Master's Thesis

Meeting the Energy Challenges of Japan through the Optimization of Distributed Generation

The Case of the Kyushu Electric Power Company

By

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Abstract

The traditional electrical power generation system model used in Japan involves centrally-located power plants and a vast web of transmission and distribution networks. Although this model has been employed since 1886, the flaws associated with this system, accompanied by the difficult nature of Japan’s landscape, have contributed to environmental degradation, threats to public health and economic instability. Many of these issues can be mitigated through distributed generation (DG) shifts in the traditional design of power generation and distribution systems. DG relocates the source nearer to the end user to reduce transmission costs and pollution. It also increases efficiency and promotes the inclusion of renewable energy sources. This study is an attempt at understanding the energy situation in Japan and finding appropriate solutions for the challenges facing the power industry. The primary goal of this study is to propose an improved model for better performance of the power generation system in the Kyushu area. The suggested model can be examined and adopted for use in various cities of Japan.

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List of Abbreviation

This table describes the various abbreviations used throughout the research, its meaning and the page on which it was defined or first used

Abbreviation	Meaning	Page
DG	Distributed generation	1
DC	Direct Current	3
KEPC	Kyushu Electric Power Company	4
PV	Photovoltaics	7
KW	Kilowatt	7
MW	Milliwatt	7
GSGF	Global Smart Grid Federation	15
TOU	Terms Of Use	19
CHP	Combined heat and power	21
FIT	Feed-In Tariff	23
R&D	Research and Development	24
LBD	Learning By Doing	24
KV	Killo Volt	38
LNG	Liquefied Natural Gas	39
GDP	Gross Domestic Product	40
MITI	the Ministry of International Trade and Industry	41
MOF	Ministry of Finance	44
FY	Financial Year	45
GRP	Gross Rating Point	46
METI	Ministry of Economy Trade and Industry	46
IT	Information Technology	51
JEPX	Japan Electric Power Exchange	52
USD	United States Dollar	75
BESS	Battery Energy Storage Systems	96

Certification Page

I, Heba Ahmed Abdelbaqi ABBADI (Student ID#: 52115607) hereby declare that the contents of this Master's Thesis / Research Report are original and true, and have not been submitted at any other university or educational institution for the award of degree or diploma.

All the information derived from other published or unpublished sources has been cited and acknowledged appropriately.

Heba Ahmed Abdelbaqi, ABBADI

2017/07/09

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Chapter 1: Introduction

The traditional electrical power generation system model is comprised of centrally located power plants and wide webs of transmission and distribution networks (Barg, 2011). Although this model has been employed in Japan since 1886, when the country was supplied with electricity for the first time (FEPC), its flaws, accompanied by the difficult nature of Japan's landscape, have contributed to environmental degradation, threats to public health and economic instability. Japan, a resources-poor country, is dependent on imports by 95% of its energy supply (FEPC, 2015). After the oil crisis, people became more conscious of the problem and understood the importance of energy conservation. At the governmental level, Japan diversified energy resources by increasing the use of nuclear power, coal and natural gas, as well as by promoting energy efficiency and conservation. However, still about 40% of energy supplies are based on imported oil. In Jun 2015, the Japanese government announced a "strategic energy plan," which restated the importance of including a certain level of nuclear power (up to 20-22%) in the energy mix in 2030, while increasing the use of renewable energy (METI, 2015).

To ensure the stability of electricity supply in Japan, optimal solutions for safe power resources need to be found that can provide energy security, environment preservation, as well as economic efficiency. The approach proposed in this analysis is referred to as Distributed generation (DG). It can mitigate many of the issues associated with the traditional system. It modifies the traditional design of power generation and distribution, relocating the source nearer to the end user, increasing efficiency by reducing transmission cost and pollution, and promoting the inclusion of renewable energy.

The primary goal of this analysis is to propose an electrical power system model which addresses the flows associated with the traditional system through reconfiguration of the traditional electrical grid. The main goal of the model is improving air quality, public and environmental health and mitigation of global climate change.

DG has several benefits, it operates on a smaller scale compared to the traditional system. Multiple DG sites can be installed near the end user to reduce transmission costs (Figure 1). Sources are directly connected to the lower voltage end of the distribution network, which requires no transmission. Traditional systems require stepping up voltage at the generation point and then stepping it down near the load centers. DG bypasses many of the steps necessary for traditional systems, eliminating cost and complexity (Barg, 2011).

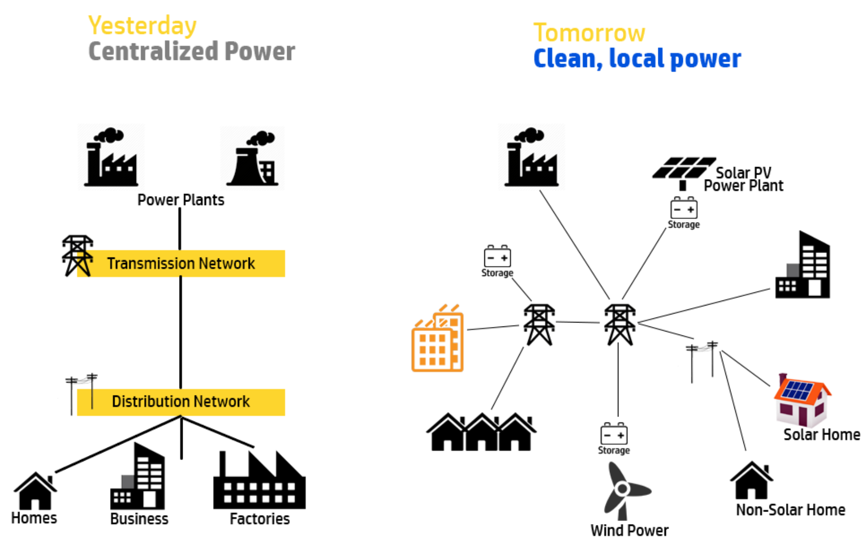


FIGURE 1: TRADITIONAL POWER GENERATION VS. DISTRIBUTED POWER GENERATION.
SOURCE: OSCEOLA-ENERGY (2015)

Although the term "Distributed Generation" wasn't coined until 2002, DG existed even before the development of the electric transmission grid (California Energy Commission, 2002). The first power plant supplied electricity only to neighborhood customers, and supplied power was limited. The first grid was DC (Direct Current) based and balancing demand and supply was done by batteries.

DG has several features and advantages; it provides modularity, adaptability, high efficiency, small scale and less waste. It is conducive to the implementation of various renewable energy sources. It has a wide range of applications, as it can be used as a supplement for the traditional system as a base or during peak demand periods, and it can be the optimal solution for facilities with specific conditions and remote areas.

The following research questions are addressed in this analysis:

- Identify challenges facing electricity generation in Kyushu area, taking into consideration the nature of Japan's landscape;
- What can electrical power companies do, with in a limited time frame, to meet those challenges?
- Is DG the optimum solution for meeting those challenges?
- Which sustainable distributed generation energy technologies are optimal for the Kyushu area?

There are two main hypotheses in this research:

1. *The main challenges facing electricity generation in Japan include*:
    - Deregulation
    - Ageing facilities
    - Fluctuations in crude oil prices
    - Environmental challenges:
        - CO_2 emissions
        - Difficult nature of Japan's landscape

  - Nuclear power challenges
- Demand forecasting:
  - Fluctuation in sales because of changing demand
  - Ageing of society
- Providing service for outlying islands
- Renewable energy challenges
- Meeting customers' needs

2. Distributed Generation leads more often to performance enhancement compared to the traditional power generation systems Model.

This analysis will address DG definitions, discuss DG technologies and other technological considerations, and explore DG benefits and Cost benefits, applications, challenges, and barriers to implementation. The Kyushu area was chosen as the study area, and Kyushu electric power company, hereinafter referred to as KEPC, is used as a case study in this analysis. KEPC was selected because their information is readily available. A model will be proposed which can be adopted for use in various cities of Japan. Smart-grid-interconnection is part of this proposed model. Since the use of traditional systems can't be eliminated, retaining grid interconnection allows the traditional grid to provide back-up power if necessary. It also facilitates the creation of micro-grids. Smart-grid can provide a dual way dialog where electricity, as well as, information is exchanged between utility companies and customers.

Chapter 2: Literature review

Distributed Generation (DG), also called Decentralized Generation (Martin, 2009), has received considerable attention from researchers and practitioners. Although DG might sound relatively new in the energy industry and the economics literature discussing electricity markets, however, the idea behind it is not new. During the early days of power generation, decentralized generation was the rule not the exception. For the first power plant supplied electricity to neighborhood customers, the supplied voltage was limited, the first grid was DC based, and balancing demand and supply was done by batteries networks (Barg, 2011). Later, with technological evolution, demand increased and the need for massive power systems emerged. However, over the past decade, the viability of this comprehensive (now traditional) system has been questioned, which has resulted in additional academic research. This research acknowledged the flaws associated with the traditional configuration, and began to explore new methods for power generation and distribution.

The literature review chapter will address research that explores DG definitions, DG technologies and technological considerations, its benefits and costs, DG applications, and the challenges and barriers to implementation. This chapter aims at providing a foundation from which analyses and recommendations can be made.

2.1. Definitions of DG

There are several terms which refer to DG. It is, for example, called "embedded generation" in Anglo-American countries (Ackermann et al, 2000), "Dispersed generation" in North America, "Embedded generation" in South American countries, and "Decentralized generation" in Europe and some Asian countries. However, many researchers recommend the name Distributed Generation (Pepermansa et al, 2005). It is a term first coined by the research and development division of the Pacific Gas and Electric Company of the California Energy Commission (California Energy Commission 2002).

Analysis of the relevant literature shows, however, that there is no consistent definition that is generally accepted by all concerned parties to describe Distributed Generation (Ackermann et al, 2000), a situation which is confirmed by a survey conducted by the International Council on Large Electricity Systems (CIRED) in 1999 and distributed among member countries (Purchala and Belmans, 2000). Nevertheless, there are some definitions that can be considered as common for most purposes. Some of these start from the principle that Distributed Generation units are connected directly to the distribution networks. Others define it in terms of the voltage level, or in terms of its location, capacity, technologies, environmental impact, ownership, or basic characteristics such as using renewable resources and being non-despatchable, and so on (Ackermann et al, 2000). Some literature allows for the inclusion of large-scale co-generation units, while others focus only on the small-scale units connected to the grid (Purchala and Belmans, 2000; Elmubarak and Ali, 2014).

The USA Internal Energy Agency defines DG as "the units producing power on a customer's site or within local distribution network" (IEA, 2002). They, however, do not make any reference to the level of the generating capacity (Elmubarak and Ali, 2014). The European Commission defined it by "a source of electric power connected to the distribution network or the customer side." Such definition allows for a broad range of power generation technologies such as renewable energy (Elmubarak and Ali, 2014).

In terms of its purpose, DG is defined as "the system used to supply customers with their current power demand or as a standby supply" (El-Khattam and Salama, 2004). It is defined by Momoh et al (2012) as "small-scale power plants using friendly technologies, such as photovoltaics (PV), or more conventional technologies, such as micro turbines and reciprocating engines that are fueled by renewable fuels". They also mentioned that DG includes generation facilities built near the end user, regardless of size or power source. This study also stated that any qualifying facilities under the *Public Utility Regulatory Policies Act* of 1978 (PURPA) fall under the definition of Distributed generation. In terms of size, they mentioned that DG ranges from a few KW to 50 MW capacities based on the application.

The IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems defined it as "the generating of electricity by facilities that are sufficiently smaller than central generating plants, so as to allow interconnection at nearly any point in a power system" (Elmubarak and Ali, 2014).

CIRED has formed a work group, devoted to Distributed Generation. They define DG as "all generation units with a maximum capacity of 100 MW usually connected to the distribution network that are neither centrally planned nor dispatched" (Purchala and Belmans, 2000). Ackermann et al (2000) define DG, in terms of location and connection, without any limit on the technology or capacity, as the electric power generation connected directly to distribution networks or on the customer side of the network. This definition is preferred by Pepermansa et al (2005), who conclude that most literature seem to agree on the small-scale generation unit connected to the distribution grid, close to the load or at the customer side, to be considered as part of DG.

In conclusion, there is no consistent definition for DG. Those definitions should be discussed by all concerned parties to come up with one definition that is commonly accepted by everyone.

2.2. DG technologies and Technological Consideration

The technologies associated with Distributed Generation have been discussed by several researchers and classified. This section will discuss the literature on DG technologies various classifications, applications and technological consideration. Elmubarak and Ali (2016), and Martin (2009), followed the International Energy Agency (IEA, 2002) in dividing the range of technologies used for DG to include Fuel cells, reciprocating Engines, Renewable sources, gas and micro turbines. The reciprocating engines convert mechanical energy to electricity by using a mixture of compressed fuel and air, lit up by a spark, to move a piston. Most reciprocating engines operate by using natural gas, fuel and biogas extracted from waste and biomass. The reasons for this mature technology's large spread are its low investment requirement, capability for fast start-up, as well as its high efficiency. Problems associated with this technology include noise, costly maintenance, and high emission rates.

Fuel cells are compact and quiet power generators converting chemical energy into electricity using natural gas, oxygen, or hydrogen. This technology has great potential, especially if overcoming its main drawbacks of high capital cost and lower efficiency. Gas Turbines are widely used due to their low emission levels and low cost compared to other technologies (IEA, 2002; Elmubarak and Ali, 2016; and Martin, 2009).

Micro turbines and gas turbines share the same characteristics. However, Micro turbines operates on smaller scale, higher operation speed and lower capacities (IEA, 2002; Elmubarak and Ali, 2016; and Martin, 2009).

Renewable technologies; wind, PV, and thermal etc. are increasingly used for power generation. They are one of the technologies used for DG, and have a wide range of applications due to their low or zero emission (IEA, 2002; Elmubarak and Ali, 2016; and Martin, 2009).

Fisseha and Mengistu (2001) divided DG technologies into generation and storage, and divided the generation into combustion, chemical conversion and renewables. Combustion Technologies convert chemical fuels into electricity. They used to be standby reciprocating diesel and gasoline engines, while recently using the micro turbine technology. The direct chemical conversion refers to the emerging field of Fuel Cells, which directly convert the fuel into electricity, bypassing the thermal and mechanical stages associated with the combustion technologies. This technology includes different variants, however, the chemical reaction is a combination of oxygen and hydrogen gas to create heat, water vapor and electricity. This technology is recommended due to its efficiency and the environmental-friendliness. Renewables technologies including solar technologies such as PV and solar thermal application, as well as, wind energy and micro hydropower.

Figure 2 presents a summary for installed and operating costs of the various DG technologies:

Product	Diesel Engine	Gas Engine	Simple Cycle Gas Turbine	Micro-turbine	Fuel Cell	Photovoltaics	Wind Turbine
Rollout	Commercial	Commercial	Commercial	Commercial	1996 – 2010	Commercial	Commercial
Size Range (kW)	20 – 10,000+	50 – 5,000+	1,000+	30 – 200	50 – 1000+	1+	10 kW - 1MW
Efficiency (HHV)	36 –43%	28–42%	21– 40%	25 – 30%	35– 54%	N/A.	25% - 40%
Genset Package Cost ($/kW)	125 –300	250–600	300 – 600	350 –750*	1500 – 3000	N/A.	
Turnkey Cost- no heat recovery ($/kW)	350 –500	600–1000	650 – 900	600 –1100	1900–3500	5000 – 10000	1,000
Heat Recovery Added Costs ($/kW)	N/A.	$75–150	$100 – 200	$75 – 350	incl.	N/A.	N/A
O&M Cost ($/kWh)	0.005–0.010	0.007–0.015	0.003 – 0.008	0.005 – 0.010	0.005 – 0.010	0.001–0.004	0.01

FIGURE 2: COST SUMMARY OF DISTRIBUTED GENERATION TECHNOLOGIES
Source: (Fisseha and Mengistu 2001)

El-Khattam and Salama (2004) divided Distributed Generation technologies into two types; traditional combustion generators and non-traditional generators. They, however, focused on types and technologies of new emerging DG, including micro turbines and fuel cells.

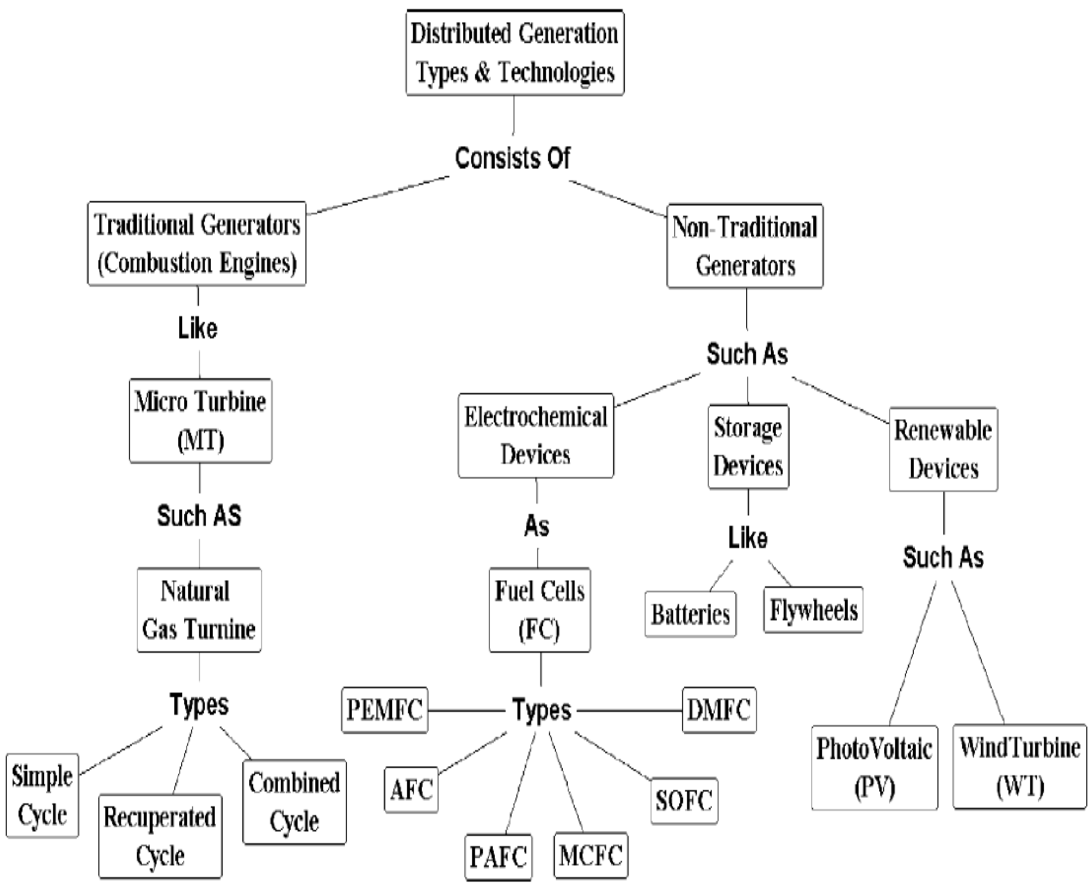


FIGURE 3: DG TYPES AND TECHNOLOGIES
SOURCE: (EL-KHATTAM AND SALAMA 2004)

Pepermansa et al (2005) didn’t discuss different DG technologies in detail, however they, provided a table including different DG technologies and the main characteristics of each type (Figure 4).

	General information	Application range	Electric conversion efficiency	Application	Fuel	Comments
Reciprocating engines		Diesel: 20 kW_e 10+ MW_e (IEA) Gas: 5 kW_e 5+ MW_e (IEA) By far most common technology below 1 MW_e	Diesel: 36% 43% (IEA) Gas: 28% 42% (IEA)	Emergency or standby services CHP	Diesel, also heavy fuel oil and biodiesel Gas, mainly natural gas, biogas and landfill gas can also be used	
Gas turbines		1 20 MW_e (IEA)	21 40% (IEA)	CHP Peak power supply units	Gas, kerosene	
Micro turbines		30 kW_e 200 kW_e (IEA) 35 kW_e 1 MW_e (A) Small-scale applications up to $<1 kW_e$	25 30% (IEA)	Power generation, possible with CHP added	Generally uses natural gas, but fiare, landfill and biogas can also be used	
Fuel cells	Molten carbonate: MCFC Proton-exchange membrane: PEMFC Solid oxide: SOFC Phosphoric acid: PAFC Direct Methanol : DMFC Only PAFC is currently commercially available	50 kW_e 1+ MW_e (IEA) PAFC: 200 kW_e 2 MW_e MCFC: 250 kW_e 2 MW_e (A) PEMFC: 1 kW_e 250 kW_e (A) SOFC: 1 kW_e 5 MW_e (A)	35 60% (IEA) MCFC: +50 55% (IEA) PAFC: +35% (IEA) PEMFC: +35% (IEA) SOFC: +50 55% (IEA) Electric efficiency of small-scale applications : ~25%	PEMFC: low temperature applications in transport and stationary use MCFC: high temperature Transport sector is major potential market SOFC: high temperatures Power generation is the most likely immediate application CHP, UPS	Methanol Hydrogen or natural gas. Reforming of CH_4 to H_2 leads to decreased efficiency	
Photovoltaic	Generates no heat	1+ kW (IEA) 20+ kW (A); Every range possible when using more cells	not applicable	Household and small commercial applications Off-grid applications Developing countries Small scale applications	Sun	Non predictable output; capacity factor ~10 15% in Western Europe
Wind	On shore and in-land	200W 3 MW (A)	Not applicable		Wind	Non-predictable output Capacity factor on shore ~20 25%
Other renewables	Includes thermal solar, small hydro, geothermal, ocean…		Not applicable			

FIGURE 4: DISTRIBUTED GENERATION TECHNOLOGIES AND CHARACTERISTICS
SOURCE: (PEPERMANSA ET AL 2005)

The U.S. DOE divides DG technologies into two types. DG technologies that require a Supplied Fuel, including micro turbines, fuel cells, Sterling Engines, and internal combustion reciprocating engines. Another type is DG technologies that don't require supplied fuel, including solar and wind. Barg (2011) focused on the technologies associated with incorporating DG into the traditional power system, including fuel cell, PV, wind generation, and cogeneration, and emphasized that while there is no perfect configuration for DG, it is important for DG applications to be implemented successfully to consider topography, local climates, regulations, and so on. He also emphasized the importance of the cost of various DG technologies in determining the economic benefits of its implementation.

2.3. DG benefits and Cost benefits

There are several factors behind the interest in Distributed Generation, including liberalization of utilities market, development of DG technologies, increased demand for reliable energy source, cost and concerns about CO_2 emissions and climate change. The IEA (2002) stated that liberating the electricity market affected the development of DG in two ways; one way is the engagement of new players increased the competition and forced them to identify essential niche markets for DG. Another way is that liberalized markets understate the flexibility where DG technologies have an advantage over traditional systems due to its small size and short lead times. Market liberalization is expected to increase the interest in constructing new transmission lines to expand transmission interconnections and meet consumers' increased demand for reliable energy sources, however, environmental concerns are limiting this process. DG is a possible solution to meet the increasing demand.

Technical advances are another factor affecting the interest in DG. Renewable technologies, such as wind, PV and thermal etc. are some of the technologies used for DG, and have a wide range of applications due to their low emission and convenient cost. Figure 5 summarizes the main characteristics of technologies used for distributed generation, including size, efficiency, cost, etc. presented by (IEA, 2002).

Technology	Diesel Engine	Gas Engine	Gas Turbine	Micro-turbine	Fuel cell	Photo-voltaic
Size (kW)	20-10 000 +	50-5 000 +	1 000 +	30-200	50-1 000 +	1 +
Efficiency (%)	36-43	28-42	21-40	25-30	35-54	n.a.
Generator cost (USD/kW)	125-300	250-600	300-600	500-750	1 500-3 000	n.a.
Turnkey cost (USD/kW)	350-500	600-1 000	650-900	1 000-1 300	1 900-3 500	5 000-7 000
Heat recovery cost (USD/kW)	n.a.	75-150	100-200	200-600	included	n.a.
O&M cost (USD/MWh)	5-10	7-15	3-8	5-10	5-10	1-4
CO_2 emissions (kg/MWh)	650	500-620	580-680	720	430-490	0
NO_x emissions (kg/MWh)	10	0.2-1.0	0.3-0.5	0.1	0.005-0.01	0

FIGURE 5: DISTRIBUTED-GENERATION TECHNOLOGY DATA
SOURCE: (IEA, 2002)

Pepermansa et al (2005) summarized the number of factors presented by IEA (2002) in to two major factors; the electricity market liberalization and environmental concerns. They stated that DG is an interesting tool enabling players to fill in niches in liberalized electricity markets and flexibly respond to customers' needs. Its small size and short construction lead-times is changing the market conditions. They also emphasized the role of the environmental concerns and policies to find clean energy and cost-efficient solutions, issues that can be mitigated by DG.

	Standby	Peak Shaving	Reliability	Avoiding grid expansion	Grid support (ancillary services)	Co-generation	Green power	Cheap fuel opportunities
Reciprocating engines	Yes	Yes	Yes, if dispatchable	Yes, if dispatchable	Yes, if dispatchable	Yes	No–yes[a]	No–yes[a]
Gas turbines	Yes	Yes	Yes, if dispatchable	Yes, if dispatchable	Yes, if dispatchable	Yes	No–yes[a]	No–yes[a]
Micro turbines	Yes	Yes	Yes, if dispatchable	Yes, if dispatchable	Yes, if dispatchable	Yes	No–yes[a]	No–yes[a]
Fuel cells	Yes	No	Yes, if dispatchable	Yes, if dispatchable	Yes, if dispatchable	Yes	No–yes[b]	No
Photovoltaic	No	No	No	Difficult	Difficult	No	Yes	Yes
Wind	No	No	No	Difficult	Difficult	No	Yes	Yes
Other renewables	No	No	No, except hydro	Difficult	Difficult	No, except biomass as fuel	Yes	Yes

FIGURE 6: DISTRIBUTED GENERATION TECHNOLOGIES AND THEIR POTENTIAL BENEFITS
SOURCE: PEPERMANSA ET AL (2005)

GSGF (2014) mentioned a number of environmental and social benefits of DG, providing case example from several countries, such as Australia, Canada, Japan and Taiwan. Those benefits have contributed in providing a context for constructing strong policy and regulatory schemes in those countries. The economic efficiency in Australia, reducing the high carbon emission level in Canada, the need for reliable resources and promoting renewable energy after 2011 Fukushima disaster in Japan, and the government effort to reduce the carbon content in what is called decarburization in Taiwan, are examples of the benefits driving the increasing interest in DG.

DOE (2007) defined the potential benefits of DG by “direct and/or indirect benefits received by electricity distribution/transmission service providers, customers served by electricity distribution/transmission service provider and/or the public in the area served by the public utility in which the co-generator or small power producer is located”. The study didn’t include the potential benefits of DG units to owners/operators. Figure 7, presented by DOE, is providing the different categories of DG benefits.

		Benefit Categories							
		Energy Cost Savings	Savings in T&D Losses and Congestion Costs	Deferred Generation Capacity	Deferred T&D Capacity	System Reliability Benefits	Power Quality Benefits	Land Use Effects	Reduced Vulnerability to Terrorism
DG Services	Reduction in Peak Power Requirements	✓	✓	✓	✓	✓	✓	✓	✓
	Provision of Ancillary Services –Operating Reserves – Regulation – Blackstart –Reactive Power	✓	✓	✓	✓	✓	✓	✓	✓
	Emergency Power Supply	✓	✓			✓	✓		

T&D= transmission and distribution.

FIGURE 7: MATRIX OF DISTRIBUTED GENERATION BENEFITS AND SERVICES
SOURCE: DOE (2007)

Some research has addressed the flows associated with the traditional systems to highlight the benefits of DG. Elmubarak and Ali (2014) compared between centralized and decentralized (DG) systems. They mentioned five main drivers for DG development. Transmission and distribution cost about 30% of the of delivered electricity cost due to line and converting losses. In rural areas, grid extension is difficult and fuel transportation and logistics are challenging and costly. There is also the need for increasing energy efficiency without requiring higher pressure and handling the steam and heat transporting problem. Security and reliability, in terms of fuel diversity and back-up generation. And finally, environmental issues such as carbon and greenhouse gas are other factors triggering the interest in developing DG.

Barg (2011) recommended a combination of both DG and traditional system, using virtual utilities to facilitate the interaction between both systems (Figure 8). The approach presented in this paper provides a solution for compatibility problems and optimizes the management of the demand-side to accurately match the supply side. The surplus power can be sold to the main grid as a type of reimbursement. The author also emphasized the importance of the cost of various DG technologies in determining the economic benefits of its implementation.

Technology	Long term cost (per kW)
Solar Photovoltaic Panels	$6,000 - $10,000
Wind Turbines (farm scale)	$1,000
Wind Turbines (indiv. building scale)	$2,500 - $3,500
Microturbines	$700 - $1,100
Proton Exchange Membrane Fuel Cell	$1,000
Solid Oxide Fuel Cell	$1,000 - $1,500
Molten Carbonate Fuel Cell	$1,200 - $1,500
*Heat Recovery Systems (Cogeneration)	add 30 - 70% to initial cost

FIGURE 8: LONG-TERM COSTS OF DISTRIBUTED GENERATION TECHNOLOGIES
SOURCE: BARG (2011)

El-Khattam and Salama (2004) discussed DG benefits from two different views: economics and operations. By relocating the source near the end user, DG saves distribution and transmission losses. It can provide the required loads and reduces or avoid the need for constructing new or updating existing transmission and distribution lines. In addition, it can reduce the capacity of the network. DG is modular and adaptable; it can be easily installed anywhere in a short period and in small increments. It operates independently form other modules and immediately after installation, and the total capacity can be easily modified. DG applications can be more economic by improving their efficiency.

By supplying electricity to the main grid, DG can contribute in reducing prices in the wholesale power market. It also increases the system and equipment lifetimes. It saves fuel and uses diversified types of resources and fuels. DG reduces distribution and transmission power losses, distribution loads requirements, the power flow within the transmission networks to meet specific constraints and positively improve their voltage profile. DG applications maintain system stability and reliability, and very helpful in load management programs. DG capacity varies from micro to large size, which makes it flexible to be installed on various voltage distribution network sizes. DG promotes the inclusion of renewable energy, which have positive effect on the environment.

2.4. DG applications

DG technologies (Figure 9) are a desirable alternative to conversational generation for many applications due to its many characteristics, such as small size and location. DG applications can be designed to meet a wide-range of customers' needs and vary according to load requirements which affects the type of technology used. The literature on DG different applications are summarized in the following section.

2.4.1. Standby: also called back up, where DG is used as a standby or a backup system to provide the required energy for sensitive loads such as in hospitals, in cases of emergencies such as during power cut periods. (El-Khattam and Salama, 2004; EEA, ICF, and ERG, 2007; SAIC and EG&G, 2002; Hedman and

Hampson, 2004; RDC, 2001). NETL (2010) mentioned three types of Standby. Interconnected: where generators include spinning reserves connected to the grid, generating little amount of power during the year except for offering regulation services for utilities. Emergency power systems: which work independently from the grid and provide power to limited loads for a limited time when the main system fails. The last type is a combination of both.

2.4.2. Standalone: DG can be used as standalone power provider in isolated areas and islands instead of connecting to the grid, which is challenging and costly (El-Khattam and Salama, 2004).

2.4.3. Rural and Remote Applications: Distributed Generation can provide the standalone remote applications, such as heating, cooling and communication, with the required loads. In addition, it can provide ancillary services at T&D levels and help regulate system voltages for rural applications that are connected to the grid (El-Khattam and Salama, 2004; SAIC and EG&G, 2002; Hedman and Hampson, 2004; RDC, 2001). In that case, customers should consider DG technologies of low installation and maintenance cost, as well as, high reliability (Hedman and Hampson, 2004; RDC, 2001).

2.4.4. Peak Load Shaving: also called demand response peaking. One of DG technologies characteristics is flexibility and cost saving. Some DG technologies can be used to supply some loads at peak periods to reduce the electricity cost for TOU (Terms of Use) payers (El-Khattam and Salama, 2004; SAIC and EG&G, 2002; NETL, 2010; Hedman and Hampson, 2004). Another suggested type of peak load shaving called customer-driven peak shaving. This strategy can be used by customers in several situations, such as putting off retail power purchases during high-price periods and reducing utility demand charges. In that case, customers should consider DG technology with low installation and maintenance costs, quick startup and high electric efficiency (Hedman and Hampson, 2004; RDC, 2001; RDC, 2001).

Energy type	Main applications
Micro-turbines	Help for peak load shaving, co-generation, and as a base load. Commercially available in small units with sizes 30–75 kW [1].
Fuel cells	Suitable for providing CHP for air-conditioning, cooling, and heating purposes. Large stations are suitable for base load applications. Commercially available in small units with sizes 3–250 kW and connected as modular to serve large loads [1].
Photovoltaic	Stand alone and base load in some rural applications if combined with batteries. It can be considered as a maintenance free supply for telecommunication and road lighting and advertising.
Wind turbines	Remote homes and farms and process industry applications.
Traditional internal combustion engines (diesel engines)	Already in use for several years, but they have high emissions and operation and maintenance costs in addition to diesel's hazardous during transportation to remote consumers [1]. Most of them are used for peak load shaving and backup operation (for reliability purposes) not for continuous operation.
Central power generation (fossil fuel)	Main electricity generation as the main base load. Used for peak load shaving and backup operation.

FIGURE 9: A CLASSIFICATION OF DG APPLICATIONS AND RELATING THEM TO COMMON ENERGY TYPES
SOURCE: EL-KHATTAM AND SALAMA (2004)

2.4.5. Combined heat and power (CHP): DG technologies can efficiently provide CHP as a cogeneration energy. The heat produced from converting fuel to electric power process is used for a wide range of applications, such as in process industries and large commercial areas. However, emission might be one of the implementation barriers (El-Khattam and Salama, 2004; EEA, ICF, and ERG, 2007; NETL, 2010; SAIC and EG&G, 2002; Hedman and Hampson, 2004; RDC, 2001).

2.4.6. Base load: Some DG technologies are used as base loads. Their job is providing part of the required power and supporting the grid by enhancing the system voltage profile, reducing the power losses and improving the system quality (El-Khattam and Salama, 2004; Hedman and Hampson, 2004).

2.4.7. Continuous Prime Power: also called Premium Power and continuous Generation (Figure 10). Contrary to the base load, and similar to standby, in continuous prime power mode DG can be used as onsite primary source of power during a scheduled shutdown or failure of main system, where it is very useful in improving power quality and reliability. It is, however, suggested that customers should consider comparing grid prices against both installation and operations costs before implementing such system (SAIC and EG&G, 2002; EEA, ICF, and ERG, 2007; NETL, 2010; Hedman and Hampson, 2004; RDC, 2001).

Application	Low Cost	High Efficiency	Thermal Output	Emissions	Start-Up Time	Fixed Maint.	Variable Maint.
Continuous Power	◒	●	○	◒	○	◒	●
CHP	◒	●	●	◒	○	◒	●
Peaking	●	◒	○	○	◒	●	◒
Green	◒	◒	◒	●	○	◒	◒
Emergency	●	○	○	○	●	●	○
Standby	●	○	○	○	◒	●	○
True Premium	◒	◒	○	◒	●	◒	◒
Peaking T&D Deferral	●	○	○	○	◒	●	○
Baseload T&D Deferral	◒	●	◒	◒	○	◒	●
Spinning/ Non Spinning Reserve	◒	◒	○	○	●	◒	◒
Reactive Power	◒	◒	○	◒	◒	◒	◒
Voltage Control	◒	◒	○	◒	◒	◒	◒
Local Area Security	●	○	○	○	◒	●	○

Key: ● Important Characteristic
◒ Moderately Important / Important in Certain Applications
○ Relatively Unimportant

FIGURE 10: DG APPLICATION TYPES AND IMPORTANT CHARACTERISTICS OF EACH
SOURCE: (RDC, 2001)

2.4.8. Green Power: DG can use zero or low-level emission technologies such as PV and wind technologies and fuel cells with low emissions, for customers who have a special concern for the environment (SAIC and EG&G, 2002; RDC, 2001).

2.4.9. Residential Fuel Cells: due to its small size, modularity, and the short construction lead-times, DG can be a particularly attractive and practical solution for individual households. Given today's technology, the market most likely to develop for 4 to 7 kW fuel cells, which can be installed in both new construction and retrofits of existing housing stock (SAIC and EG&G, 2002).

2.4.10. Selling power to the grid under net metering: In countries applying the Feed-In-Tariff (FIT) system, customers generating their own electricity, using renewable resources, might be eligible for net metering, selling excess generation back to the grid for specific price, which makes economics for small residential and commercial DG installations substantially enhanced (SAIC and EG&G, 2002).

Rastler (1997) divided DG applicator into a big industrial segment and small industrial/commercial applicators. In the big industrial segment applications, he mentioned cogeneration. And in the small industrial/commercial segment applicators he mentioned peak shaving, back-up generation, heat and hot water and premium quality power services. He also suggested that utility's retail and energy services can benefit from several DG applications by applying several strategies, to increase customer satisfaction and loyalty.

2.5. Challenges and barriers to implementation

To realize its benefits and applications' full potential in a timely manner, DG challenges and barriers to implementation need to be recognized and eliminated. The GSGF report (2014) mentioned that from a technological viewpoint, power quality, increasing consumption, voltage and frequency levels, interoperability and standardization issues, are some of the major challenges of implementing DG. Other challenges include: limited storage which still requires connecting to the main grid and the high cost of replacing old systems. There are also the challenges related to regulations and policies, which include regulatory complexity and instability, the need for interoperability and standardization, lack of a clear understanding of roles and responsibilities, the lack of incentives and cost-efficiency and limiting competition by governmental monopoly.

Andrepont (2009) mentioned two types of barriers. Those related to monopoly regulation of electric power, such as retail electric sale prohibitions, laws banning transmission competition, the interconnection rules and the limitation of backup power, and those related to well-intentioned but often self-defeating environmental regulations, such as ignorance of the input-based rules for efficiency, extending the use of inefficient plants, and the lack of pollution offsets.

IEA (2002) mentioned the low number of choices among primary fuels, and accordingly, reducing the diversification of main energy supplies, when increasing the share of DG generation in installed generation. Pepermansa et al (2005) stated that, despite the various benefits of DG, the excess in applying DG might also have some economic and environmental costs. The mix and size of the installed DG capacity depends on the relative cost and benefit of each technology. The challenge remaining then is to design a framework that has the ability to reflect these costs and benefits in both environment and economy.

Gillingham and Sweeney (2012) mentioned that several challenges associated with the traditional system also applied to DG. These challenges include the possible market failures in renewable resources, such as high cost and poor information about prices, damage caused by fossil fuel emissions, national security externalities, as well as market failures in R&D and LBD. Lobato et al (2009) mentioned the problems of market access, aggregation of units and size limitations. For example, some DG technologies are not permitted to sell in some markets due to their non-adherence to minimum size requirements.

A range of topics has been discussed throughout this literature review chapter as a foundation from which the analysis and recommendation shall be made. DG offers several advantages that cannot be achieved by the traditional system. DG is still a relatively new concept that is beginning to receive more recognition, and there is much capacity for more research and expansion.

Chapter 3: Methodology

This chapter presents the methods adopted to answer the research questions. The main method used is the case study. The Kyushu area was chosen as the study area for this research due to its distinguished location, being a home of leading industries, high technology businesses, scale of the economy, and proven success in the field of energy. Kyushu electric power company (KEPC) was used due to the accessibility of information. This company has established a standard level of quality in terms of sustainable energy, and it seemed appropriate to analyze an organization that enjoys a history of success in this area to determine how to further improve the effectiveness of Distributed Generation implementation projects.

This research also adopts the results from a group of surveys conducted by seven organizations of the public opinion on nuclear power generation, presented in a paper by Kitada (2013). The results from that paper were updated by a survey conducted by the researcher of 42 participants from different areas of Japan. This chapter provides details about both the surveys and the case study, as well as, the procedures, tools and principles employed to achieve the objectives of the analysis.

This study is an attempt at understanding the energy situation in Japan and finding appropriate solutions for the challenges facing the power industry. The primary goal of this study is to propose an improved model for better performance of the power system. The analytical framework includes a historical analysis of the established literature from secondary materials (books, journals, articles) on DG, aimed at providing a foundation from which analysis and recommendations can be made.

To achieve that goal, this analysis employed a cross-sectional mixed (qualitative and quantitative) approach. According to Zheng (2015), cross-sectional research is an approach used to describe the state of affairs in a population at a certain period. Due to resource limitation and time constrains inherent in this study; the sampling method has been utilized for data collection. Applying this method, researchers collect the required data using a sample of population to get information about the population as a whole.

To implement this qualitative approach, the case of Kyushu electric power company (KPC) was adopted to answer the research questions. The ability to gather primary data in this research analysis was dependent on gaining access to appropriate sources within the company. The level to which these sources are considered appropriate or not is based on both the research questions and objectives (Saunders et al, 2012). Since this ability was limited due to the company's refusal to offer an internship for the researcher, the main source of primary data employed in this analysis was the company annual reports 2001-2016, as published on the company website. 16 annual reports were analyzed and interpreted by the researcher to meet the objectives of the analysis, which is understanding the energy situation in Japan and optimizing appropriate solutions for meeting the challenges facing power generation. The case study method is used as a tool to test the research hypothesis that "*Distributed Generation leads more often to performance enhancement compared to the traditional power generation systems Model*".

The quantitative method was another tool used for data collection. The results from already designed group of surveys, which published in a paper by Kitada (2013), have been used in this research. The surveys were conducted by Eight News Media after one year from Fukushima Daiichi accident, in addition to the surveys conducted by newspaper companies, television stations and telecommunications companies, almost every month, since 1993 to 2011, after the accident. The main objective of those surveys was to investigate the public acceptance of using nuclear power as one of the main sources for energy generation in Japan. The main objective of the paper was to investigate the changes in public opinion over the past 30 years and the influence of the Fukushima Daiichi accident on those results.

To update and verify the results from the paper, a survey, designed by the researcher, was handed to participants in either electronic form, using google drive survey designer, or in a hard copy form. The survey was designed to meet different participants' styles and abilities. The questions used in the researcher's survey were borrowed from the paper by Kitada (2013). The main objective of this survey was not only to measure public opinion on using nuclear power for energy generation, but also, their opinions on other new and renewable energy generation sources, such as solar and wind energies, as well as their willingness to accept the changes associated to utilizing these resources. 42 participants, males and females, from different age and financial levels, and from different areas in Japan, took part in the survey. The main factors used for analyzing the survey results were gender and age. The survey included eleven (11) questions. The results from one of the eleven questions was neglected because the multiple answers provided for the participants seemed to be biased and misleading.

Limitations

The main limitation of this study was gaining proper access to Kyushu electric power company (KEPC) for data collection and analysis verification. Therefore, this study is limited to the information in the annual reports provided on the company website.

Due to time and resources limitations, the sampling method has been used in this study. The researcher tried to get access to participants from different areas of Japan, however, the willingness and capacity of participants to respond to the survey was also low. Therefore, the number of participants in the survey was limited to 42 participants only.

Chapter 4: Analysis

This chapter includes the data obtained along with the analysis of these data. The data were collected and processed in response to the research questions posed in chapter one. The analysis chapter discusses three topics; the current state of energy generation in Japan, the case of the Kyushu electric power company, and public opinion on nuclear power generation. The results from these analyses are used as evidence supporting the arguments which will be discussed in the following chapter.

4.1. Overview of the situation of Energy generation in Japan

This section explores energy generation in Japan. The main objective is to provide a foundation for understanding the current energy situation in Japan and the challenges facing power generation. Data collected from governmental sources; such as the Federation of Electric Power Companies of Japan, in addition to other credible sources, such as WorldBank.Com are used. We begin by providing a brief about the nature of Japan landscape, brief history of energy generation in Japan, energy policies, such as deregulation policy, the Kyoto protocol and FIT. This approach serves the objective of this research; which is providing information on optimizing the appropriate solution for meeting the challenges facing power generation in Japan.

4.1.1. The Nature of Japan's landscape

Japan (日本) is an island nation in the Pacific Ocean located in East Asia. The land area of Japan is about 377,972.28 km2, of which more than 50% are mountains that are covered with forests. It consists of four main islands; Kyushu, Hokkaido, Shikoku and

Honshu, in addition to thousands of small islands, and politically structured of 8 regions or areas and 47 prefectures (Figure 11).

FIGURE 11: JAPAN DETAILED MAP
SOURCE: WORLD ATLAS

Japan is an island nation, and about 12% of its total area is water, with hundreds of dams, and more than 500 natural waterfalls (日本の滝百選, 1990). With this type of resource, Japan can produce more clean, reliable and low-cost energy from water. The current population of Japan is 126,113,652 as of April 2017 (Figure 12), according to the latest estimates of the United Nations. The population density is 346 per Km2 (896 people per mi2).

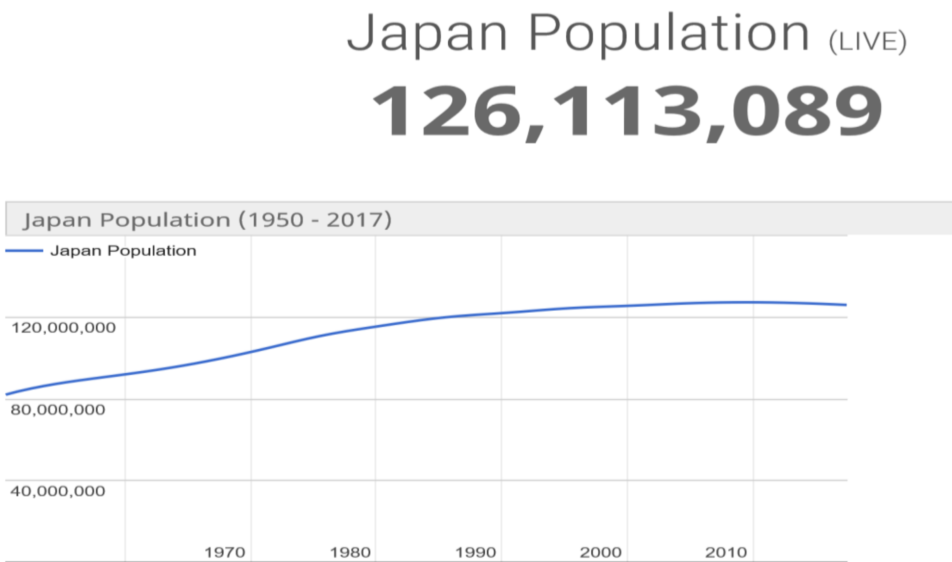


FIGURE 12: JAPAN POPULATION (APRIL 2ND 2017)
SOURCE: WORLD METERS INFO

The current statistics show a considerable decline in Japan's population (Figures 13-16. Not only that, they also show that Japan is purported to have the highest rate of senior citizen, not only in rural areas, but also in urban areas of Japan. Lasts estimates show that about 33% of citizens are above the age of 60, about 26% are above the age of 65, while more than 12% are above the age 75 (Japan Statistics Bureau, 2015).

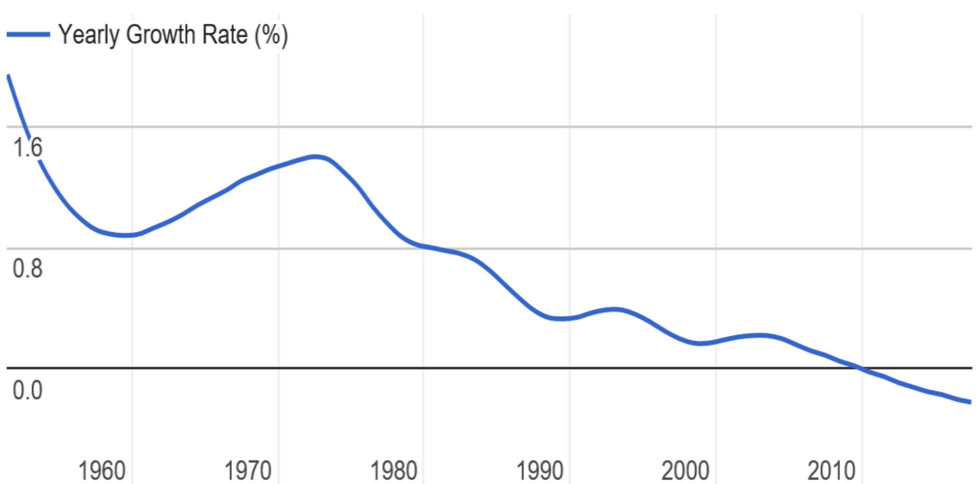


FIGURE 13: JAPAN YEARLY POPULATION GROWTH RATE (%)
SOURCE: WORLD METERS INFO

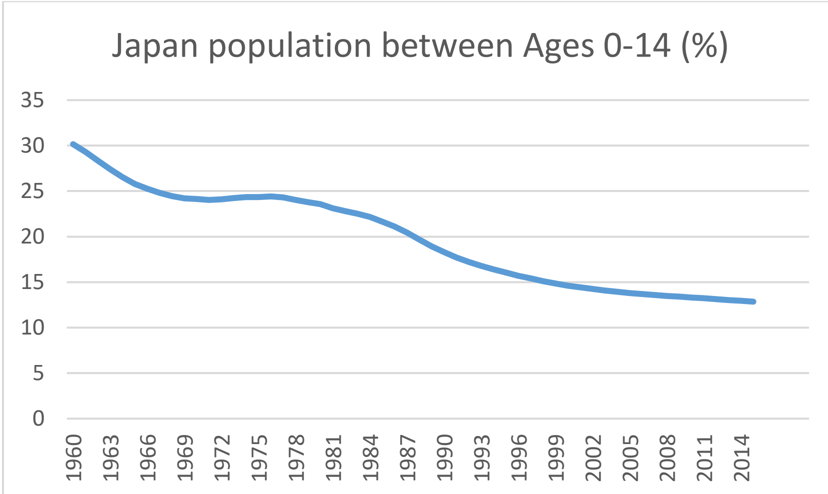


FIGURE 14: JAPAN POPULATION BETWEEN AGES 0-14
SOURCE: WORLD BANK

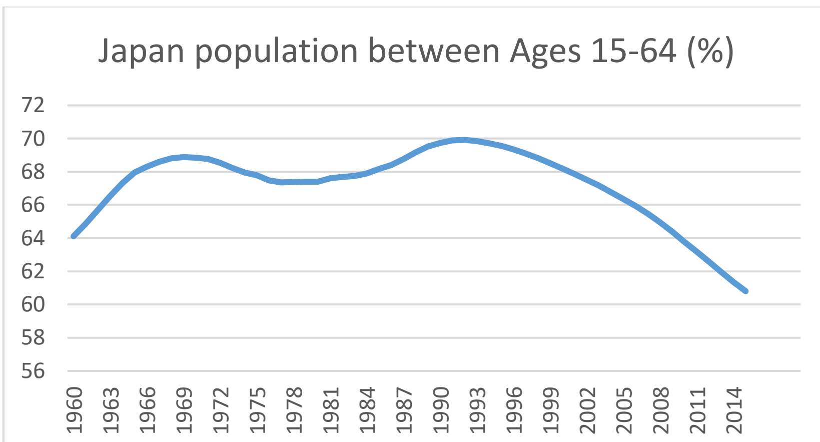


FIGURE 15: JAPAN POPULATION BETWEEN AGES 15-64
SOURCE: WORLD BANK

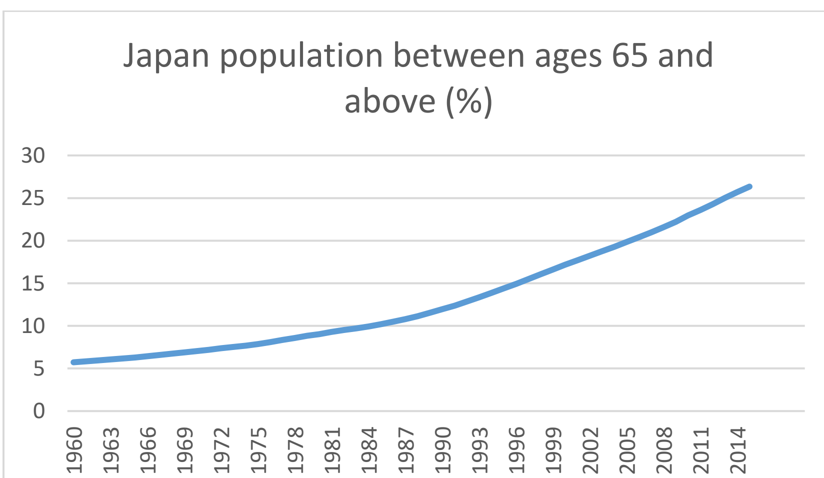
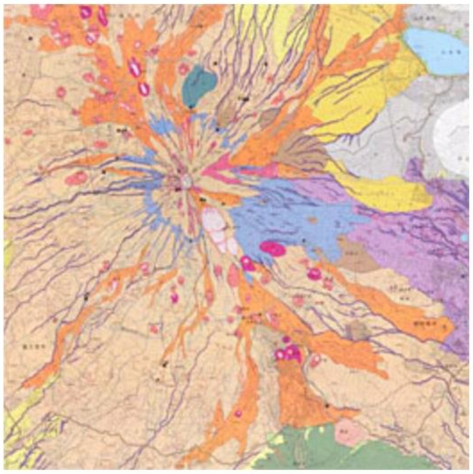


FIGURE 16: JAPAN POPULATION BETWEEN AGES 65 AND ABOVE
SOURCE: WORLD BANK

Japan falls in a region where several continental and oceanic tectonic plates meet. This is why the country is the site of several types of natural disasters, including Earthquakes, Volcanos, Tsunami, Typhoons and floods. In addition, the country is subject to many wind and rain related disasters due to the steep landforms. However, the government is always prepared for such experiences (JNTO). The Geospatial Information Authority of Japan (GSI) is an organization responsible for providing data needed for disaster prevention and mitigation, such as research on prediction of Earthquake and Volcano eruption and thematic maps which are very helpful in such situations, as well as the formulation of countermeasures against such hazards (Figure 17).



Volcanic Land Condition Map

(Mt. Fuji)

Active Faults in Urban Area of Map

(Kobe)

FIGURE 17: SAMPLE THEMATIC MAPS
SOURCE: GSI

The climate also varies dramatically throughout the country due to its large north-South extension. The weather in most cities varies from temperate to sub-tropic and consists of four seasons. The winter is mild and snowy, while summer is hot and humid. There is a rainy season which comes in summer and is accompanied by typhoons which hit many areas of the country every year, some of which so strong that they bring the country's transportation system to a stop and the announcement of emergencies (JMA).

Carbon dioxide (CO_2) emissions and greenhouse gas are one of the hottest issues concerning the world these days (Figures 18-20). CO_2 contributes largely in greenhouse gas causing global warming and climate change. Recent trends in global CO_2 emission show that, although Japan is among the top five countries in terms of CO_2 emission. However, in the past three years, Japan noticeably decreased its CO_2 emission by 2.4% in 2014, and 2.2% in 2015, yielding a share in the global CO_2 emission by 3.5% (PBL, 2016)

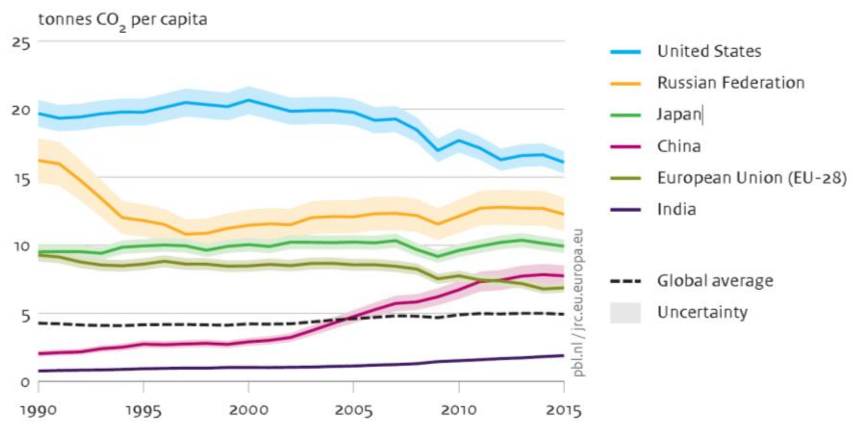


FIGURE 18: CO_2 EMISSION IN TOP 5 EMITTING COUNTRIES AND EUROPEAN UNION (1970-2015)
SOURCE: PBL (2016)

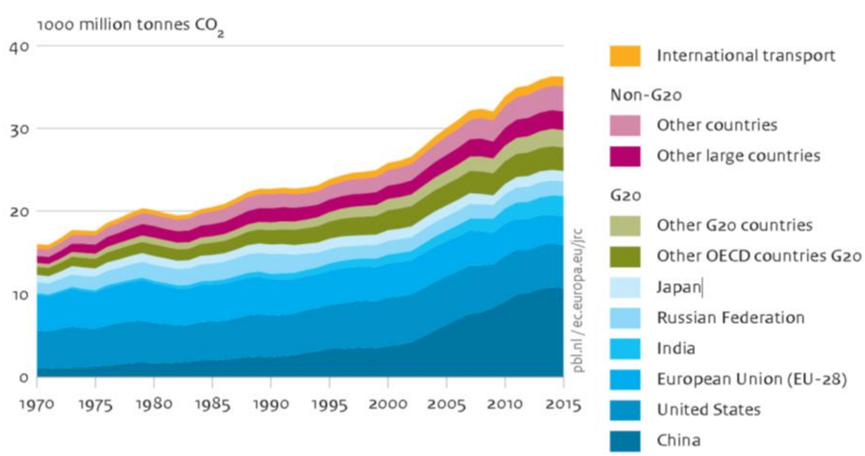


FIGURE 19: GLOBAL CO_2 EMISSION PER REGION (1970-2015)
SOURCE: PBL (2016)

After the Fukushima Daiichi disaster, Japan CO_2 emissions increased dramatically. The data from Japan Ministry of Environment showed that the country's level of CO_2 emissions increased to its second-highest level in the year to March 2014 (PBL, 2016). Fukushima accident negatively affected the public trust in Japan energy strategy of supplying half the country's electricity using nuclear power, which forced the government to shut down most of nuclear power plants. To fill the gap left by giving up nuclear power, the country had to increase the use of fusil fuel to generate electricity, which negatively affected the level of CO_2 emission (KEPC, 2013). However, Japan is still planning to reduce CO_2 emission by 20% compared to the 2013 level by the year 2030 (KEPC, 2015).

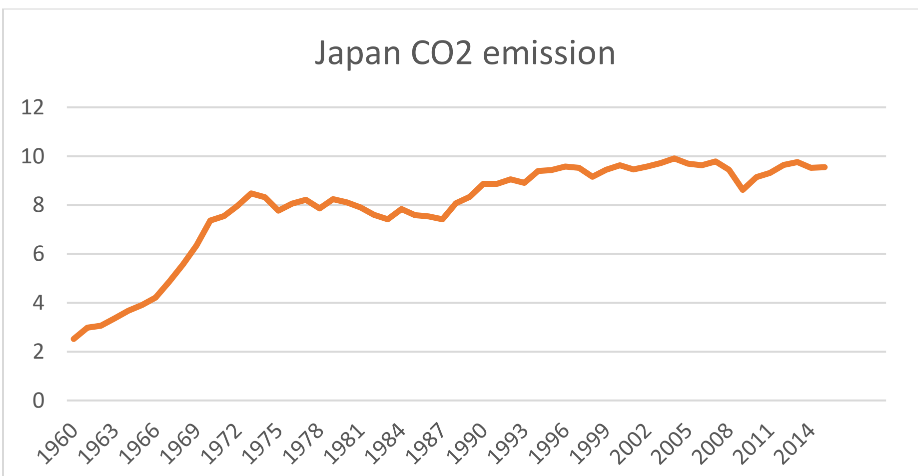


FIGURE 20: JAPAN CO_2 EMISSION 1960-2015 (METRIC TONS PER CAPITA)
SOURCE: WORLD BANK

4.1.2. Energy generation in Japan

The first electric beam in Japan was from an arc lamp in the Toranomon Institute of Technology in March 1878. About eight years later, and in 1886, Tokyo Electric Lighting, a private company, and Japan's first electric power company, supplied the public with electricity for the first time. In the beginning, electricity was only used for lighting, however, the demand gradually increased due to the increase in electricity applications as a result of the modernization of Japan and the development of its industrial sector, subsequently, the number of electric company has increased. In 1951, after the end of World War II, as a result of serious discussions aiming at democratizing the economy of Japan, nine regional privately owned and managed general electricity companies were established. The nine companies include Tohoku, Hokkaido, Chubu, Tokyo, Hokuriku, Chugoku, Kansai, Shikoku and Kyushu (FEPC).

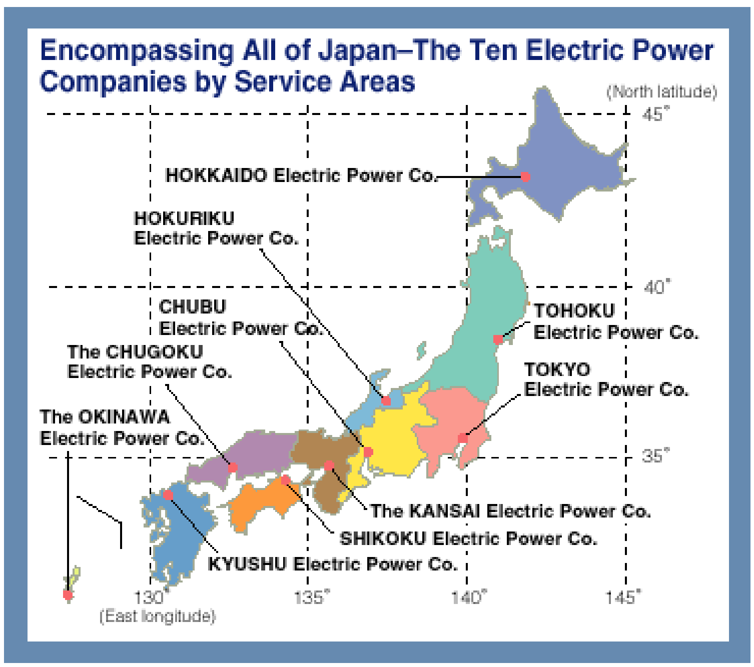


FIGURE 21: LOCATION OF JAPAN 10 POWER COMPANIES
SOURCE: GENI (2016)

After the return of Okinawa to Japan in 1972, Okinawa electric power company was established, making 10 companies (Figure 21). By the end of the 20th century, emerged a trend towards deregulation calling for liberalizing the electric utility industry. The country, in December 1995, and for the first time since the establishment of its regional companies in 1951, allowed some independent power producers to provide electricity wholesale services. The scope of liberalization began to expand since March 2000, when the government implemented the revised Electric Utility Law, deregulating the retailing of high-voltage power (20 KV or above). Japan allowed several Japanese and foreign companies to enter the power market which was previously dominated by regional monopolies, seeking a liberalization model based on transparency and fair competition while maintaining a vertical integration of generation, transmission and distribution to ensure a stable electricity supply. The full retail liberalization was planned to finally start in April 2016 (FEPC).

Japan is a resource-poor country, and imports substantial amounts of natural gas, crude oil, and other resources needed for energy generation. The country's dependence on imports, in 1999, was over 79%. Before the Fukushima incident, about 30% of total energy was provided by LNG, about 25% by coal, about 8% by oil, about 30% by nuclear power, while renewable resources represented only 10% of total energy (Figure 22). After Fukushima, the dependence on nuclear decreased to be covered by other resources.

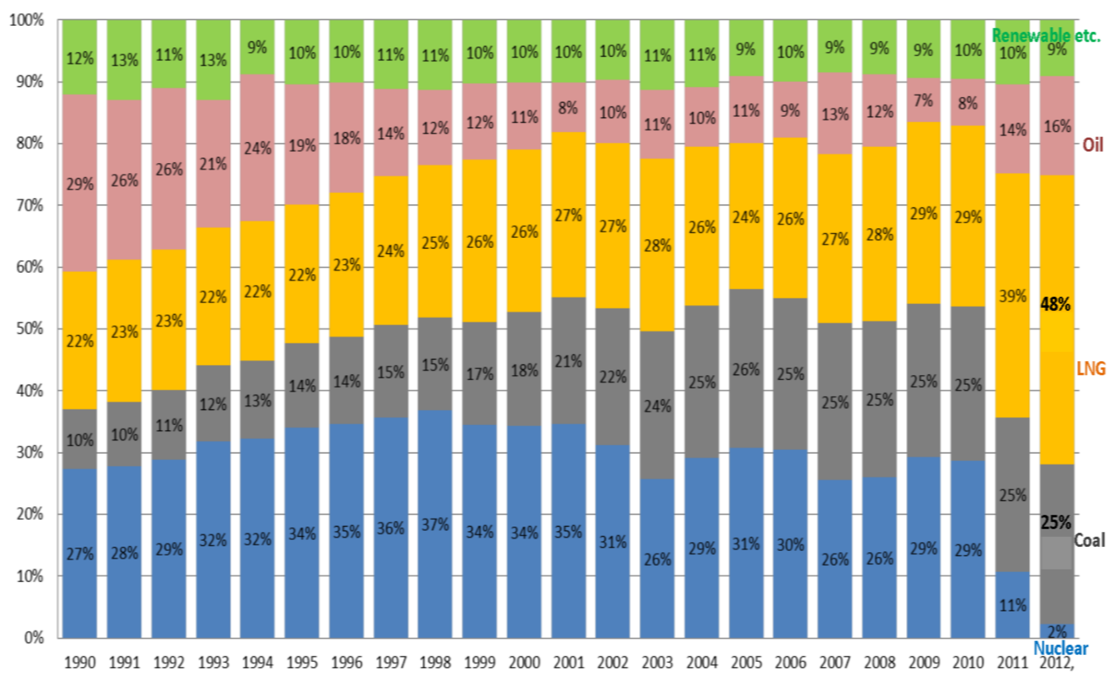


FIGURE 22: TREND OF JAPAN ENERGY MIX (1990-2012)
SOURCE: PARI

In Jun 2015, the Japanese government announced the "strategic energy plan" which stated the importance of including a certain level of nuclear power, with a proportion at 20-22% of the energy mix in 2030, while increasing the use of renewable energy (METI, 2015; Figure 23).

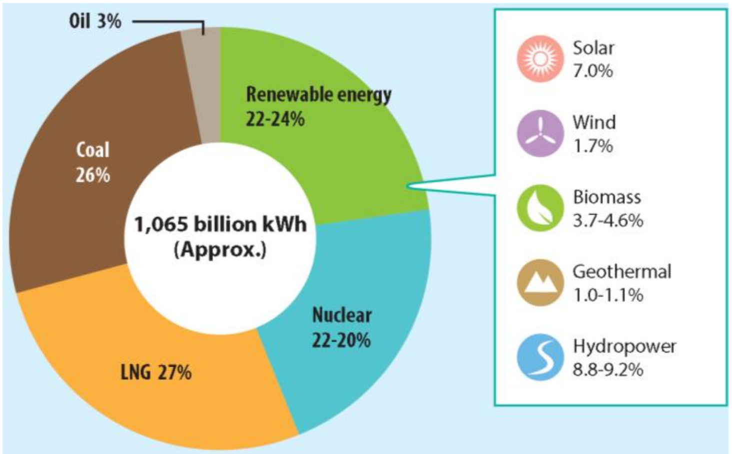


FIGURE 23: JAPAN 2030 ENERGY MIX TARGET
SOURCE: MEIT (2015)

About half of Japan's energy is used for industrial purposes, and the rest is used for residential, agricultural, transportation and service sectors (GENI). According to the recent statistics published in the Global Energy Statistical Yearbook (2016), its energy intensity of GDP is amongst the lowest in the world (Figure 24).

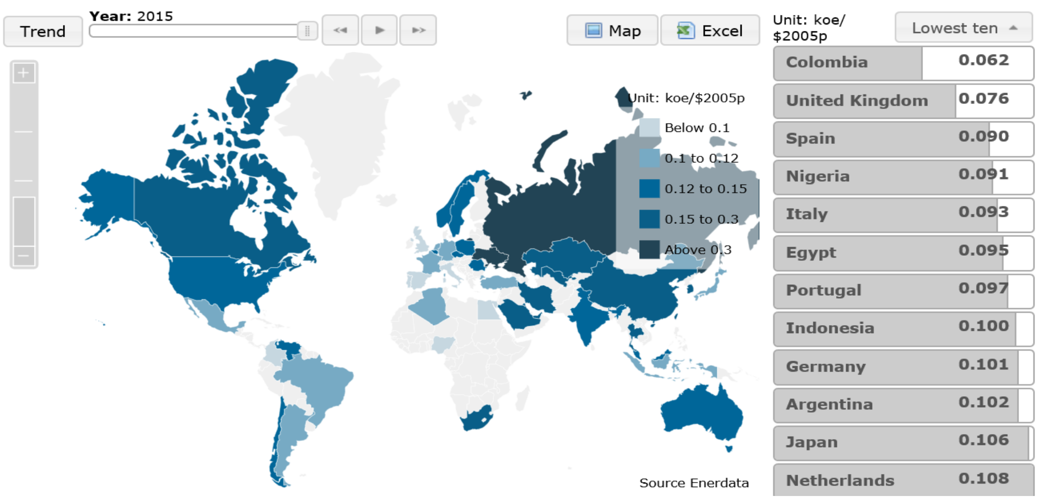


FIGURE 24: ENERGY INTENSITY OF GDP (200-2015)
SOURCE: GLOBAL ENERGY STATISTICAL YEARBOOK (2016)

Due to heavily relaying on imports, electricity costs in Japan are very high, which negatively reflects on its competitiveness in the industrial and manufacturing fields. Part of its 2030 plan is reducing energy costs to enable Japan to provide a stable energy supply with convenient prices, and promote economic efficiency while ensuring safety (METI, 2015).

4.1.3. Energy Policies

4.1.3.1. Deregulation policy

Deregulation became necessary for the sake of Japan's competitiveness in the international market (Figure 25). Although electricity is a domestic commodity whose price should not be compared to international prices, the price of Japanese products, produced in factories using electricity, are commonly compared to products from countries with lower electricity rates. Deregulation can also help the industry in meet increasing peak loads. Utilities at high demand areas should witness an increase in the Independent Power Producers (IPPs) which will provide them with an alternate source of electricity to meet high peak demand (Asano et al, 1995). The Electric Utility Law has been revised by the Electric Utility Council, which is an advisory party to the Ministry of International Trade and Industry (MITI). They were responsible for revising the power supply and safety regulations specified in the Electric Utility Law.

According to Asano et al (1995), this revision focuses on the following:

1. Defining the main objectives of the revision, including, encouraging competition to reduce the rate level to an internationally competitive one and ensuring efficient utilization of non-utility sources.
2. The main points under revision include:
   - The liberalization of the wholesale market, including the bidding system for wholesale generators, the wheeling from NUG to other utility and the liberalization of the entrance;
   - The formation of a new system for direct power supply;
   - Ensuring flexibility for utilities to apply for the tariff;
   - The relaxation of technical regulation which will encourage other players to enter the market.

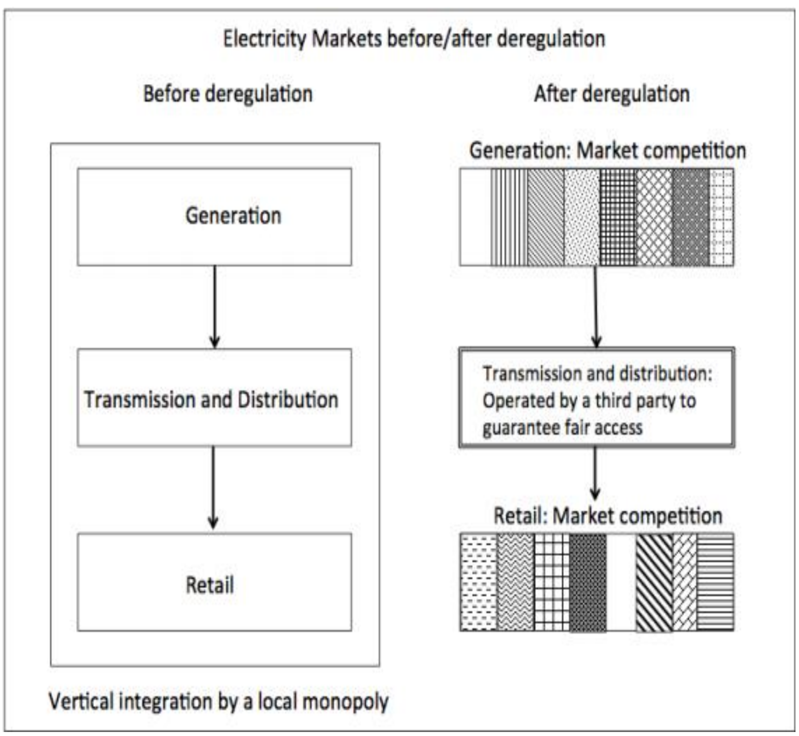


FIGURE 25: COMPARISON (ELECTRICITY MARKET BEFORE AND AFTER DEREGULATION)
SOURCE: ITO (2016)

Based on what is mentioned above, these reforms to the utility law should bring opportunities to the Japanese economy in two ways. First, it will bring competition to the previously monopolized market. This should improve the efficiency of both electricity generation and retail services which have been absent due to the absence of economic incentives. This competition should also provide customers with lower electric utility bills. Second, the new comers to the market of nontraditional companies are expected to enrich the industry innovative energy services derived from their knowledge and experience (ITO 2016).

4.1.3.2. Kyoto protocol

The Kyoto protocol to the United Nations framework convention on climate change, hereinafter referred to as the Kyoto Protocol, is an international treaty which commits participating countries to reduce green house gas emission. This agreement was made based on the premise that global warming is a result of man-made CO_2 emissions. The protocol was negotiated in 1995, adopted in Japan in 1997, and entered into force in 2005. The number of participating parties was 192 (Figure 26).

The main objective of the protocol is to find flexible ways to meet reduce green house gas emissions by total of 5.2% compared to the year 1990 (Kyoto protocol Background, 2014). One of the important features of the Protocol lies in that leading industrial countries who have agreed to sign are forced to apply mandatory targets on green house gas emissions. The targets vary from -8% to +10% of each country's 1990 emission levels, so that the overall reduction would be 5.2% of the 1990 level within the commitment period 2008 to 2012 (Kyoto protocol Background, 2014).

There are several reasons why the protocol was slow to be acted upon. For example, it had to be effective against a complicated worldwide problem, and be politically acceptable. In addition, committees and panels are being conducted to monitor the application of its various programs, and although it was approved in 1997, further negotiations were and still being made to decide on the instruction on how it should operate in the future (Kyoto protocol Background, 2014).

Party	Quantified emission limitation or reduction commitment (percentage of base year or period)
Australia	108
Austria	92
Belgium	92
Bulgaria*	92
Canada	94
Croatia*	95
Czech Republic*	92
Denmark	92
Estonia*	92
European Community	92
Finland	92
France	92
Germany	92
Greece	92
Hungary*	94
Iceland	110
Ireland	92
Italy	92
Japan	94
Latvia*	92
Liechtenstein	92
Lithuania*	92
Luxembourg	92
Monaco	92
Netherlands	92
New Zealand	100
Norway	101
Poland*	94
Portugal	92
Romania*	92
Russian Federation*	100
Slovakia*	92
Slovenia*	92
Spain	92
Sweden	92
Switzerland	92
Ukraine*	100
United Kingdom of Great Britain and Northern Ireland	92
United States of America	93

FIGURE 26: EMISSION REDUCTION PER COUNTRY
SOURCE: KYOTO PROTOCOL (1998)

According to the Guardian (2011), several countries expressed concern about the world commitment to apply the protocol. In 2011, Canada and Russia announced that they no longer wish to take on further Kyoto targets. On 15 December 2011, Canada announced its withdrawal from the treaty. In December 2010, according to MOF, the Japanese government announced that although Japan is committed to continue its ambitious emission reduction efforts beyond 2012, it does not want to be under the obligation of the second commitment period of the protocol after 2012. At the following climate summit, Japan didn't sign the extension of the protocol (the Paris Accords).

4.1.3.3. Feed-In Tariff (FIT)

After the Fukushima disaster, nuclear power activities were suspended which significantly affected the country's power generation capacity. As a result, the government resorted to the promotion of renewable energy to compensate for the reduction in generating ability (Johanston, 2012). They encouraged the public to generate their own electricity, and forced utility companies to buy the excess electricity at a fixed price over a certain period (Figures 27-29). Utility companies, in turn, can require customers to pay a surcharge for renewable energy generated according to the amount they used (METI).

The main objective of the FIT system is to encourage investment in renewable energy resources. This should be accomplished by guaranteeing renewables generators a profit over time, and ensuring stability of prices for the purchases required by utility companies. FIT is cost-efficient, taking into consideration saving cost of setting up a production/distribution system and reducing the investment risk caused by establishing renewable generation facilities. In Japan, there are 5 types of renewable sources; Solar, wind, biomass, geothermal and mini-hydro. A utility company enters a contract with providers who have METI approval (METI).

(1) Electricity generated by photovoltaic power for non-household customers (10 kW or more)

	FY 2015	FY 2016
Purchase price (excluding tax)	27 yen/kWh =>	24 yen/kWh

(2) Electricity generated by photovoltaic power for household customers (10 kW or less)

		FY 2015	FY 2016
Purchase price	When generators are not required to have output control equipment installed	33 yen/kWh =>	31 yen/kWh
	When generators are required to have output control equipment installed	35 yen/kWh =>	33 yen/kWh

(3) Other renewable energy (land-based wind power, offshore wind power, geothermal power, small and medium hydropower, and biomass)

FIGURE 27: FY 2016 PURCHASE PRICES FOR NEWCOMERS
SOURCE: METI

Category			FY 2015	FY 2016
Photovoltaic power	10 kW or more		29 yen (April 1 to June 30), 27 yen (from July 1)	24 yen
	Less than 10 kW	When generators are not required to have output control equipment installed	33 yen	31 yen
		When generators are required to have output control equipment installed	35 yen	33 yen
Land-based wind power	20 kW or more		22 yen	22 yen
	Less than 20 kW		55 yen	55 yen
Offshore wind power	20 kW or more		36 yen	36 yen
Geothermal power	15,000 kW or more		26 yen	26 yen
	Less than 15,000 kW		40 yen	40 yen
Small and medium hydropower	1,000 kW or more but less than 30,000 kW	Installing completely new facilities	24 yen	24 yen
		Utilizing existing canals	14 yen	14 yen
	200 kW or more but less than 1,000 kW	Installing completely new facilities	29 yen	29 yen
		Utilizing existing canals	21 yen	21 yen
	Less than 200 kW	Installing completely new facilities	34 yen	34 yen
		Utilizing existing canals	25 yen	25 yen
Biomass	Wood (unused)	2,000 kW or more	32 yen	32 yen
		Less than 2,000 kW	40 yen	40 yen
	Wood (general)		24 yen	24 yen
	Wood (waste materials from building demolition)		13 yen	13 yen
	Waste materials		17 yen	17 yen
	Methane fermentation		39 yen	39 yen

FIGURE 28: FY 2016 LIST OF PURCHASE PRICES
SOURCE: METI

Basis for calculating the surcharge rate

Surcharge rate 2.25 yen/kWh =
(i) Purchase cost 2,300 billion yen - (ii) **Avoidable costs** 497.5 billion yen + **Administrative expenses of expense-sharing coordinating bodies** 290 million yen
(iii) **Amount of electricity** sold 802.5 billion kWh

Breakdown of the figures

	Estimate in FY 2015	Estimate in FY 2016	
(i) Purchase cost	1,837 billion yen	2,300 billion yen	・Increased the hours of usable sunlight for electricity generated by photovoltaic power for household customers and also increased the number of solar facilities which will newly start operations in FY 2016.
(ii) Avoidable costs	514.8 billion yen	497.5 billion yen	・Considered the risk of a fall in avoidable costs associated with a fall in fuel adjustment costs.
(iii) Amount of electricity sold	836.6 billion kWh	802.5 billion kWh	・Calculated based on the results for the amount of electricity sold in 2015, taking into consideration the downward trend in the amount in recent years.*

FIGURE 29: FY 2016 SURCHARGE RATES
SOURCE: METI

4.2. The Case of the Kyushu electric power company

This section will discuss the case of the Kyushu electric power company, and begins by exploring the physical characteristics of the Kyushu area which are relevant to energy system; such as climate, space and natural landscapes. Then it will provide the results from analyzing the Kyushu electric power company annual reports, including company background, history, current status, and the challenges faced by the company.

4.2.1. Characteristics of Kyushu area

Kyushu (九州) is the third island of Japan, with an area of 42 Km^2 and a population of 13 million as of October 2015. It comprises seven prefectures; Fukuoka, Oita, Nagasaki, Miyazaki, Saga, Kumamoto and Kagoshima (Figures 30-31). It falls in the southwest of Japan, and is known for its tropical weather, active volcanos, beautiful beaches and hot springs.

FIGURE 30: MAP OF KYUSHU AREA
SOURCE: KYUSHU TOURISM INFORMATION (WWW.WELCOMEKYUSHU.COM)

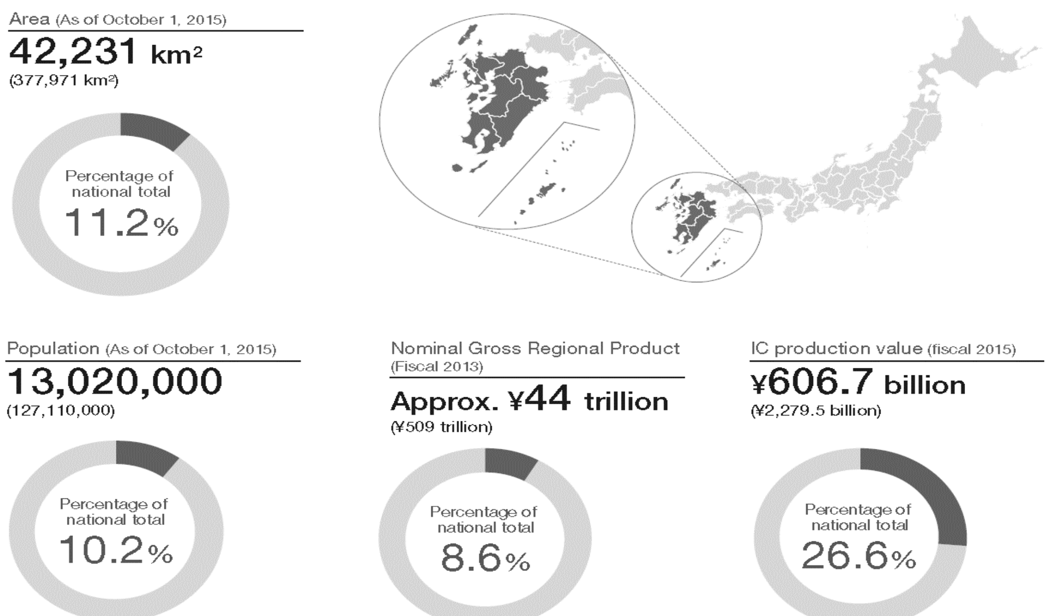


FIGURE 31: SNAPSHOT OF KYUSHU AREA
SOURCE: KEPC ANNUAL REPORT (2016)

Kyushu represents 10% of Japan economy, and in terms of population and GRP, is the fourth highest statistics for being a local area (Kyushu Economic Research Center). Kyushu is also known for convenience of access to Asian countries such as Hong Kong, Korea, and Indonesia (Figures 32-33).

	Fukuoka	Tokyo (Narita)
Airport to the downtown area	10 min.	50 min.
Pusan (South Korea)	50 min.	2 h. 30 min.
Seoul (South Korea)	1 h. 20 min.	2 h. 40 min.
Shanghai (China)	1 h. 30 min.	3 h. 30 min.
Taipei (Taiwan)	2 h. 10 min.	4 h.
Hong Kong	3 h. 20 min.	5 h. 20 min.
Ho Chi Minh (Vietnam)	5 h.	6 h. 40 min.
Bangkok (Thailand)	5 h. 10 min.	7 h.
Singapore	6 h. 15 min.	7 h. 40 min.

FIGURE 32: COMPARISON BETWEEN DISTANCE BETWEEN ASIAN COUNTRIES TO KYUSHU AREA AND TOKYO
SOURCE: KYUSHU BUREAU OF ECONOMY, TRADE, AND INDUSTRY (2016)

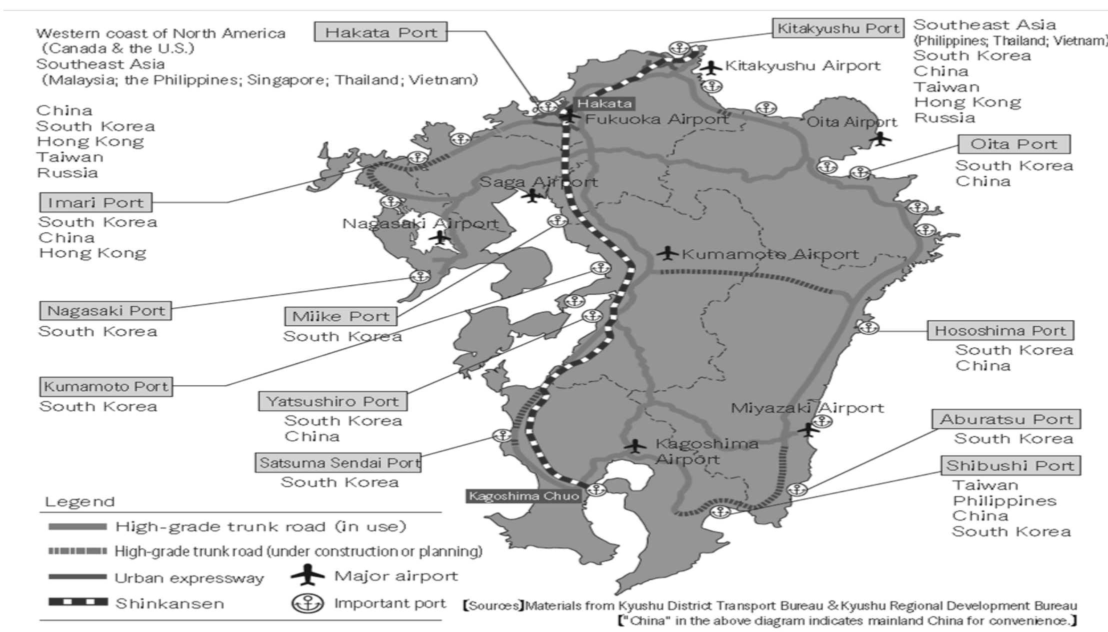


FIGURE 33: EXPRESSWAYS ROUTES, AND INTERNATIONAL CARGO ROUTES IN AND AROUND KYUSHU AREA.
SOURCE: KYUSHU BUREAU OF ECONOMY, TRADE, AND INDUSTRY (2016)

Kyushu is a leading automobile production center in Japan (Figure 34), representing about 15% of Japan automobile production capacity, for being the home of leading automobile companies, such as, Toyota, Nissan and Daihatsu. It is also known for being a major base for food production, representing about 20% of Japan agricultural products (Kyushu Bureau of Economy, Trade and Industry, 2016).

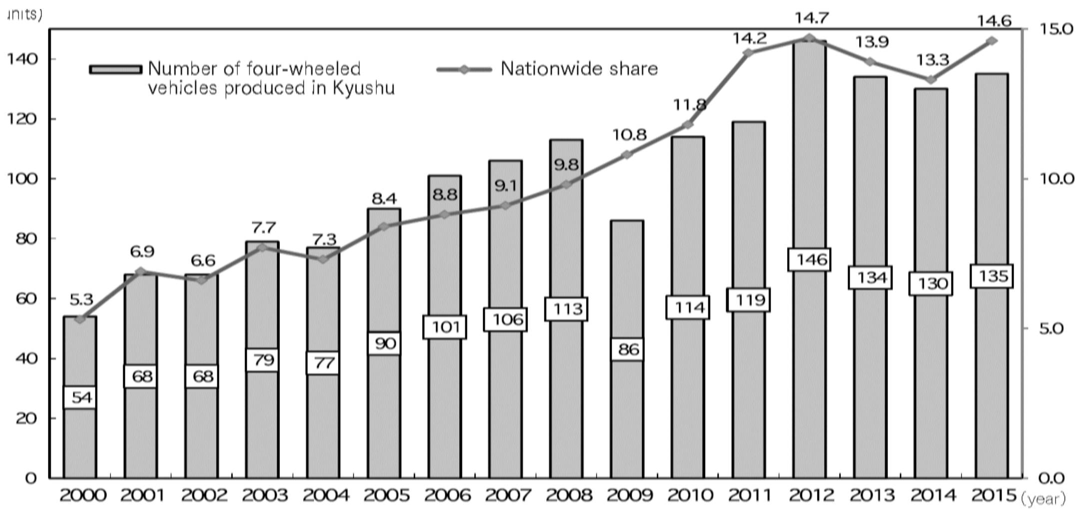


FIGURE 34: THE CHANGE IN NUMBER OF FOUR-WHEELED VEHICLES PRODUCED IN KYUSHU AREA
SOURCE: KYUSHU BUREAU OF ECONOMY, TRADE AND INDUSTRY (2016)

In terms of scale of economy, its economy is ranked among the top 30 economies, with a regional GDP that can be compared to some countries' economies, such as Taiwan and Austria (Figures 35-36; Kyushu Bureau of Economy, Trade and Industry, 2016).

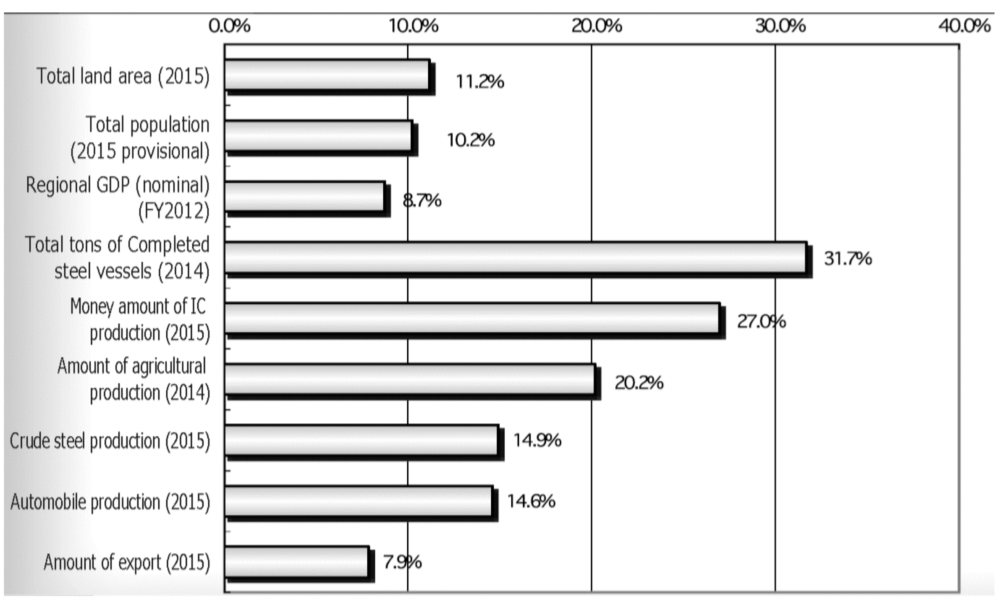


FIGURE 35: KYUSHU' ECONOMY SHARE COMPARED TO JAPAN AS A WHOLE
SOURCE: KYUSHU BUREAU OF ECONOMY, TRADE AND INDUSTRY (2016)

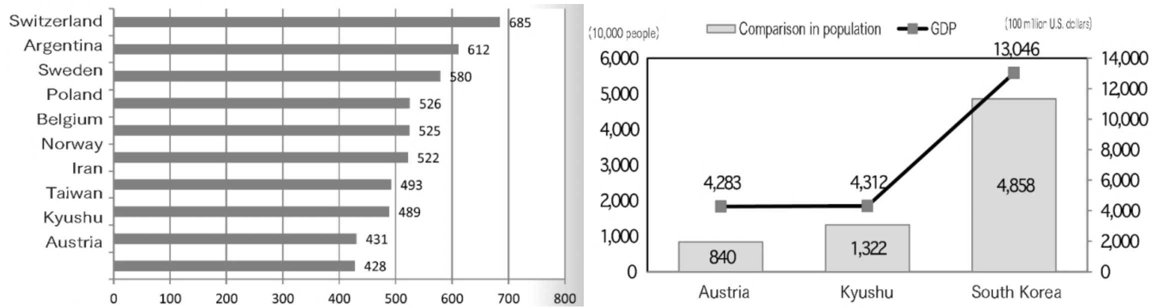


FIGURE 36: COMPARISON BETWEEN KYUSHU SCALES OF ECONOMY WITH SOME COUNTRIES
SOURCE: KYUSHU BUREAU OF ECONOMY, TRADE AND INDUSTRY (2016)

4.2.2. The Kyushu Electric power Company (KEPC)

Kyushu electric power company, is one of the biggest Japanese power generation companies, and provides power to the seven prefectures and some parts of Hiroshima Prefecture (Honshu) - the first Energy Company which provides power outside its area. The headquarters is located in Fukuoka, and 17 subsidiaries operate under the company name. The company operates in four main segments; electric power, energy related segment, IT & telecommunication and others. The electricity segment deals with power supply and transmission. The energy related segment deals with handling, obtaining and supplying LNG, and other business related to energy which responds to the various needs of its customers. While IT and telecommunication segment provides IT related services. Other segment in which the company is involved are the products of the R&D activities aiming at increasing the electricity power demand, such as, cookers, heat pumps and cars' batteries.

The company electricity capacity is diversified to include LNG, Nuclear, Hydroelectric, coal and renewable energy (Figure 37). In addition, the company, due to its location, is running the largest geothermal electricity generation in the country. The company is known for taking the best and highest possible environmental conservation measures, such as promoting renewable energy as a measure against global warming, while satisfying power requirements.

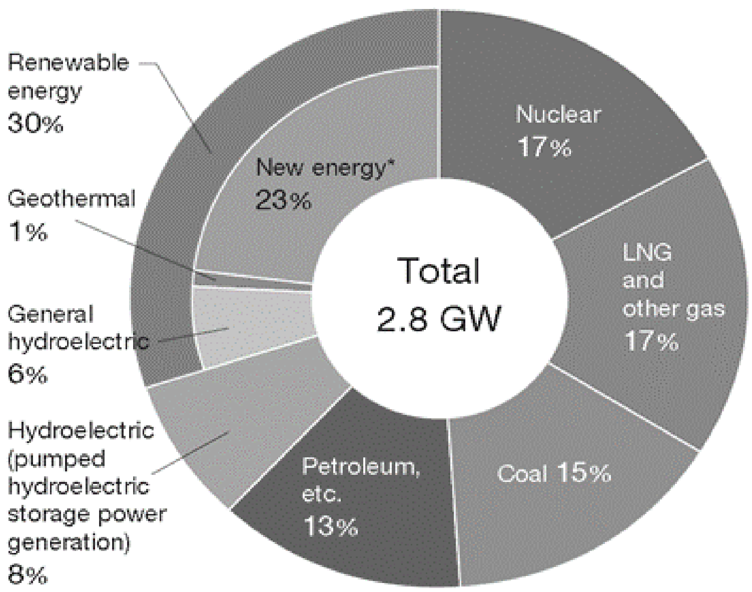


FIGURE 37: KYUSHU ELECTRIC POWER COMPANY ELECTRICITY PROFILE MIX
SOURCE: KEPC (2016)

Kyushu electric power company was established in 1951, together with nine other companies, after the end of World War II, as a result of serious discussions aiming at democratizing the economy of Japan (FEPC). Since its establishment, the company has been committed to the provision of quality services and comfort for its customers by ensuring stable supply and convenient prices. Through its life time, the company has faced several challenges witnessing several national changes, including the post war era reconstruction and war subsequent economic growth, 1970s oil shock, the rapid technological development and the deregulation of power industry (KEPC, 2013).

By the year 2000, the major challenges faced by the company could be summarized in the following:

- The liberalization of electricity retailing by the Japanese government;
- The increasing demand due to the high economic & industrial growth, as well as, the Japanese lifestyle improvements.

In March 2000, the government implemented a revised Electric Utility Law, deregulating the retailing of high-voltage power (20 KV or above). Several foreign energy companies, as well as, Japanese gas, trading and manufacturing companies entered the power market, which resulted in fierce competition in a market which was previously dominated by regional monopolies. The full-scale liberalization of power retailing was supposed to take place by the year 2016 (KEPC, 2004). To remain competitive and meet the public obligation of ensuring stable power supplies, the company applied some management reform measures, on the financial, customer and human resources levels; making the most of the facilities, technologies and expertise, and focusing its management resources on business areas that best reflect the strengths of the company (KEPC, 2005).

By April 2005, the scope of deregulation has expanded to include all customers who signed for high and extra high voltage power contracts. Japan Electric Power Exchange (JEPX), which is an organization dedicated to electric power wholesale supply, as well as, abolishing the power transition for other utilities fee are other deregulation initiatives which have been taken in the same year and resulted in intensifying the competition (ANRE, 2015). Moreover, due to the technological development, resulting in the demand for electricity to increase, in addition to the increase in the crude oil prices, which prevented the company from having a clear forecast for trends in the future market.

To save its business, and improve its business environment, the company decided to apply the Total-Energy Business solution (Figure 38). According to the online Business

Dictionary, Total- Energy Business, also called co-generation system, is defined as "Electricity generator that recovers and reuses its own waste heat to generate steam that drives auxiliary turbines to produce additional power."

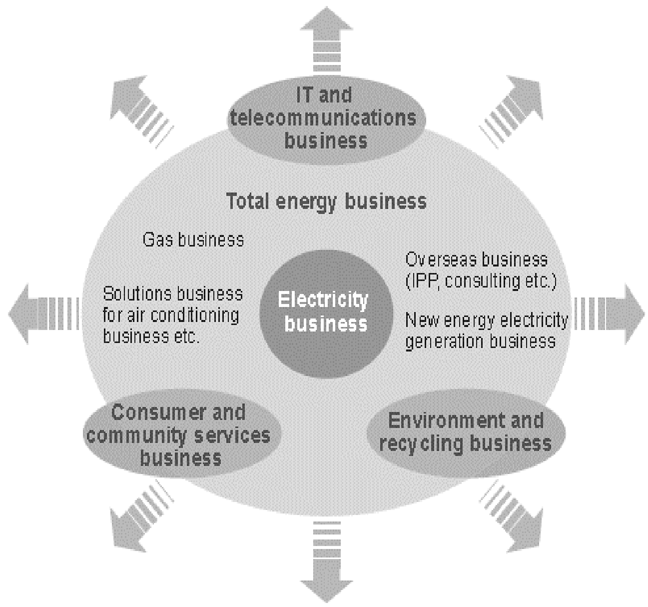


FIGURE 38: DIRECTIONS OF BUSINESS EXPANSION
SOURCE: KEPC ANNUAL REPORT (2006)

The company's 2006 action plan included five environmental policies, including; promoting environmental management, addressing global environmental issues, Promoting the optimal Combination of Power Sources, promoting the use of renewable resources, establishing a recycling society, implementing demand-side measures such as encouraging the use of energy-saving equipment, and so on. (KEPC, 2006). But by the end of fiscal year (2006), the company faced numerous challenges with power stations. In 2007, the Ministry of Land, Infrastructure and Transport and the Ministry of Economy, Trade and Industry carried out inspections of generation facilities and identified more than 600 instances of unsatisfactory situations in hydroelectric facilities, and in thermal facilities (KEPC, 2007). Although none of these were a threat to safety or the environment, they however, represented a total unacceptable failure of the trust placed in the company by society. As a response, major decisions were made reflecting poor awareness of compliance requirements, complacent reliance on old operational practices, and inadequate knowledge of laws and regulations governing the operations. By Jun 2007, a new management team, including a new president, was in place (KEPC, 2007). Although there has been no indication in the annual reports to link the change of the management team to the above mentioned situation, it is assumed however that they are connected. Major changes resulting from appointing the new team, appear even in the way of publishing the annual reports, but more importantly included developing a long-term plan for the first time in the history of the company.

The results for fiscal 2008 (the year ended March 31, 2009), showed a major income decline, and the company faced its first loss in 29 years, due to wild fluctuations in the price of crude oil, and a global economic recession triggered by the financial crisis in the United States. Amid these changes in the business environment, and as a response to the hardships the company was facing, it has been necessary to initiate company-wide activities to address these issues. A new medium-term management policy covering a 3-year period- fiscal year 2009 to fiscal year 2011- has been established to appropriately respond to the adverse business environment (KEPC, 2009). The initiative consisted of five pillars as shown in Figure 39.

Five Pillars of Key Initiatives

1. Measures to ensure the stable supply of electric power for the future and a response to global environmental problems

- ○ Promote nuclear power and develop renewable energy
- ○ Implement stable, long-term facilities development

2. The provision of high-value-added services that combine comfort with environmental friendliness

- ○ Deliver high-quality electric power and services
- ○ Support energy conservation with customers to reduce CO_2

3. Contribution to the creation of sustainable societies in Kyushu, in Asia, and around the world

- ○ Activities with communities to build sustainable societies
- ○ Technology for stable energy and for global CO_2 reduction with a focus on Asia

4. Measures to develop an income and expenditure structure adaptable to changes in circumstances

- ○ Adaptable income and expenditure structure
- ○ Efficient risk-based resource allocation, fuel cost reductions and new charge plans
- ○ Lowest cost levels and stable dividends

5. Work style reform and organizational development in response to next-generation needs

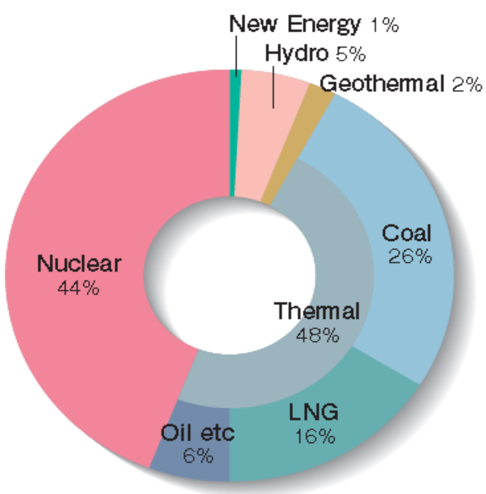
- ○ Change work style in line with needs of graying society
- ○ Serve employee and social needs, while promoting workplace opportunities and satisfaction

Figure 39: The five-pillars of key initiative
Source: KEPC annual report (2009)

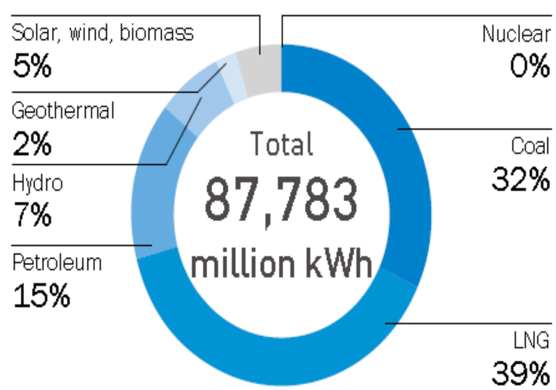
The year 2011, and for 5 years, were very difficult times for Kyushu electric power company. The company was facing consequent losses, and regardless all efforts made, still the company couldn't reduce these losses. The trouble began in March 2011, when the energy accident at Fukushima Daiichi Nuclear Power Plant took place. The disaster was initiated primarily by a tsunami following the Tōhoku earthquake on March 11. In September 2011, The Japanese government announced that they are working on new policies and security standards regarding nuclear power. As response, KEPC initiated a rehabilitating process for all nuclear power facilities. In summer 2012, the Japanese government announced the suspension of all nuclear activities, including Kyushu electric power company nuclear activities (Figure 40), the timetable for when operations would resume was unclear. In addition, the high fuel costs, the increase in the general dues payable of the nuclear damage facilitation fund, and costs of the new nuclear safety measures set by the government, as well as the high interest charges accompanying the increase in bank loans, made the conditions for profitability likely to be even more difficult (KEPC, 2012).

The company faced its first loss, mainly due to the following:

- Suspension of nuclear power activities resulting in losing about 40% of their energy production;
- Increases in thermal power fuel costs;
- Cost of maintaining the nuclear facilities and meeting the new government safety standards;
- Decreases in demand resulting from customers' cooperation in conserving electric power.



THE COMPANY'S SHARE OF NUCLEAR POWER
SOURCE: KEPC 2006



THE COMPANY'S SHARE OF NUCLEAR POWER
SOURCE: KEPC 2015

FIGURE 40: COMPANIES OF NUCLEAR POWER 2006 VS. 2015

To compensate for some of its continuous losses, the company increased electricity rates as of May 2013 by an average of 6.23% for customers in the regulated area. By April 2013, the company gradually implemented a rate increase averaging 11.94% for customers in the deregulated area. In addition, a plan for cutting cost and selling some assets has been developed (KEPC, 2013).

2015 was a crucial year to the company. It represented the preparation stage for full scale liberalization of electricity retailing which was supposed to take place in 2016. Also in that year, an electrical utility business act reform measure was passed separating the distribution sector from the production sector as part of electricity system reforms. The act determines the legal unbundling of the distribution and transmission sectors as of April 2020. In addition, finally, and after 4 difficult years, the re-introduction of the commercial operation of nuclear power facilities began in September (KEPC, 2015).

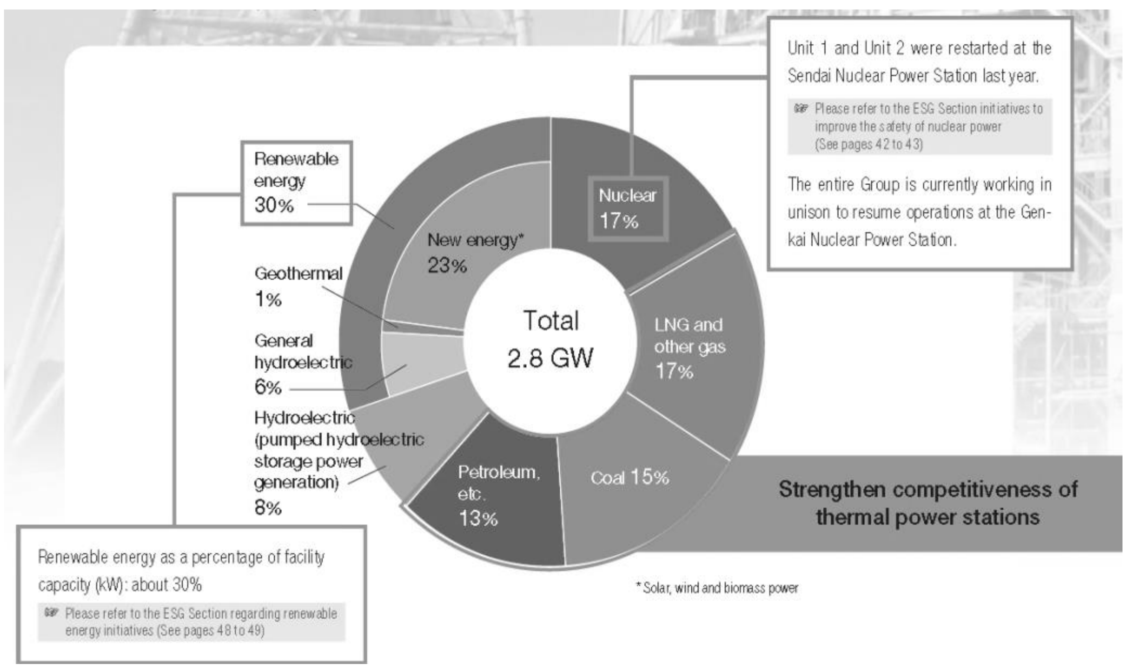


FIGURE 41: COMPOSITION OF CAPACITY FOR ALL FACILITIES INCLUDING POWER PURCHASED FROM OTHER COMPANIES SOURCE: KEPC ANNUAL REPORT (2016)

Finally, in 2016, Kyushu electric power company began producing electricity using nuclear power by (17% of total output; Figure 41). For the first time in 4 years the company makes profits. A plan to expand the business scope from a company that delivers electricity into a corporate group that provides Japan's best energy services has been developed. Now, Kyushu electric power company keeps working on improving the safety measures and facilities of nuclear power, in addition, it is working on expanding the scale of renewable energy business (KEPC, 2016).

4.3. Public opinion on nuclear power generation

The dangerous side-effects of nuclear energy resulting from nuclear fuel cycle disruption, in addition to the effects of nuclear accidents have concerned not only scientists, but also the public. Japanese citizens have several bad memories of the uses of nuclear power, not only in war such as the memories of Hiroshima and Nagasaki, but also in peaceful uses, such as power generation and the aftermath of Fukushima earthquake and tsunami.

Public surveys are one of the more effective tools to measure public opinion, which have been used for years and in several occasions. This study adopts the results from previous surveys conducted by eight news media after one year from the Fukushima Daiichi accident, as well as the results from the surveys conducted by newspaper companies, television stations and telecommunications companies, almost every month, since 1993 to 2011. The results from the surveys were published in a paper by Kitada (2013). To update and verify the results from the paper, a survey, designed by the researcher, was handed to participants in both electronic and hard copy forms. The questions used in the researcher's survey were borrowed from the main paper by Kitada (2013).

4.3.1. Results from the Kitada (2013) paper

The main objective of the paper was to investigate the changes on the public opinion over the past 30 years and the influence of the Fukushima Daiichi accident on those results. The results from the surveys show that 70% of participants have negative opinions regarding nuclear power generation, which used to be 20-30% before the Fukushima accident. The results also suggest abolition or reduction. Although 60% of participants regarded the use of nuclear power is inevitable, however, they still expressed their rejection of the idea of future expansion by replacement or new construction of nuclear power plants. Although public rejection of nuclear power generation and concerns about energy shortage still the same after the accident, however, their anxiety, worries and lack of trust in nuclear power generation has significantly increased due to the accident. Finally, there is the concern that people lack knowledge of the various consequences of reducing nuclear power generation, however there is an unwillingness to accept a significant increase in electricity rates as a result of using renewable energy as an alternative to nuclear power.

4.3.2. Results from the researcher's survey on public opinion on nuclear power generation

The survey aimed at measuring the public opinion on using nuclear power for energy generation, their opinion on other new and renewable energy generation sources, as well as, their willingness to accept the changes associated to utilizing these resources. 42 participants, males and females, from different age and financial levels, and from different areas in Japan, took part in the survey (Figure 43).

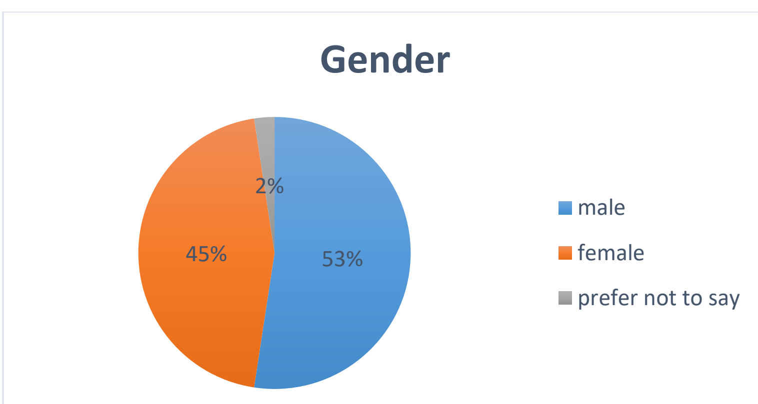


FIGURE 42: GENDER OF PARTICIPANTS

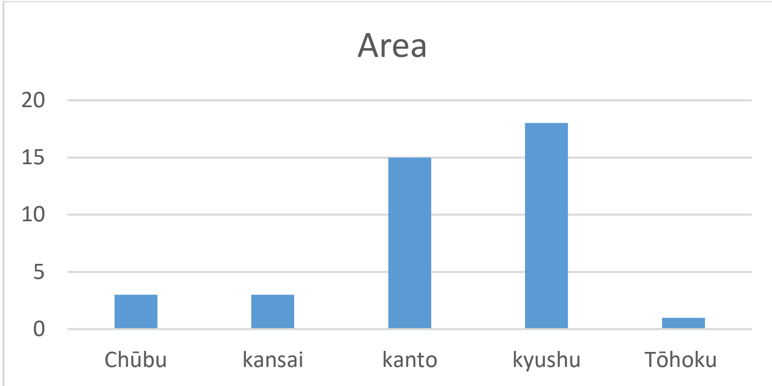


FIGURE 43: PARTICIPANTS BASED ON LOCATION

The survey included 11 questions. The main factors used for analyzing the survey results were gender and age. Following are the results from the survey, divided based on the main evaluation factors.

4.3.2.1. Results based on gender factor

The number of participants was 42, 53% male and 45% female (see Figure 42). Majority of participants believe that developing research on nuclear power generation is not of importance for the society, as shown in Figure 44.

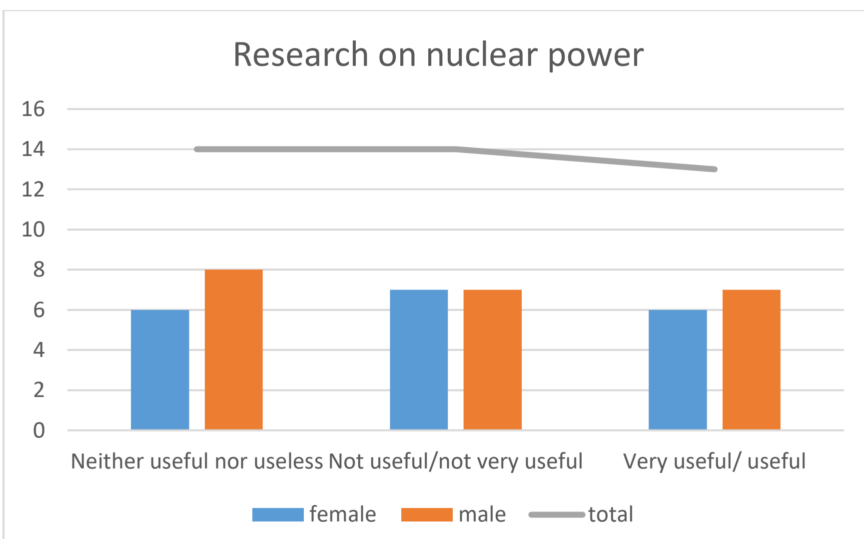


FIGURE 44: RESEARCH ON NUCLEAR POWER GENERATION

Figure 45 shows the public preferences on power generations method which forms the mainstay for Japan's future power generation. Only 5% of participants agree on developing further research on nuclear power. While majority, with more than 50% of participants prefer new and renewable energy resources.

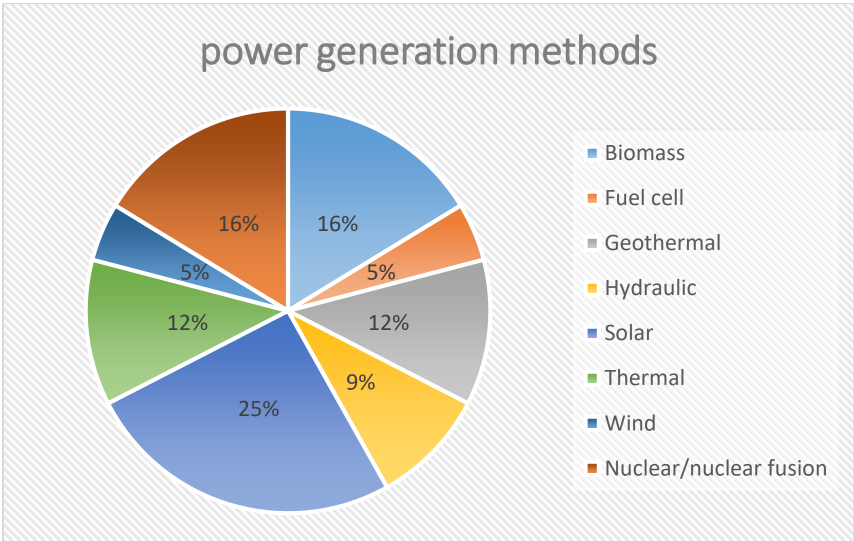


FIGURE 45: PREFERENCES OF POWER GENERATION METHODS

Regarding the sufficiency of power generation capacity in Japan after 10 years, a majority of participants felt it could supply enough to meet the demand (Figure 46). However, about 40% of total participants feel worried, 56% of which are female.

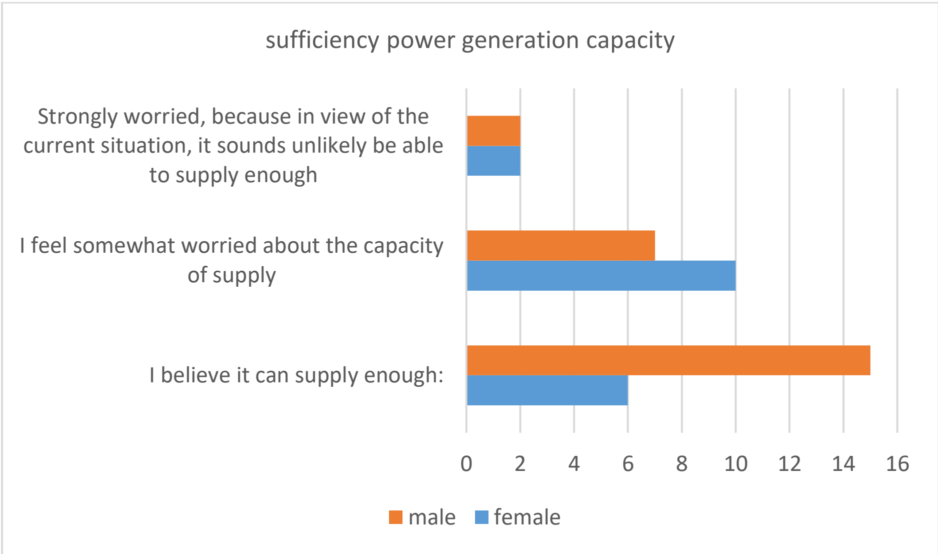


FIGURE 46: SUFFICIENCY OF POWER GENERATION CAPACITY IN JAPAN

As for the public trust in the usefulness of nuclear power generation as a reliable source of electricity, 58% of total participants believe that nuclear power is somewhat of a reliable source for power regeneration, 85% of which are female, however, the majority of males believe it's hardly or not reliable (Figure 47).

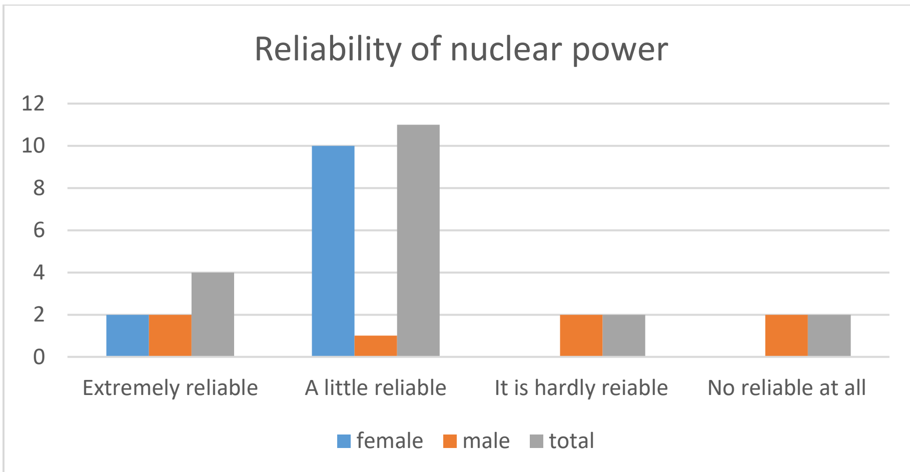


FIGURE 47: PUBLIC OPINION ON RELIABILITY OF NUCLEAR POWER

48 shows a low level of public knowledge on nuclear power's negative impact on humans and environment. About 36% of total participants, 43% of which are female, are not sure whether nuclear power can be used without adversely affecting humans and the environment or not, while majority of participants, about 58% of which are male, believe it can't be used without negatively affecting humans and the environment.

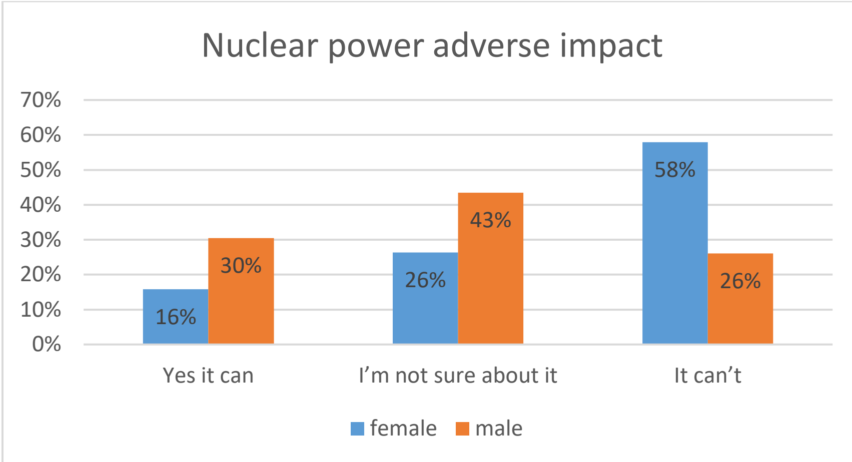


FIGURE 48: NUCLEAR POWER IMPACT ON HUMAN AND ENVIRONMENT

Participants disagreed on replacing or reconstructing nuclear power plants in the case of them being demolished due to the lifespan factor, regardless of the fact that this might affect the capacity of nuclear power generation (Figure 49).

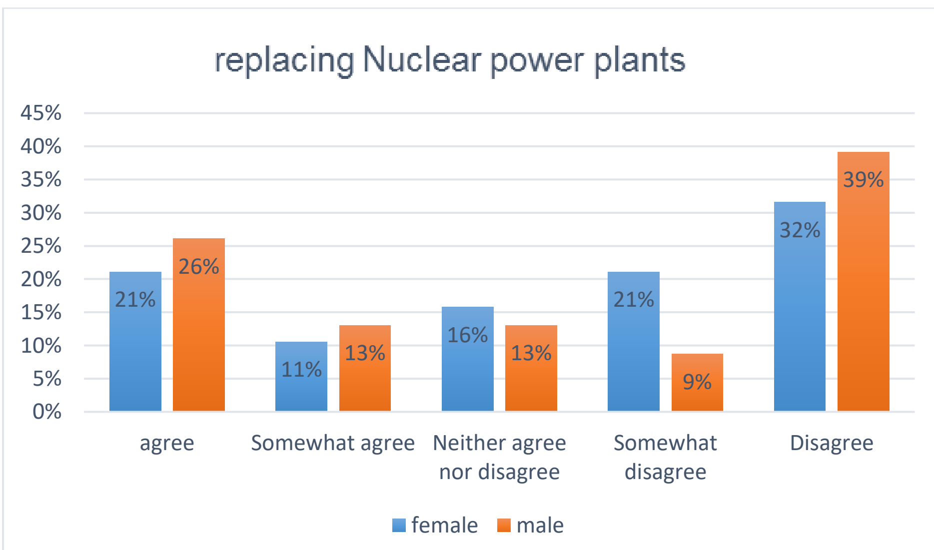


FIGURE 49: PUBLIC OPINION ON REPLACING NUCLEAR POWER PLANTS

If we stop nuclear power generation and switch to renewable energy such as solar and wind power, about 40% of total population believe it will take about 20 years to actively realize a promoting energy policy (Figure 50). However, women show more optimistic attitude, for that almost 50% of total women population believe it will take only 10 years.

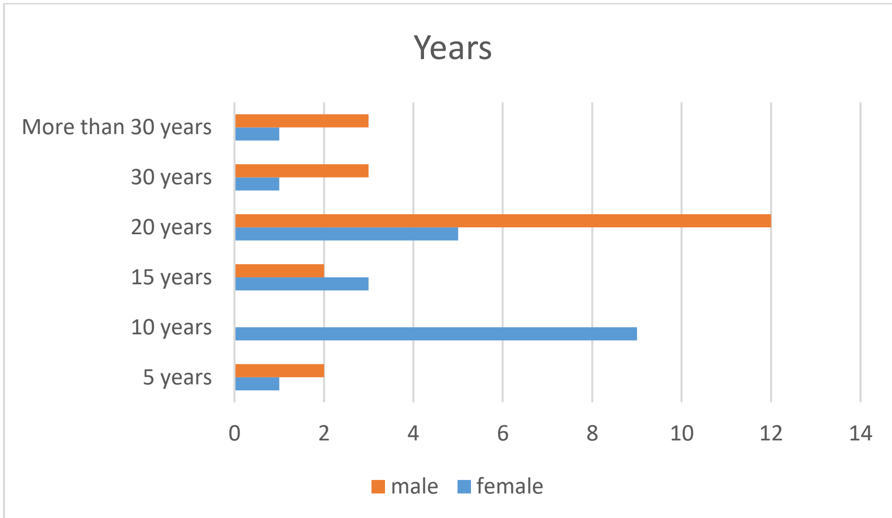


FIGURE 50: PERIOD REQUIRED TO ACTIVELY REALIZE A PROMOTING ENERGY POLICY

The results show that about 90% of participants agree to the increase in electricity prices due to the inclusion of renewable energy (Figure 51).

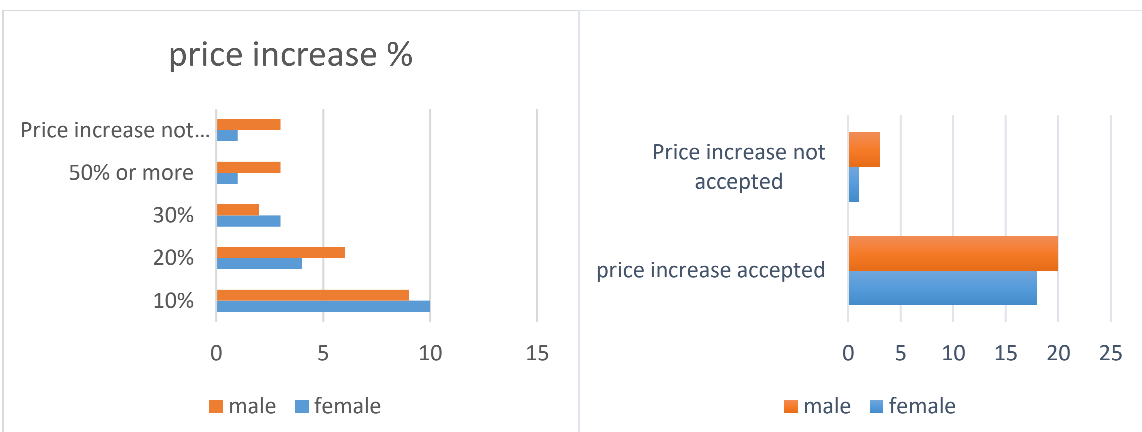


FIGURE 51: ACCEPTANCE OF PRICE INCREASE

4.3.2.2. Results based on Age factor

The age of participants varied as shown in Figure 52. Since the number of participants (~18) and (70~) is only one in each category, their answers were not taken into consideration because the sample was too small to represent the entire population in their category. However, their answers will be shown on the charts.

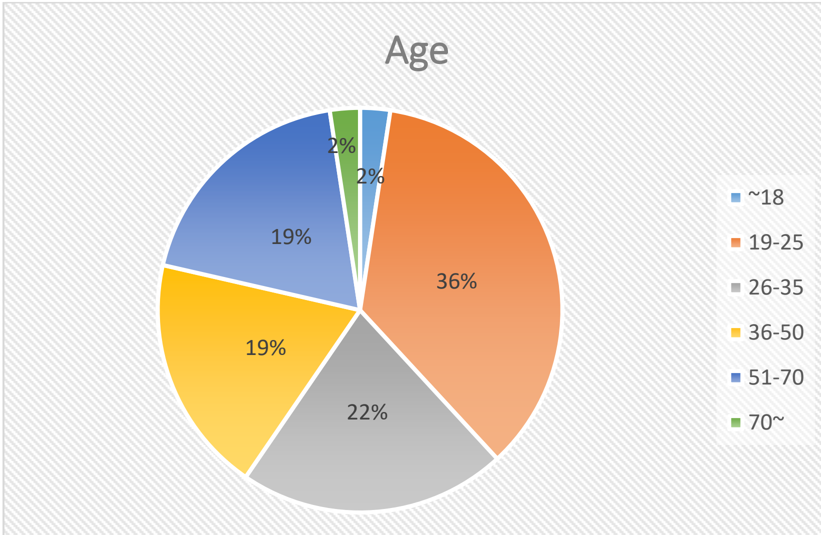


FIGURE 52: AGE VARIATION

As shown in Figure 53, participants from different groups show that positive and negative opinion towards the importance of conducting further research on nuclear power generation is very close. This could be interpreted by the different level of knowledge on nuclear power generation.

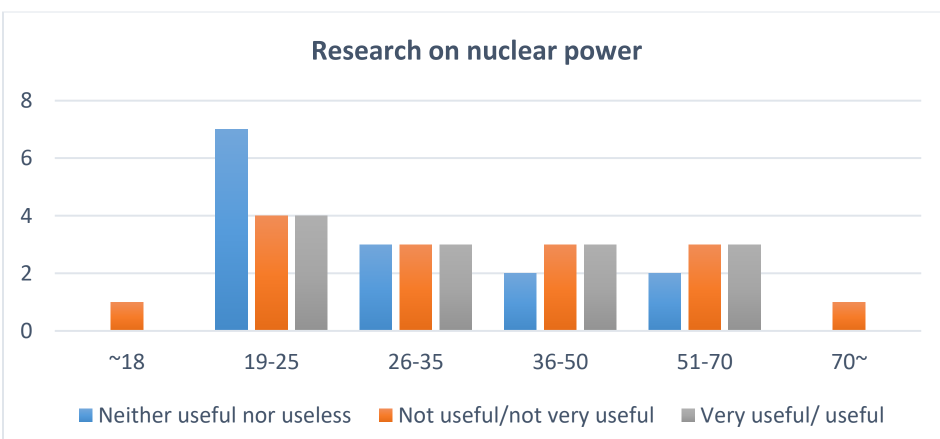


FIGURE 53: RESEARCH ON NUCLEAR POWER GENERATION

Figure 54 shows the preferences on different power generation methods which forms the mainstay for Japan's future power generation. Unexpectedly, the majority of younger generation (19-25) respondents prefer other traditional power generation methods, while their attitude towards renewable resources and nuclear is very close. Older generations show very close, yet positive, attitude towards new and renewable energy methods.

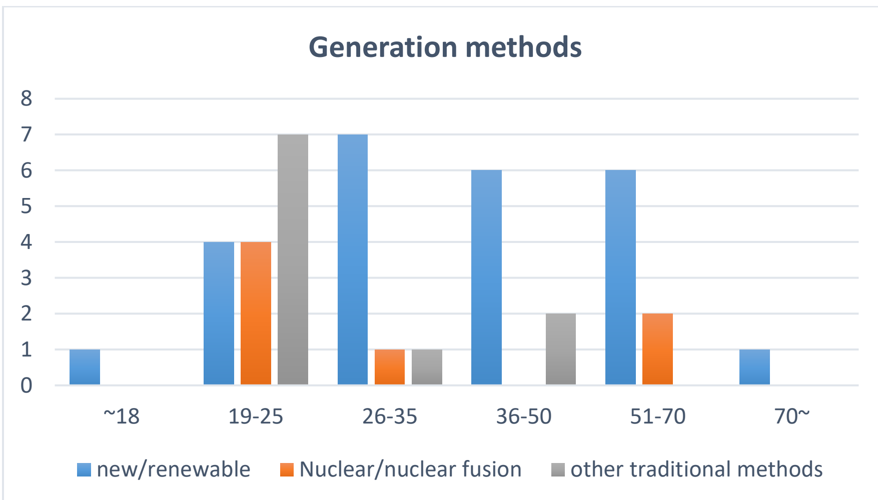


FIGURE 54: MAINSTAY FOR JAPAN'S FUTURE POWER GENERATION

Participants from different ages show similar, yet, positive attitudes regarding the sufficiency of power generation capacity in Japan after 10 years (Figure 55). The majority of participants from different groups believe the country can supply enough to meet the demand. However, about 40% of participants still feel worried.

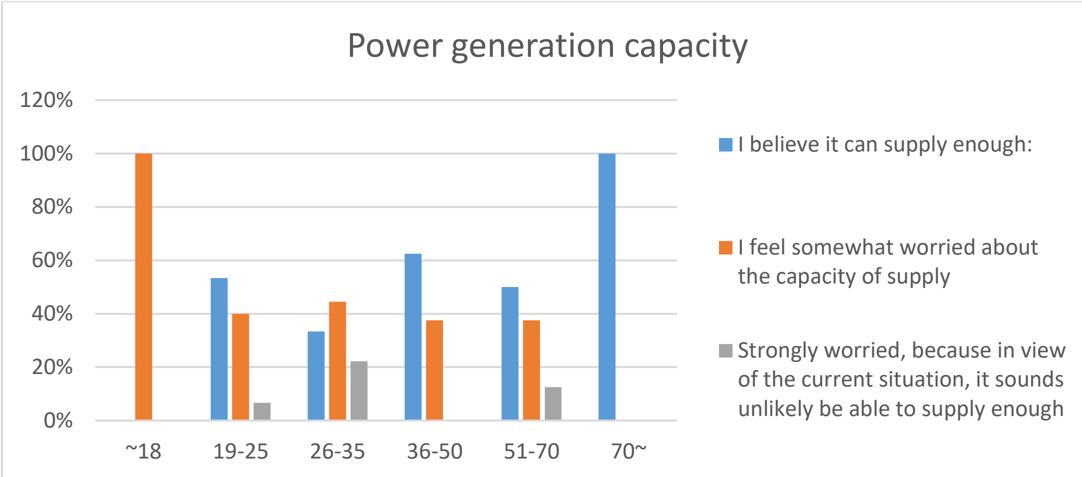


FIGURE 55: SUFFICIENCY OF POWER GENERATION CAPACITY IN JAPAN

Three of the four groups, 19-25, 36-50, and 51-70, have low trust in the usefulness of nuclear power generation as a reliable source of electricity, while the fourth group, 26-35, believe it is extremely reliable (Figure 56).

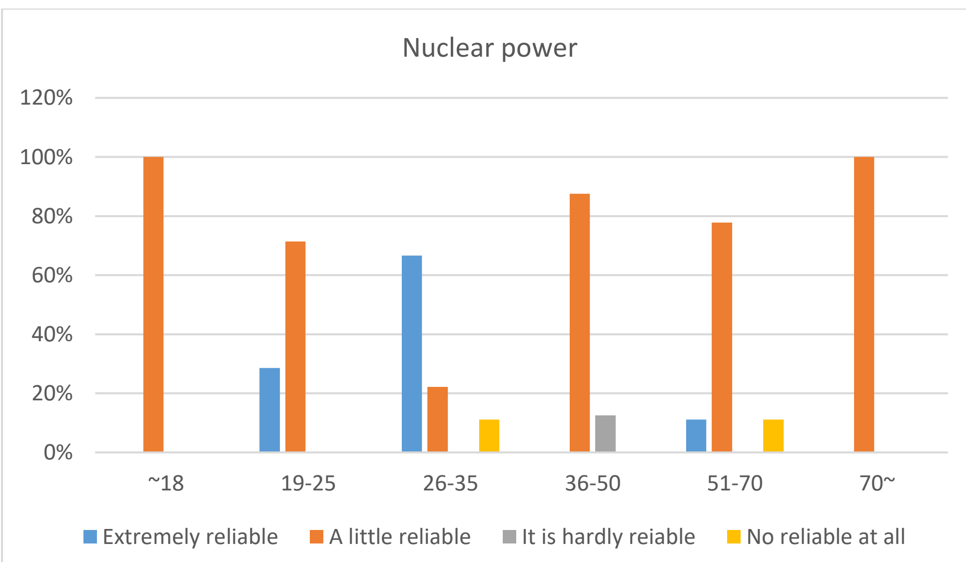


FIGURE 56: RELIABILITY OF NUCLEAR POWER

Again, participators from different groups show a low level of knowledge on nuclear power's adverse impact on humans and the environment (Figure 57). Yet still the percentage of those who believe that nuclear power can't be used without negatively threatening human beings and the environment is higher than those who believe it can.

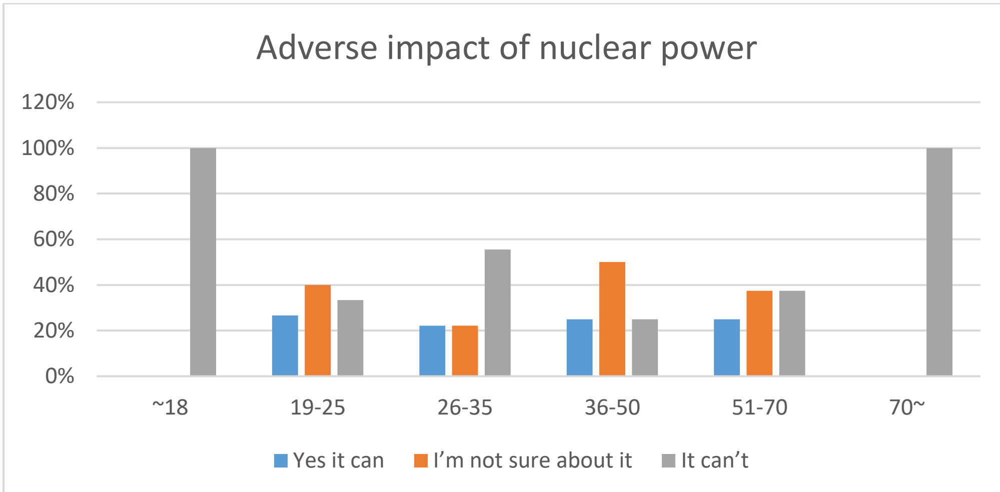


FIGURE 57: ADVERSE IMPACT OF NUCLEAR POWER ON HUMAN AND ENVIRONMENT

The majority of participants in each age group disagree on replacing or reconstructing nuclear power plants in the case of them being demolished due to the lifespan factor, regardless the impact of this on the capacity of nuclear power generation. However, the percentage of participants agreeing on replacing or reconstructing nuclear power plants is considerable (Figure 58).

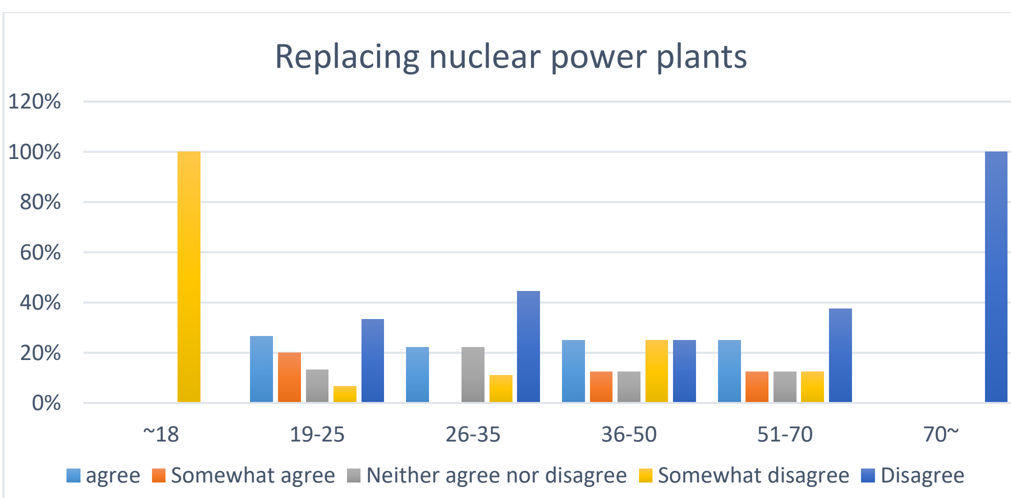


FIGURE 58: PUBLIC OPINION ON REPLACING/BUILDING NUCLEAR POWER PLANTS

About 80-90% of participants from each age group believe that, if we stop nuclear power generation and switch to renewable energy such as wind and solar power, it will take less than 20 years to actively realize a promoting energy policy (Figure 59).

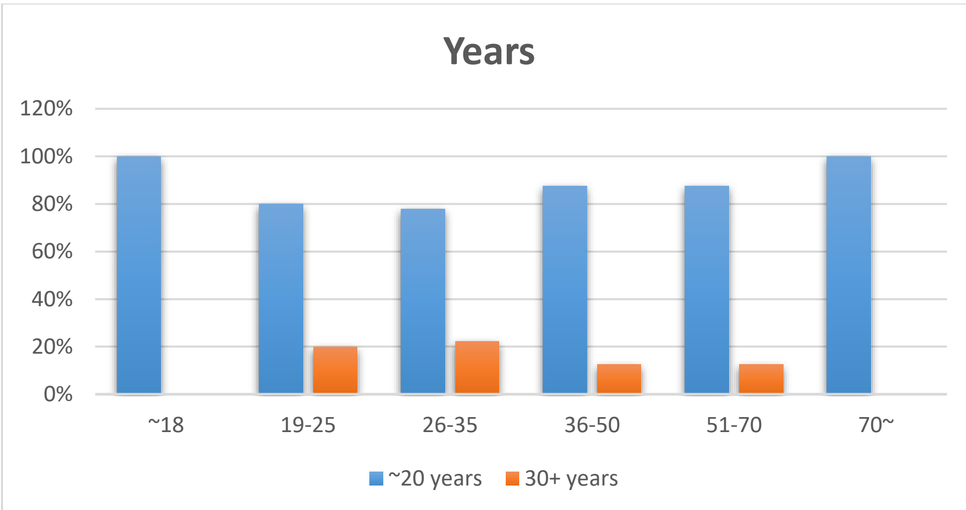


FIGURE 59: PERIOD REQUIRED FOR ACTIVELY REALIZE A PROMOTING ENERGY POLICY

The results also show that about 90-100% of participants from each age group agree to the increase in electricity prices due to the inclusion of renewable energy (Figures 60 and 61).

FIGURE 60: PUBLIC ACCEPTANCE OF PRICE INCREASE (1)

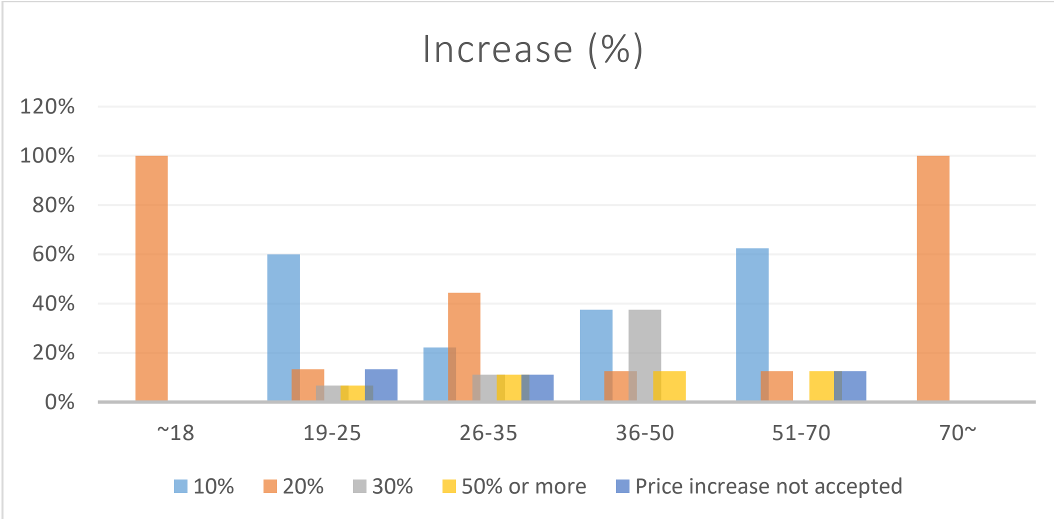


FIGURE 61: PUBLIC ACCEPTANCE OF PRICE INCREASE (2)

Chapter 5: Energy challenges in Japan

Energy sounds like one of Japan's most critical vulnerabilities, in terms of environmental issues and assuring reliable sources of supply. The country's long-term energy policy 2030 is "securing stable and reliable energy supply at low cost". Although this sounds simple, however, in terms of implementation it is not as easy as it sounds. Especially in industries that are global, dynamic and rapidly changing. Chapter 5 discusses the challenges facing energy generation in Japan with evidence from topics discussed in the previous chapter; history of power generation in Japan, the history of Kyushu electric power company and the results from the survey.

5.1. Deregulation

Because of the implementation of deregulation, several foreign companies and Japanese companies entered the power market, which resulted in a fierce competition. As a response, Kyushu electric power company had to resort to price reduction to face increasing competition, which affected its annual income. According to the Agency for Natural Resources and Energy (2015), the negative aspects of regional monopoly systems include the lack of a system-capable of transmuting electricity beyond areas, little competition and high price control, as well as, limitations-in-handling change in the energy-mix, including the increase in renewables. Although this deregulation is beneficial for customers who are expected to have better service and lower electricity bills, however, for utility companies it means lower market share. As for the Japan government, to successfully overcome this challenging situation, it must fully control the game, secure fair access to transmission and distribution lines for all market players, and ensure the steady supply and convenient prices for customers that are the main objectives behind the deregulation, are delivered. Ito (2016) states that several countries resorted to unbundling generation and distribution from local monopolists, to prevent them from providing new comers unfair access to transmission lines and making it hard for independent entities.

5.2. Ageing facilities

In 2007, the Ministry of Land, Infrastructure and Transport and the Ministry of Economy, Trade and Industry carried out inspections of the KEPC generation facilities, and identified more than 600 instances of unsatisfactory situations in hydroelectric facilities and in thermal facilities, reflecting the aging of the company facilities. These situations were a total unacceptable failure in the trust placed in the company by society. As response, the company increased the maintenance budget, which affected its annual income.

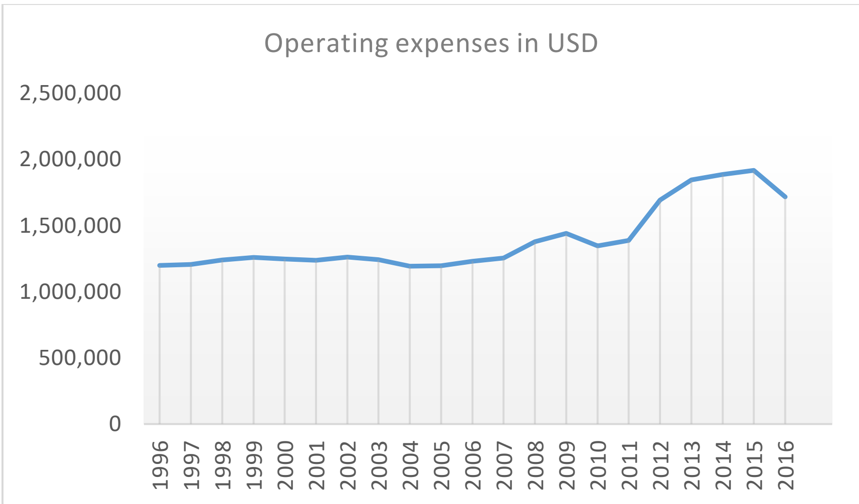


FIGURE 62: OPERATING EXPENSES COST ACCORDING TO COMPANY FINANCIAL REPORT

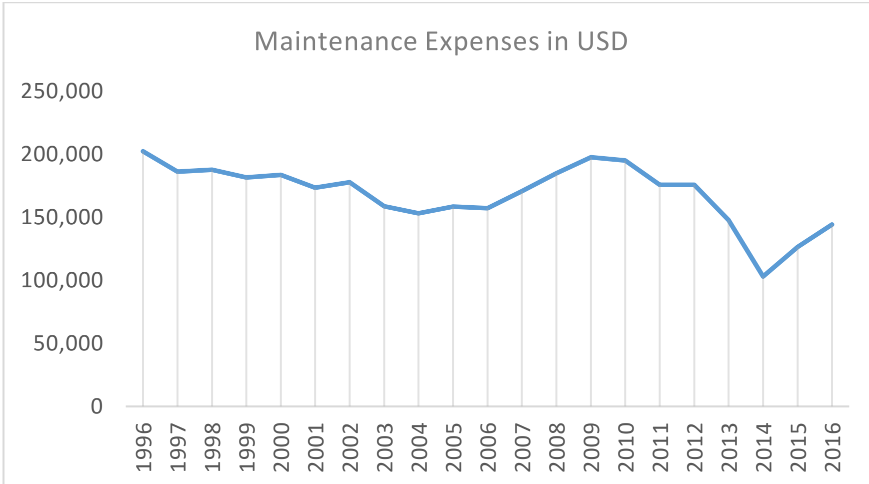


FIGURE 63: MAINTENANCE COST ACCORDING TO COMPANY FINANCIAL REPORTS

Figure 62 shows the trend of operating expenses according to the company financial reports, as of 1996 to 2016. It is noticed that the operating expenses are increasing as of the fiscal year 2007 and the years after. One of reasons for that increase is the increase in cost of maintenance, as shown in Figure 63.

5.3. Fluctuating prices of Crude oil

The supply and demand for crude oil plays a significant role in the rise and fall of its prices, which, consequently, affects the electric utility sector depending on crude oil in generating electricity.

FIGURE 64: CRUDE OIL PRICES (USD) IN THE PAST 10 YEARS
SOURCE NASDAQ.COM RETRIEVED: APRIL 2, 2017.

FIGURE 65: CRUDE OIL PRICES (USD) IN THE PAST 6 MONTHS
SOURCE NASDAQ.COM RETRIEVED: APRIL 2, 2017.

Figure 64 and 65 show the trend in oil prices, in the past 10 years and in the past 6 months, respectively. It shows clearly the unstable price of oil that makes it difficult for electricity companies to have a clear forecast for trends in the future markets. Although Japan reduced its imports of crude oil and other oil products by about 0.8%, and its imports of gas by about 4% in 2015, it remains amongst the world largest importers. Its share of world gas imports is up to 11.3% of the total gas traded globally, while its imports of oil are up to 7.2% of the total oil traded globally in 2015 (PBL, 2016).

5.4. Environmental challenges

5.4.1. CO_2 emissions

Carbon dioxide (CO_2) emission results from the burning of fossil fuels and the manufacture of cement. It includes the carbon-dioxide produced during consumption of solid, liquid, gas fuels and gas flaring (World Bank). CO_2 is the main anthropogenic or greenhouse-gas which affects the Earth's radiative balance, leading to increasing the temperature at the surface. It is also related to negative effects on climate, as well as to sea level rise and world agriculture. Since it dissolves in water, forming carbonic acid, it is also considered as one of the main sources of ocean acidification. CO_2 contributes largely in greenhouse gas causing global warming and climate change. The Kyoto Protocol, which is an environmental agreement adopted by many parties in 1997, as part of the United Nations Framework Convention on Climate Change, works globally towards curbing carbon dioxide (CO_2) emissions (World Bank). Although the government currently does not intend to be under the obligation of the second commitment period of the Kyoto protocol after 2012 (the Paris Accords), Japan is remains committed to continue its ambitious emission reduction efforts beyond 2012. And to fulfill its obligations, the country is looking for other sustainable, accessible, and efficient energy resources such as, renewable resources and nuclear power (METI). That leads us to 2 very important points that must be taken into consideration in Japan's journey to find better resources. These are the difficult nature of the Japanese landscape, and nuclear power challenges.

5.4.2. Difficult nature of Japan landscape (Natural disasters)

Japan is the third largest economy in the world, and to maintain its economic level, technological power and high standard of living, it need a steady flow of an enormous amount of energy. In recent years, nuclear power was the focus of several governments, including Japan, for its significant of being a stable and cheap source of energy, as well as a solution for reducing the emission of carbon dioxide caused by other sources of energy. However, the Japanese landscape makes its plans to develop further research on nuclear power questionable, especially after the Fukushima disaster in 2011. Although this accident was made worse by human error, the main cause was natural hazard. Japan’s location makes it vulnerable to several types of natural disasters, including earthquakes, volcanos, Tsunami, Typhoons and floods. The question is, can nuclear power plants be safe and fully immune to natural disasters? Ideally, nuclear facilities should be established in areas that are not subject to natural disasters. And in a country with a natural environment like Japan’s, the risk is high and nuclear facilities cannot be absolutely safe from accidents. Although the country is using highly sophisticated systems and technologies for risk management, accidents like Fukushima prove that the system is not perfect.

5.4.3. Nuclear power challenges

The disadvantages of traditional power systems, such as the lack of fossil fuel and pollution, encouraged scientists to search for better alternatives with less problems. Nuclear power is one of the suggested alternatives due to its accessibility, possibility and efficiency. Yet nuclear power does include some technical disadvantages that are still debated among scientists, such as safety, security and impact on the environment.

Nuclear energy produces less emissions compared to other resources (see Figure 66), and requires fewer resources, which is considered a contribution to environmental protection. Nuclear power is also considered highly efficient, in 2011, the amount of electricity supplied by the world's nuclear power plants was 2518 TW/h (billion kW/h). It is also suggested that the problem of nuclear waste could be solved by development of reprocessing nuclear fuel (world nuclear association).

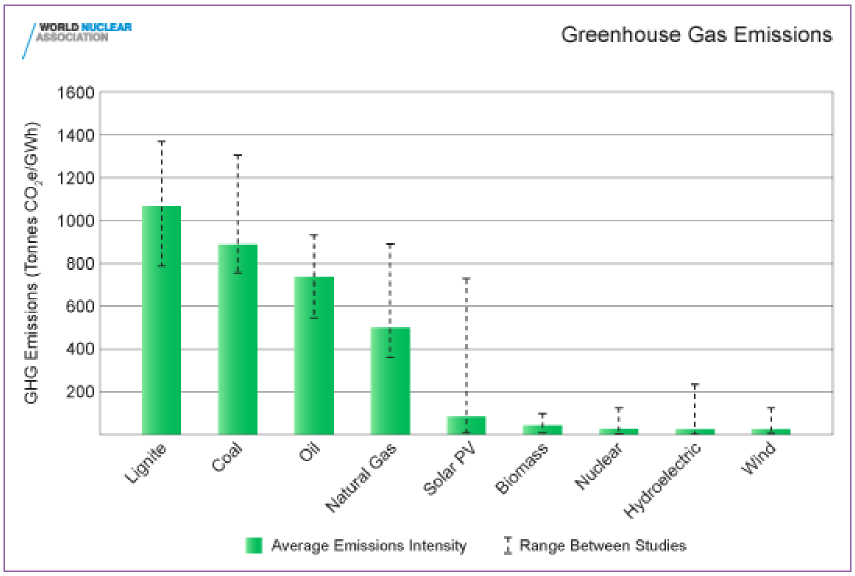


FIGURE 66: COMPARISON BETWEEN GREENHOUSE GAS'S EMISSION OF DIFFERENT RESOURCES
SOURCE: WORLD NUCLEAR ASSOCIATION

However, the sustainability of nuclear power is questionable, given both security and safety concerns. Nuclear sites are vulnerable to natural disaster, one accident at one nuclear power station could cause thousands of human losses. The leakage of nuclear material is threatening to millions of human lives, and is still being experienced in the aftermath of Fukushima earthquake and tsunami in Japan. In addition, the disposal of nuclear waste material is debatable due to the containment requirements of this dangerous material (Barg, 2011).

Nuclear power does not only cause human losses, but also economic losses. For example, in the case of the Kyushu electric power company, after the Fukushima accident the government decided to suspend all nuclear power activities in 2012, which caused the company to lose 40% of its main production (see Fgure 67). That resulted in the company having loses for more than 5 years. Not only that, to meet the area demand for electricity, the company had to ask customers for cooperation in conserving electric power, which resulted in causing the company further losses due to the decrease in demand.

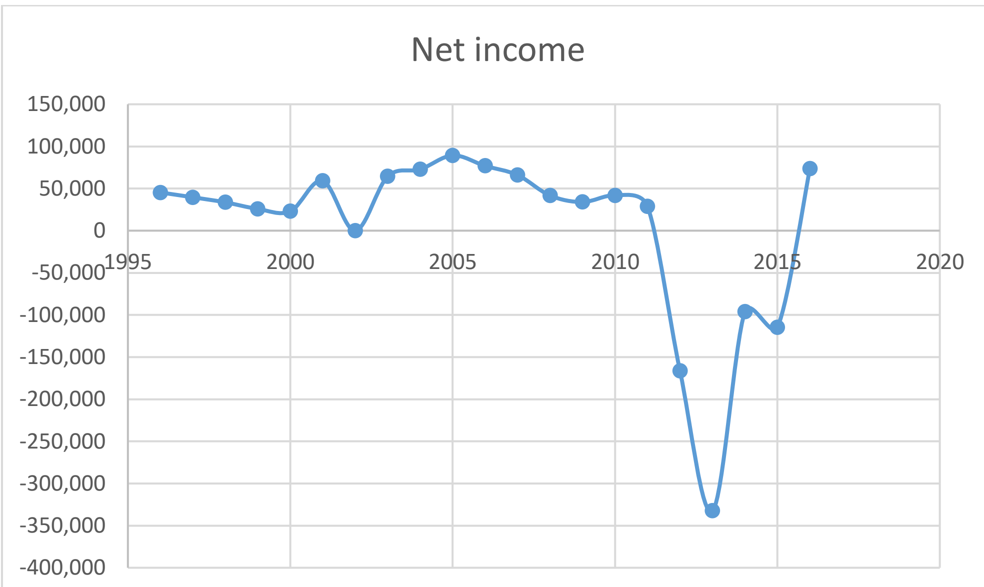


FIGURE 67: COMPANY NET INCOME (1996-2016)
SOURCE: KEPC

Figure 67 shows the trend of net income according to the company financial reports, as of 1996 to 2016. It is noticed that the company experienced significant losses after the accident. One of the reasons for their losses was the suspension of nuclear activities

One of the claimed reasons for using nuclear power is that it is considered a cheap energy source compared to other traditional and non-traditional resources. For example, Japan is a resources-poor country, which is dependent on imports by 95% of its energy supply (FEPC, 2015). When oil prices go high, the government look for other nonpetroleum resources to reduce its expenses by reducing its dependency on imported oil. However, governments forget that nuclear power still utilizes natural finite and expendable minerals; plutonium and uranium, which are concentrated in certain areas of the world, and Japan has to import those two minerals oversees in order to generate electricity using nuclear power. Expectedly, the prices of such material will increase due to the increase in demand.

5.4.4. Public acceptance of nuclear power

Japan has long and painful history with nuclear power. These painful memories affect Japanese opinion regarding the use of nuclear power, even in peaceful purposes such as power generation. Japan is a democratic country, and public opinion has the power to affect and control the direction which the government takes. Several surveys were made to measure the public opinion on nuclear power. After the Fukushima Daiichi disaster, Japanese negative opinion regarding nuclear power significantly increased, and the call for abolishing or reducing the dependence on nuclear power became very real. Even those who considered nuclear power inevitable rejected the idea of future expansion. Now, even after 5 years from the accident, still the public trust in the reliability of nuclear power is very low, especially among women, and majority of Japanese prefer renewable energy, especially older generation. Although public knowledge of the negative impact of nuclear power on humans and the environment hasn’t developed much, particularly among women, the Japanese mainstream is against replacing or reconstructing nuclear power plants regardless the impact of this on the capacity of nuclear power generation. Japanese society is very optimistic regarding the period required for actively realizing the promotion of renewable energy policy, especially among women. Supporting this is their very high willingness to accept a reasonable increase in electricity prices due to the inclusion of renewable energy.

5.5. Demand forecasting

In Japan, there are several factors affecting the public demand for electricity. One factor is the deregulation which allowed several companies to enter the industry, which made it difficult for utility companies to accurately forecast customers demand, instead, they got involved in attracting customers. Another factor is the decreased demand due to the application of FIT, and government encouragement of the public to generate their own electricity. Now customers became self-sufficient, and resort to the main grid only in peak periods. The aging society is another important problem that can affect the demand. The current statistics show a considerable decline in Japan population. Not only that, they also show that Japan is purported to have the highest rate of senior citizens, not only in rural areas, but also in the urban areas of Japan. This will affect demand in two ways: first, the decline in population will cause a decline in demand; second, the high number of senior citizens will decrease demand, since the older generation has less interest in modern technologies which require electricity (Czaja, 2006).

5.6. Providing service for outlying islands

Japan is an island nation. It consists of four main islands, in addition to thousands of small islands. Providing service on the four main islands is not a problem; the problem is in providing services for the outlying islands that do not have linkages with the main islands, and grid extension is difficult and fuel transportation and logistics are challenging and costly. In Japan, utility companies, such as the Kyushu electric Power Company, mainly supply electricity power by means of internal combustion power generation, from plants individually built on each island, using heavy oil as fuel (KEPC, 2010).

5.7. Renewable energy challenges

The increase in energy demand, accompanied by the need to reduce CO_2 emissions, could create uncertainty in energy security, especially in a country like Japan, which relies largely on imported fossil fuels. Japanese energy policy is built upon three goals; energy security, economic development, and environment sustainability. And, to achieve these goals, the government has developed a strategic energy plan which consists of 3 main targets: first, raising the energy independence ratio by 25% above pre-2011 levels, by leveraging renewable and nuclear energy; second, decreasing the amount of CO_2 by 21.9% by FY 2030 versus FY 2013; and finally, reducing costs by 2.5% from 2015 levels by reducing fuel expenses through expanding the use of renewable energy, restarting nuclear power plants, and efficiency improvements in thermal power generation (METI, 2015). The government put the FIT system to action to incentivize and accelerate the use of renewable resources. Renewable energy has great potential in Japan. Results from the survey showed public high interest in renewable resources even energy will cost a little more than when produced by traditional resources. However, there are several challenges associated with the use and the implementation of these alternative energies.

One of the most important challenges is economies of scale. Traditional systems are manufactured on assembly lines, where mass production can significantly reduce costs. However, in case of new technologies, such as renewable resources, as long as relatively few units are established, prices will remain high, which will result in low demand, and consequently low production volumes (UCS, 1999). Also, developing renewable resources requires large initial investments in infrastructure. These investments will be reflected in an increase in the cost of electricity, especially during the early years. In Japan, for example, although FIT provides some incentive to install solar panels, the initial startup cost can be a barrier for those who are uneducated about the benefits, lack interest in renewable resources, or are the less wealthy members of society. And because solar systems are expensive to implement, they have a long-payback time (Chen & Riffat, 2011).

Marketing and commercialization are another barrier faced by new technologies, such as renewable energy, competing with mature technologies. In the past, customers didn't have much choice regarding the source of electricity. However, after deregulation, with several companies entering the market, customers now have various choices. In such a situation, public education is a critical tool, and these companies need to communicate the benefits of renewable energy to persuade customers to switch from traditional to new resources (UCS, 1999). In terms of location, sites need to be found for establishing renewable plants. These locations should be publicly accepted, with good resources, suitable for the type of renewable source involved, and have access to transmission lines (UCS, 1999).

Another challenge related to renewable resources is predicting the exact amount of power needed, and the time that will be taken for delivery. Wind speeds or sunshine are difficult to predict. Also, solar power can't provide a continuous and stable supply because of the lack of solar radiation during cloudy days or at night (Chen & Riffat, 2011).

5.8. Meeting customers' needs

It is expected that customer satisfaction will become increasingly important for electric utilities companies. It is already important, even when we hardly have any choice regarding electricity suppliers; when competition is limited to government monopoly. And it should become even more important after deregulation when customers have further choices with the existence of several competitors. Not only that, customers now even having the opportunity to invest in their own equipment, generate their own electricity and bypass the grid (Zarakas et al, 2013). This will even become more explicit when FIT and renewable generation options becomes more widespread. For utility companies to keep their customers, they are expected to compete by providing a stable supply, quality safety standards, and convenient and stable prices. Customers might forgive utility companies for increasing electricity rates, in exchange for service improvement, greater reliability, high quality standards, and safety, and as long as the increase is within a reasonable limit (Zarakas et al, 2013).

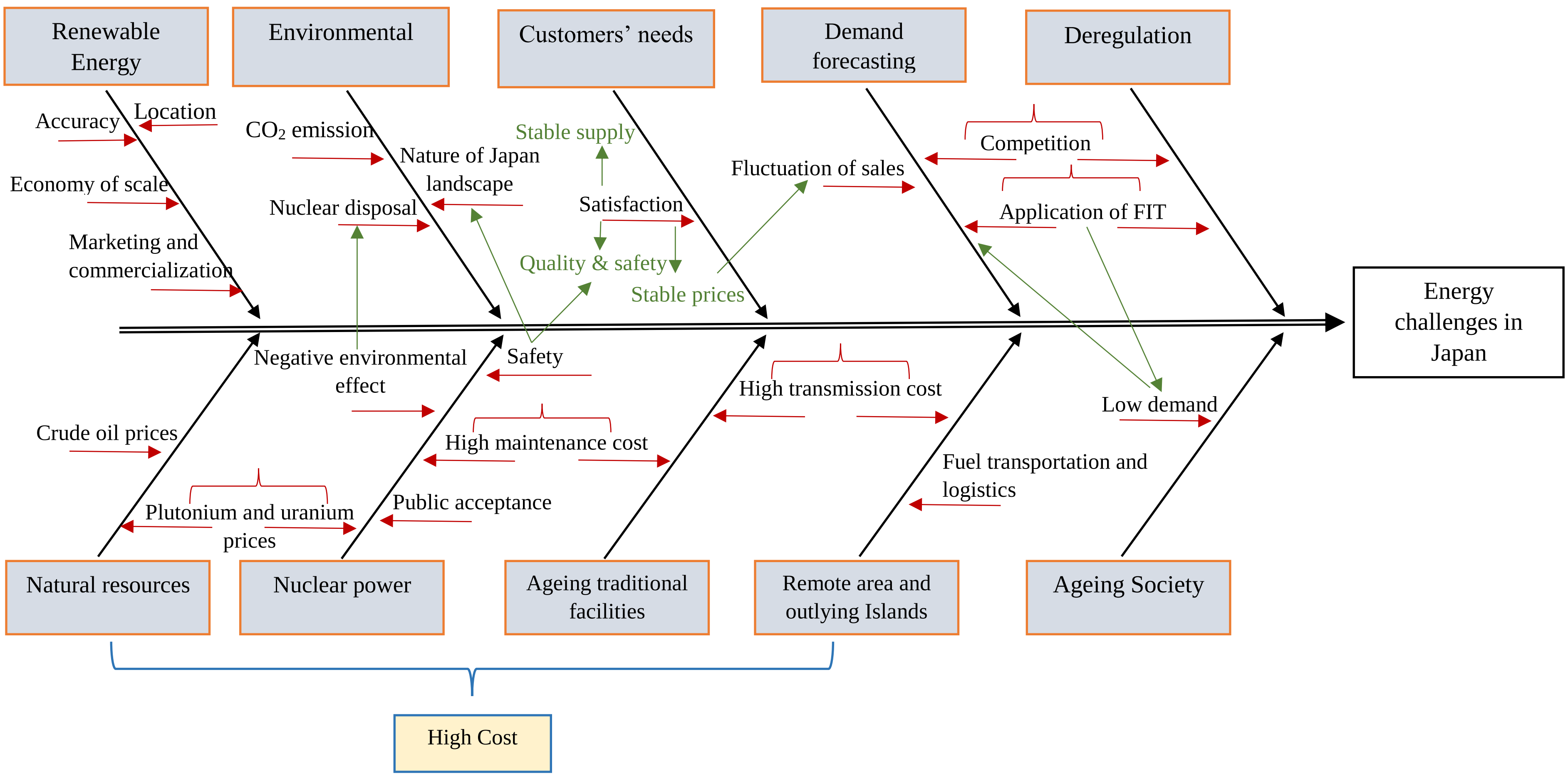


FIGURE 68: SUMMARY OF ENERGY CHALLENGES IN JAPAN

Chapter 6: A Proposed Distributed Generation Optimization Model

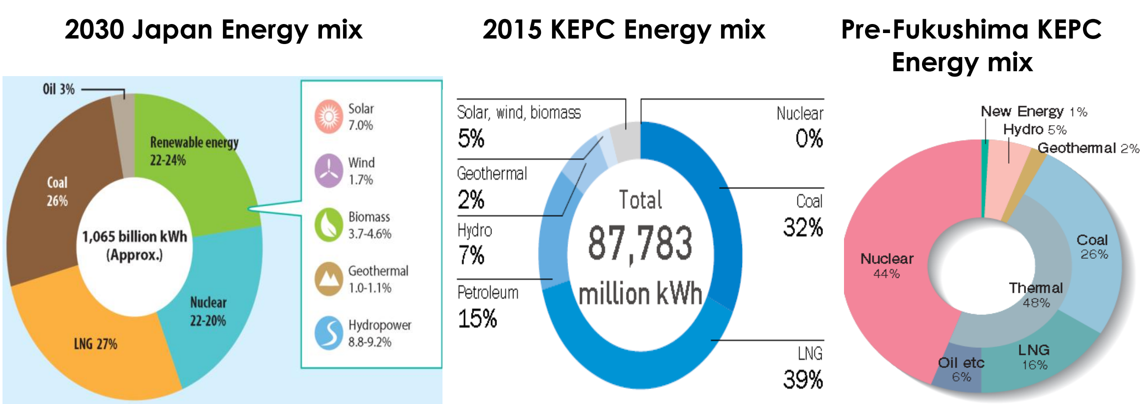
To ensure the stability of electricity supply in Japan, taking into consideration the need for countermeasures against the global warming caused by CO_2 emissions resulting from the use of energy, optimal solutions are needed for finding safe power resources which can provide energy security, environment preservation, and economic efficiency.

Previous chapters explored many issues related to the advantages of DG, technologies and technological considerations, benefits, and applications. They also explored the energy situation in, and the landscape characteristics of Japan, as well as the energy situation, and landscape characteristics of the Kyushu area. Some of the relevant policies, such as the Kyoto protocol and FIT, were also presented to understand the decision-maker's points of view behind already implemented strategies, and to provide them with a foundation for understanding the benefits of improving the efficiency of current power systems by altering traditional systems and incorporating DG into them. This should help improve air quality through increased efficiency and incorporation of more renewable power sources.

This chapter applies the knowledge presented in this research to develop an optimal electricity mix and system model to replace the traditional power system for the Kyushu area. The suggested mix and model can be examined, by power companies, first on a smaller scale, and then adopted for use in various cities of Japan.

6.1. Proposed Changes to Japan's Electricity Mix

Lacking natural resources pushed the Japanese government to announce a "strategic energy plan," which stated the importance of including 27% from LNG, 26% from coal, and a certain level of nuclear power (up to 20-22%), in the energy mix in 2030, while increasing the use of renewable energy. However, the public's desire to abandon nuclear power in the wake of the Fukushima disaster, in addition to the dramatic increase in CO_2 emission level to its second-highest level in the year to March 2014 due to the shutdown of nuclear power plants, have made the challenge even more severe. The government needs to increase the use of renewable resources, and gradually reduce reliance on gas, coal, and nuclear power. Changing the power generation mix, shifting away from nuclear and thermal powers towards expanding the mix of renewable power sources became a necessity (Figure 69).



SOURCE: MEIT (2015) SOURCE: KEPC 2015 SOURCE: KEPC 2006

FIGURE 69: ENERGY MIX COMPARISON

Although Distributed Generation has several benefits, it doesn't necessarily mean clean generation. Some technologies used in DG include different levels of emissions, such as reciprocating engines and Gas Turbines. DG, to be a sustainable and reliable alternative to the traditional systems, is better to rely on clean technologies, or, at least, favor technologies which maximize energy efficiency, air quality, and reduce emissions, such as cogeneration.

Japan has a reputation of being poor in natural resources, especially fossil fuels, however, it is rich in natural landscape and renewable energy resources, such as water, sun, wind, and geothermal energy, which can help improve its energy situation. Given the consideration of the difficult nature of the Japanese landscape, such technologies can also be the optimal energy mix that can offer that offer safety, self-sufficiency, reliability and controllability.

6.1.1. Hydroelectric

Water is one of the natural resource with which Japan is well supplied. Japan is an island nation, with about 12% of its total area in water, hundreds of dams and natural waterfalls, many of them are in the Kyushu area (Figure 70). Out of the KEPC electricity generation mix, 6% is general hydroelectric, and 8% is hydroelectric pumped. With this natural resource, KEPC can produce more clean, reliable, and low-cost energy.

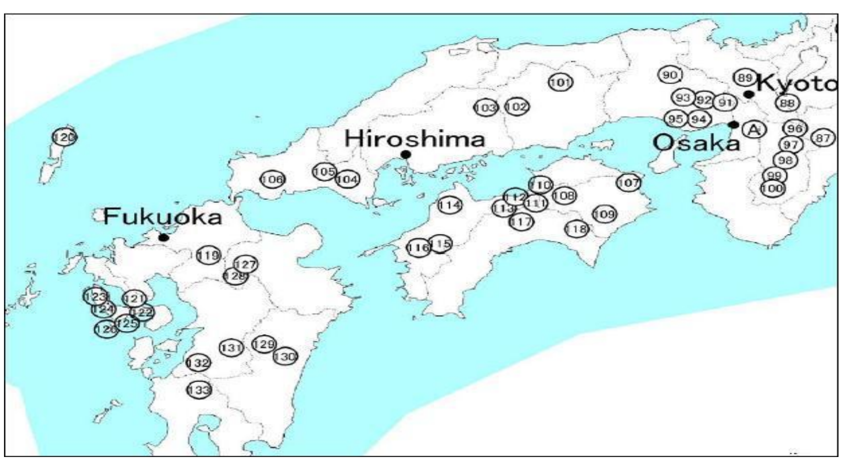


FIGURE 70: MAJOR DAMS IN WEST AND SOUTH JAPAN
SOURCE: (ICOLD)

6.1.2. Geothermal power

It is a fact that Japan suffers from frequent volcano eruptions. However, these volatile tectonics give rise to another natural resource, geothermal energy. Geothermal power is almost CO_2 emission free, and the steam emitted can help generate cheap electricity. Japan owns the world's third largest geothermal reserves; 60% of which can be developed. The Kyushu area is blessed with natural hot springs, to which people come from all over the world. KEPC, due to these location characteristics, is running the largest geothermal electricity generation in the country; 1% of KEPC energy mix is from geothermal sources.

Geothermal power is cheap compared to other power generation sources (Figure 71). Focusing research and development work on geothermal power can help increase renewable energy capacity in Japan. Geothermal is of high potential, and with the FIT ranging from 26 to 40 yen per kWh, geothermal power generation is expected to grow quickly in Japan.

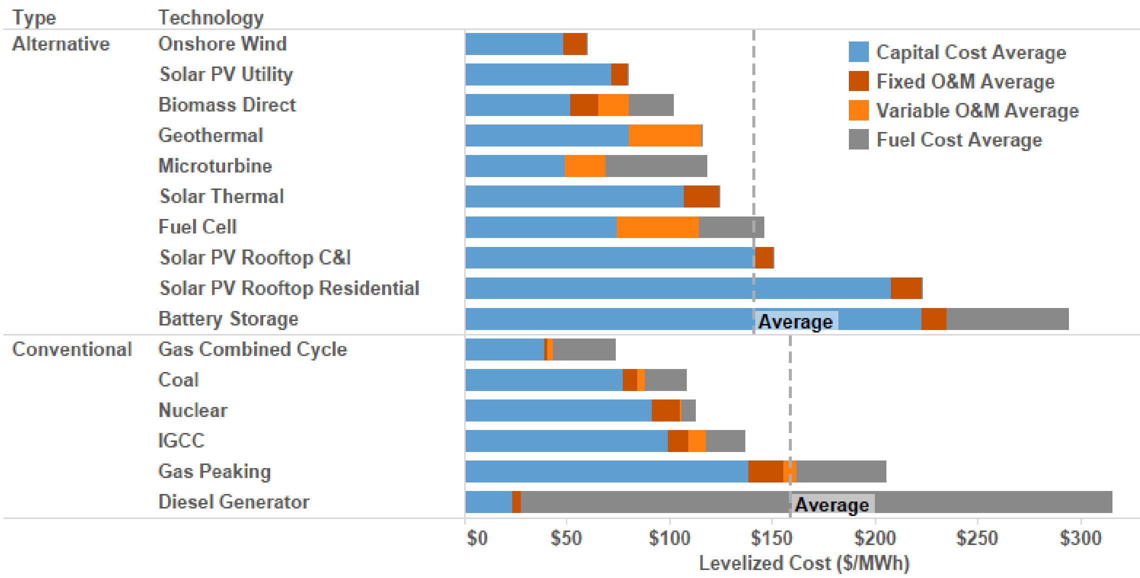
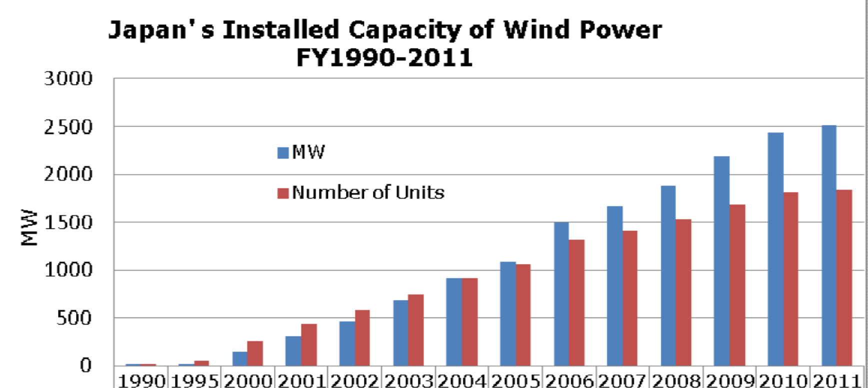


FIGURE 71: LEVELIZED COST OF DIFFERENT POWER GENERATION RESOURCES
SOURCE: ENERGY INNOVATION: POLICY AND TECHNOLOGY (2015)

6.1.3. Wind Energy

Japan has long history in wind energy (Figure 72), begins in 1980, however, it reached its full-force with the introduction of 1,000 kW generating systems in 1999 (Komatsubara, 2012). The current electricity situation in Japan provides a new incentive for re-evaluating, re-organizing and re-boosting the Japanese wind energy industry. The FIT system leverages the possibilities of wind energy generation. Furthermore, an offshore floating wind farm off the coast of Fukushima will test the potential of Japanese technology and industry as a whole. By focusing efforts on wind energy, as part of the Japanese energy mix, and with the continuous support by the Japanese government for wind energy research projects and field-tests, Japan can finally have a clean and reliable source of energy.



	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
MW	1	10	144	313	464	681	925	1085	1490	1675	1880	2184	2440	2522
Number of Units	9	54	259	434	576	741	920	1059	1316	1413	1531	1679	1807	1840

FIGURE 72: WIND POWER 1990-2011
SOURCE: KOMATSUBARA (2012)

6.1.4. Solar Energy

Japan is the fourth largest energy consumer in the world. It has been expanding its research on solar power since late 1990s. Japan is one of the leading manufacturer of photovoltaics and among the largest installers of domestic PV systems, with most of them connected to the grid. Solar power gained its importance as a national project when the shift in policies toward renewables began after 2011. It became the second largest market for PV in the world in 2013 and 2014. And by the end of 2015, Japan had the world's third largest PV installed capacity, after China and Germany (Watanabe, 2011).

Solar power represents about 5% of total energy mix of KEPC (see Figure 69 and 73). Solar is one of the promising renewables and has great potential for further expansion. It is one of the solutions for reducing environmental pollution. Using PV means high reliability, environmental friendly, low operation and construction cost, and modularity. With the application of FIT, consumer can sell their excess electricity to the utility companies. In addition, as promotion effort from the country for household, the Japanese government offers subsidies for installation costs.

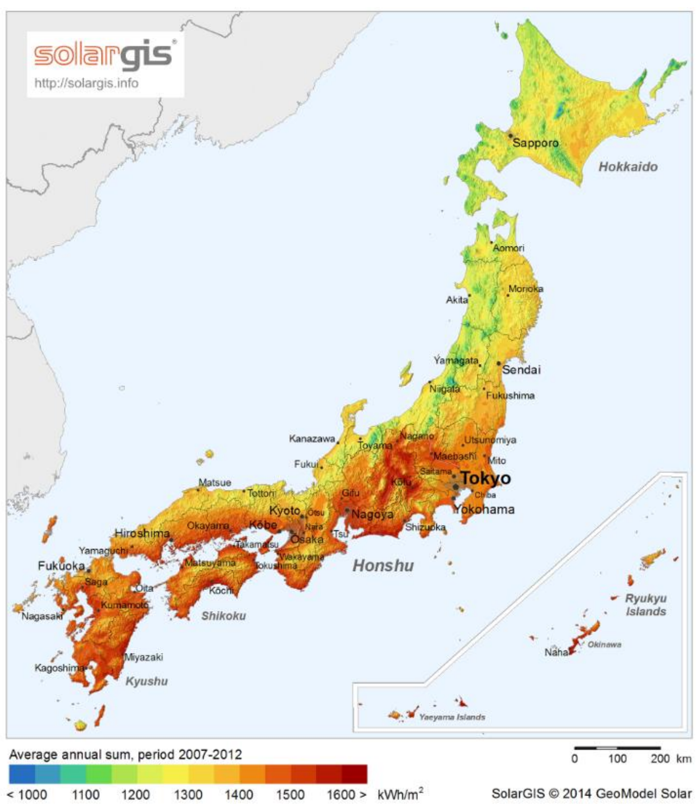


FIGURE 73: JAPAN SOLAR POTENTIAL
SOURCE: SOLAR_GIS (2014)

6.2. The Suggested model

The DG system's benefits, in particular flexibility and adaptability, result in better supply and demand management, simple and considerate siting decisions, easier and rapid installation and maintenance, lower cost, and, along with the expansion in renewables, lower negative environmental impact. The DG model proposed in this research is "Smart-Gird Interconnection", which consists of:

- grid interconnection;
- Virtual utilities;
- Storage batteries.

Since we can't eliminate the use of traditional systems, grid-interconnection allows the traditional grid to supply back-up power if necessary. This shall help achieve a wide-spread acceptance among users and cool down the public's concern regarding the significant changes in the power system. Human nature makes us skeptical about altering the configuration of traditional systems we have used for a long time. And, to gain their trust that new configurations can provide reliable power supply, they need to have access to backup power supplied by traditional grid networks. Grid-connection also facilitates the creation of micro-grids by simply connecting multiple DG nodes or interconnected DG sources which form a larger distribution network.

The creation of a micro-grid allows energy systems to completely pull away from the traditional grid model, as nodes supply back-up power for others within the micro-grid. Basically, these micro-grids create more efficient and wide networks of power distribution that are capable of serving a variety of power needs (Barg, 2011). In addition, users will have the option to buy or sell to the main grid, and to employ different strategies based on their needs. For example; buying off-peak when prices are cheaper, and selling off-peak when prices are expensive. Grid-interconnection may also solve some technical problems associated with DG systems, such as the intermittent nature of solar and wind energy. This can result in voltage fluctuation. This problem can compromise grid security and reliability if proper prevention measures are not taken (California Energy Commission 2002). Old grid systems also need to be upgraded to be able to handle the inclusion of power supplied from DG sources. This requires investment in current infrastructure. Once systems are upgraded and capable of handling power from DG sources, micro-grids can be formed (Barg, 2011).

Although the analysis of relevant literature showed that there is no consistent definition that is generally accepted by all concerned parties to describe DG, there are some considerable hints in that literature. DG can be recognized as an electrical energy source with limited capacity, which is directly connected to the distribution network and located near the load center, where natural resources are available to be served to end users (Colmenar-Santos, 2016). Smart-grids, according to the IEA (2010), are electrical networks in medium voltage that use advanced digital technologies for monitoring and managing the transport of electricity from different generation sources to meet various electricity demands. Developing such networks should facilitate the coordination of capacities with the needs of electricity markets, optimization of resources and minimization of environmental impact, while maintaining the reliability, durability and stability of systems. In that sense, smart-grids can be considered as intelligent transmission and distribution networks based on interactive communication between involved parties in the energy chain (Figure 74). They connect centralized and decentralized generation units to power generators, grid operators, power market stakeholders, and end-users, through an efficient energy management system. They provide flexible and real-time monitoring and control over the power generation and distribution process, and prevent network overload.

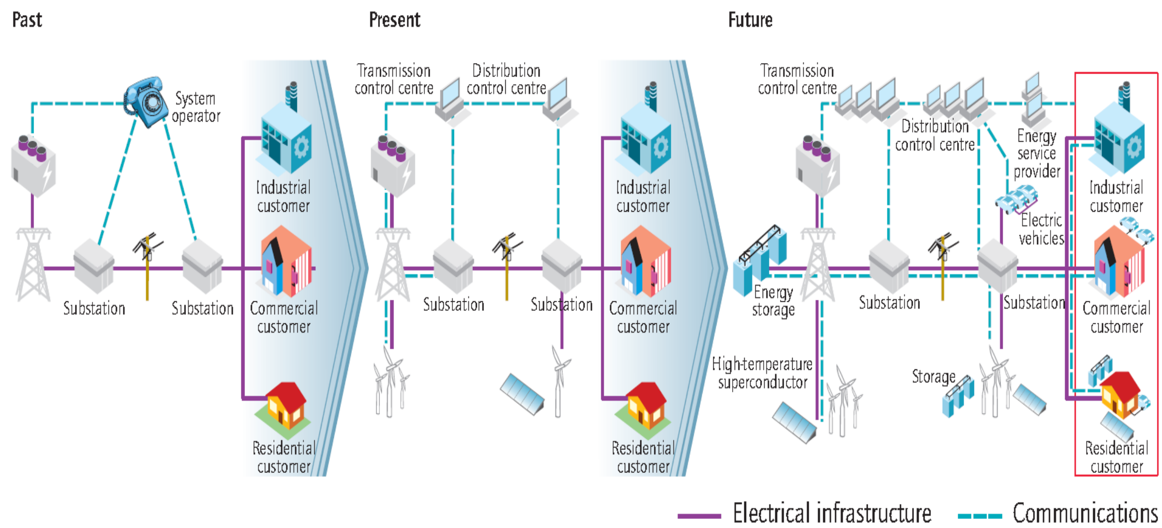


FIGURE 74: SMART ELECTRICITY SYSTEMS
SOURCE: IEA (2010)

According to the IEA, smart-grids have several characteristics. Accommodating all generation and storage options; including centralized and decentralized power generation sources. This should create opportunities for new products, services and markets for variable stakeholders. The competition resulting from such opportunities guarantees varying grades of power quality features and prices for the range of needs. Smart-grids apply the latest technologies to optimize the full use of their assets. Advanced control tools and methods are used to monitor fundamental components. This should enable rapid diagnosis and solutions to unexpected events affecting power quality, which provides resilience in disturbances and natural disasters.

According to Bayod-Rújula (2009), the concept of virtual utility refers to a range of DG sources controlled by a central management system. Operators, under virtual utilities, can prioritize sources of lowest pollution level to minimize environmental impact and optimize the efficiency of the entire network (Barg, 2011). The formation of the micro-grid from multiple nodes raises many concerns about power dispatching proper system control. Virtual utility models centrally control micro-grids to ensure that power quality and reliability are maintained. They can control voltage inputs and create a hierarchy among power sources. Uncontrolled inputs from several sources may result in straining systems and voltage fluctuations. This might cause outages or equipment failures. For example, prioritizing renewable sources with low emissions to produce base loads, and pulling from other power sources only when demand increases, forming a hierarchy based on relative characteristics (Barg, 2011).

Electricity has two characteristics which create issues in its use, and drive the need for electricity storage systems. The first is that electricity is consumed at the same time it is generated. Traditional system models were designed to meet forecast levels of demand at some point around 15 to 20 years in the future (Almeshaieia and Soltan, 2011), and electricity is generated regardless of whether production and demand are properly aligned, which might result in unused capacity (Barg, 2011). Theoretically, the proper amount of electricity should be provided to meet the demand. Any imbalance between supply and demand can lead to damaging the quality and stability of the power supply (IEC).

Another characteristic is that the places where power is generated are often located far from consumers. Power plants and consumers are connected through the power grid network. This might result in several problems, such as power losses, as well as the congestion resulting from power flows concentrated in a specific transmission line. The failure in some lines due to congestion leads to interruption of supply, which affects the balance between supply and demand (IEC). In such cases, storage batteries can be an effective solution. The power generated during low demand periods can be stored to meet future demand at peak periods, which will guarantee continuity and flexibility of supply.

Battery Energy Storage Systems (BESS) can provide flexible energy management solutions to improve the quality of service provided for renewable energy users. New developments in BESS are recently used for multiple applications. They are used for frequency regulation, meeting hourly variations in price and demand, diminishing congestion, grid stabilization, transmission loss reduction, wind and solar energy smoothing, increased reliability, spinning reserve, load leveling, peak-shaving, uninterruptible power sources, grid services, and electric vehicle charging stations (Li et al, 2013).

In supplying remote areas with electricity, the high connection cost and challenges of grid extension often lead to a search for other options, such as stand-alone hybrid systems, to supply energy. Stand-alone hybrid systems are usually dependent on multiple renewable sources and are one of the promising ways to meet energy demand for such areas. They require a suitable control strategy which can effectively regulate power output levels, and help balance demand and supply. In such cases, storage of electricity is the proper solution (Abd El-Motaleb et al, 2016).

Batteries can also be used to back intermittent energy sources and smoothing the power fluctuation in wind and solar power generation, which is a technological problem associated with some small and medium sized systems. With the high wind and PV penetration associated with the application of Fee-in tariff in some countries, cost free surplus energy is often available. Such surpluses can be stored in batteries to be used as a mean of reducing generation costs. From a consumer's perspective, storage systems are capable of lowering electricity costs. The electricity bought at low off-peak prices can be stored and used later during peak periods instead of expensive power. Customers applying FIT can charge batteries with excess power during off-peak periods and sell it later to utilities companies or other customers during peak periods (Li et al, 2013).

To avoid line overloads, utility companies try to predict areas of future congestion. To solve this problem, electricity storage batteries can be located at substations at the ends of heavily loaded lines. This can help mitigate congestion, by storing electricity when transmission lines are maintaining enough capacity while using it when transmission lines are overloaded due to congestion (IEC).

Chapter 7: Conclusions and recommendations

The old business model of the electricity utility industry in Japan is faced with significant changes from innovative technologies, stricter environmental regulations, changes in customer preferences, and tighter regulatory pressure. In addition, industry management is faced by shortage of natural resources, unstable fossil fuel prices, low customer growth due to the aging society, and consequently, low growth of energy usage, aging infrastructure, and an absolute need to maintaining stable and reliable service. Understanding the energy situation in Japan, how utility companies can confront the above challenges and the possible solutions have been explored in this research. An improved model for better performance of the power generation system is proposed for examination and adaption for use in various areas of Japan.

The Kyushu area was chosen as a study area for this research due to the distinguished characteristics it enjoys, such as location, economic level, industries and proven success in the energy field. Kyushu electric power company was chosen as a case study due to the accessibility of information. This company has established a standard level of quality in terms of sustainable energy, and it sounded appropriate to analyze an organization that enjoys a history of success in this area to determine how to further improve the effectiveness of Distributed Generation implementation.

The model proposed in this research is called Distributed Generation (DG). The analysis of the relevant literature shows that there is no consistent definition that is generally accepted by all concerned parties to describe DG. Some researchers define it based on the voltage level, or in terms of its location, capacity, technologies, environmental impact, ownership, or just its basic characteristics. However, there are some definitions that can be considered as common. DG can be recognized as an electrical power system with limited capacity, which operates on a small scale, is directly connected to the distribution network, and is located near the end user. It is highly recommended that the DG definition is discussed by all concerned parties to come up with a commonly accepted definition.

DG applications can be designed to meet a wide range of customers' needs and vary according to load requirements that affects the type of technology used. It can be used as standby, rural and remote applications, stand-a lone, peak-load shaving, CHP, and so on. To realize its benefits and applications' full potential in a timely manner, DG challenges and barriers to implementation need to be recognized and eliminated. Some of the challenges facing the implementation of DG are power quality, increasing consumption, voltage and frequency levels, interoperability and standardization issues, limited storage, and the high cost of replacing old systems. There are also the challenges related to regulations and policies, which include regulatory complexity and instability, the need for interoperability and standardization, lack of a clear understanding of roles and responsibilities, the lack of incentives and cost-efficiency, and the limiting competition role of governmental monopoly.

There are thus several factors behind the interest in Distributed Generation, including developments in DG technologies, utilities market liberalization, cost, increased customers' demand, constraints on the construction of new transmission lines, the need for reliable energy sources, and concerns about climate change. Energy policies has played an effective role in shaping the future of power generation in Japan, especially those that provide financial incentives such as FIT. Increasing the capacity of the program will definitely stimulate growth among renewable energy generators. As for policies related to reducing CO_2 emission, although the Japanese government announced that the country does not intend to be under the obligation of the second commitment period of Kyoto protocol after 2012, Japan is committed to continue its ambitious emission reduction efforts beyond 2012.

Lacking natural resources pushed Japan to announce its 2030 "strategic energy plan" which stated that increasing the energy self-sufficiency rate, including a certain level of nuclear power up to 20-22%, while increasing the use of renewable energy, was to be sought. However, the public's desire to abandon nuclear power in the wake of the Fukushima disaster, in addition to the dramatic increase CO_2 emission levels due to the shutdown of nuclear power plants, have made the challenge even more severe. Changing the power generation mix, shifting away from nuclear and thermal power towards renewable energy, and expanding the mix of renewable power sources became a necessity.

The physical characteristics of Japan shapes energy decisions. The country is an island nation, surrounded by water, with varied topography, fluctuating weather patterns, difficult landscape, and several types of natural disasters. Given these considerations, it is appropriate to promote power technologies and energy mixes that can stand in the face of such difficult natural surroundings, and minimize space occupation, to produce a mix that is immune or unaffected by the country's topography while supplying sufficient power. Such physical conditions force some significant constraints on the power system, and it may be better to adopt power sources that offer safety, reliability and controllability, such as wind, solar, and hydraulic and geothermal technologies. In addition, DG, to be a sustainable and reliable alternative to traditional systems, is better to rely on clean technologies, which maximize energy efficiency, air quality, and reduce emissions, such as cogeneration.

The DG model proposed in this research is "Smart-Gird Interconnection," and consists of grid interconnection, virtual utilities, and storage batteries. One of the critical benefits of DG is its ability to shift the traditional energy generation design. However, since we can't eliminate the use of traditional systems, grid-interconnection allows the traditional grid to supply back-up power if necessary. DG nodes can be strategically located in a way that facilitates the implementation of grid-interconnection and the expansion when demand increases. Grid interconnection has several benefits:

- From the financial perspective, it is considered to be cost and time efficient. In traditional systems, electricity is generated regardless of the proper alignment of supply and demand, which might result in unused capacity, and, with the increase in demand, make costly and time intensive upgrades to power system necessary. DG can be incorporated into conventional systems rapidly and at lower cost instead of upgrading the entire system to create grid interconnection;
- It can help cool down the public's concern regarding the significant changes in the power system;
- It shall also facilitates the creation of micro-grids, creating more efficient and wide networks of power distribution, which are capable of serving the variety of power needs;
- Through grid interconnection, users will have the option to buy or sell to the main grid and to employ different strategies based on their needs; and

- It solves some technical problems associated with DG systems, such as the intermittent nature of energy generated using solar and wind technologies.

Smart-grids are intelligent transmission and distribution networks based on interactive communication between involved parties in the energy chain. Developing such networks should facilitate the coordination of capacities and needs of electricity markets' users, monitoring and managing the transport of electricity from different generation sources, optimization of resources and minimization of environmental impact, while maintaining reliability, durability and stability of systems. This can be achieved through virtual utility, which is known by a range of DG sources controlled by a central management system. Virtual utility models centrally control micro-grids to ensure that power quality and reliability are maintained. They can control voltage inputs and create a hierarchy among power sources.

BESS can provide flexible energy management solutions to improve the quality of service. They are used for frequency regulation, meeting hourly variations in price and demand, diminishing congestion, grid stabilization, transmission loss reduction, PV and wind energy smoothing, increased reliability, spinning reserve, load leveling, peak-shaving, grid services, uninterruptible power sources, and electric vehicle charging stations. They are also used in stand-alone hybrid systems to supply energy for remote areas and to back intermittent energy sources and smoothing the power fluctuation in PV and wind power generation. Moreover, electricity storage batteries can be used by utility companies to mitigate congestion and avoid line overloads.

A great deal of progress can be made by the reconfiguration of energy generation and transmission systems. The model introduced in this study shows how effective DG can be in reducing CO_2 emissions and improving power efficiency, while maintaining sustainable technologies. While traditional systems won't be replaced by DG models overnight, it is important to begin shifting practices to those that can more efficiently use our resources. By shifting away from the traditional model of central plant power generation and long-distance transmission, great steps can be made to improve air quality and provide customers with reliable and stable supplies of electricity.

Due to time and resources limitation, this research has focused on Kyushu area, using Kyushu Electric Power Company as a case study. For future research, it is recommended that research hypotheses are tested in the rest of Japan. It is also recommended that the proposed mix and model should be examined and adopted for use in various areas of Japan.

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