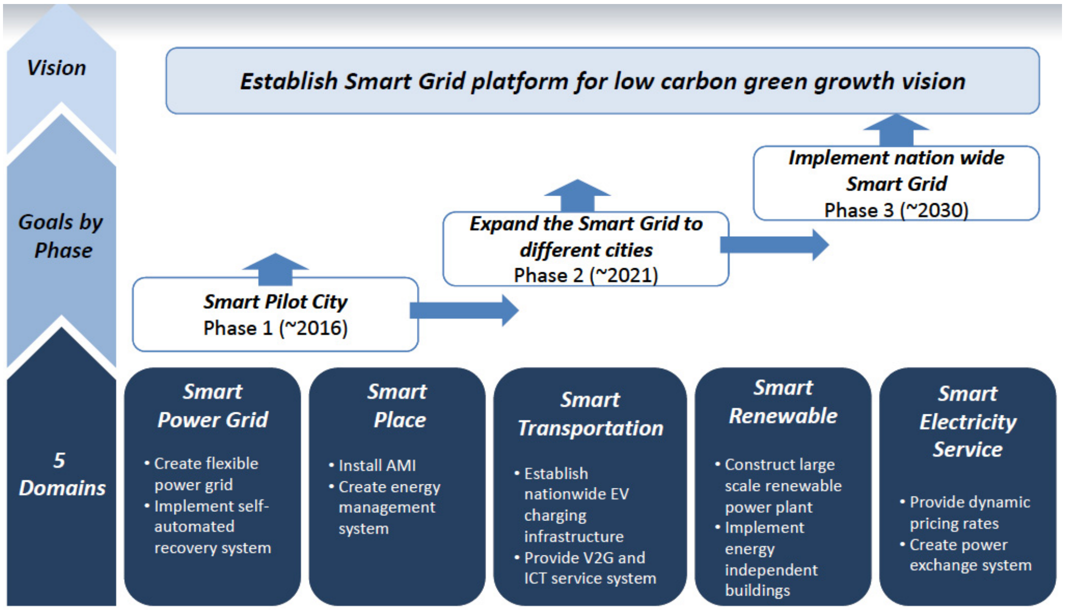

Figure 5.2 Korea's smart grid roadmap (Jung, 2012)

Notably, 1. Smart metering system, DC power distribution, and security, Electric-car charging method and self -restoration grid and mass storage systems are the key strategic technologies for Korea among five domains.

5.1.4 Common barriers to implementation

Table 5.1 Common barriers addressed in smart grid implementation in South Korea

Barrier category	Barriers
Technology disorientation	· Mixed technology · Business oriented policy
Dilemma between converged businesses	· Incompetent convergence collaboration of information communication
Leadership weakness	· Government policy/KEPCO's confused judgment on its business management
Procedures for innovation and its progress speed	· Counter procedure from that of U.S. (though it has parallel government initiatives) · U.S. is accelerating into market penetration after establishing its infra and standard. Korea preceded R&D first, then established infra
Technology Track disorientation	· Power IT version, converged BMs version, demonstration version, various simultaneous versions · Dynamic application of limited supplies

At first Korea confronted mixed technologies and dilemma between converged business in terms of collaboration of information and communications. Definitely, KEPCO was quite new for implementing new smart grid. However, Korea has been pursuing its own way which is R&D oriented.

5.2 Analysis for Mongolian energy industry

5.2.1 Main strengths and weakness of the power sector of Mongolia

Table 5.2 Main strengths and weakness of the power sector of Mongolia

	Strengths	Weakness
S&T	• Increasing attention to scientific research • Technology innovation initiatives started • Capable human recourses • Favorable relationship between research among institutions inside of the country	• Aging power plants, transmission line, and distribution networks • Weak investments and attention for R&D than maintenance • Difficult to afford significant R&D software and technologies as well as a human resource to work with. • Air pollution

	Strengths	Weakness
M&I	• Abundant coal and renewable energy resources • Relatively cheap fuel and generation cost • Capable regulation and dispatching • Supporting tariff for renewable energy resources	• Inappropriate tariff, inconsistent price with generation cost • lack of market design to penetrate new generation facilities • weak financial and inefficient energy utilities • High dependence on import
P&M	• Supporting policy to encourage distributed energy generation and renewables • Determined view on sustainable energy industry • Well enacted laws, principles, and rules • Stable politic environment • Strong internal interest and support to establish cross-border electricity trade.	• Needs mitigation strategy • Needs better planning and measuring at the strategy level • Political interest and government participation • Influence of government and leaders

Where: S&T- Science and Technology, M&I- Market and Industry, P&M- Policy and Measures

Science and Technologies, Market and Industry, as well as Policy and Measures were taken into account for conducting SWOT analysis. Through SWOT analysis, Mongolia's internal and environmental situation briefly defined in order to give comprehensive understanding about the whole market. Provided that, abundant energy recourses which has been revealed from negligible territories, determined view of sustainable energy industry, capable dispatching, supporting tariff and increasing attention are considerable strengths. However, behind technologies, inconsistent price set-up, import dependency and planning mitigation strategies are vulnerable to accelerate economic achievements, innovation and penetrate new producers in the market.

5.2.2 Main opportunities and threats

Table 5.3 Main opportunities and threats of the power sector of Mongolia

	Opportunities	Threats
S&T	• High attention from overseas in cross-border energy projects • Multinational and overseas supported research • Favorable relationship between related overseas research institutions	• Behind technologies due to high growth of technologies in developed countries
M&I	• Possible perspective to be energy exporting country • Surrounded by neighbors, have well-developed market structure	• Need powerful domestic research on cross-border project • High dependence on import products
P&M	• Supporting clean energy technologies • Increased political relationship • Developed neighbors involving Russia, Korea, and Japan	• Need for value added export

Given environmental analysis, high attention from neighboring countries to collaborate on cross-border energy projects, surrounded by countries where developed comprehensive smart grids, as well as well political relationship are described as main opportunities. In contrast, behind technologies might be barrier and vulnerable to launch distributed energy generators further big cross-border projects. Technologies and products completely depend on outside market of the country.

According to IRENA (International Renewable energy agency), one of the challenges in renewables readiness in Mongolia is software for the dispatching renewables and forecasting renewable energy production. The central energy system(CES) has been dominated by coal-fired power plants. With Mongolia's first wind farm in operation for three years, the grid operators have gained some experience in dealing with variable renewable sources and have also encountered some challenges. The final report of "Renewables Readiness in Mongolia" says that must enhance National Dispatching Center (NDC) capacity. Therefore to accurately forecast the available wind resource is particularly important for the grid operator. An advanced wind recourse forecast software needs to be integrated into the NDC operation. Also, problems about the renewables integration in Mongolia (Ministry of Energy of Mongolia, IRENA, March 2016).

6. DISCUSSIONS

6.1 Overcome challenges using ICT convergence while strengthening the opportunities towards sustainable electricity grid.

Unlike many other countries district heating systems, in other words, co-generation makes the opportunity to supply both of thermal and electric energy.

The challenging issues mainly determined by the shortage of generating facility and aging transmission system as well as a distribution network. While prioritizing technical issues in the forefront, other strategic policies are staying behind such as R&D, favorable market structure, actions toward to attract new generating facilities and foreign investment as well as comprehensive milestone and mitigation plan. While conducting SWOT analysis, internal weakness is greater than external threats that requires taking policy action.

Currently, the integration of renewables is in low level. Only a negligible part of regions have exploited by energy resources. Currently, solar and wind deployment has been largely limited to off-grid applications, mainly for nomadic herders or isolated mini-grids and middle scale renewables including solar, the wind and hydro. While conventional hydropower has been in use for decades, the first grid-connected wind farm, with installed generating capacity of 52 MW, started operation in July 2013. The problem as mentioned before is the fluctuations of production lead to difficulties in dispatching.

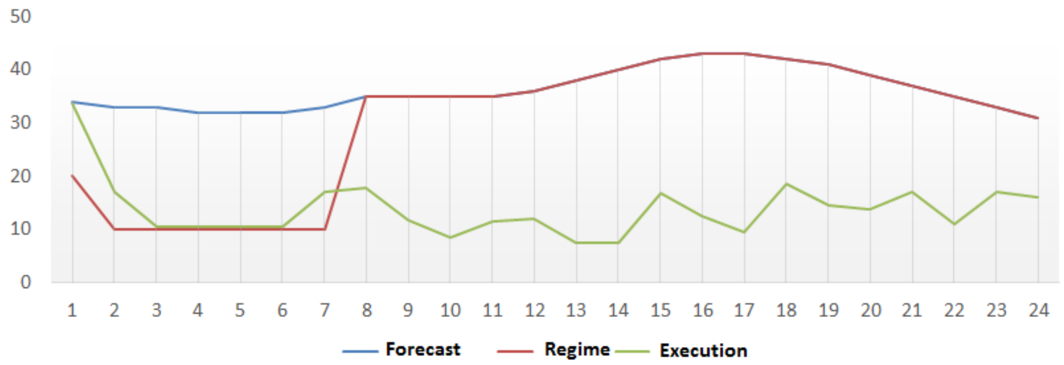

Figure 6.1 Salkhit wind power generation by hour, 25th Jan 2016

Above figure shows, the wind farm can not reach its obligated production. For example, during the peak hour, it generated 8.5-17.5 MW from its scheduled 32-35 MW. This too much fluctuation leads to make pressure for other power stations that engaged with the system and exaggerating importation. This unscheduled production difference influences financial loss for the whole system (Mongolia N. d., 2016). But the according to some international experts, Mongolian central energy system can accommodate more than 150 MW each of the wind and solar PV, representing about 30% of the current total installed capacity (IRENA, International renewable energy agency, 2016).

On the other hand, regarding with the issues of aging power plants and growing consumption lead to a situation that mitigates the challenges through using country's biggest advantage. It has been provided that Mongolia has a huge potential renewable energy. Mongolia stands among the top ten mineral richest countries in the world with only 17 percent of its vast territory properly explored. In 2015, IRENA and Ministry of Energy jointly executed Research that Renewable energy readiness in Mongolia. In this report emphasized solar and wind potential can reach 15000 TWh per year. Solar, 270-300 sunny days in a year, 3.5-5.4 kWh/meter or higher per day Wind, 10 % of the total land area can be classified as excellent for utility scale applications, Power density 5.4 kWh/m2, Mongolia can yield 4774TWh of solar electricity per year. And the realistic potential of hydro can reach 1200 MW to 3800. Furthermore, the potential for geothermal energy is under the survey and bioenergy recourse can be build from livestock (Ministry of Energy of Mongolia, IRENA, March 2016).

6.2 Proposed framework to solve the renewables integration into the grid

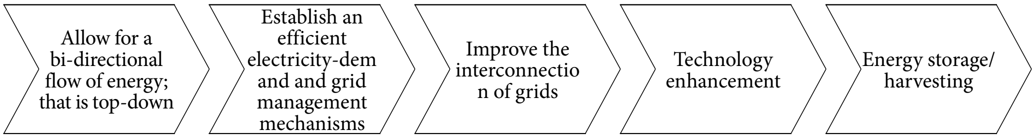

Figure 6.2 Proposed framework to solve the renewables integration into the grid

As shown in Figure 6.1 significant share of renewables requires creating affordable market structure followed by customer management, interconnection, technology enhancement and energy storage/harvesting systems. Considering this framework, distribution networks building the favorable market and infrastructure prior to enacting demand side management and grid managements. In terms of integrated system, provided that Mongolia has built 4 regional system connected with each other by the high voltage transmission line. In addition, the capacity of the transmission has to be improved. Among five stages within the proposed framework, the very first stage is the most crucial once have done, other actions can enact simultaneously. All the framework only eligible under the convergence of the ICT.

6.3 Learnings from effective smart grid deployment

Effective smart grid implementation comprises many aspects including clearly defined strategies that includes objective and goals, development phases including actions, potential barriers, and mitigations. At the same time, the well-developed milestone can be obtained. In general, the aim of the smart grid is to achieve sustainable energy system. For instance, South Korea has defined its objectives driven by energy efficiency, CO2 reduction and to establish new growth engine. To reach the goal, the country divided phases into three basic stages. The special and the most successful approach was the launch of the pilot project in Jeju island. In light of that testbed project, Korea has defined general barriers and got the bulk of experiences. Based on the key participants in the smart grid, the further concept can be defined. In theoretically, energy resources, demand and grid management and loads comprises smart grid as a platform that allows the two-way communication system to manage grid as a resilience and reliable by integrating variable and renewable microgrids and distributed grids. ICT components include Wide-area monitoring and control, information and communication technology integration, renewable and distributed generation integration, transmission enhancement, distribution grid management, advanced metering infrastructure, electric vehicle charging infrastructure, customer-side systems in the area of generation, transmission, distribution, industrial, service, and residentials. As smart grid is an evolutionary process, implementation of each technology is as an individual project such as advanced metering infrastructure, customer side systems, distributed energy resources as well as energy storing technologies. Change of the stakeholders and newly established stakeholders formed due to the change of the system structure and new services. Usually, functions for service increases in the distribution network. Different category of barriers has been obtained from pilot projects namely legal and regulatory, project delivery and workforce capability (project planning, knowledge or experience gaps, human resource development, technical and product solutions), financial, electricity market and system, social and cyber security. While planning the project mentioned barriers have to be addressed in order to implement realistic and reliable ICT enabled, sustainable power grid.

6.4 ICT contribution to smart sustainable energy industry

ICT role in the smart grid to build environmental, economic and socially sustainable energy sector has a comprehensive action that requires effort from both supplier and customer side.

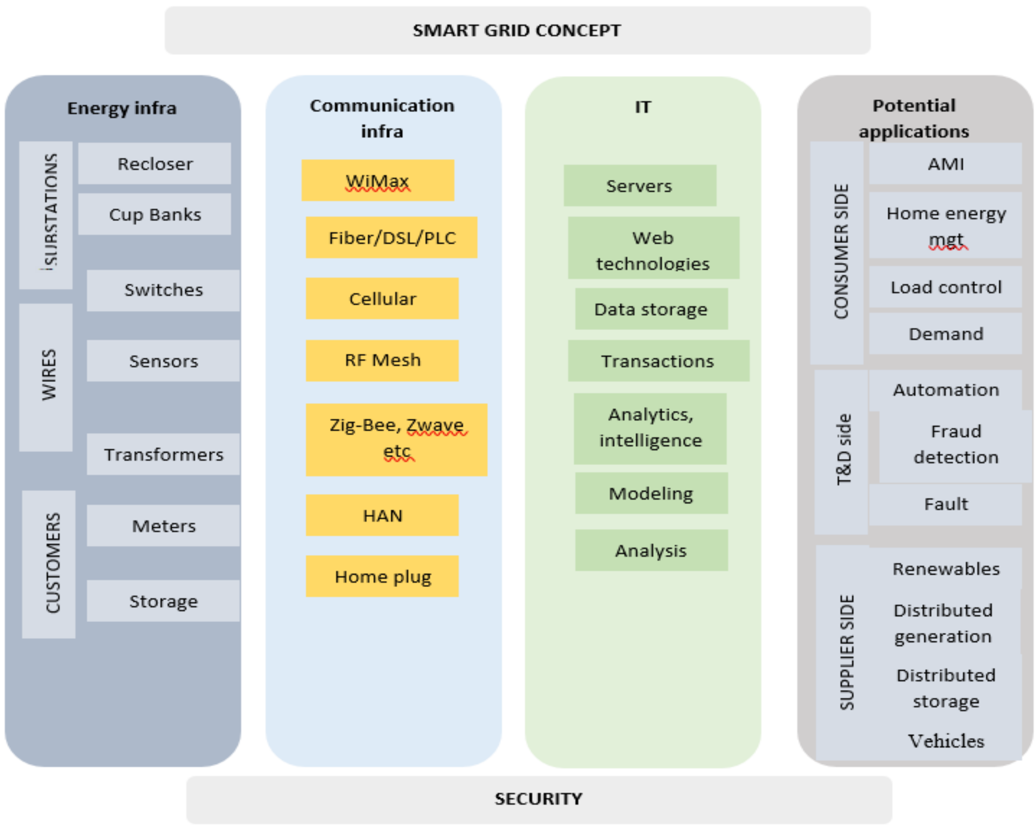

Figure 6.2 Recommended smart grid concept for sustainable energy industry

In terms of environmental aspect, CO_2 reduction by accelerating energy efficiency, demand response and attribution to the other sectors such as transportation and water by using communication tools such as in-home control devices, Zig-Bee network, WiMax, cellular and other applications as seen in the Figure 6.2. In terms of information technology area, devices and applications to create servers, data storage, analysis, transactions and others. Likewise, increased customer participation enabled applications and smart home allow them to reduce overall energy consumption, real-time pricing, flexible microgrids transform the grid into the sustainable grid. Hereby, the following figure shows ICT as a key point of whole smart grid framework may be a design for demonstrative projects in Mongolia.

7. RECOMMENDATIONS AND CONCLUSIONS

The smart grid is an evolutionary change for existing grids, consumer lives, traditional grid by using information communication technologies. In order to strengthen the sustainable power industry, it's crucial to plan comprehensive approach to integrate suppliers, transmission, and distribution network and consumer engagement. Furthermore, ICT is the key confidence for all industry to achieve enhanced productivity, efficiency while fulfilling world sustainable development goals.

- In the first place domestic market enhancement, R&D, and well eloborated roadmap are crucial to establish better approach for nation-wide smart grid and acclerate cross border energy. Especially, science and technology area is vulnerable to launch new technolgies and adopt further advanced grid.
- Well benchmarkings from advanced countries in which have particular technologues vital to create foundations for ICT deployment and renewables integration and distributed energy generations.
- Mongolia's policy in the energy sector should give specific attention to strengthen its ICT capacity and consumer engagement. Comparatively well-developed communication infrastructure, advanced metering infrastructure can be an advantage to create ICT enabled, flexible energy system for existing network.
- Due to the centralized middle scale power plants, the country will take a long way to integrate renewables and will meet various barriers regulation and economic dispatching. The paper may suggest that give attention for particular regions where can establish demonstrative projects such as microgrids, consumer engagement, vehicles and other aspects of smart grid in order to obtain domestic experience. Indeed, based on the experience from different countries

demonstrative projects are based its particular advantages, resources or commitments.

- Infrastructure and R&D is one of the vital contributors to succeed the initiative rather than other interests. Opportunities mainly regional power grid projects, renewable energy integration could be fulfilled through efficient deployment of ICT in the grid. In other words, vulnerable realization and deployment of ICT convergence cause to stay behind in the view of sustainable development and readiness for future technologies. However, policy documents well focused on CO2 reduction, renewable energy shares, supporting mitigations, technologies or supportive plans are uncertain, spends much time to research and meet difficulties to match the standards.
- Government initiative, investment and effective public and private collaboration have to be improved. Currently, government and public collaborations are not well tied.

Overall, Mongolia have been declared energy industry as a strategic sector to be exporting country. Altough, government of Mongolia has strong entusiasm to cooperate cross-border electricity trade in Northeast Asian countries, Mongolia has to be strenghten its key technolgies and overcome existing weakness. R&D, technology innovation are needed to create sustainable energy industry. Furthermore, government support, collaboration, consistency should well centered to the national interest rather than business and individual's interests. Significantly, potential applications in energy infrastructure and smart metering have been developing, are giving favorable foundation to the next steps. To sum up, Mongolia has great potential in energy export while sustaining energy sector through the penetration of ICT technologies and further establishments in the existing infratructure.

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