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Revival of Bataan Nuclear Power Plant

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Abstract

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The Philippine economy is growing rapidly and so is the demand of electricity. In pursuance of economic growth, the energy security and the affordability must be sustain. In the past, certain incidents caused by lack of supply in the Luzon grid have resulted to electricity prices in the market to shoot up. In order to provide electricity in the Luzon grid, the construction of 623 MW Bataan Nuclear Power Plant (BNPP) began in 1976. However, it was inactivate due to safety and political constraint.

In the Philippines, 48 percent of the power plants rely on coal. Coal-fired power plant has significant GHG emission impact in the environment. Furthermore, foreign investors are appalled to higher electricity costs due to tight gap of electricity supply and demand. Also, existing power plants were forecasted to insufficiently provide electricity in the near future. Hence, the revival of BNPP is the main objective of the study to assist existing plants in providing electricity in Luzon grid with relatively less cost of electricity and environment friendly. Regression models were used to forecast the Luzon peak demand of electricity up to year 2030.

Since nuclear energy is a controversial topic globally, the case of other countries e.g. Germany, Japan and South Korea were considered also in

this study. The three big nuclear incidents in the history (Three Mile Island, Chernobyl and Fukushima) were also discussed. While conducting this study, the cost of electricity and the mitigation of GHG emissions constraints were encountered since the Philippine government is a signatory in the Paris agreement.

In addition, the Philippine government is allocating a substantial amount of budget annually just for the maintenance of the idle power plants. The existing predicament of the Philippine government in terms of unstable prices of electricity due to insufficient supply and the unattainable target of GHG emissions reduction for Paris agreement without restructuring the energy mix can be categorized as path dependency. With the actual cases in other countries regarding the benefits and the tragedies caused by nuclear power plant, the Philippine government will learn from this study that through the revival of BNPP, it will aid in additional supply of electricity in the Luzon grid. Economically, energy cost could be stabilized, CO_2 emissions will be of less threat to the environment and lastly BNPP will switch from citizen's liability into asset.

Keywords: Nuclear Energy, Energy Security, Cheap Electricity, Paris Agreement, Base load, Demand Forecast, Social Impact, Path Dependence

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List of Abbreviations

ALD	Automatic Load Dropping
BNPP	Bataan Nuclear Power Plant
BWR	Boiling Water Reactor
CDU	Christian Democratic Union
CO2	Carbon dioxide
DOE	Department of Energy of the Philippines
EPIRA	Electric Power Industry Reform Act
FDP	Free Democrats Party
FEPC	Federation of Electric Power Companies of Japan
FIT	Feed-in-Tariff
GHG	Greenhouse gas

GW	Gigawatts
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IET	Institution of Engineering Technology
ILP	Interruptible Load Program
INES	International Nuclear and Radiological Event Scale
IPCC	International Panel on Climate Change
IPPs	Independent Power Producers
KEPCO	Korean Electric Power Company
KWh	Kilowatt-hour
LCOE	Levelized Cost of Electricity
LNG	Liquefied Natural Gas
MERALCO	Manila Electric Company
MIT	Massachusetts Institute of Technology
MLD	Manual Load Dropping
MW	Megawatt
NDC	National Determined Contributions
NGCP	National Grid Corporation of the Philippines
NPC	National Power Corporation of the Philippines
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NSDC	National Snow and Data Center
OECD	Organization for Economic Co-operation and Development
PAEC	Philippine Atomic Energy Commission
PNRI	Philippine Nuclear Research Institute
PPM	Parts Per Million
PSALM	Power Sector Assets and Liabilities Management
PWR	Pressurized Water Reactor

RES	Renewable Energy Sources
TMI	Three Mile Island
TRANSCO	National Transmission Corporation of the Philippines
TWh	Tetrawatt-hour
UNFCC	UN Framework Convention on Climate Change
WESM	Wholesale Electricity Spot Market of the Philippines
WHO	World Health Organization
WNA	World Nuclear Association

1. Introduction

Towards the end of the Second World War, nuclear energy discovered through the process called fission of uranium. Because of its promising advantages, the construction of nuclear power plants worldwide in the late 20th century boomed. Lately, nuclear energy became a broadly controversial due to what happened to Fukushima Dai-chi nuclear power plant in 2011. Awareness of nuclear safety and started a wave of debates worldwide about future electricity generation from this source has become a trend. In Germany, the composition of energy sector will change dramatically, as the Government completely decided to shut down all its 17 nuclear reactors by 2022. However, energy demand globally grown rapidly and will probably continue to grow due to the role of electricity to growing populations and economies.

The Philippines, particularly in Luzon has the biggest economy among the three biggest islands has been experiencing tight gap between electricity supply and demand thus an additional power plants is badly needed. However, the Philippines has one nuclear power plant located in the province of Bataan, though its construction is fully completed, still it was never commercialize. President Duterte already gave the order to his experts to have a detailed study of reviving the Bataan Nuclear Power Plant (BNPP) in order to help the government accommodate the increasing demand of the Philippines electricity specifically in Luzon.

1.1 Purpose

The aim of this thesis is to determine the following:

a) Whether energizing the Bataan Nuclear Power Plant will accommodate the increasing electricity demand in the Luzon Grid;
b) Whether the said nuclear power plant has fewer contributors to climate change; and
c) Whether the electricity rates coming from the said nuclear power plant is cheaper compared to other existing power plants fueled by renewable energy connected to Luzon Grid.

1.2 Significance

This study will contribute as a preliminary step for any attempt toward the proposition of reviving the said power plant.

2. Theoretical Framework

2.1 Theory of Supply and Demand

Quantity demanded exceeds quantity supplied will results to consumers will offer money for something in an attempt to secure a sufficient supply (Kreinin, 2017). We cannot argue more in the notion that as the demand increases so is the price of the supply will follow. The electricity demand increased due to the economy of that region is booming. However, if the is not sufficient to accommodate the increasing demand, there is a possibility in order to regulate the electricity market by market competition the price of the electricity will increase so that the consumers themselves will be the one to manage the usage of electricity. If not, interruption of supplies in other regions will surely experience.

Quantity supplied exceeds quantity demanded will results to an excess supply the producers will compete down the price to dispose of the

excessive supply (Kreinin, 2017). It is better for the consumers to have an excess supply of electricity so that the price of electricity will surely go down due to competition in the market. Furthermore, the electricity service also will improve because of the competition.

2.1.1 Demand of electricity skyrockets

According to the Philippine Statistics Authority, the Philippines economy grew an annual 6.5 percent in the June quarter of 2017, following a 6.4 percent expansion in the previous quarter and above market consensus of a 6.2 percent growth. As the Philippine economy grows so is, the demand of electricity follows. In order to sustain the growing nation's economy, the supply of electricity must catch up since the 44.8 percent of total Philippine exports are electrical machinery and equipment while 13.8 percent is machinery including computers as per World's Top Export, 2017. It is impossible to produce and export these products without the help of cheap electricity. The supply of electricity must be always greater than the demand in order to maintain the price of electricity stable through competition.

2.2 Theory of Climate change

In the early 1950s, the chemist Charles David Keeling figured out a way that measures the concentration of CO_2 in air accurately. Keeling discovered an annual cycle in CO_2 concentrations and these two cycles are seasons and carbon cycle. According to him during winter the earth, exhaled CO_2 through the process like the decomposition of falling leaves, but in summer in the north, the earth inhaled the extra CO_2 by increased photosynthesis. Without the help of human, globally, lots of plants and trees are growing due to pollination. Thus, growing and absorbing CO_2 is greater than the decaying and releasing it. Another major thing that he discovered was that CO_2 concentrations is increasing over time. The CO_2 measurements at Mauna Loa by Charles Keeling and his colleagues known as the "The Keeling

Curve" showed that CO_2 in the atmosphere is increasing *see Appendix A*. In year 2014, the earth was near 400 ppm and increasing by about 2ppm per year. In the 19th century, the major source of human CO_2 emissions was deforestation. But now the main contributors to GHG emissions by economic sector comes from heat and electricity production (C. Change, 2014). The major contributors per fuel are coal, petroleum and natural gas. The earth also stabilize CO_2 in the atmosphere by absorbing the extra by plants and soils and other by carbon sinks such as oceans. However, the CO_2 that stays in the atmosphere is the culprit that makes the earth's temperature hotter. Also humans and animals as we inhale oxygen and exhale CO_2 contributes to CO_2 emissions in a small fraction of the natural cycle. Overtime it adds up due to the increasing population of the earth. According to co2.earth, last 2014 the CO_2 level in the atmosphere was 43 percent above the level when the Industrial Revolution started in 1750.

2.2.1 Relationship of CO_2 and Global Temperature

Solar energy, mostly in the form of visible light, is absorbed by the earth's surface and reemitted as longer wavelength infrared (ir) radiation. Certain gases in the atmosphere, primarily water vapor and to a lesser degree CO_2, have the ability to absorb the outgoing IR radiation which is translated to heat. The result is a higher atmospheric temperature than would occur in the absence of water vapor and CO_2. This temperature enhancement is called the greenhouse effect, and gases that have the ability to absorb ir and produce this effect are called greenhouse gases (GHG). According to the Wiley Encyclopedia of Energy and Environment,

> *"Without the naturally occurring concentrations of water vapor and CO_2, the earth's mean surface temperature would be negative 18 °C."*

2.2.2 Impact of Increased Atmospheric Temperature

Many scholars studied the effects of increased atmospheric temperature in the world. One of the famous documentaries regarding the effects of global warming is the *Inconvenient Truth* by Al Gore. The film describes the problems of an increase atmospheric temperature. The film is a collection of clips that explains the overlapping between increases in carbon emissions and increases in global temperature. Based in Al Gore's documentary, global warming causes other powerful natural catastrophes worldwide like typhoon Katrina. Hurricanes formed over warm ocean waters. This is why it is common for tropical countries to have frequent storms and hurricanes. Warm air, together with moisture from evaporation from the ocean surfaces rises, creating low pressure on the water surface, which immediately replaced by cooler air. According to Al Gore, even though hurricanes were already here before the rising of atmospheric temperature, however, the hurricanes since global warming were more frequent and stronger than before. The most recognizable impact of global warming is the melting of ice shelves and Snowcap Mountains. The heat melted the glaciers and sea ice, especially at the Earth's poles.

Scientists monitored the breakdown of ice sheets naturally in West Antarctica, Greenland and Arctic sea ice. The melting of snow will increase the volume of seawater resulting to the submersion of some islets. According to National Snow and Data Center (NSDC), the Antarctic Peninsula juts norths towards South America, into warmer waters. The Peninsula has warmed 2.5 degrees Celsius since 1950, making it one of the fastest- warming places on Earth.

According to National Geographic, many species have been impacted by rising temperatures. The researcher Bill Fraser has tracked the decline of the Adélie penguins on Antarctica, where their numbers have fallen from

32,000 breeding pairs to 11,000 in 30 years. Precipitation (rain and snowfall) has increased across the globe, on average. These are some of the few impacts of global warming across the globe.

According to The Guardian, insects numbers are collapsing, a 27-year study in Germany shows flying insect numbers have fallen by 76 percent. The scientist believes that the decline of insects threatens all life on earth wild plants depend on insects for pollination and some birds rely on insects for foods scientist believed that one of the reasons of the decline is due to droughts caused by climate change.

There are lots of threat in the world, terrorism, poverty, human rights, global warming and so on. However, global warming, better known as climate change, is an issue that everyone on earth is surely affected. Whether small or big countries all are living on the same planet. Whether the country has different types of climates like tropical, temperate, dry, polar, highland or continental, still in anyhow affected by climate change. This climate change whether we believe it or not is a real threat to humanity. And the IPCC officially declared in 2001 that "most of the observed warming over the last 50 years is to have been due to the increase in GHG concentrations" (Richard, 2001).

It is nice to see the world where all people have an access to electricity. However, it is not enough to provide a temporal pleasure to humanity when it is a well-known fact that the price it must pay is a shorten life particularly for those who are poor and weak and the next generation to come. The government must really work hard to replace the fuels that contributes to GHG emissions. Population in the world is no doubt growing rapidly so is the GHG emissions that contributes to heat the world.

2.3 Basic Theory of Nuclear Energy

The present inquiry into the source of nuclear energy can be best explain by picturing the structure of atoms first. The atom[1] has a nucleus[2], which carries positive electrical charge. This nucleus is composed of protons and neutrons. Protons carry the positive electrical charge, and neutrons, which are of similar mass but electrically neutral (W. Marshall, 1983). The release of energy that is stored in fuels of all kinds involves the conversion of part of the mass of their atoms into usable energy. Einstein as expressed the equivalence of mass (m) and energy (E):

$$E = mc^2$$

Where c is the velocity of light. Velocity of light is equivalent to $3x10^8$ m/s. small amount of changes in the mass are equivalent to large amount of energy that can be use.

In order to understand how the process of nuclear energy it is better to look into the structure of the nucleus of the atom. Nucleons[3] are held together in the nucleus by very strong nuclear forces, which bind together the mixture of protons and neutrons despite the electrical repulsion that exists between positive the positively charged protons. A nucleus can increase its proton to neutron ratio by converting a neutron into a proton plus an electron. This results in the formation of an atom of a new element and rejection of the *negatively charged beta particle*[4]. This process is known as *beta* (β) radioactivity[5]. Alternatively, the nucleus may emit a neutron directly, resulting this time in an atom of the same chemical species having a nucleus

[1] The smallest part of an element that can exist.
[2] The central core of an atom that contains most of its mass. It is positively charged and consists of one or more nucleons (proton and neutrons)
[3] A proton or a neutron
[4] An electron
[5] The spontaneous disintegration of certain atomic nuclei accompanied by the emission of alpha particles, beta particles or gamma radiation.

lighter by one mass unit. This process is important in controlling the power in nuclear reactor[6]. A nucleus can decrease its proton to neutron ratio by the following processes: It can emit an alpha particle (α), which is a stable group of two protons plus two neutrons (4 atomic mass units). This process known as α – radioactivity and, takes place amongst the heavier elements, where an additional requirement for stability is the reduction of the nuclear mass of beta radioactivity in which a positively charged beta particle emitted, leaving an atom with atomic number less by one but having approximately the same mass as before. It can covert proton into a neutron. All of these radioactive decay processes are accompanied by a small loss of mass and therefore a release of energy.

The process where the source of energy produced inside the nuclear reactor is called fission. Fission is when the energy is released if a nucleus of high mass number is divided into two parts *see Appendix B*. The heavy nuclei being those of uranium[7] or plutonium[8] can undergo fission when bombarded by neutrons that are sufficiently fast. The only naturally occurring nucleus which satisfies this condition is uranium-235, containing 92 protons and 143 neutrons. The uranium nucleus absorbs a neutron to from momentarily the new uranium isotope uranium-236, which then splits into isotopes of barium and krypton releasing three neutrons in the process. There are many other pairs of isotopes, which the fission process can generate, but them all release two or three neutrons.

Early workers observing the fission of uranium-235 realized that if one of the neutrons emitted during fission were to strike another uranium-235 nucleus and cause it to fission, the process would repeat itself over and over

[6] A device in which a nuclear fission or chain reaction is sustained and controlled in order to produce nuclear energy.
[7] A white radioactive metallic element.
[8] A dense silvery radioactive metallic transuranic element.

again. This sequence is called chain reaction. If more than one neutron per fission were to cause further fissions, the reaction would build up rapidly, while if less than one neutron per fission were available to cause further fissions, the reaction would rate would slow down or stop. All nuclear reactors to date uses uranium as their basic fuel. Uranium is a radioactive metal which is widespread in earth's crust. Unlike coal or oil fired power plant the nuclear reactor has its fuel sealed inside metal or ceramic cans so that the waste products, instead of being discharged into the air and on to the land, remain encapsulated when the fuel is finally discharged. These fissions products are themselves radioactive and toxic but the quantity produced in generating a given amount of energy is so very small compared to other fuels using the formula $E = mc^2$. The energy released by nuclear fission is large compared to the energy produced in the burning of other fuels, which is why it is possible to generate large quantities of electricity with small amounts of uranium. For example, one kilogram of uranium used as fuel in a reactor can produce 50,000 kWh, while one kilogram of coal can produce only one kWh (J. Goldemberg, 2012). Seven out of every 1,000 atoms of uranium are useful for the production of energy (R. Evans, 2008). For this reason, uranium elements need to be refined in order to be usable in the nuclear reactors for electricity production.

Nuclear power plant works from atom produces heat energy through fission inside the reactor while control rods composed of cadmium and boron are responsible to control the chain reaction inside the reactor. Water passing thru the reactor collected the heat energy and constantly flows into a loop creating a steam and this steam will then turn the turbine generator to rotate resulting to creation of electricity. This is for Boiling Water Reactor (BWR) design. For Pressurize Water Reactor (PWR), it generate electricity in a process whereby pressurized boiling water produced in the reactor is sent to

the steam generator, where it converts water flowing through another system into steam, which is then used to drive the turbine.

2.4 Literature Review

Nuclear energy is a controversial topic globally. The usage of this technology adopted mostly by developed countries. While in recent years, developing countries are trying to embrace this technology in terms of electricity production. The benefits and the risk of this nuclear energy is subjective. Thus, there are countries that wish to discontinue the usage of this technology for they believed that the risk is more than the benefits. However, there are countries as well who believes that it is not yet the proper time to remove nuclear energy in the energy mix because it has also contributed potentially to the society. One of the major reason is that using nuclear energy in electricity production helps the government in mitigating their carbon emissions. It is worthy to note that, carbon emissions is also a major problem globally. As discussed on the above theoretical framework, carbon emissions in the atmosphere contributing to heat the Earth's surface by blocking the IR radiation back to the Sun. Therefore, the Paris agreement treaty was a decision of United Nations (UN) to agree on something that the leaders in the world must make a commitment that will surely reduce their carbon emissions individually.

2.4.1 Paris agreement

Carbon dioxide (CO_2) is a heat trapping gas that covers earth, in that way keeping the earth warm enough to support life. Climate is a region of the earth having specified climatic conditions (Meriam Webster, 2017). The climate of a region or city is its typical or average weather. Some countries has a climate of mostly sunny and warm, but some countries like, South Korea and Russia is mostly cold. While the Earth's climate is the average of

all the world's regional climates (Sandra, 2017). Therefore, climate change is a change in the usual weather of a region. This could be a change in a region's average annual rainfall or long sunny season. Climate change is also a change in Earth's overall climate. This could be a change in Earth's average temperature (Sandra, 2017).

The Inter-governmental Panel on Climate Change (IPCC) is the authoritative source on the science and impacts of climate change. Established in 1988 by the World Meteorological Organization and the Environmental Programme of the United Nations IPCC prepare assessments based on the weight of the scientific evidence. IPCC includes representatives from many nations, which most observers consider a major strength. IPCC data shows that emissions from power plants are the largest (27 percent) and fastest growing contributor to CO_2 releases. In a developed countries, according to some scientists, 39 percent of 'the energy forms that produce CO_2 is used for generating electricity, 36 percent is used for generating heat for buildings and industry, and 25 percent is used in transportation' (Baruch 2008: 112).

Thus, on 12 December 2015, 196 Parties to the UN Framework Convention on Climate Change (UNFCCC) adopted the Paris Agreement, a new legally-binding framework for an internationally coordinated effort to tackle climate change. The Agreement represents the culmination of six years of international climate change negotiations under the auspices of the UNFCCC. It reached under intense international pressure to avoid a repeat failure of the Copenhagen conference in 2009.

The summary of the Paris Agreement contains (Note, 2015):

- *An ambitious collective goal to hold warming well below 2 degrees with efforts to limit warming to 1.5 degrees;*

- *An aim for greenhouse gas emissions to peak as soon as possible, and to achieve net-zero emissions in the second half of this century;*
- *A requirement for mitigation measures of individual countries to be expressed in Nationally Determined Contributions (NDCs);*
- *A process that demands a revision of NDCs at least every 5-years representing progression beyond the last NDCs;*
- *A mechanism for countries to achieve NDCs jointly, sharing mitigation targets, and a mechanism for countries to cooperate in achieving NDCs. Countries can meet their NDC targets by transferring 'mitigation outcomes' internationally – either in the context of emission trading, or to allow results-based payments;*
- *A mechanism for private and public entities to support sustainable development projects that generate transferrable emission reductions;*
- *A framework for enhanced transparency and an expert review of NDCs;*
- *A Global Stock take from 2023 and every 5 years thereafter to review progress;*
- *Encouragement for Parties to implement existing frameworks for REDD+*[9] *including through the provision of results-based payments;*

[9] Stands for countries' efforts to reduce emissions from deforestation and forest degradation, and foster CONSERVATION, sustainable management of forests, and enhancement of forest carbon stocks.

- *A global goal of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, and commitment to providing enhanced support for adaptation;*
- *A decision to adopt the Warsaw International Mechanism for Loss and Damage, noting that the agreement does not involve or provide a basis for any liability or compensation;*
- *A commitment to a collective goal of providing USD 100 billion per year to 2025, and beyond 2025 with USD 100 billion as a floor. Developing countries are encouraged to provide voluntary support. Public funds will play a 'significant role' in finance, and developed countries must report twice a year on levels of support provided;*
- *An enhanced transparency framework for action and support with built-in flexibility which takes into account Parties' different capacities with the goal to understand climate change action in the light of the objective of the UNFCCC and the Paris Agreements; and*
- *A non-punitive compliance mechanism that is expert based and facilitative in nature.*

2.4.2 Status of Nuclear Power Globally

Nuclear power projected to expand globally in the coming years, even as the pace of growth slows amid competition from low fossil fuel prices and renewable energy sources, according to an IAEA study. Each year in Energy, Electricity and Nuclear Power estimates for the period up to 2050, the IAEA presents its projections of the world's nuclear power generating capacity. According to its 36th edition of publication:

"Nuclear energy, in the long run, will continue to play an important role in the world's energy mix," said IAEA Deputy Director General Mikhail Chudakov, Head of the Department of Nuclear Energy. "With populations and demand for electricity growing, nuclear power can help ensure reliable and secure energy supplies while reducing greenhouse gas emissions. In other words, nuclear power can help lift millions of people out of energy poverty while also combatting climate change."

The new projections indicate a slowing in nuclear power growth, in keeping with the trend since the 2011 Fukushima Daiichi accident. Nuclear power generating capacity projected to expand by between 1.9 percent and 56 percent by 2030, compared with the previous estimate of between 2.4 percent and 68 percent from 2014. Uncertainty related to energy policy, license renewals, shutdowns and future constructions accounts for the wide range. The projections from 2030 to 2050 involve greater degrees of uncertainty. Developed by world experts who gather each spring at the IAEA, the projections take into account developments through April 2016. IAEA assumed that current rates of economic and electricity demand growth, particularly in Asia, would continue. It also envisages a bigger role for nuclear power in assisting Member States on meeting their commitments to reduce greenhouse gas emissions under last year's Paris Agreement on climate change (IAEA Sees Global Nuclear Power Capacity Growing Through 2030).

As of the middle of 2016, 31 countries were operating nuclear reactors for energy purposes. Nuclear power plants generated 2,441 net terawatt-hours (TWh or billion kilowatt-hours) of electricity in 2015 (IEA, 2015). A 1.3 percent increase, but still less than in 2000 and 8.2 percent below

the historic peak nuclear generation in 2006. Without China—which increased nuclear output by 37.4 TWh (just over 30 percent), more than the worldwide increase of 31 TWh—global nuclear power generation would have decreased in 2015. Nuclear energy's share of global commercial gross electricity generation remained stable over the past four years, but declined from a peak of 17.6 percent in 1996 to 10.7 percent in 2015. Over the past two decades, nuclear power lost a small part of its share in every single year, except for the years 1999 and 2001, and probably in year 2015 (+0.05 percentage points), should the figure be confirmed in the coming years. The main reason for this is the stagnation in the world's power consumption (+0.9 percent, slightly below the modest increase in nuclear generation of 1.3 percent).

2.4.3 Continuous usage and proponents of nuclear power

In 2015, nuclear generation increased in 11 countries (down from 19 in 2014), declined in 15 (up from 9), and remained stable in five. Five countries (China, Hungary, India, Russia, South Korea) achieved their greatest nuclear production in 2015, of these, China, Russia and South Korea connected new reactors to the grid. China started up a record eight units. Only the two leading nuclear countries in the world, the U.S. and France have ever started up that many reactors in a single year, the U.S. in 1976, 1985 and 1987, and France in 1981. Besides China, two other countries increased their output by more than 20 percent in 2015—Argentina as it started up a third reactor in 2014, and Mexico that brought the second unit back on line after uprating *see Appendix C*. Two countries saw their nuclear generation drop by over 20 percent—Belgium and South Africa are struggling with technical issues. According to the projections of IEA, the world's nuclear power generating capacity is seen to expand up to 390.2 GW(e) by 2030. One gigawatt is equal to one billion watts of electrical power. It is the Far East will see the biggest expansion, especially in China and the Republic of Korea. India is also

leading the expansion in the Middle East and South Asia, where capacity is seen at 27.7 GW(e) by 2030. Eastern Europe presents a mixed picture. The region includes Russia, with seven reactors under construction, as well as Belarus, which is building its first two units (IEA, 2015). Proponents of nuclear energy portrait it as a relatively a sustainable energy source and will help the reduce CO_2 emissions (Greenberg, 2013).

The Institution of Engineering and Technology (IET) in 2005 conducted a poll to its power engineers if they believe that nuclear generation is necessary to cut carbon emissions. The poll resulted to 73 percent who participated in the poll believed that nuclear generation is necessary to cut carbon emissions while twenty 22 percent believed differently and the remaining five percent were undecided (Hawley, 2005). It is unquestionable that renewable energy also helps to mitigate carbon emissions however; there was empirical evidence from the United States that nuclear energy consumption reduces carbon emissions in both the short and long term. But renewable energy reduces CO_2 emissions only in the short run (Baek, 2016).

2.4.4 Phase-out of nuclear power

After the Fukushima accident in Japan, the German government ordered the shutdown of its eight nuclear reactors that had started operating before 1981. In Belgium and Switzerland, their government reconsidered previous decisions to extend lifetime of its reactors. While In Italy, a referendum rejected a plan to build new reactors (Furlan, Guidolin, & Guseo, 2016). The contretemps against nuclear energy revolve largely around the impact of radiation on human health and the environment, the closely related issue of waste disposal, and security concerns linked with terrorist attack and proliferation of nuclear weapons. Regarding safety, the accidents of Three Mile Island, Chernobyl and Fukushima often used to frame public concerns. It is important that any deliberation is based on accurate and precise information

so that the risks are properly understood (Commission, 2012). Thus, the main reason why some people are not into the concepts of nuclear energy as beneficial to a society is due to the risk that can derived from nuclear power plant accidents. It is also worth noting why after Japan's Fukushima Dai-chi power plant meltdown some country like Korea, the citizens are still in favor to continue the construction of the two nuclear power plants even though it was suspended by the Korean President Moon Jae-In. While in Japan, the current administration under President Shinzō Abe still wanted to continue the usage of nuclear energy as a source of electricity but its citizens speaks differently based on survey. This will be further discuss in the data anaylsis.

3. Methodology

The author of this paper gathered data directly from the experts and some came from books and other materials e.g. journals and documentaries related to the topic. The National Grid Corporation of the Philippines (NGCP) gave the five (5) year peak demand of the Luzon grid. While the Department of Energy (DOE) of the Philippines gave its list of power plants connected to Luzon grid. The author forecasted the annual peak demand of Luzon grid with different linear regression models.

3.1 Energy security in Luzon

The electricity demand in Luzon Grid is rising and the existing power supply is insufficient to cater this increasing demand thus, a need to construct new power plants in Luzon Grid is necessary. However, it requires appropriate methods of analysis to forecast the electricity demand in Luzon. Historical data of five (5) years electricity system peak demand in Luzon Grid are required to forecast its future electricity demand. The forecasting of electricity demand in Luzon relies entirely on historical data provided by the

system operator, NGCP. Since NGCP has the data of the overall demand of Luzon grid, the forecasting method in this study used trend analysis.

3.2 Pollution and Environment Impact

Is nuclear power a clean energy? Secondary data analysis by gathering information through studying different type of texts, such as, written text like books and papers, audio-visual text like TV programs, documentary movies and videos related to nuclear power plant operation about its contribution to the environment during operation.

3.3 Electricity pricing

Finally, economic analysis is required to provide the information needed to make a judgment or a decision in the future. Will the electricity rate coming from nuclear energy will be cheaper than the other energy resources? To completely analyze the investment in Bataan Nuclear Power Plant requires to analyze each year of the life of investment, taking into account relevant direct costs, indirect and overhead costs, taxes, and returns on investment, plus any externalities, such as environmental impacts, that are relevant to the decision to be made. The Levelized Cost of Electricity (LCOE) calculations made by the Organization for Economic Cooperation and Development (OECD)/International Energy Agency (IEA) were based on data for 181 plants in 22 countries (including three non-OECD countries[10]). Different kinds of fuels considered in this analysis: 17 natural gas-fired generators 13 combined-cycle gas turbines and four open-cycle gas turbines, 14 coal-fired power plants, 11 nuclear power plants, 38 solar photovoltaic plants and 4 solar thermal plants, 21 onshore wind plants, 12 offshore wind plants, 28 hydro plants, six geothermal, 11 biomass and biogas plants and 19 combined heat and power of varying types.

[10] Brazil, China and South Africa

In this study, the combination of theory regarding impacts of nuclear energy in the society as well as the analysis of case studies in countries like Japan, Germany and South Korea considered in the decision making of reviving the BNPP.

4. Data

In the Luzon grid, Philippine government never commercialized the BNPP. Thus, in this study, the case of nuclear energy in Japan, Germany, and South Korea considered the impact of the Fukushima accidents in terms of pollution, cost of electricity and social impact.

4.1 Case Study

4.1.1 Japan

Prior to 2011 earthquake and tsunami, 31% of power plants in Japan were fueled from nuclear energy and planned to expand its share in energy mix to 53% in order to mitigate its energy-sector GHG to 70 percent by 2030 (Deng, Xiong, Xiong, Li, & Ng, 2014). However, after the Fukushima disaster, Japan's governmental advisory body recommended to reduce its nuclear power dependency and to replace nuclear energy with renewable and fossil-fuel-generated energy (Hong, Bradshaw, & Brook, 2013). But Japan has almost no natural fossil fuel resources making them to rely on imports (Ã, Mogi, & Albedaiwi, 2008). Originally, Japan is poor in energy resources thus the energy self-sufficiency ratio of Japan in 2014 was six percent that was a low level even compared to OECD countries. Japan depends on fossil fuels such as oil, coal and natural gas (LNG) imported from abroad see *Appendix D*. According to Federation of Electric Power Companies of Japan (FEPC) the nation's energy dependency increased form 62 percent in 2010 to 88 percent in 2014. By relying on fossil fuels to take over the lost supply due to Fukushima power plant shutdown the cost of electricity rose up. Compared to

fiscal year 2010, in fiscal year 2014, electricity from homes increased by approximately 25 percent, rates for industries increased by approximately 39 percent according to the reports of electricity demand by FEPC, and financial materials of each electric power company. To phase out nuclear power plants completely in Japan will move the Japanese economy into uncertainty due to a higher electricity rates.

Moreover, GHG emissions in Japan after the earthquake also increased. This is because of the shifting the energy production from nuclear power plants to thermal power plants[11]. According to comprehensive energy statistics, environment action plans (FEPC) the amount of CO_2 emissions increased from fiscal year 2010 1,304 millions tones to fiscal year 2014 1,364 millions tones.

4.1.2 Germany

Prior to Fukushima incidents anti-nuclear movement were already in Germany. The movement started back in the 1970s when local protesters organized a demonstration against the plan of the government to build nuclear power stations. In 1975, the protesters hold and stop the construction site of a nuclear power plant in Wyhl. After the two historical nuclear accidents, Three Mile Island in 1979 and in Chernobyl 1986, the protesters grew in numbers. Public protests continued until after 1989 building of new commercial nuclear power stations no more. After the Social Democrats (SPD) and the Green Party won the elections in 1998 the government of Gerhard Schroeder reached what became known as the “nuclear concensus” with the big utilities. They agreed to limit the life span of nuclear power stations to 32 years. New nuclear power plants were banned altogether. The agreement became law in 2002 (Atomgesetz). However, the opposition Christian Democratic Union (CDU) and its chairperson, Angela Merkel, objected the agreement, calling it

[11] Thermal power plant are usually fueled by fossil fuels: LNG, coal and crude oil

a “destruction of national property.” When CDU/CSU won the elections in 2009 and formed a coalition with the Free Democrats Party (FDP), they extended the operating time by eight years for seven nuclear power plants and 14 years for the remaining ten. This became known as the “phase-out of the (nuclear) phase-out” (Ausstieg aus dem Ausstieg). However, in the wake of the nuclear catastrophe in Fukushima, Japan, Chairperson Merkel decided in June 2011 to change the nuclear and energy policy. The Fukushima disaster dramatically demonstrated the social, environmental and economic risks involved in an energy strategy relying on nuclear technology. The German government decided to phase-out all its nuclear electricity capacity by 2022, and the eight oldest of Germany’s 17 nuclear power plants (NPPs) were immediately put out of operation (Rehner & McCauley, 2016). This moved constitutes part of the overall energy strategy called “Energiewende” (translated: energy turn-around), which sets out the goal of increasing the share of re-newables within the electricity mix, to reduce oil and gas imports, contribute to the mitigation of climate change, as well as ending the reliance on nuclear energy as a resource. It is worthy to note that Germany also aims to cut GHG emissions by 40 percent in 2020 and up to 95 percent in 2050 compared to 1990 levels (Bruninx, Madzharov, Delarue, & William, 2012). Currently, based on cleanenergywire.org as of 2017, the energy mix in Germany are composed of: 22.7 percent natural gas, 12.2 percent hard coal, 11.4 percent lignite, 6.9 percent nuclear, 12.6 percent RES, 34 percent oil and 1.8 percent others. However, by phasing out nuclear power plants the renewable energy are not yet fully reliable to replace nuclear energy as base loads power plants thus, Germany are still relying on power plants run by fossil fuels during peak loads. Moreover, as the German government promotes RES that will eventually replace fossil and nuclear power, guaranteed fixed price for feeding solar energy into the grid for a payoff of 20

years introduced. Because of this, the installation of solar panel by private entities increased drastically causing the major increases in electricity prices (Renn & Marshall, 2016).

4.1.3 South Korea

South Korean economy is growing, with the 1.4 percent expansion on fourth quarter in the three months to September 2017. It is the highest growth rate in seven years, mainly due to rebounds of in manufacturing and construction according to tradingeconomics.com. South Korea has a limited natural resources thus the largest shares in the energy mix are 44 percent petroleum and other liquids, 31 percent coal, 14 percent natural gas, 13 percent nuclear and one percent RES (Administration, 2017). South Korea is number four in the world that produces electricity from nuclear energy next to Russia. According to World Nuclear Association, South Korea has three new reactors under construction domestically as well as four in the UAE. However, President Moon Jae-In during his presidential campaigns pledge to phase out coal and nuclear energy, because of the public's concern about air pollution and nuclear safety (Young, The, & Oct, 2017). After winning the election early in 2017 and assumed the position as president, his administration has immediately suspended the construction on two nuclear reactors as well as shifting the nation's energy resource to natural gas. Even though it was obvious that President Moon Jae-In is against nuclear energy, he still honored the freedom of choice of the citizens by allowing the Real meter survey, conducted on 501 adults on Friday, found that 60.5 percent back a nuclear phase-out policy while only 29.5 percent are against it. Ten percent said they are unsure about what is best. The poll had a margin of error of plus or minus 4.4 percentage points. South Korean President Moon Jae-In accepted the results of the poll and announced last October 22, 2017 that he would resume the construction of two nuclear reactors, which had been temporarily halted

since mid-year of 2017. However, the President still stressed out that the government will gradually close nuclear reactors little by little when their asset life is in full, rather than rushing to shut them down quickly.

4.2 Overview of the case

4.2.1 Luzon energy crisis

Insufficient supply of electricity in Luzon Grid is a major problem of the Philippine government and its citizens. Especially during summer season where some hydro power plants were in poor performance, thus, resulting to lack of electricity supply. This kind of problem will result to rotating black out in Luzon or an increase in electricity rates due to the increasing price in the electricity market. Then there was a power crisis in 1990s, Filipinos-especially those who live in Luzon experienced long hours of rotating brown outs daily.

This prompted the government to create the Electric Power Crisis Act of 1993 (R.A. 7648) and the expanded BOT Financing Law of 1994 (R.A. 7718) that allowed the Independent Power Producers (IPPs) to deal directly with distribution utilities and neglect the National Power Corporation (NPC). In this way, the generation has now become a competitive segment of the industry. After the Philippine government commenced on privatization and restructuring program in the energy industry envisioned to ensure the adequate supply of electricity that would energize its developing economy. The restructuring was realize in Republic Act No. 9136, the Electric Power Industry Reform Act (EPIRA). EPIRA restructured the power industry by organizing it into four sectors: generation, transmission, distribution, and supply; and introducing the following major reforms: (1) restructuring of the entire power industry to introduce competition in the generation sector; (2) change from government to private ownership through privatization; and (3)

introduction of a stable regulatory framework for the electricity sector. In implementing the restructuring of the power sector, the EPIRA created the Power Sector Assets and Liabilities Management (PSALM) Corporation, a wholly-owned and -controlled government entity, to take over the ownership of all existing generation assets of the NPC, IPP contracts, real estate, and all other disposable assets including the transmission business of the National Transmission Corporation (TRANSCO). Similarly, PSALM concluded all outstanding obligations of NPC arisen from loans, issuances of bonds, securities, and other instruments of indebtedness. The principal purpose of PSALM, as mandated by the EPIRA, is to manage the orderly sale and privatization of these assets with the objective of liquidating all of NPC's financial obligations in an optimal manner. By privatization, the government power plants assets helped bolster competition in the generation sector. The Wholesale Electricity Spot Market (WESM) was created through EPIRA law for a venue for trading electricity as a commodity. WESM is where the generators sell their excess capacities not covered by contracts and where the customers buy additional capacities on top of their contracts. WESM provides another option for sourcing electricity requirements or selling capacities, other than through bilateral contracts between a distribution utility and the power generation companies. The contractual transactions are settled outside of the WESM, and the counterparties based their contract price in the approval of ERC *see Appendix E.*

2016 Luzon power situation

The year 2016 was characterized by a significant increase in electricity consumption at 10 percent and peak demand at 8.7 percent attributed to several factors such as, increase in temperature and utilization of cooling equipment aggravated by the strong El Niño. The residential and industrial sectors remained the major drivers of electricity consumption in the

country while Luzon remained the largest on a per grid basis. Notably, the growth of the country's supply base supplemented the increase in demand with the growth of total installed capacity at 14 percent from 18,765 MWh (2015) to 21,423 MWh (2016), majority coming from coal-fired power plants *see Appendix F*. The Department of Energy (DOE) is continuously encouraging investments in power generation in view of the increasing peak demand which is expected to grow by more than triple in 2040. In 2016, several yellow and red alerts were declared by the system operator in Luzon. Luzon reached new all-time high system peak demand at 9,726 MW which occurred on 03 May 2016 at 1:52 PM with corresponding 11,137 MW available capacities. This is nine percent higher than the 2015 peak demand at 8,928 MW.

4.2.2 Luzon highlights and significant incidents in electricity supply

- In December 2013, there was a contentious increase in the rates of Manila Electric Co. (Meralco) due to a hike in generation charge which due to the scheduled and forced outages of power plants all over Luzon and the maintenance shutdown of the Malampaya natural gas field. Amid the tight supply, Meralco was forced to buy supply from spot market where prices have surged, and pass on the higher generation charges to consumers, leading to record increases in overall power rates;
- Yellow Alert occurred once in April 2016 due to tight supply caused by forced outages, planned outages of power plants and limited dispatch of hydro as an effect of El Niño. It is then followed by a Red Alert the next day for the same reason;

- On 03 May 2016, the all-time high peak demand of Luzon grid occurred at 9,726 MW, an increase of 9% from the previous year;
- For the month of June 2016, Luzon grid experienced five (5) Yellow Alert occurrences due to tripping and maintenance of power plants with large capacities;
- At the last week of July 2016 to first week of August 2016, Luzon Grid experienced ten (10) Yellow Alert Notices and four (4) Red Alert Notices due to the forced outage and planned outage of some major power plants. The maximum capacity outage was 3,146 MW which occurred on 05 August 2016. To alleviate Red Alert Notices, the Interruptible Load Program (ILP) was implemented within the MERALCO franchise area;
- On September 2016, Luzon experienced one (1) Yellow Alert Notice and one (1) Red Alert Notice while another Yellow Alert Notice on November 2016 was experienced; and
- Luzon grid experienced 34 ALD and three (3) MLD for 2016. Most of ALDs occurred in the month of June with seven (7) ALDs due to the tripping of power plants with large capacities. On the average, most of the outages caused by the load dropping were not sustained for more than 15 minutes.

History of the 623 MW Bataan Nuclear Power Plant (BNPP)

The Philippine nuclear program started in 1958 with the creation of the Philippine Atomic Energy Commission (PAEC) under Republic Act 2067. Under martial law, Marcos announced the decision to build a nuclear power plant in July 1973. This move was in response to the 1973 oil crisis, since the Middle East oil embargo had put a heavy strain on the Philippine economy,

and Marcos believed that nuclear power was the solution to meeting the country's energy demands and decreasing dependence on imported oil. Construction on the BNPP began in 1976 and was completed in 1984 at a cost of $2.3 billion. A Westinghouse company constructed a light water reactor which designed to produce 621 megawatts of electricity. Following the 1979 Three Mile Island accident in the United States, construction on the BNPP was stopped, and a subsequent safety inquiry into the plant revealed over 4,000 defects. It was built near major earthquake fault lines and close to the then dormant Pinatubo volcano.

BNPP was about 98% complete in February 1984, and in June 1985 public hearings were set to be conducted for the Operating License of BNPP as requirement prior to initial nuclear fuel loading to the nuclear reactor. This is in preparation for the commercial operation of the plant.

The IAEA-Operational Safety Analysis Review Team (OSART) I and II (July 1984 and February 1985, respectively) as the world's advisory body to utilities on the safe operation of a nuclear power plants has inspected BNPP twice, the. Although it identified issues and made recommendations, the IAEA said the plant's construction met international standards. After the second inspection, the IAEA said that the plant was ready to receive fuel and begin start-up testing for its commercial operation. President Corazon Aquino, who succeeded Marcos, decided not to operate the plant days after the Chernobyl explosion in April 1986. Among other considerations taken was the strong opposition from Bataan residents and the negative reaction of the whole nation. The Bataan Nuclear Power Plant (BNPP) is a Westinghouse Pressurized Water Reactor Nuclear Power Plant, was the most popular reactor design in the industry. It took 10 years to construct and has been on preservation mode since 1986 at a cost of Php40 to Php50 million a year.

4.2.3 BNPP advocates

Former law maker congressman Mark Cojuanco proposed a bill in the congress to let the Bataan Nuclear Power Plant operate in the Grid to be useful for the Philippine government. He insisted that this will surely help to mitigate CO_2 emissions coming from the power plants that are run by fossil fuels. Additionally, according to him, the said electricity rates coming from the nuclear power plant is cheaper compared to other power plants. However, his proposal in accordance to the electricity rates was not supported by data analysis. According to other nuclear power advocate former director of the Philippine Nuclear Research Institute (PNRI) Dr. Carlito Aleta said mothballing the BNPP was “an economic blunder” and “a setback for science and technology.” This makes it relevant to revisit the case of the Bataan Nuclear Power Plant (i.e. BNPP, also sometimes referred to as the Philippine Nuclear Power Plant), a mega project initiated and completed during the administration of President Ferdinand Marcos. By letting the Bataan Nuclear Power Plant idle, this created the Philippine electric industry unstable in terms of energy security. Manila Electric Company (MERALCO) experienced a high cost of electricity in generation rate in January 2012, due to lack of supply of electricity in the grid.

4.2.4 Philippine Energy Plan (2017-2040)

Some of the DOE Philippines strategic directions for the year 2017 – 2040 is to ensure that the energy security of the nation by appropriate portfolio of installed and dependable power capacity mix of seventy percent (70%) baseload, twenty percent (20%) intermediate and ten percent (10%) peaking plant categories matching peak demand and reserves. Promoting a low carbon future by increasing the RE Capacity by 2030 and promoting technology innovation through research, development, demonstration and

deployment clean efficient and smart energy technologies. The 2040 base load target is around 25,265 Megawatts.

4.2.5 Base load Plants – Peak Load Plants

Load in a power system varies all the day. Electrical power generated by the generating stations depends on the demand for electrical power. During day time demand for electricity will be more and hence all the generating units will be running under full load. During nights, load on the generating stations will be minimal. The unvarying load which occurs almost the whole day on the power plant is called the base load. Whereas the various peak demands of the load over and above the base load of the power plant is called peak load see *Appendix G.* Power plants that provide baseload power often run year round - therefore having a high capacity factor - and use non-renewable fuel. Some baseload power plants include coal-fired power plants and nuclear power plants.Nuclear power plants are suitable only for base load operation due to its capability of operating for longer periods. Nuclear power plants have the highest load factor[12] of over 0.8 to 0.9 while gas turbine power plants are best suited for peak load power plant operations.

4.3 Factors and Criteria

In order to convince the Filipino citizens to allow the usage of nuclear energy in power plants, the proponents must inform the public the existing and future situation of the nation's electricity industry and the possible impact of nuclear energy in the country. This section discussed the factors and criteria that must be consider in one of the many ways to solve the research problem. As discussed in the introduction, the lack of electricity supply in the Luzon grid caused electricity prices in that region increased. Thus, additional power plants are needed in order to prevent this kind of scenario. However, in

[12] The ratio of an average load to the maximum load (G.H.F. Nayler 4th Ed, 1996)

this study, other factors e.g. global warming must also be given importance since the relationship of energy sector and global warming is significant (Environmental & Reviews, 2011). Social risk even though difficult subject it is also worth noting to consider in this section.

4.3.1 Energy Security in Luzon Grid

The trend analysis method was used by getting information of the past peak demand to forecast the load of the future. This approach is simple to understand and inexpensive to implement. The electricity peak demand of the past eight years was recorded by the system operator (NGCP) thru energy meters. The system operator has the capacity to monitor the demand in the grid while the DOE monitors the supply. In order to find the impact of energizing the Bataan nuclear power plant in the grid, the author will forecast the peak demand in Luzon and see the difference in the system with and without the Bataan nuclear power plant.

Table 1: History of Luzon Peak Demand

Year	**Megawatts (MW)**
2011	7,552
2012	7,889
2013	8,305
2014	8,717
2015	8,928
2016	9,726

Source: NGCP

These regression models forecasted the peak demand of Luzon Grid using Microsoft Excel *see Appendix H*.

In essence, the forecast model that has the following criteria must be chosen: (1) r-squared nearest to 1 and; (2) *t*-test of greater than 2 or less than -2, and P –Value of less than 0.1. The Mean Absolute of Percentage Error

(MAPE) of less than five percent and the forecasted data with annual average growth rate near the recent actual growth rate. It is important to choose the right model to be able to see the situation of energy security in Luzon in the future.

4.3.2 Eco-friendly

Since the Philippine government overtly targets the reduction of GHG emissions due to Paris agreement though rich in natural resources, it still needs to evaluate the sources of its energy if eco-friendly. Even though the citizens will have sufficient supply of electricity but if in the end the people will suffer due to the pollution coming from the energy is also not enjoyable.

4.3.3 Cheap electricity

Another factor to consider is the affordability of the electricity even though the existing supply has enough capacities to accommodate the existing and future demand and the energy sources are eco-friendly, but the if it is only some level in the society can afford to use the electricity then that is not also beneficial to the citizens. The Philippines has the highest of income inequality in Southeast Asia, with a Gini coefficient of 44 percent in 2010 which was higher than 42.5 percent in Thailand, 39.4 percent in Indonesia, 37.9 percent in Malaysia, and 37.8 percent in Vietnam (PNA, 2011). The government needs to ensure that the cost of electricity is affordable to every citizen of different class.

4.3.4 Social Risk

The oxford dictionary defines risk as a situation involving exposure to danger. Every power plant have different level of risk either during normal operation or during a force majeure, government and the citizens must be aware of which level of risk is tolerable particularly to those community who lives near the power plant. The safety issues of a power plant are the biggest

concern of the public nowadays since Philippines is a tropical country where strong typhoon often visited the islands annually. Not only that, the island of Philippines also belongs to the Pacific Ring of fire where frequent number of earthquakes and volcanic eruption occurs.

5. Analysis

In this section, analysis of the research problem regarding the demand and supply of electricity in the Luzon Grid will undertake at the energy security of Luzon. The lack of electricity supply in Luzon made the cost of electricity to shoot up thus, in order to prevent this kind of event the Philippine government welcomed the investors to invest in generation. Furthermore, there were policies that introduced in order to give favor to RES. The implementation of the FIT system from RA No. 9513, *"An Act of Promoting the Development, Utilization and Commercialization of Renewable Energy Resources and For Other Purposes"* is now going. RES (Wind, Solar, Ocean, Run-of-river Hydro & Biomass) have now priority connection to the grid, priority purchase and transmission of, and payment for, such electricity by the grid system operators, fixed tariff by technology. This policy invite all parts of a society to become RES electricity producers, ranging from private households to large utilities. FIT typically make use of long-term agreements and pricing tied to costs of production for RES producers. However, this policy is not yet fully effective because the shares of RES in the mix is too small. Furthermore, the RES technology due to its volatile supply (the sun does not always shine and the wind does not always blow) and low capacity factor of RES. First, forecasted Luzon demand analysis is essential in order to see the problem in the grid thus the government can make a plan to prevent the same problem.

5.1 Energy security

By trend analysis, the researcher forecasted the Luzon grid peak demand using different regression models with the given six years (2011-2016) historical peak demand. Then, carefully examined the results of the forecast models and selected the best-fit model that is nearest to the latest actual growth grate (2015-2016). Eight models have passed the criteria. Below is the tabulation of results *see Appendix I.*

After analyzing the qualified forecasted models, it was found that the $y = a + bt^3 + logt$ model was the best fit, with the R^2 nearest to 1, *t*-Test of greater than 2 or less than -2, and p-Value of less than 0.1. The Mean Absolute of Percentage Error (MAPE) was less than five percent and the annual average growth rate was only -2.83 percent. In comparison to the other models, this was the closest gap between the average growth rates of the forecasted 2017-2030 against the actual growth rate of 2015-2016. Thereby, the result of this forecast model was used as the predicted demand for 2017-2030. The table and graph shows the forecasted demand of Luzon grid with the corresponding target of the DOE *see Appendix J.*

Figure 1: Forecasted Peak Demand of Luzon

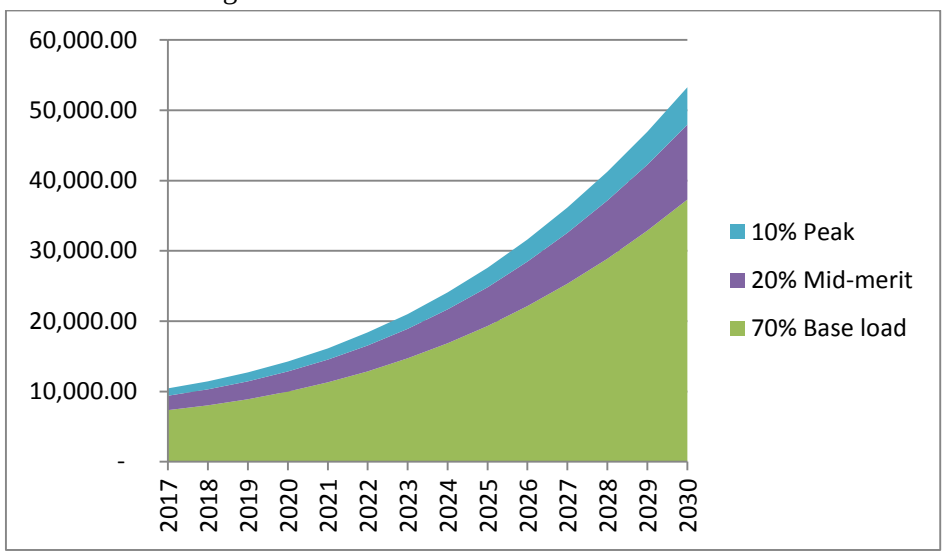


Table 2: The composition of energy shares in Luzon grid on the year 2016.

Fuel Type	**Installed**	
	MW	**Percent Share**
Coal	14,584	47.69%
Oil Based	2,329	7.62%
Natural Gas	6,130	20.05%
Renewable Energy	7,536	
Geothermal	966	3.16%
Hydro	3,670	12.00%
Wind	1,334	4.36%
Biomass	176	0.58%
Solar	1,390	4.55%
Total	**30,579.40**	**100%**

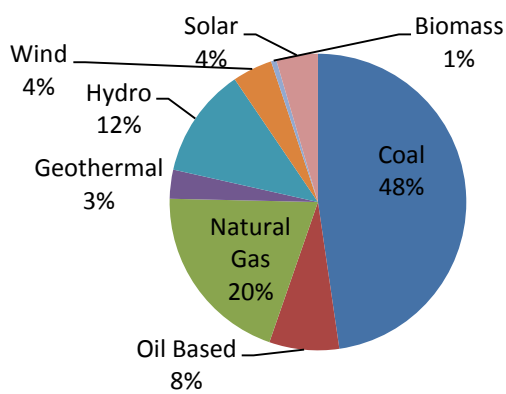
Source: 2016 Philippine Power Situation Report, DOE

As can be seen from the above table the total installed capacity (30,579 MW) in 2016 is not enough to accommodate the forecasted demand (53,289 MW) up to 2030. Which means that the supply in Luzon grid must

have an additional capacity by constructing new power plants or by upgrading the existing power plants capacity if possible. Additionally, fossil fuel power plants in Luzon (coal, oil-based and natural gas) have the highest percentage shares, 75 percent in total. While the RES (Geothermal, hydro, wind and solar) have only 25 percent shares.

A pie chart of Luzon's power plants shows the percentage shares per fuel type. The target of the DOE is to ensure that seventy percent base load of peak demand.

Figure 2: Pie chart of Luzon power plants



As can be seen on the above chart, the coal-fired power plants have the highest percentage share, which means that the GHG emissions coming to these power plants have a significant impact on the environment. It is worthy to note, that base load power plant sources can consistently generates power required to provide the minimum level of demand on a grid over 24 hours. These plants typically run at all times throughout the year, except in case of repairs or maintenance. Electricity coming from base load plants is the lowest rates due to its designed for maximum efficiency, and can run continuously at high output. Thus, Geothermal plants, nuclear plants, coal plants and biomass plants almost always operate as base load plants (Burton et al., 2008). Since

BNPP belongs in the category of base load power plants, this study will focus on the target of DOE: The 70 percent base load of the maximum demand.

To be able to see the ideal set-up of the generation system, basic assumptions contemplated the definition of terms of the base load power plants. However, in the Philippines, the BNPP is not yet commercialized thus the composition of its base load power are coal, geothermal, biomass and natural gas. Below is the indicative capacities supply in Luzon per category.

Table 3: Indicative capacities supply in Luzon

Category	**Total (MW) per category**	**Fuel Type**	**Total (MW)**
Base	**21,856**	**Coal**	14,584
		Geothermal	966
		Biomass	176
		Natural Gas	6,130
Mid	**3,670**	**Hydro**	3,670
Peak	**5,053**	**Solar**	1,390
		Wind	1,334
		Oil Based	2,329
Total			**30,579**

Table 4: Forecasted Base load of Luzon grid without BNPP

Year	Demand		Supply	
	Maximum Demand (MW)	**70% of Max Demand (MW)**	**Base-load power plants**	**Base-load Power plant percentage loaded**
2017	10,456	7,319.20	21,525.00	34%
2018	11,459	8,021.30	21,525.00	37%
2019	12,720	8,904.00	21,525.00	41%
2020	14,272	9,990.40	21,525.00	46%
2021	16,150	11,305.00	21,525.00	53%
2022	18,388	12,871.60	21,525.00	60%
2023	21,020	14,714.00	21,525.00	68%
2024	24,079	16,855.30	21,525.00	78%
2025	27,600	19,320.00	21,525.00	90%
2026	31,615	22,130.50	21,525.00	103%
2027	36,158	25,310.60	21,525.00	118%
2028	41,263	28,884.10	21,525.00	134%
2029	46,962	32,873.40	21,525.00	153%
2030	53,289	37,302.30	21,525.00	173%

Table below shows the impact of the 70 percent forecasted demand in the installed base load power plants in Luzon grid **with revival of the 620 MW BNPP in year 2021.**

Table 5: Forecasted Base load of Luzon grid with BNPP

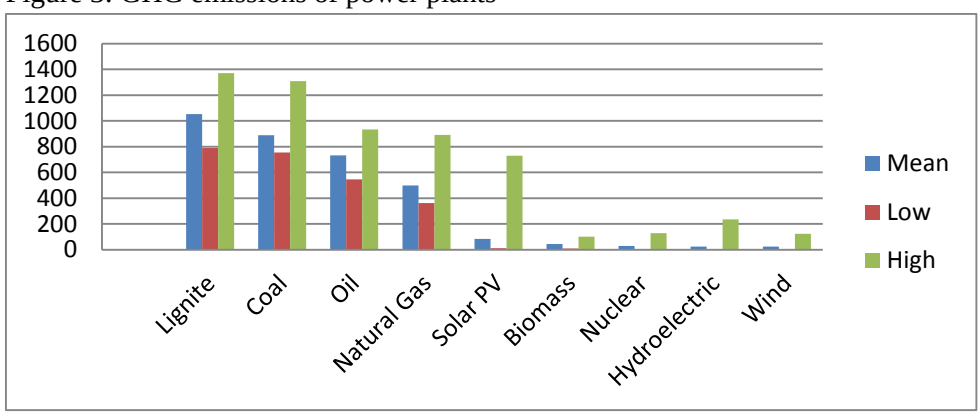
Year	Demand		Supply	
	Maximum Demand (MW)	**70% of Max Demand (MW)**	**Base-load Power plant**	**Base-load Power plant [13] percentage loaded**
2017	10,456	7,319.20	21,525.00	34%
2018	11,459	8,021.30	21,525.00	37%
2019	12,720	8,904.00	21,525.00	41%
2020	14,272	9,990.40	21,525.00	46%
2021	16,150	11,305.00	22,145.00	53%
2022	18,388	12,871.60	22,145.00	60%
2023	21,020	14,714.00	22,145.00	68%
2024	24,079	16,855.30	22,145.00	78%
2025	27,600	19,320.00	22,145.00	90%
2026	31,615	22,130.50	22,145.00	103%
2027	36,158	25,310.60	22,145.00	118%
2028	41,263	28,884.10	22,145.00	134%
2029	46,962	32,873.40	22,145.00	153%
2030	53,289	37,302.30	22,145.00	173%

This shows that the existing capacities of the base-load power plants can still supply the 70 percent target of DOE but only up to year 2025. However, if the BNPP will be revived and put into operation in the year 2021 (since most NPP needs at least 4 years to energize) the base load power plants will extend for another year before it will experience overload. This, however, were all based on assumptions using the demand forecasted. Furthermore, it is worthy to emphasize that 66 percent of the base-load power plants are run by coal-fired power plants which has the highest CO_2 emissions intensities

[13]Baseload power plants are composed of: coal 14,584 MW; Natural gas = 6,130 MW; Geothermal = 966 MW; Biomass = 176 MW; BNPP 620 MW

(Report, 2011) and also 28 percent are natural gas that belongs to the top GHG emissions (C. C. Change, 2015). If the BNPP will be revive, the 620 MW can be use as base-load power plant and can replace some of the energy coming from a coal-fired in order to mitigate the carbon emissions in the energy sector. As we have seen in the table below, nuclear power plants emits almost no CO_2 during operation.

Figure 3: GHG emissions of power plants



Source: (Report, 2011)

Additionally, the uranium mineral resources needed to fuel nuclear power plant exist in abundance and are possible to be discovered to provide significant growth in nuclear capacity in the longer-term (Island, 2000). The nuclear fuel cycle: Uranium extracted from the earth (mining) then it must undergo a series of process to be able to use as nuclear fuel (enriched). The by-product of enrichment is depleted uranium.

Table 6: The top leading countries that exports natural uranium according to world top exports by 2016

Top	**Countries**	**Percent shares**
1	Kazakhstan	US$1.7 billion (40.8% of exported natural uranium)
2	Canada	$1.2 billion (27.6%)
3	United States	$483 million (11.3%)
4	Uzbekistan	$288 million (6.8%)
5	France	$194.3 million (4.6%)
6	Ukraine	$129.7 million (3%)
7	Netherlands	$125.1 million (2.9%)
8	Russia	$50 million (1.2%)
9	Czech Republic	$26.9 million (0.6%)
10	South Africa	$24.3 million (0.6%)
11	Germany	$22.4 million (0.5%)
12	Malaysia	$2.3 million (0.1%)
13	Japan	$635,000 (0.01%)
14	Hungary	$555,000 (0.01%)
15	United Kingdom	$61,000 (0.001%)

The above listed 15 countries shipped 99.99% of global natural uranium exports in 2016 by value. Four of the above top countries increased their exports of natural uranium since 2012: United Kingdom (up 771.4%), Malaysia (up 735%), Netherlands (up 145.1%) and Germany (up 28.4%).

Countries that declines in their exported natural uranium sales were led by: France (down -59.1%), Japan (down -55.6%), Russia (down -40.7%), Kazakhstan (down -34.7%) and Canada (down -34%). Below are the 15 countries that exported the highest dollar value worth of enriched uranium during 2016 (worldexports.com):

Table 7: 15 countries that exported the highest dollar value worth of enriched uranium during 2016

Top	Countries	Percent shares
1	France	US$727.7 million (34% of total enriched uranium exports)
2	Germany	$538.5 million (25.2%)
3	Netherlands	$520.6 million (24.3%)
4	China	$135.6 million (6.3%)
5	United States	$103.9 million (4.9%)
6	Spain	$45.8 million (2.1%)
7	Kazakhstan	$33.1 million (1.5%)
8	Canada	$19.5 million (0.9%)
9	Sweden	$6.3 million (0.3%)
10	Japan	$4.7 million (0.2%)
11	Brazil	$4.3 million (0.2%)
12	Belgium	$228,000 (0.01%)
13	Brunei Darussalam	$76,000 (0.004%)
14	United Arab Emirates	$21,000 (0.001%)
15	Norway	$20,000 (0.001%)

The above listed 15 countries shipped 99.999% of global enriched uranium exports in 2016 by value. Among the above countries, the fastest-growing enriched uranium exporters since 2012 were: Canada (up 19,225%), Brunei Darussalam (up 5,600%), Spain (up 1,484%) and Sweden (up 90.7%). Those countries that posted declines in their exported enriched uranium sales were led by: Belgium (down -98.7%), Norway (down -98.3%), United States (down -89.7%), Japan (down -78%) and Netherlands (down -68.3%).

Below are the 15 countries that exported the highest dollar value worth of depleted uranium during 2016:

Table 8: 15 countries that exported the highest dollar value worth of depleted uranium during 2016

Top	Countries	Percent shares
1	Germany	US$22.3 million (65.7% of exported depleted uranium)
2	United States	$3.4 million (10%)
3	Netherlands	$1.9 million (5.5%)
4	United Kingdom	$1.8 million (5.2%)
5	Czech Republic	$1.2 million (3.6%)
6	Italy	$893,000 (2.6%)
7	Canada	$853,000 (2.5%)
8	India	$567,000 (1.7%)
9	France	$332,000 (1%)
10	Spain	$313,000 (0.9%)
11	Russia	$98,000 (0.3%)
12	South Africa	$92,000 (0.3%)
13	Australia	$62,000 (0.2%)
14	Slovakia	$54,000 (0.2%)
15	Malaysia	$45,000 (0.1%)

The above listed 15 countries shipped 99.7% of global depleted uranium exports in 2016 by value. Among these countries, the fastest-growing depleted uranium exporters since 2012 were: Canada (up 9,378%), South Africa (up 9,100%), United Kingdom (up 254.8%) and Australia (up 226.3%).

Those countries that posted declines in their exported depleted uranium sales were led by: France (down -98.4%), Spain (down -94.6%), Malaysia (down -77%), Russia (down -70.9%) and United States (down -69.1%).

According to NEA, identified uranium resources total 5.5 million metric tons, and additional 10.5 million metric tons remain undiscovered-roughly 230-year supply at today's consumption rate in total (S. Fetter, 2009).

Which means even if there will be new constructed NPP that will run this year or next year it will reach its useful life of 60 years and still the supply of uranium is stable.

The 620 MW BNPP capacity is not enough to meet target of DOE, however, the revival of BNPP is a big help in terms of other factors like air pollution mitigation and stabilizing electricity prices.

5.2 Air pollution and environment Impact

Global climate change is a serious threat to humanity. Through satellite observations, the experts monitored the movement of glaciers and they believed that due to the increase on earth's temperature glaciers globally are constantly melting which resulted to increase in sea levels. In Greenland Ice Sheet the glaciers contribution to sea level rise is approximately 8.3 millimeter per decade (A. Bradford, 2017). Another thing to measure the effect of global warming is the increase of temperature around the world. According to the National Oceanic and Atmospheric Administration (NOAA), the average global temperature has increased by about 0.8 Celsius over the past 100 years. The gradual heating of Earth's surface, oceans and atmosphere were due to many factors. However, scientists globally believes that the main contributors to this is by human activity. The main contributors to global warming is the carbon emissions coming from power plants. Thus, it has become one of the most growing concerns in recent years is in order to prevent global warming the main contributors to global warming which is CO_2 must be curb. There are other GHG that contributes to global warming, like Methane, Nitrous Oxide and Fluorinated gases, however these are only a portion around ten percent, five percent and three percent respectively. Moreover, these gasses last a short time in the atmosphere compared to CO_2.

Thus, reducing the carbon emissions from the electricity sector plays a big part in order to keep global temperature rise below 2 degrees Celsius.

According to the study led by University of East Anglia, the tropical countries are more susceptible to the worst effects of climate change than countries located in more regions that are temperate. In addition, most of these countries are developing countries. According to World Bank's list of nations most in danger of experiencing more typhoon and intense storms is Philippines. In the last five years, the Philippines experienced several typhoons that have resulted in severe damage and losses. Some have hit new areas such as Mindanao, which historically, this island has no experience of heavy storms. As early as 1979, an increase in mean temperature recorded in the Philippines. Typhoons like Haiyan, Thelma, Ike, Fengshen, Washi, Durian, Bopha, Trix, Amy and Nina, these are the ten deadliest typhoons of the Philippines in the period of 1947 and 2014. Five of the ten have occurred since 2006, affecting and displacing thousands of citizens every time. Seven of these ten deadly storms each resulted in more than 1,000 casualties. However, the deadliest storm on record in the Philippines is Typhoon Haiyan, known locally as Typhoon Yolanda, which was responsible for more than 6,300 lost lives, over four million displaced citizens in 2013. Since Philippines is a tropical country, it is particularly vulnerable to extreme weather. In recent years, the nation has suffered from even more violent storms like Typhoon Haiyan. On average, about 20 tropical cyclones enter Philippine waters each year, with eight or nine making landfall and over the past decade, these tropical storms have struck the nation more often and more severely.

Prior to Fukushima accident in 2011, Japanese government has set a target of 80 percent emission reduction by 2050 (Pambudi, Itaoka, & Kurosawa, 2016) and also planned to raise the nuclear share in the generation

mix to 53 percent by 2030 to accomplished its targeted reduction in carbon emission (Deng et al., 2014). However, after its nuclear disaster all its nuclear reactors in Japan had stopped operating in 2014 (Pambudi et al., 2016).

According to the Japan's Ministry of Economy, Trade and Industry (METI) after the nuclear power plants shut down, the low-cost base load shortfall largely made up by expensive fuel oil and LNG. These types of fuels emit a lot of CO_2 during operation they are major contributors of carbon emissions. The first year after the Fukushima accident, Japan's overall greenhouse gas emissions increased to seven percent than prior to March 2011. This was mainly due to the increased use of fossil fuels to generate electricity, and carbon emissions per kilowatt hour in the power sector increased nearly 40 percent (Duffield, 2011). As of now, it is difficult for Japan to meet the targeted CO_2 reduction. Other scholars suggest that at least thirty five percent of nuclear energy in the energy mix in order to meet the target (Hong et al., 2013). Moreover, the Japanese government are still in favor to use nuclear energy to fuel their electricity after the political candidates running on anti-nuclear platforms lost the elections on year 2012, while the pro-nuclear Liberal Democratic Party won.

In the 1990s, Germany did not connect any new Nuclear Power Plant to the grid and 2011 it announced the end of its nuclear activities by 2022. However, tensions between coal and nuclear power competing for base-load power intensified when the Social Democratic Party supported the nuclear phase-out. By 2002, a negotiated law by the Greens and the Social Democratic Party were introduced prohibiting the construction of new Nuclear Power Plants and limiting the lifetime of existing reactors to 32 year on average (Cherp, Vinichenko, Jewell, Suzuki, & Antal, 2017).

After the Fukushima accidents, eight of its old nuclear units shut down and the share of nuclear in the generation mix fell from 23 percent to 16

percent while the share of renewable energy in energy production increased dramatically from 17 percent to 20 percent. However, the share of lignite increased at the same rate that the nuclear decreased in the mix due hard coal and gas were not competitive in the electricity market. Albeit RES supply most almost half of the installed capacity in Germany, they produce only 16 percent of all electricity. This is due to the volatility of supply of wind and sun (Bundesministeriums, 2015). Phasing out of nuclear power plants is one of the main reasons why CO_2 emissions in Germany increased from 2011 to 2013 albeit the share of RES drastically increased from 17 to 26% of the electricity production this is because solar and wind were not always available thus backup coal-fired power plants are needed in order to prevent power interruptions. In 2014, the transition of Germany's supply of electricity from fossil fuel to RES is due to *Energiewende*[14].

5.3 Electricity prices

Not only energy security and eco-friendly aspects of power plant should be considered but also the price of electricity will affect the acceptance of the community to support different energy sources. Moreover, it is difficult to attract foreign investors if the cost of electricity, which is considered as a regular spending, is expensive.

The Organization for Economic Cooperation and Development (OECD) released the 2015 edition of its *Projected Costs of Generating Electricity*, which examines the cost of electricity with different types of energy sources using levelised costs of electricity (LCOE)[15]. They studied

[14] "Energiewende" is the country's planned transition to a low-carbon, nuclear -free economy. But there is much more to it than phasing out nuclear power and expanding renewables in the power sector (R. Russel, 2017).

[15] A useful tool for comparing the unit costs of different technologies over their operating life. These costs are discounted to the commercial operation of an electricity generator. Calculate average lifetime leveled costs based on the costs for investment, operation and maintenance, fuel, carbon emissions and decommissioning and

different countries such as OECD members (Austria, Belgium, Denmark, Finland, France, Germany, Hungry, Italy, Japan, Korea, Netherlands, New Zealand, Portugal, Slovak Republic, Spain, Switzerland, Turkey, United Kingdom and United States) and Non-OECD members (Brazil, China and South Africa). To simplify, only the nuclear energy were considered with three discount rates (3%, 7% and 10%). The capital (investment costs, refurbishment and decommissioning costs), operation and maintenance, fuel and waste.

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dismantling provided by OECD member countries and selected non-member countries.

Table 9: Comparison of Baseload power plants

	NPP			Coal			Geothermal			Natural gas			Biomass		
	Discount Rate			Discount Rate			Discount Rate			Discount Rate			Discount Rate		
	USD/MWh														
Countries	**3%**	**7%**	**10%**	**3%**	**7%**	**10%**	**3%**	**7%**	**10%**	**3%**	**7%**	**10%**	**3%**	**7%**	**10%**
Belgium	51.5	84.2	116.8	72.0	83.4	94.0	-	-	-	113.1	116.9	120.3	-	-	-
Finland	46.1	77.6	109.1	-	-	-	-	-	-	-	-	-	-	-	-
France	50.0	82.6	115.2	-	-	-	-	-	-	92.8	97.2	101.2	-	-	-
Hungary	53.9	89.9	125.0	-	-	-	-	-	-	96.9	101.2	105.1	-	-	-
Japan	62.6	87.6	112.5	94.8	107.4	119.3	-	-	-	133.2	138.4	143.1	-	-	-
Korea	28.6	40.4	51.4	76.0	82.1	87.7	-	-	-	118.5	122.3	125.8	-	-	-
Slovak	53.9	84.0	116.5	-	-	-	-	-	-	-	-	-	-	-	-
United Kingdom	64.4	100.8	135.7	-	-	-	69.9	100.2	128.5	117.1	120.4	123.4	204.8	220.0	233.8
United States	54.3	77.7	101.8	82.6	93.8	104.0	59.1	84.9	107.9	60.8	66.0	70.6	99.2	119.6	138.4
China	28.2	42.4	56.6	73.6	77.7	81.6				90.2	92.8	95.1	-	-	-
Average	**49.4**	**76.7**	**104.1**	**79.8**	**88.9**	**97.3**	**64.5**	**92.5**	**118.2**	**102.8**	**106.9**	**110.6**	**152.0**	**169.8**	**186.1**

Table 10: Ranking of power plants per discount rate, see table below.

Fuel	3%	7%	10%
Nuclear	1	1	2
Coal	3	2	1
Geothermal	2	3	4
Natural gas	4	4	3
Biomass	5	5	5

Note: 1 is the cheapest and 5 is the most expensive

In this study, the results in the 2015 Projected Costs of Generating Electricity were calculated to get the average electricity prices of countries per discount rate in order to compare the prices of different fuels. At three and seven percent discount rate, nuclear energy is the cheapest while biomass got the highest rates. At 10 percent discount rates coal got the cheapest next is nuclear while biomass still the most expensive for base load power plants.

In Japan, there was a survey made prior to Fukushima accidents. During the survey it explained the advantages *(generate electricity at high efficiency, reduce CO_2 emissions and reduce the reliance on fossil fuels)* of nuclear power plant to Japan. It confirmed that half of the population approximately supported the acceptance for NPP in Japan. This was composed by 11 percent in favor of expansion and 42 percent in favor of just maintaining the current plants in operation (Park & Utama, 2011). However, after the Fukushima accidents the voice of the people changed, in fall 2012, *Asahi Shimbun* conducted a telephone poll, the result was 18 percent chose to terminate immediately, 66 percent chose gradually phase out while only 11 percent chose to continue (States, 2015). In spite of that, the person who advocates nuclear power won the 2012 election presidency. One of the main reasons why after what happened to Fukushima disasters, the cost of electricity increased by 8-10 percent is due to the reliance on imported fuels

e.g. coal, oil, and natural gas to provide base-load electricity as a replace the shutdown of Fukushima Dai-chi power plant.

In Germany, their decision to shut down the operation of its eight nuclear power plants built before 1980 and the transition to implement *Energiewende* resulted to an increase of more than 90 percent above the average level of 2000 in retail power prices early in 2016. This is due to *Erneuerbare Energien Gesetz* (EEG)[16] surcharge (WNA, 2017). Since the capacity factors for RES (wind and solar PV) were relatively small to be able to function as base-load plants thus, Germany needs to maintain some fossil fuel plants as a backup, this also contributing to an increase in electricity prices. It is as if maintaining two vehicles instead of a one-bog vehicle since most of the time the RES capacity factors is too small to become base load power plants.

In South Korea, unlike Japan, the current president Moon Jae-in is against nuclear power plant. He vowed to stop the construction of new reactors and cancel the extensions on older power plants. He is eager to shift Korea's energy from nuclear and fossil fuels to renewables and natural gas. However, after consulting the public thru survey it found out that a majority of almost 60 percent are in favor of resuming the stalled construction of two reactors. I believe, Koreans is an educated society, they knew that replacing nuclear energy by natural gas and renewables will increase the cost of its electricity.

The Feed in Tariff (FIT) policy allows the public to get involved in promoting Renewable Energy Sources (RES). Its features shapes the distribution of households' disposable incomes by charging a levy that is proportional to household electricity consumption and by transferring financial resources to households who are feeding green electricity into the

[16] Germany's Renewable Energy Sources Act

grid. This is a guaranteed payment for a fixed rate in a period of years. Countries which currently implement FIT include US, Germany, Italy, Denmark, Spain and among others. FIT is also a subsidy from public to promote RES that resulted to increase its shares in the generation mix.

In Philippines, they have a Wholesale Electricity Spot Market (WESM) where trading in the electricity is made. It was created by virtue of Section 30 of EPIRA. It is where the generators sell their excess capacities not covered by contracts and where the customers buy additional capacities on top of their contracts. The purpose of WESM is to make a competitive, efficient, transparent and reliable market of electricity, which operates in Luzon and Visayas. The electricity price in WESM is not regulated – this is to encourage investors to engage in electricity industry. This is also a way to bring down electricity prices by allowing competition in the generation sector.

However, even though WESM is already operating, still it is not enough to bring down or stabilize the electricity price in Luzon grid. The main problem was the tight relationship between supply and demand. Thus, there was an incident where shutting down of big power plants almost at the same period due to maintenance brought the demand and supply unbalance resulted to a higher price of electricity in the market.

5.4 Nuclear Power Plant Major Accidents

As we have learned, nuclear energy have benefits to the society. That is why hitherto it is still a disputable topic globally due to the risks associated with it. In this section, the reason why it is difficult to promote nuclear energy will be discuss. We all know how devastating nuclear power plant created after the three big incidents of nuclear fallout, the Three Mile Island (TMI) in 1979, USA, Chernobyl in 1986, Ukraine and lastly Fukushima in 2011, Japan.

These three incidents have different causes of nuclear power plant breakdown. Based on the report of Nuclear Regulatory Commission (NRC), the TMI incidents is due to mechanical failure and human error. Chernobyl incidents was a major disaster in comparison to TMI and Fukushima, according to Robert J. Budnitz[17] the poor design of Chernobyl and human errors were the two possible major causes of the accidents. The design of the Chernobyl reactors originally are for nuclear weapons and not to produce electric power thus had no containment. The operators also was lack of knowledge, as well as experience and training. In the Fukushima incidents, it is very different from the two incidents. It all started in a great earthquake, followed by a 15-meter tsunami. This is purely a force majeure event.

Table 11: Comparison of major NPP accidents in the world

INCIDENTS	**DESIGNED BY**	**REACTOR TYPE**	**CAUSES**	**EVACUATION ZONE**	**DIRECT DEATHS FROM MELTDOWN**	**INTERNATIONAL NUCLEAR EVENT SCALE (INES)**
TMI	GE	PWR	mechanical failure human error	8 kilometer	Zero	five
CHERNOBYL	SOVIET	RBMK	flawed design human error	30 kilometer	31	seven
FUKUSHIMA	GE	BWR	FME	20 kilometer	Zero	seven

Note: In the INES one is the lowest and seven is the highest severity impact on people and the environment. Data comes from spectrum.ieee.org and world-nuclear.org

In TMI, according to history.com, the cleanup of the radioactive fuel and water lasted for 14 years and were stored in nuclear waste storage facility, Idaho. TMI to date still generating power from its unit 1reactor. However, due to the introduction of natural gas and its low cost of electricity Exelon Corporation that it would close the plant in 2019 even though its license to operate will expires in 2034.

[17] A safety expert from Harvard University.

There is no doubt that the impact of nuclear disaster is really a traumatic experienced to the people. To date Chernobyl within 30-kilometer exclusion zone is still not a safe place for human to live with. In order to have a permission every visitor needs an official tour guide. More implemented checkpoints on every designated spot. In Fukushima People are continuously learning. Innovation is moving at fast pace. Since after the Chernobyl incidents Pripyat is still a ghost town today. This town was created to serve the said nuclear power plant and had grown a population of around 50,000 people according to mentalfloss.com. Even now, the experts are continuously monitoring the radiation level within the exclusion zone and there is no definite time yet when it will be recommendable to lift the restriction. Experts said an estimates of 20,000 years before the land could bring itself to a normal life (N. Hines, 2016). However, even though the exclusion zone is ongoing, some people chose to go back illegally and reside within the exclusion zone. Animals also came back and propagating. Until now, the exclusion zone including the town of Pripyat is still consider contaminated resulting to futile land. Ukraine government therefore is attracting investors by offering "relative high feed-in tariffs," according to Bloomberg New Finance. This is to convert the futile land into solar farm. The one megawatt in size of solar power plant and cost about one million is expected to commission this December 2017.

In Fukushima, the Japanese government reported to IAEA its update regarding the progress in recovery operation at the Fukushima Daiichi Nuclear Power Station. IAEA is an international organization within the United Nations. The agency is assisting Japanese government, in the cleanup operation in Fukushima. IAEA also assessed the events and progress report of the Japanese government. According to IAEA's latest assessments:

"Based on the information provided by Japan, no significant changes were observed in the monitoring results for seawater, sediment and marine biota during the period covered by this report. The levels measured by Japan in the marine environment are low and relatively stable. Xxx"

"Based on the information provided by the authorities of Japan, the situation with regard to the safety of food, fishery and agricultural production continues to remain stable. No significant changes were observed since the previous report. Xxx"

This confirms that the situation or the clean-up project is under control. However, critics of the clean-up project, Mitsuhiko Tanaka, a former Babcock-Hitachi nuclear engineer said the situation is not under control. Since the Scorpion – a robot capable of penetrating the most dangerous parts of Fukushima Daiichi's reactors died after due to lumps of fuel and debris. According to Shaun Burnie, a senior specialist at Greenpeace Germany, assessed the situation and concluded that "unprecedented and almost beyond comprehension."

5.5 Social Impact of Reviving BNPP

We have learned so far the benefits of having a nuclear in the energy mix. Based on actual practices nuclear energy categorized as base load power plant due to its abundant and stable supply of fuel relatively. Unlike the RES e.g. wind and solar where the sun does not always shine and the wind does not always blow resulting to a low capacity factor. We also learned that many countries are abundant in Uranium minerals thus the price of nuclear fuel is

stable resulting to a low electricity prices relatively. Furthermore, we learned that nuclear power plant emits no GHG during operation because it produces heat through Uranium fission instead of burning fuel like coal and gas power plants. The benefits of cheap cost electricity and eco-friendly have seen in the cases of Japan and Germany, after shifting from nuclear to other sources of energy e.g. natural gas, coal and oil in Japan while in Germany RES and coal.

As we have seen in the forecasted demand and supply of Luzon grid, the supply is still insufficient in terms of a long-term solution, by the year 2025, the supply will be overloaded. Moreover, the shares of coal (48%) and natural gas (20%) in the generation mix have the majority. These types of fuel are both contributors to climate change by emitting a lot of CO_2 on the atmosphere during operation. Based in the World Resources Institute Climate Analysis Indicators Tool (WRI CAIT), the Philippines' GHG emissions in 2012 were dominated by the energy sector (54%). The 1990 to 2012 period there was an average annual change of 2.1 percent in the energy sector. It is unlikely to meet the set 70 percent reduction in carbon emissions by 2030 due to the increasing usage of coal-fired power plant.

Additionally, the price of electricity coming from coal belongs to the cheap electricity but the energy coming from natural gas is more expensive than coal and nuclear energy in average. In our analysis, even though the waste and the decommissioning cost are included in the computation of LCOE done by IEA and NEA still nuclear in average is cheaper electricity among the other base load energy (coal and natural gas) in Luzon.

The author cannot deny the facts that citizens are concerned about the dangers associated with radioactive waste produced from NPP. Another thing that adds up to the fear of the public to accept BNPP is the claim of the Aquino administration that the BNPP was contaminated with corruption as the Marcos administration were accused to received kickbacks from

Westinghouse which means the quality of the construction is dubious. Assuming that the quality of the construction is sturdy, what could be an effect to the citizens of Bataan if the BNPP will be revive and the citizens know nothing about it other than the negative aspects of it, or worse if the construction of BNPP cannot stand a big earthquake whenever it arrives? Different opinions of experts about the quality of the facilities makes the government dilly-dally in the decision making of reviving or abandoning the subject power plant. Moreover, according to a geologist Kelvin Rodolfo the location of BNPP lies in an active earthquake fault that runs through Natib volacano. Based on the data from the US Geological Survey National Earthquake Information Center, many earthquakes occurred on Mt. Natib between 1951 and 2016 (T. Orejas, 2016). We never can tell if a big earthquake or volcanic eruptions will hit Luzon again since it has a history of both. The 1990 earthquake left massive of damages and casualties in the cities of Baguio, Cabanatuan in Nueva Ecija, and Dagupan in Pangasinan. While the 1991 Pinatubo volcanic eruption hit Bacolor, Pampanga hard that it erased from the map.

According to Central Luzon's website, Bataan province has 760,650 population last 2015 (Statistic, 2015) and Bataan continues fundamentally an agricultural province despite of the very fast industrialization during the last ten years. This province is a major producer of banana, mango and *palay*. There are big industrial establishments in Bataan such as export processing zone, modern oil refinery, munition and carbon plants, pulp and paper mills, and thermal plants. Mariveles is the place of an export-processing zone that is the cause for heavy industry in Bataan. Brooms, ropes and shell craft are some of the home industries. Some livelihood programs are cattle and carabao fattening, hog rearing, and poultry industry particularly in broilers, ducks and

egg production. Tinapa is one of the livelihood products of the coastal towns in Bataan. Bataan also has amazing beach resorts.

It is clear that not only the citizens of Bataan will gain from reviving BNPP since the 620 MW capacity of BNPP is too much for their electricity demand. However, in case of nuclear accidents they will be the one to get the direct hit. Nonetheless, fear no more, because of the three historical nuclear major accidents that took place in Three Mile Island, Chernobyl and Fukushima, people learned and innovations are improving at fast phase. Filipinos are intelligent people, as the saying goes, "experience is the best teacher" but I think learning from the experienced of others is the best teacher. The experience of Japan, Ukraine and USA in nuclear accidents will make the Philippine government more prepared in order to prevent the nuclear catastrophe. To date, Russian experts from Russia's state nuclear corporation would help Philippines develop a nuclear infrastructure under a memorandum of agreement with the Department of Energy and assessment of BNPP will do likewise. We can also study more the benefits of nuclear energy in South Korea, Japan and China even though they know the consequences nuclear accidents brought still nuclear power plants are continuous operating or construction are expanding. People who lives in worries never try anything new, more so in leading a country. This is fine if there are no existing problems. However, pollution and high electricity prices are also major problems. I believed that Filipino citizens not only in Luzon would benefit more in reviving BNPP than having it as mothballed facilities. Because if the climate change will pursue due to continued increase of CO_2 in the atmosphere, the tropical countries like Philippines will mostly likely to get a harder hit. The threat of climate change is more troublesome in archipelago than having nuclear power plant in the backyard. The nuclear accidents is preventable and much easier to handle than solving climate issues and energy

security without allowing nuclear energy in the mix. For not adopting the technology and continuously relying in thermal power as sources of energy, falls into path dependency [18] and will eventually destroy Filipinos. The Philippine will not be able to meet the set reduction in CO_2 emissions. By taking the Paris agreement frivolously, Philippines reputation internationally shall taint. It is important to discuss to the Filipino people their fears of reviving the BNPP were focus on outrage and give less credence to measurable risk.

Likewise, reviving the BNPP will free the Philippine government in spending money around $773,600 - $967,000 annually just to preserve and maintain the idled BNPP since 1986. The capital cost plus the maintenance cost of 31 years of investment is indeed a substantial amount for a developing country like Philippines to gain nothing in return.

6. Conclusions

6.1 Summary

In this paper, we have seen that DOE Philippines has a plan to attain base load power plants connected to Luzon grid of at least 70 percent of its maximum demand. Based on our predicted demand in Luzon grid the existing supply in Luzon is inadequate to meet the set target of DOE. DOE Philippines welcomed the construction of committed and indicative power plants resulting to 60 percent shares coal-fired, 22 percent RES, 17 percent natural gas and one percent oil-based, which means 78 percent, are contributors to pollution. However, the Philippine government pledged 70 percent carbon emissions cut by 2030 (H. Chen, 2017). Furthermore, the major contributors of GHG

[18] An idea that tries to explain the continued use of a product or practice based on historical preference or use. This holds true even if newer, more efficient products or practices are available due to the previous commitment made.

emissions in Philippines comes from energy sectors with 54 percent shares (USAID, 2016). The main contribution of this research is to assess the impact of reviving BNPP in terms of energy security, air pollution and environment and electricity prices in Luzon using forecasting and the case study of Japan and Germany after Fukushima disasters. Reviving the BNPP, will help secure the energy security although in a temporary basis since the predicted demand in Luzon is too much for the aid of BNPP alone.

However, as we have seen in the case of Japan and Germany the shifting of energy supply from nuclear energy to fossil fuel increased their GHG emissions, while in Germany replacing nuclear power plants with RES increased the electricity retail prices. Therefore, including the BNPP in the generation mix in Luzon grid would surely make an impact in the energy security, reduction in GHG emissions from the energy sector and lastly make the electricity prices stable due to lower electricity prices coming from nuclear energy in retail supply relatively. The electricity prices in the market is not in the scope of this study since market price is volatile.

Though the arguments that nuclear power plant must be revive in order to accommodate the increasing demand of Luzon will not be a long term solution but still it will be beneficial for the consumers of Luzon in terms of eco-friendly and cheap electricity relatively. Nonetheless, if there will be benefits, there will also risk associated in reviving the BNPP. *Table* below shows the summary of the benefits and the risk of reviving BNPP:

Table 12: Summary of NPP's benefits and risks

Reviving BNPP	
Benefits	**Risk**
can be use as base load power plant	social impact
does not emit CO^2 during operation	storage of spent fuels
low cost electricity relative to RES	broad and long remediation in case of force majeure event
long asset life	fuel relies on import

Nevertheless, the fear that would instill to the inhabitants of Bataan is understandable since they know nothing about the potential benefits they could gain in reviving the BNPP. However, after the three major nuclear accidents globally (TMI, Chernobyl and Fukushima), the Philippine government will be better equip, knowledgeable in handling the BNPP and with the assistance of Russian nuclear experts the risk can be minimized and manageable.

6.2 Policy Implications

The status quo of BNPP is already liabilities to the Filipino people. The problems in energy security, affordability and mitigation of CO_2 will be a dilemma for Filipinos without adopting nuclear energy in the energy mix.

6.2.1 Challenges

The biggest challenges to the Philippine government to date are as follows:

- How to accommodate the rapid increase of electricity demand particularly in Luzon grid while the additional supply is languid;

- How to meet the target of 70 percent reduction in carbon emissions by 2030 when 76 percent of the shares in the Luzon's energy mix are CO_2 contributors (coal, oil and natural gas) while the whole country is using 72 percent; and
- How to maintain the price of electricity stable when the supply is lacking.

Firm Decision-making

The useful life of a NPP is approximately 60 years (UNWTO, 2015). As of now, BNPP is already 34 years old and since it does not do, what it is supposed to do, it considers as a white elephant of the government. The cost of capital and the operation and maintenance spent to BNPP is too much for a developing nation without contributing benefits in the society. Even though it will be crucial to decide whenever BNPP should be revive due to different opinions of an experts regarding safety issues, the government must stop dilly dallying and has to decide firmly if the subject must go on. The fact that the government is allocating a substantial amount of budget annually for 34 years in order to maintain the idle BNPP is already a big loss in the society.

The Philippines is a democratic nation ensuring all freedom for all its citizens. Applying the role of government as a protective organization that protects the rights of individual citizens should consider the people's choice on choosing which fuel must be use in the generation of electricity. The government can make a survey to the people who are residing near the BNPP stating the benefits and the risks that can be derive in reviving the power plant. Just like what happened in South Korea where President Moon Jae-in is against NPP, but he let an independent panel to study public opinion on the issue and make a recommendation. After three months of study, 59.2 percent

are in favor to resume the construction of BNPP while the remaining 40.5 percent supported the abandoning the project.

6.2.2 Reviving or Abandoning

Philippine government can take two policy directions. One path will be the path dependence route, where the policy will direct at abandoning the BNPP. If the government finally decides to abandon BNPP and will continue to use coal and natural gas as the major base load power plants, this will clearly shows as well as sending messages internationally that the Philippine will not be able to meet its ambitious emissions target reduction. At the same time, the power plant itself will continue as an absolute Philippine government's white elephant property.

The second policy direction is innovation driven, where the policy will directly adopt the revival of BNPP. In order to persuade the Filipino citizens to revive the BNPP and allow the nuclear energy in energy mix, proper dissemination of information regarding the benefits derived from nuclear energy and the consequences of climate change if not solve collectively must be done. Local, regional and global has a role to play in combating climate change. The environmental impact of thermal power plants is serious hence should never set aside. Extreme drought and floods are the produce of climate change. This will surely affects Luzon citizens, for most part in Luzon relies in agriculture industry. This causes many damages to human beings in a larger scale in comparison to nuclear accidents. Countries who does not emits pollution are experiencing climate change. Therefore, in essence this must be the priority of leaders around the world. Including nuclear energy in the energy mix as for now is the best solution to mitigate CO_2 emissions while accommodating the increasing electricity demand thus resulting to stabilize electricity prices. The potential of RES is truly remarkable. However, RES alone is not practical and sustainable sources of

energy. The land requirements needed in Wind energy is 0.4-1.7 hectares per megawatt; solar energy is 3.0-7.0 hectares per megawatt while for Nuclear is 0.8-1.0 hectares per megawatt (P. Berinstein, 2001). Germany is still in the process of experimenting, shifting its nuclear energy to RES but the coal-fired power plants are not yet ready for phase out since this serves as a backup power supply. This results to higher prices of electricity in retail. Furthermore, reviving BNPP will surely be a game changer in the Philippine electricity industry. This will result to a creation of new nuclear independent agency that will supervise the BNPP. In addition, change will also come in the public transportation sector since NPP virtually produces non-GHG emissions therefore the government will mostly likely upgrade the public utility vehicle to use electric vehicle instead of conventional vehicles. It will also affect the universities. Universities may offer specific courses for nuclear energy. Alternatively, perhaps creation of Nuclear Academy to be able to train personnel who will maintain and operate BNPP well. Since the cases of TMI and Chernobyl accidents is due to human error. It is without a doubt that the revival of BNPP will affect not only the energy sector but also different sectors. The government must choose carefully in the location of spent fuels storage among the 7,107 islands. Free from any terror attack and far from civilization. If the citizens of Bataan will have more advantage in term of the cost of electricity than the other province, then the adoption of reviving the BNPP is smooth. After all, they are apparently the neighbors of BNPP.

On a final note, all known successful people in life are risk takers. The researcher believes, that path dependence route in energy production will not be sustainable since it will surely compromise the ability of future generations. What good will it be for the Filipino citizens to have cheap and ample supply of electricity (coal), but eventually their health will be in jeopardy due to air pollutions produced by coal-fired power plants. Not to

mention, global, regional temperature increases and sea level rises and its impacts. Only nuclear power plant as of now can provide sustainable, affordable and eco-friendly energy. In even weightier matters, the risk of nuclear power plant will slight. People are continuously learning and so technologies are improving. Therefore, risk of reviving BNPP will be minimized to the lowest possible level. For the time being, to include nuclear energy in the energy mix will be beneficial to the society.

References

Ã , M. K., Mogi, G., & Albedaiwi, W. H. (2008). Overseas oil-development policy of resource-poor countries : A case study from Japan, *36*, 1764–1775. https://doi.org/10.1016/j.enpol.2008.01.037

Administration, U. S. E. I. (2017). Country Analysis Brief : South Korea, 1–20.

Baek, J. (2016). Do nuclear and renewable energy improve the environment? Empirical evidence from the United States. *Ecological Indicators*, *66*, 352–356. https://doi.org/10.1016/j.ecolind.2016.01.059

Bruninx, K., Madzharov, D., Delarue, E., & William, D. (2012). Impact of the German nuclear phase-out on Europe ' s electricity generation, (MAY), 10–12.

Bundesministeriums, E. (2015). Ein Strommarkt für die Energiewende.

Burton, T., Wind, W., Rev, H., Swt-, S., Dam, T. G., & Dam, H. (2008). Baseload power plant.

Change, C. (2014). *CLIMATE CHANGE 2014 Mitigation of Climate Change Summary for Policymakers and Technical Summary Mitigation of Climate Change*.

Change, C. C. (2015). uclear Energy: Combating Climate Change. *OECD*, *7208*.

Cherp, A., Vinichenko, V., Jewell, J., Suzuki, M., & Antal, M. (2017). Comparing electricity transitions : A historical analysis of nuclear , wind and solar power in Germany and Japan. *Energy Policy*, *101*(May 2016), 612–628. https://doi.org/10.1016/j.enpol.2016.10.044

Commission, B. P. (2012). THE FUTURE OF NUCLEAR, (July 2012).

Deng, S., Xiong, J., Xiong, G., Li, D., & Ng, D. (2014). Post-Fukushima Japan : The continuing nuclear controversy. *Energy Policy*, *68*, 199–205. https://doi.org/10.1016/j.enpol.2014.01.014

Duffield, J. S. (2011). Japanese Energy Policy after Fukushima Daiichi : Nuclear Ambivalence, *131*(1), 133–162. https://doi.org/10.1002/polq.12431

Environmental, O., & Reviews, P. (2011). *OECD Environmental Performance Reviews: Slovak Republic 2011*.

Furlan, C., Guidolin, M., & Guseo, R. (2016). Has the Fukushima accident influenced short-term consumption in the evolution of nuclear energy? An analysis of the world and seven leading countries. *Technological Forecasting and Social Change*, *107*, 37–49. https://doi.org/10.1016/j.techfore.2016.04.004

Greenberg, M. (Rutgers U. (2013). *Lecture Notes in Energy*. (M. (Rutgers U. Greenberg, Ed.) (2nd ed.). Springer. https://doi.org/10.1007/978-1-4471-4231-7

Hawley, R. (2005). Power engineers vote " yes " for nuclear energy, (November), 2005.

Hong, S., Bradshaw, C. J. A., & Brook, B. W. (2013). Evaluating options for the future energy mix of Japan after the Fukushima nuclear crisis. *Energy Policy*, *56*(March 2011), 418–424. https://doi.org/10.1016/j.enpol.2013.01.002

IEA. (2015). Southeast Asia Energy Outlook. *World Energy Outlook Special Report*, 131. https://doi.org/10.1787/weo-2013-en

Island, M. (2000). Uranium: Demand and Supply, (71).

Kreinin, M. E. (2017). DEMAND & amp ; SUPPLY, *30*(Aug), 2–4.

Murray, R. L., & Holbert, K. E. (2015). *Nuclear Energy An Introduction to the Concepts , Systems , and Applications of Seventh Edition* (7th ed.). Elsevier.

Note, B. (2015). The Paris Agreement Summary, (December), 1–6.

Pambudi, N. A., Itaoka, K., & Kurosawa, A. (2016). Future Japan Power

Generation Sector by Introducing Hydrogen Plant with 80 % CO 2 Emission Reduction Target : A Preliminary Analysis, 66–69.

Park, S., & Utama, N. A. (2011). Community acceptance of nuclear power generation in Japan and relevant influencing factors, 248–252.

PNA. (2011). Philippines : Stratbase : Philippines has highest income inequality in Southeast Asia, (July), 1–3.

Rehner, R., & McCauley, D. (2016). Security, justice and the energy crossroads: Assessing the implications of the nuclear phase-out in Germany. *Energy Policy*, *88*, 289–298. https://doi.org/10.1016/j.enpol.2015.10.038

Renn, O., & Marshall, J. P. (2016). Coal, nuclear and renewable energy policies in Germany: From the 1950s to the "Energiewende." *Energy Policy*, *99*, 224–232. https://doi.org/10.1016/j.enpol.2016.05.004

Report, W. (2011). Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources.

Richard, A. (2001). It â€™ s official : Humans are behind most of global warming, 5504.

States, U. (2015). Nuclear Power for Good : Articulations in Japan ' s Nuclear Power Hegemony, *8*, 448–465. https://doi.org/10.1111/cccr.12092

Statistic, P. A. (2015). Philippine S tatistics A uthority, 1–6.

UNWTO. (2015). 2015 Edition UNWTO, 16. https://doi.org/10.1787/cost_electricity-2015-en

USAID. (2016). Greenhouse Gas Emissions in the Philippines, (2012), 2015–2016.

Young, S., The, J., & Oct, T. (2017). South Korea â€™ s Nuclear Energy Debate, (5), 1–5.

www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx, (November 2016)

Before the Flood documentary by National Geographic with RATPAC Documentary Films (2016)

powerphilippines.com/2016/09/19/pros-cons-reopening-bataan-nuclear-power-plant/Janis Alano (September 19, 2016)

Ronald U. Mendoza, Ateneo School of Government, Yla Gloria Marie P. Paras

Ateneo School of Government, Donald Jay Bertulfo, University of the Philippines Working Paper, (September 2016)

www.postguam.com/the_globe/philippines_asia/duterte-says-he-won-t-honor-paris-climate-deal-agreed/article_9b7bc2d6-500d-11e6-b0a2-a713c5c90378.html

www.climaterealityproject.org/blog/how-climate-change-affecting-philippines, (January 19, 2016)

Shadz Loresco, Rappler, (January 10, 2016)

Fukushima a nuclear story 2015 written by Christine Reinhold, Matteo Gagliardi and Pio d' Emilia (2015)

Philippine Daily Inquirer, TACLOBAN CITY—How long should a temporary period be? By Leila B. Salaverria – Reporter, (October 23, 2015)

South East Asia Network for Development (SEANET), Comparative electricity prices in Asia, Bienvenido S. Oplas, Jr. heads a free-market think tank (August 13, 2015)

newsinfo.inquirer.net/733826/yolanda-survivors-yearn-for-more-permanent-homes#ixzz4SRJau8Vg

Daniel Razon, Getting Straight Episode, UNTV Channel, (September 2, 2014)

blog.noah.dost.gov.ph/2013/11/22/philippine-storm-surge-history (November 22, 2013)

www.washingtonpost.com/news/worldviews/wp/2013/11/12/this-map-shows-why-the-philippines-is-so-vulnerable-to-climate-change, (November 12, 20130)

Federico D. Pascual, Jr., Philippine Star, (August 6, 2013)

Anthony Taberna, DZMM, DOS POR DOS, (May 22, 2013)

matcha-jp.com/en/828

archive.adl.org/terror/tu/tu_0404_philippines.html (The Philippine and Terrorism, April 2004)

https://www.worldnuclearreport.org/The-World-Nuclear-Industry-Status-Report-2016-HTML.html#_Toc455973185

https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-climate-change-58.html

http://www.centralluzon.com/content/view/21/53/

https://www.nrdc.org/experts/han-chen/philippines-joins-paris-agreement-climate-change

https://www.scientificamerican.com/article/how-long-will-global-uranium-deposits-last/

https://www.cleanenergywire.org/dossiers/germanys-energiewende-easy-guide

https://www.livescience.com/37057-global-warming-effects.html

https://www.theguardian.com/science/2016/may/17/global-warming-will-hit-poorer-countries-hardest-finds-research

https://tradingeconomics.com/south-korea/gdp-growth

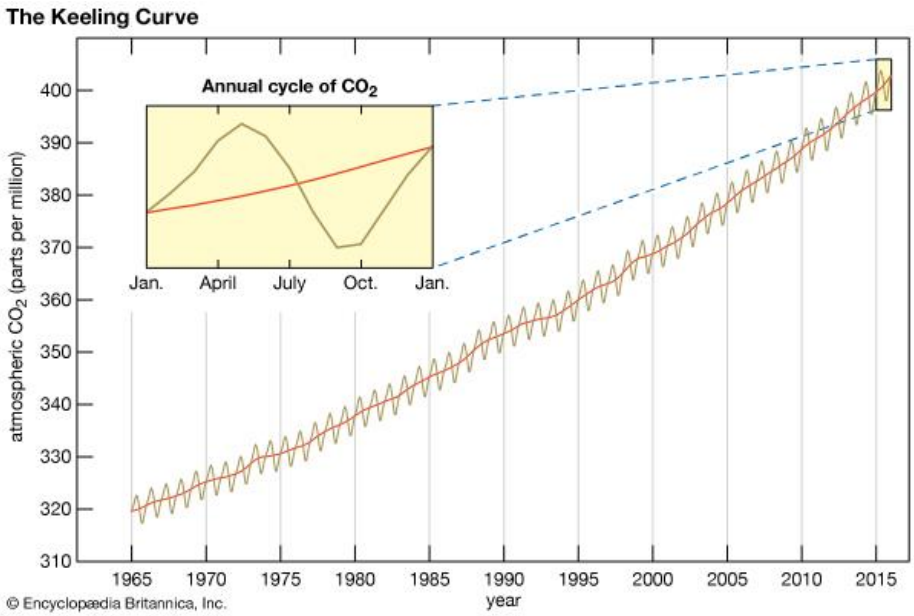
https://www.youtube.com/watch?v=kcuM8n_OciI

https://www.inverse.com/article/14741-is-chernobyl-safe-it-depends-how-you-define-safe

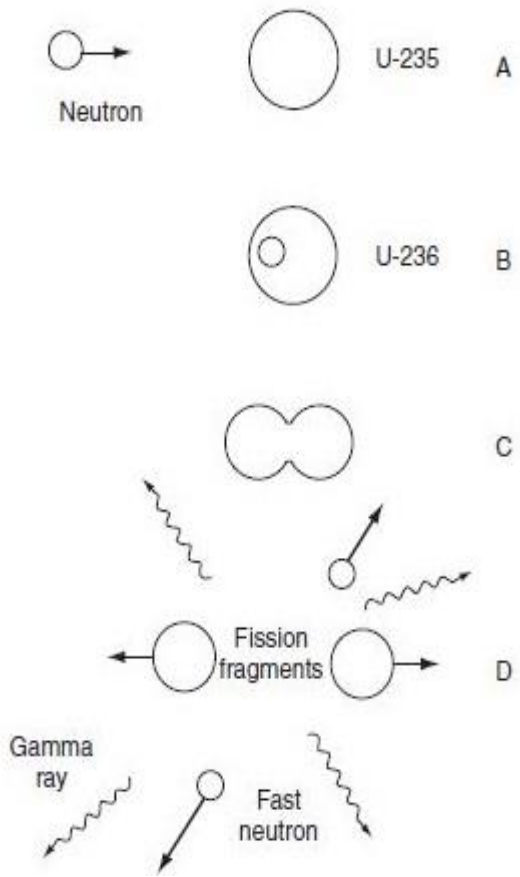
https://www.britannica.com/science/Keeling-Curve

Appendices

Appendix A: Keeling Curve



Appendix B: Fission Process



Source: (Murray & Holbert, 2015)

Appendix C: Nuclear power plants worldwide, in operation and under construction

IAEA as of 27 November 2016.

Country	In operation		Under construction	
	Number	Electr. net output MW	Number	Electr. net output MW
Argentina	3	1.632	1	25
Armenia	1	375	-	-
Belarus	-	-	2	2.218
Belgium	7	5.913	-	-
Brazil	2	1.884	1	1.245
Bulgaria	2	1.926	-	-
Canada	19	13.524	-	-
China	36	31.402	20	20.500
Czech Republic	6	3.930	-	-
Finland	4	2.752	1	1.600
France	58	63.130	1	1.630
Germany	8	10.799	-	-
Hungary	4	1.889	-	-
India	22	6.225	5	2.990
Iran	1	915	-	-
Japan	43	40.290	2	2.650
Korea, Republic	25	23.133	3	4.020
Mexico	2	1.440	-	-
Netherlands	1	482	-	-
Pakistan	4	1.005	3	2.343
Romania	2	1.300	-	-
Russian Federation	36	26.557	7	5.468
Slovakian Republic	4	1.814	2	880
Slovenia	1	688	-	-
South Africa	2	1.860	-	-
Spain	7	7.121	-	-
Sweden	10	9.651	-	-
Switzerland	5	3.333	-	-
Taiwan, China	6	5.052	2	2.600
Ukraine	15	13.107	2	1.900
United Arab Emirates	-	-	4	5.380
United Kingdom	15	8.918	-	-
USA	99	98.868	4	4.468
Total	**450**	**391.915**	**60**	**59.917**

Source: European Nuclear Society

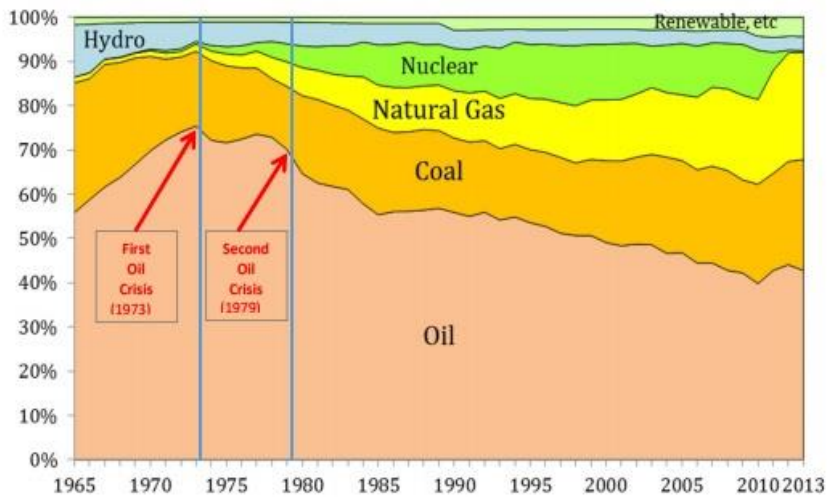
Appendix D: Energy self-sufficiency in Japan

Energy self-sufficiency in Japan

Year	1960	1970	1980	1990	2000	2005	2010	2011	2012	2013
Self-efficiency (%)	58.1	15.3	12.6	17.1	20.4	19.3	19.9	11.1	6.3	6.0

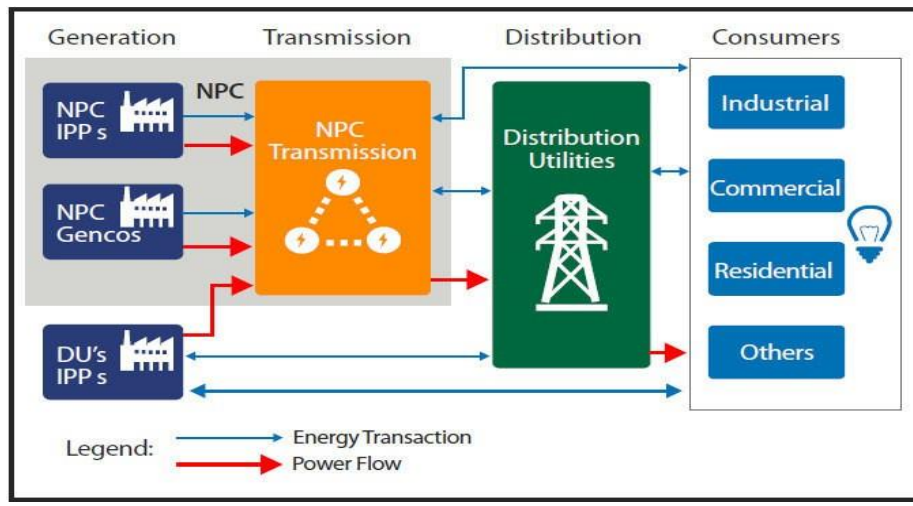
Source: Energy White Paper 2015, Agency for Natural Resources and Energy, METI

Historical change of primary energy in Japan

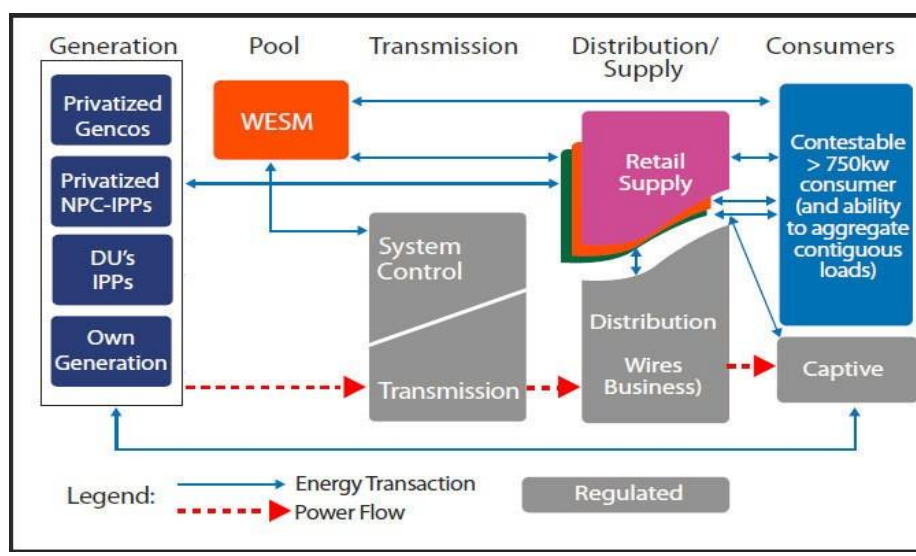


Source: Energy White Paper 2015, Agency for Natural Resources and Energy, METI

Appendix E: Pre EPIRA – Power Supply Operation



DUs = distribution utilities and electricity cooperatives, Gencos = generation company, IPP = independent power producer, NPC = National Power Corporation,
Source: KPMG. 2013. The Energy Report Philippines, 2013–2014. Manila



Genco = generation company, IPP = independent power producer, NPC = National Power Corporation, WESM = wholesale electricity spot market.
Note: TransCo is the public sector asset owner and the National Grid Corporation of the Philippines the
private operator and concessionaire for the transmission system. Source: KPMG. 2013. The Energy Report Philippines, 2013–2014. Manila

Appendix F: Installed and dependable generating capacities in Luzon

Installed

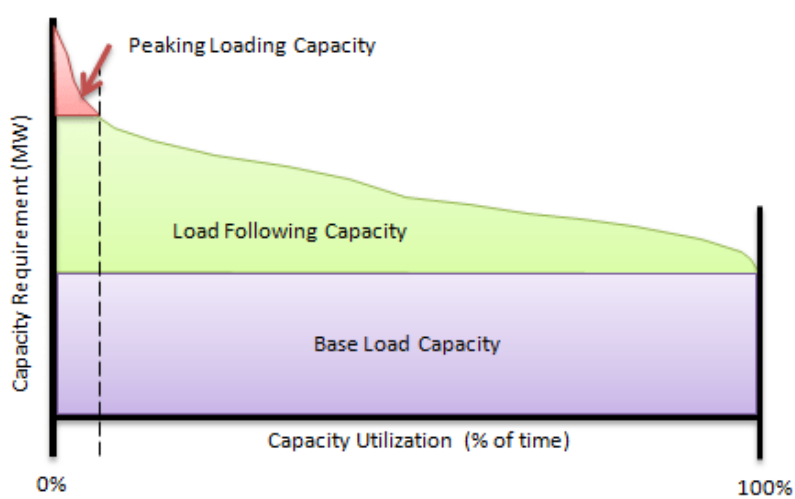
Fuel	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**% Share**
Coal	3,769	3,769	3,769	3,769	3,783	3,783	3,849	3,849	3,879	4,531	4,531	4,671	4,812	5,294	35%
Oil Based	2,514	2,514	2,404	2,333	2,363	2,100	1,984	1,984	1,757	1,778	2,020	2,033	2,133	2,133	14%
Natural	2,763	2,763	2,763	2,763	2,834	2,831	2,831	2,861	2,861	2,861	2,861	2,861	2,861	3,430	23%
Renewable Energy (RE)	2,765	3,115	3,192	3,226	3,194	3,199	3,199	3,287	3,242	3,358	3,378	3,649	3,863	4,120	28%
Geotherm	907	907	954	954	886	886	886	899	751	824	844	844	844	843	6%
Hydro	1,858	2,208	2,213	2,247	2,284	2,281	2,280	2,346	2,440	2,462	2,462	2,471	2,528	2,537	17%
Biomass, Solar, Wind	0	0	25	25	25	33	34	42	50	72	71	333	490	740	5%
Total	11,81	12,16	12,12	12,09	12,17	11,91	11,86	11,98	11,73	12,52	12,79	13,21	13,66	14,97	100%

Dependable

Fuel	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**% Share**
Coal	3,551	3,551	3,287	3,287	3,112	3,056	3,450	3,531	3,664	4,219	4,219	4,391	4,512	4,970	36.50%
Oil	2,	2,	2,	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	12.
Nat	2,	2,	2,	2,	2,	2,	2,	2,	2,	2,	2,	2,	2,	3,	24.
Renewable Ene	2,031	2,381	2,547	2,547	2,782	2,507	2,464	2,626	2,757	2,785	2,805	2,965	3,322	3,684	27.10%
Ge	6	6	7	7	7	4	4	5	5	5	6	6	6	7	5.7
Hyd	1,	1,	1,	1,	2,	2,	1,	2,	2,	2,	2,	2,	2,	2,	17.
Biomas	0	0	9	9	9	33	34	25	46	52	52	143	407	584	4.30%
Tot	1	1	1	1	1	9,	1	1	1	1	1	1	1	1	10

Source: DOE, Philippines
Note: *IPPs generation included in the utility
Generation data includes grid connected, embedded and off-grid generator. Off-grid generator not included in the Installed Capacity.
Released 27 March 2017

Appendix G: Load duration curve



Appendix H: Forecasted models

Model	Validity Tests			Accuracy Test	Growth Rate	
	R^2	*t*-test	p-value	MAPE	2016	Average Forecast
a + bt	0.96743	54.0296	0.0000	0.89%	8.94%	3.90%
		12.2273	0.0003			
a + bt + ct^2	0.97096	30.81 900835	7.51E-05	0.82%	8.94%	6.27%
		1.451555726	0.24254			
		1.219125293	0.30991			
a + bt + ct^2 + dt^3	0.97379	15.09522059	0.00436	0.73%	8.94%	16.99%
		1.538062146	0.263877			
		-0.9817844	0.429725			
		1.150489105	0.368932			
a + bt^2	0.96292	78.242493	1.6E-07	1.24%	8.94%	16.03%
		11.43894476	0.000333			
a + bt^2+ ct^3	0.96185	51.62236707	1.6E-05	1.09%	8.94%	3.22%
		2.640828209	0.077601			
		-0.94236315	0.415528			
a + bt^3	0.90488	57.5701584	5.45E-07	1.96%	8.94%	16.03%
		6.968997996	0.002229			
a + bt + ct^3	0.97410	39.70949522	3.51E-05	0.80%	8.94%	8.39%
		3.4192137	0.041867			
		1.425046849	0.249366			
a + lnt	0.84672	28.32856113	9.24E-06	2.64%	8.94%	1.29%
		5.349691411	0.005887			
a + lnt + lnt^2	0.95268	45.50903737	2.34E-05	0.99%	8.94%	3.09%
		-0.28447706	0.794551			
		3.155457747	0.05105			
a + lnt + lnt^2 + lnt^3	0.95455	45.42418146	0.000484	0.90%	8.94%	5.29%
		0.866334692	0.477631			

		-0.58136172	0.619788			
		1.060101811	0.400202			
a + lnt^2	0.96355	72.48911781	2.17E-07	0.92%	8.94%	2.95%
		11.54039966	0.000322			
a + lnt^2+ lnt^3	0.95833	53.21317216	1.46E-05	1.05%	8.94%	3.80%
		1.0436283	0.373353			
		0.706431344	0.530843			
a + lnt^3	0.95740	77.08795863	1.7E-07	1.44%	8.94%	4.94%
		10.64819176	0.00044			
a + lnt + lnt^3	0.96458	53.42216416	1.44E-05	0.85%	8.94%	4.17%
		1.345631064	0.271085			
		3.783113461	0.032375			
a + logt	0.84672	28.32856113	9.24E-06	2.64%	8.94%	1.29%
		5.349691411	0.005887			
a + logt + logt^2	0.95268	45.50903737	2.34E-05	0.99%	8.94%	3.09%
		-0.28447706	0.794551			
		3.155457747	0.05105			
a + logt + logt^2 + logt^3	0.95455	45.42418146	0.000484	0.90%	8.94%	5.29%
		0.866334692	0.477631			
		-0.58136172	0.619788			
		1.060101811	0.400202			
a + logt^2	0.96355	72.48911781	2.17E-07	0.92%	8.94%	2.95%
		11.54039966	0.000322			
a + logt^2+ logt^3	0.95833	53.21317216	1.46E-05	1.05%	8.94%	3.80%
		1.0436283	0.373353			
		0.706431344	0.530843			
a + logt^3	0.95740	77.08795863	1.7E-07	1.44%	8.94%	4.94%
		10.64819176	0.00044			
a + logt + logt^3	0.96458	53.42216416	1.44E-05	0.85%	8.94%	4.17%
		1.345631064	0.271085			
		3.783113461	0.032375			
a + bt + logt	0.96527	49.92717332	1.77E-05	0.86%	8.94%	4.53%
		3.827879648	0.031405			

		-0.86662873	0.449901			
a + bt + ct^2 + logt	0.96491	8.627775005	0.013169	0.83%	8.94%	9.19%
		-0.4673535	0.686221			
		0.984521587	0.428654			
		0.694743769	0.559074			
a + bt^2 + logt	0.97405	65.18046061	7.96E-06	0.77%	8.94%	7.15%
		4.541752981	0.019988			
		1.647829472	0.197945			
a + bt^2+ ct^3 + logt	0.96900	57.20528935	0.000305	0.80%	8.94%	13.19%
		-0.2215297	0.845242			
		0.715163388	0.548724			
		1.300687022	0.323053			
a + bt^3 + logt	0.97883	71.3918418	6.06E-06	0.78%	8.94%	11.49%
		5.095015058	0.014617			
		3.869102018	0.030546			
a + bt + ct^3 + logt	0.96843	15.36455679	0.004209	0.79%	8.94%	12.09%
		-0.10806802	0.923807			
		1.140244379	0.372331			
		0.678727178	0.567318			
a + bt + ct^-1	0.96336	15.58572942	0.000574	0.84%	8.94%	4.26%
		6.163261416	0.008597			
		0.745616118	0.510004			
a + bt + ct^2 + dt^-1	0.96300	5.325116273	0.033503	0.84%	8.94%	8.32%
		-0.17254405	0.878891			
		0.985445959	0.428292			
		-0.59580364	0.611752			
a + bt^2 + ct^-1	0.97497	38.8852961	3.74E-05	0.80%	8.94%	7.67%
		7.549402128	0.004819			
		-1.7103395	0.185731			
a + bt^2+ ct^3 + dt^-1	0.96509	14.34766224	0.004823	0.84%	8.94%	10.74%
		0.353065083	0.75778			
		0.388584611	0.735049			
		-1.13050967	0.375595			

a + bt^3 + ct^-1	0.97528	52.64396011	1.51E-05	0.88%	8.94%	13.21%
		7.598507487	0.00473			
		-3.51972693	0.038925			
a + bt + ct^3 + dt^-1	0.96664	7.487343763	0.017374	0.80%	8.94%	10.97%
		0.472590131	0.683057			
		1.13789071	0.373117			
		-0.57349318	0.624203			

Appendix I: Selected Forecast Model

Model	Validity Tests			Accuracy Test	Growth Rate	
	R^2	*t* -Test	p-value	MAPE	Actual	Average Forecast
					2015-2016	2017-2030
a + bt	0.96743	54.0296	0	0.89%	8.94%	3.25%
		12.2273	0.0003			
a + bt^2	0.96292	78.242493	1.60E-07	1.24%	8.94%	14.17%
		11.43894476	0.0003333			
a + lnt^2	0.96355	72.48911781	2.17E-07	0.92%	8.94%	2.14%
		11.54039966	0.000322			
a + lnt^3	0.9574	77.08795863	1.70E-07	1.44%	8.94%	3.76%
		10.64819176	0.0004405			
a + logt^2	0.96355	72.48911781	2.17E-07	0.92%	8.94%	2.14%
		11.54039966	0.000322			
a + logt^3	0.9574	77.08795863	1.70E-07	1.44%	8.94%	3.76%
		10.64819176	0.0004405			
a + bt^3 + logt	0.97883	71.3918418	6.06E-06	0.78%	8.94%	11.77%
		5.095015058	0.0146171			
		3.869102018	0.0305457			
a + bt^3 + ct^-1	0.97528	52.64396011	1.51E-05	0.88%	8.94%	12.81%
		7.598507487	0.0047299			
		-3.519726932	0.0389249			

Appendix J: Predicted Peak Demand of Luzon adopting $a+bt^3+logt$ forecast model

Year	70% Base load	Total Demand (MW)
2017	7,319.20	10,456
2018	8,021.30	11,459
2019	8,904.00	12,720
2020	9,990.40	14,272
2021	11,305.00	16,150
2022	12,871.60	18,388
2023	14,714.00	21,020
2024	16,855.30	24,079
2025	19,320.00	27,600
2026	22,130.50	31,615
2027	25,310.60	36,158
2028	28,884.10	41,263
2029	32,873.40	46,962
2030	37,302.30	53,289

국문초록

바탄 핵발전소 재가동

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글로벌행정전공

필리핀 경제는 급속도로 성장하고 있으며 이에 따라 전기 수요도 증가하고 있다. 경제성장을 위해서는 안정적이고 경제적인 에너지 공급이 뒷받침 되어야 한다. 과거에 루손(Luzon) 지역의 전력 부족으로 인해 전기요금이 급등한 사례가 있다. 1976 년, 루손 지역의 전력망에 전기를 공급하기 위해 623MW 규모의 바탄원자력발전소(Battan Nuclear Power Plant: BNPP) 건설이 시작되었으나, 안전과 정치적 반대로 인하여 중단되었다.

필리핀에서는 발전소의 48%가 석탄에 의존하고 있는데, 석탄화력발전소는 상당한 양의 온실가스를 배출한다는 문제가 있다. 게다가 전력 수요와 공급의 차이로 인한 높은 전기요금은 외국인 투자자의 투자 결정에 부정적인 영향을 미치기도 한다. 또한 기존 발전소들은 가까운 장래에 전기 공급이 불충분할 것으로 예측된다. 따라서 BNPP 의 재가동은 상대적으로 전력 생산 비용이 낮고 환경친화적인 전력을 루손 지역에 공급함으로써 기존의 전력 생산을 보조할 수 있음을 밝히는 것이 연구의 주된 목적이다. 회귀분석모델을 통해 2030 년까지 루손 지역의 최대전력사용량을 예측하였다.

원자력은 전 세계적으로 논쟁이 되고 있기 때문에 독일, 일본, 한국과 같은 다른 국가의 사례도 검토하였다. 또한, 쓰리마일섬, 체르노빌, 후쿠시마 등 역사상 3 대 원자력발전소 사건에 대해서도 논의하였다. 본 연구를 수행하는 동안 필리핀 정부가 파리협약에 서명하였기 때문에 전력 생산 비용과 온실가스 배출량 저감에 대한 제약이 발생했다.

또한 필리핀 정부는 유휴 발전소의 유지 보수를 위해 매년 상당한 예산을 지출하고 있다. 공급부족으로 인한 불안정한 전기 가격과 달성 불가능한 온실가스배출 감축 목표로 인해 필리핀 정부가 처한 현 상황은 경로의존성으로 분류할 수 있다. 필리핀 정부는 원자력 발전소로 인한 이익과 손해에 대한 다른 나라의 실제 사례를 검토한 이 연구를 통해 BNPP 의 재가동이 루손 지역에 추가적으로 전력을

공급하는데 도움이 된다는 것을 알 수 있을 것이다. 경제적으로 에너지 비용은 안정되고, CO2 배출량 역시 환경에 덜 위협적이며, 마지막으로 BNPP 가 시민의 부담에서 자산으로 전환될 것이다.

주제어: 핵에너지, 에너지안보, 저렴한 전기, 파리협약, 기본 하중, 수요예측, 사회적 영향, 경로의존성

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