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Analysis on the Trade-off between an Hydro-power Project and Other Alternatives in Myanmar

Nyein Nyein Aye*, Takao Fujiwara**

Abstract Myanmar's current power situation remains severely constrained despite being richly endowed in primary energy sources. With low levels of electrification, the demand for power is not adequately met. Cooperation in energy has been a major focus of future initiative for all developed and developing nations. If we want to solve climate change, and change our energy infrastructure, we need to be innovative and entrepreneurial in energy generation. This paper will help us in examining Bayesian MCMC Analysis for the parameters estimation among the arrival rates of disaster occurrences, firm's expected income-based electricity tariffs, and estimated R&D investment expenses in new energy industry. Focusing on Japan's electric power business, we would like to search the potential for innovative initiatives in new technological energy industry for the regional development and ecological sustainability in Myanmar.

Keywords Bayesian MCMC analysis, renewable energy, innovation, sustainability, regional development, cooperation

I. Introduction

1. Research Background

Growth in energy demand increasingly comes from developing economies, especially within Asia including Myanmar. Myanmar is naturally endowed with energy resources and has considerable potential in non-renewable and renewable energy resources, which can meet demand from community in the long term if it is properly managed. But they are far away to fulfill the energy requirement of the domestic population. Much remains to be done in terms of research, cost-benefit observations and experimentation together with giving priority to the awareness of environmental affects like pollution, deforestation, and so on. Thus, it has immense potential for the cooperation in the energy sector with foreign countries including Japan. Energy is necessary for socio-

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* Toyohashi University of Technology, Aichi, Japan; nyeinaye82@gmail.com
** Toyohashi University of Technology, Aichi, Japan; fujiwara@las.tut.ac.jp

economic development to meet basic needs of human beings and support the industrial development. However, the energy sector of the country has been underdeveloped due to the lack of financial power and technical capacity as well as global isolation in the past. Moreover, insufficient power supply has emerged as one of the most essential infrastructure constraints for sustainable economic growth of the country. After the country opened up to the world in 2011, the energy demand from industry, residential sectors and commerce has been on the rise, placing pressure on energy infrastructure, which has still some limitations.

Just as cooperation in energy is a major focus of future initiatives for all nations nowadays, sustainable energy has also turned into a promising way to tackle the challenges of energy demand problems for numerous worldwide consumers. Of course, the energy mix is seriously getting shift towards lower and cleaner carbon fuels, driven by environmental needs to respond to the changing nature of supporting ecosystem services, the climate adaptation and technological advances. At the same time, the industrial development mainly depends on the technological advances resulting in the economic progress of Myanmar. It should not be for the people to live in the poor mire of energy poverty in such when so much energy potential exists in Myanmar. In our opinion, Japan is one of the most developed nations in management when it comes to the commercialization technique. As Myanmar is a developing country, it needs modern innovative technology for strengthening the energy-related infrastructures and constructing the country to become a developed nation. This paper points to the fact that there are ample opportunities for regional cooperation and technological innovation between Japan and Myanmar, not only in efficiently production and utilization of natural gas, coal and oil, but also in hydroelectricity; especially in the development of new and renewable sources of energy as solar, wind, biomass, etc. Strategic cooperation with Japan would help Myanmar in strengthening energy-related infrastructures and sourcing modern technology for energy generation and supply.

2. Research Questions

Thus, this paper seeks to answer the following research questions:

1) Is it possible to propose some power source alternatives to present hydro-power projects?
2) Can the government's new energy industry survive in the Valley of Death during the period of negative profits?
3) Can we find the optimal energy mix among clean and renewable energies such as solar, hydro or biomass to secure sustainability and eco-system protection?

3. Research Objective

The first objective of this paper is to evaluate the potential of the new technological energy industry and support it in eco-system as entrepreneur. The second objective seeks to develop an appropriate model for R&D investment in innovative initiatives in production technology for the implementation of future plans for energy efficiency, conservation and sustainability. Then, the paper will search the implications for the invitation of foreign technology and capital investment from the perspective of a win-win relationship and mutual benefits for regional development in Myanmar.

4. Research Methodology

A new energy industry can be defined as a portfolio of real options by considering that the renewable energy resources are ample and that investment opportunities will result later in eco-system and commercialization (Asian Development Bank, 2012). In an era when the world is attempting to reduce CO2 emissions, it can be squarely addressed by enhancing the energy-saving performance of home appliances and utilizing building materials with high insulation performance (Nyein and Fujiwara, 2014; Bodenbender et al., 2012). Using the Bayesian Markov Chain Monte Carlo (MCMC) Analysis (Davidson-Pilon, 2016), this paper will make an effort to identify the parameter estimation in the rate of occurrence of disasters, firm’s expected income-based electricity tariffs of households, and investment expenses estimation for the new energy industry development. Particularly in this research, the Bayesian MCMC Analysis will be used for the assessment of natural disaster occurrences due to the climate changes in connection with the construction of hydro-power generation projects. Then, the analysis will be used on firm’s revenue to search for the possibility of switching between, or developing, renewable energy sources and, search for survival probability and sufficient power supply.

The Bayesian Method has its advantages for this kind of analysis because it has signaling effect on options-game theory of asymmetric information for the government, joint ventures, start-ups, etc., among noisy conditions. Moreover, the Bayesian Method makes it possible an analysis with limited availability of data. If compared with statistical frequency method, it can be run with a small amount of data. Then, in many cases, the Bayesian parameter estimation is really faster than conventional likelihood estimation. On the other hand, the implementation of the Bayesian analysis of complex data sets containing missing observations and multidimensional outcomes can be facilitated by recent findings in the MCMC methodology although it has some weaknesses

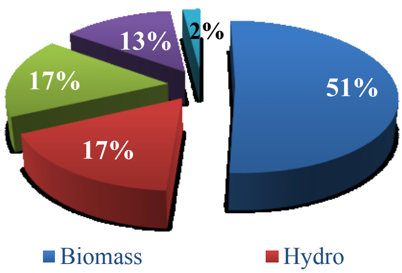
(David, 2001). Thus, it is useful for the analysis in this paper, which relies on a limited availability of data and some data noisiness from the government.

II. Country Profile and Myanmar Energy Status

The Republic of the Union of Myanmar is geographically located between the Latitudes of 9°58' N and 28°31' N and between the Longitudes of 92°10' E and 101°11' E. The population of the country is estimated at 51.5 million according to 2014 Myanmar Census. In Myanmar, 70% of the population lives in rural areas (The Myanmar Population and Housing Census, 2014). Indigenous energy sources are plentiful in the country in both non-renewable energy sources such as Natural Gas, Crude Oil and Coal, and renewable energy sources like Oil Shale, Geothermal, Hydro-power, Biomass, Wind and Solar.

1. Energy Demand and Supply

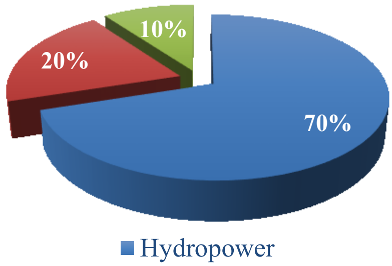
Although Myanmar is sitting on huge energy resources, currently, only 39% of households have access to electricity (Current Status of Myanmar's Energy Statistics, 2017). Only 57.01% of the population can use electricity in 2017 (Energypedia, 2018). As of 2014, only 16% of rural households had a connection to electricity power (The World Bank, 2015). This reveals a very serious disparity in electricity access between urban and rural areas. In 2014-15, the traditional biomass accounted for the largest share (51%) in primary energy supply, followed by hydro and oil & petroleum (17%) each, natural gas (13%) and coal (2%) as seen in Figure 1 (Current Status of Oil and Gas Sector, 2018).



Source: Current status of oil and gas sector, MOEE, Myanmar

Figure 1 Primary energy supply (2014-15) KTOE

According to the figures, it can be seen that biomass and traditional fuel woods are the main energy sources for residential energy consumption. Energy mix in the electricity supply of commercial energy in 2013 can be seen in Figure 2 (Nyein, 2013).



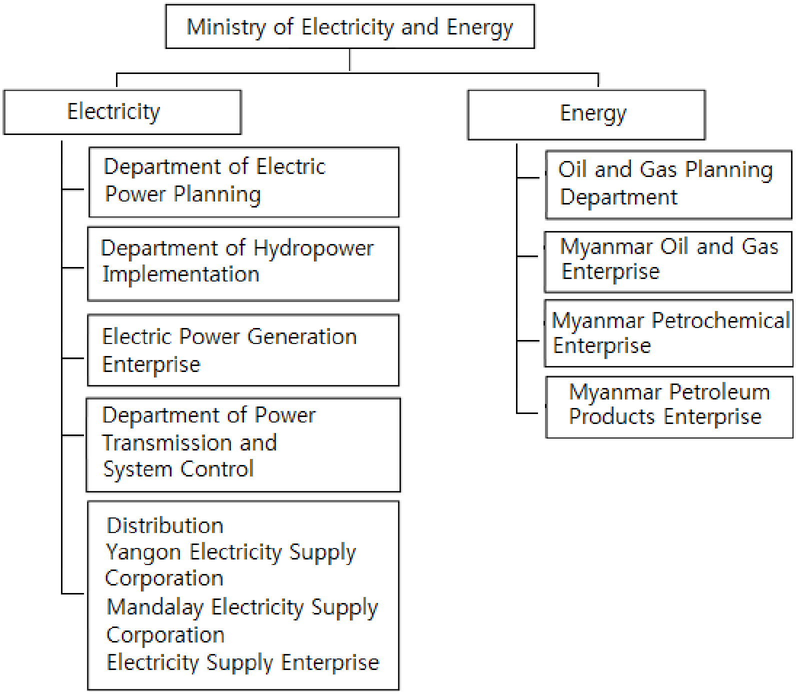
Source: Nyein Nyein Aye, Master thesis in 2013

Figure 2 The energy mix in electricity supply

2. Myanmar Power System

In April 2016, the organization of the Myanmar government was re-structured and the number of ministries was reduced from 36 to 21. In the new organization, the Ministry of Electric Power and the Ministry of Energy were merged into the new Ministry of Electricity and Energy (MOEE), which is responsible for oil, gas and electricity operations. The current organizational chart of MOEE is shown in Figure 3 (Myanmar Energy Sector Assessment, ADB, 2016). Other ministries related to the energy sector include "(i) the Ministry of Agriculture, Livestock, and Irrigation with responsibility for off-grid rural electrification, (ii) the Ministry of Natural Resources and Environmental Conservation with responsibility for coal mining, and (iii) the Ministry of Industry with responsibility for energy efficiency".

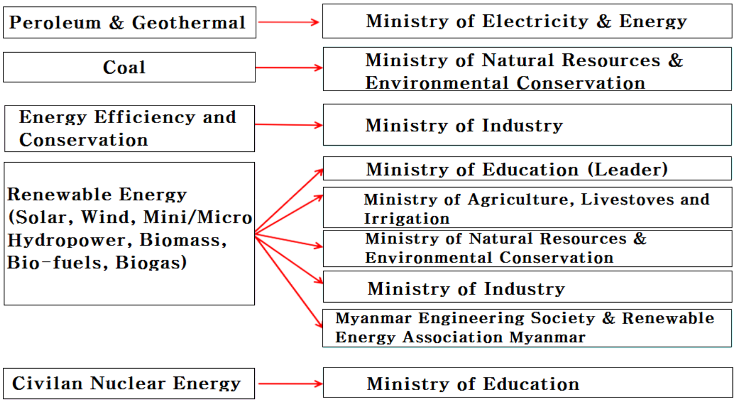
The Ministry of Education is taking responsibility not only for the research and development of the civilian nuclear energy, but also for renewable energies with other related government ministries and private organizations as seen in Figure 4. Myanmar has a unified interconnected transmission and distribution network covering some parts of the country. Off-grid distribution systems are also used in some remote regions from the national grid system. Unstable voltage, electricity shortage, and frequent blackouts are the common occurrences in electricity supply, indicating that demand by far still outstripped supply. The national grid system can be seen in Figure 5 (Myanmar Energy Summary, National Energy Grid Index, 2018).



Source: Ministry of Electricity and Energy (MOEE), 2016

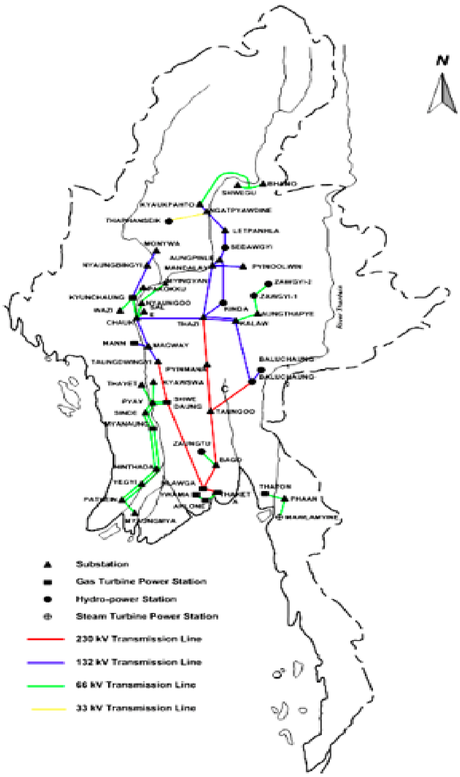
Figure 3 Organizational structure of MOEE

The local energy demand is increasing nowadays. The ongoing enhancement and expansion of Myanmar's energy (electricity) industry is thus an important part of enabling economic growth. Increase in electricity production capacity is urgently needed for Myanmar in order to accommodate rising power demands from foreign and local commercial projects and to meet ambitious economic development targets.



Source: Current Status of Oil and Gas Sector, Ministry of Electricity and Energy

Figure 4 Institutional framework of Myanmar energy sector

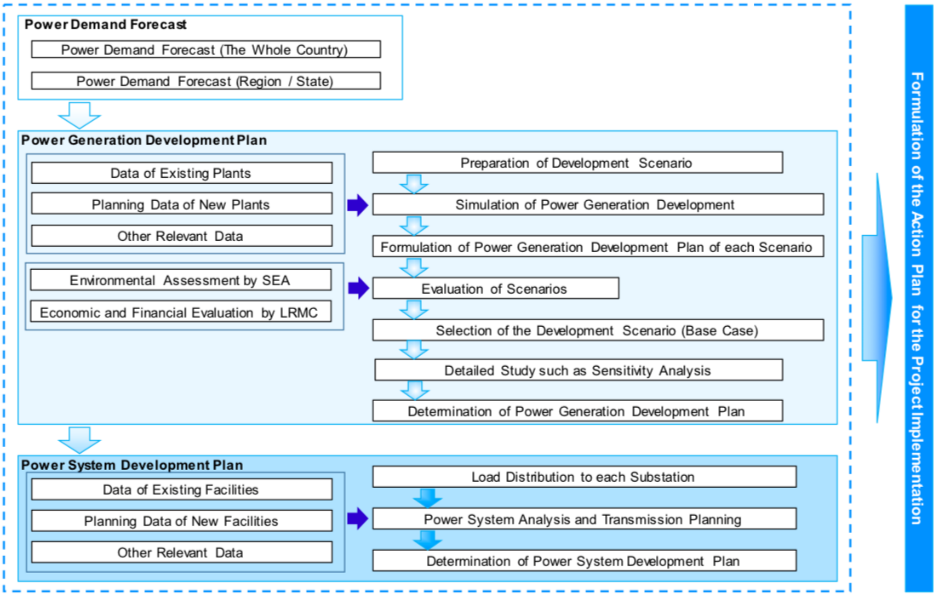


Source: Myanmar energy summary, National energy grid index

Figure 5 The national grid system

3. Development Partnership Organizations

"Compared to its population and economy, the availability and accessibility of modern energy resources in Myanmar are significantly low and hence a bottleneck to improve the living standards and support industrial activities. To tackle such constraints, the government shifted its policy toward increasing domestic energy supply and improving policy frameworks to encourage greater investment in the energy sector. This opens the opportunities for extensive international assistance including public-private partnerships." (Myanmar Energy Sector Assessment, ADB, 2016).



Abbreviation: SEA = Strategic Environmental Assessment, LRMC = Long Run Marginal Cost
Source: Final report summary on power sector development planning in Myanmar by JICA, NEWJEC Inc., The Kansai Electric Power Co., Inc.

Figure 6 The study flow of Myanmar energy master plan

The Asian Development Bank (ADB) and MOEE mainly put forward the 2015 Myanmar Energy Master Plan to be able to analyze energy demand improvement from 2014 to 2035 (Myanmar Energy Master Plan, 2018). Its study flow is described in Figure 6. A national investment strategy can be carefully planned and implemented for the energy sector infrastructure development according to its flow. Furthermore, the basic recommendation on institution building can be formed for Myanmar's future national energy planning. According to the master plan, a 15-20% share of renewable energy is envisioned out of total capacity in 2020, most of which is intended to be used for the improvement of rural renewable energy purposes.

Together with ADB, there are other development partners such as Japan International Cooperation Agency (JICA), World Bank Group, German Development Bank, and Department for International Development, The Government of Thailand and The Government of Norway. Most of the partners assist Myanmar financially for the implementation of the Master Plan and energy sector development.

4. JICA's Financial Aids and Technical Supports

"Since June 2013, JICA has been assisting the MOEE in preparing the National Electricity Master Plan focusing on power sector generation and transmission sector planning. The report was submitted in September 2014 and JICA is now assisting in its update and revision. Ongoing and planned JICA loans and grants, totaling more than $1 billion, cover all power subsectors. These include the following:

- Power Generation: (i) Urgent Rehabilitation and Upgrade in Yangon ($40 million), (ii) Infrastructure Development in Thilawa ($100 million), (iii) Rehabilitation of Baluchaung No. 2 Hydro-power ($70 million);
- Power Transmission: (i) National Power Network Development 500 kV Phase I ($250 million) and (ii) National Power Network Development 500 kV Phase II ($400 million); and
- Power Distribution and Electrification: (i) Power Distribution Improvement in Yangon ($60 million), (ii) Power Distribution Improvement in Major Cities (study completed), (iii) Rural Power Infrastructure Development Phase I ($40 million loan), (iv) Rural Power Infrastructure Development Phase II ($40 million loan under study)." (Myanmar Energy Sector Assessment, ADB, 2016).

In implementing the Master Plan, JICA brings its technical assistance in power system and development planning, economic and financial analysis, environmental and social consideration, and investment efficiency of Joint Venture/Independent Power Producer, especially as regards technical skill, technical knowledge, experience, and analytical perspectives by the staff concerned. JICA Survey Team had planned the implementation of the training for a few Myanmar staffs from MOEE based on the OJT (on-the-job training) style in order to have effective support on its technical assistance (JICA, NEWJEC and The Kansai Electric Power Co., 2015). Additionally, it also shares and transfers the advanced technologies for the power generation development.

III. Economic Assessment on the Project

The energy industry is characterized by intense technological innovation and market competition. Many investment projects for power generation have multiple decision stages. It means that management can decide to abort, delay, reduce or expand the project after obtaining new information to resolve uncertainties of the project (Kodukula and Papudesu, 2006). Regarding the life cycle of energy generation projects specifically, a general business process with huge capital investment would include three phases: planning, construction and operation. Each of the phases has a go/no-go decision making with managerial flexibility and commitment to invest in the project. In the 25 years of operation, it is quite common for power plant to increase their plant capacity as expansion phase as in Figure 7.

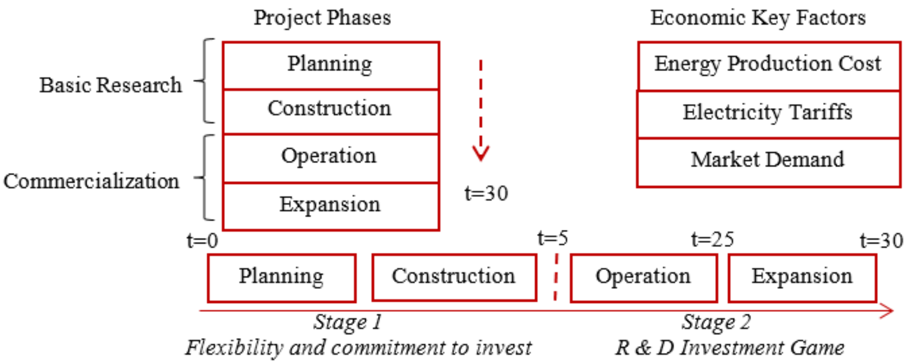


Figure 7 Power generation investment model

1. Bayesian Inferences on Power Generation Business

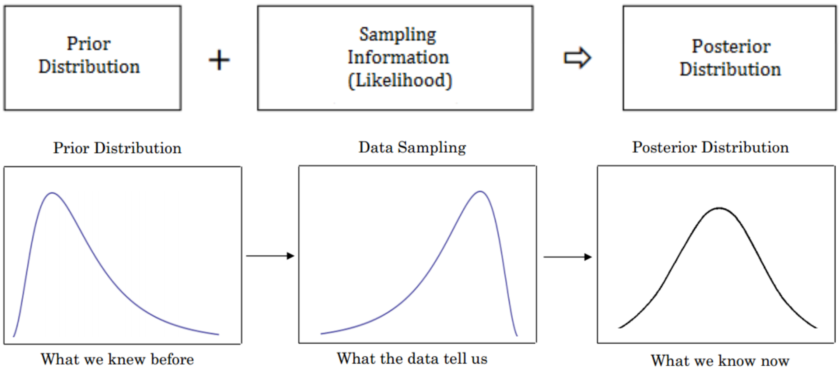
The current generation capacity of energy resources as hydro-power, renewable energy and gas and coal is insufficient for future demand. And it involves some risks in power supply. The identified renewable energy source of hydro-power has limitation in its generation during the dry season, and flood disaster cases during the monsoon season. Thus, the focus is on developing another possible renewable energy source such as solar energy generation for the backup of hydro-power energy source and the best energy mix in commercial power supply. Contributions of this analysis provide another set of risk management practice, which offers rational and logical information for the decision-making process by policy makers on power generation by considering other renewable energy source. Moreover, it can recommend key points in the policy making of power generation taking into consideration the environmental impacts. The followings are the Steps of Bayesian Data Analysis.

" 1) Identify the data relevant to the research questions.
2) Define a descriptive model for the relevant data.
3) Specify the prior distribution on the parameters.
4) Use Bayesian inference to re-allocate probability across parameter values.
5) Conduct a posterior predictive check whether the model is good fit or not. If not, consider a different descriptive model."

Bayes Theorem and the way to make Bayesian inference are as in the following method.

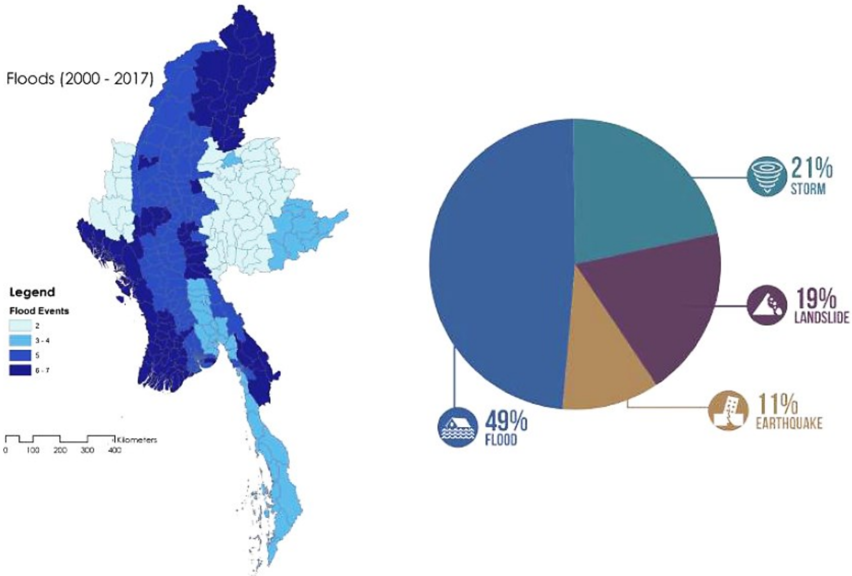
$$\text{Bayes' Theorem: } P(\mathrm{A}|\mathrm{X}) = \frac{\mathrm{P}(X|A)\mathrm{P}(\mathrm{A})}{\mathrm{P}(\mathrm{X})}$$

1) It infers the prior distribution by considering the unknown parameters as random variables.
2) It uses the information that has flowed in additionally or is gained through data sampling along with the prior distribution.
3) It draws the posterior distribution.



1.1 Flood Disasters and Dams in Myanmar

Continued heavy rain across parts of Myanmar since early July every year and the building of large dams without enough capacity for power generation projects have triggered further flooding and landslide in several regions and states in Myanmar. As the consequence of the construction of large dams, the resulting deforestation leads to climate changes, worldwide Ozone layer deterioration and global warming that destroy the natural environment. During the monsoon season, there was heavy rain in most parts of Myanmar and, at that time, the capacity of the dams was not enough to store all the water. Sometimes excess water was not collected or it provoked overflows. Usually such kinds of challenges and dangers came from the dams located in upper parts of the country. It caused damages to households and loss of life, destruction of the people's property and of physical facilities. Most of the rivers in Myanmar are used for irrigation, fishing, and navigation, and especially for hydro-power generation, so finding a solution to this flood problem is particularly important after building the large-scale dams. The average annual loss due to the flooding in the rainy season (July and August) is the maximum amount of losses among all kind of natural disasters like earthquake, storm, tsunami, etc. Figure 8 shows the percentage of floods from 2000 to 2017 in Myanmar (Reliefweb, 2018).

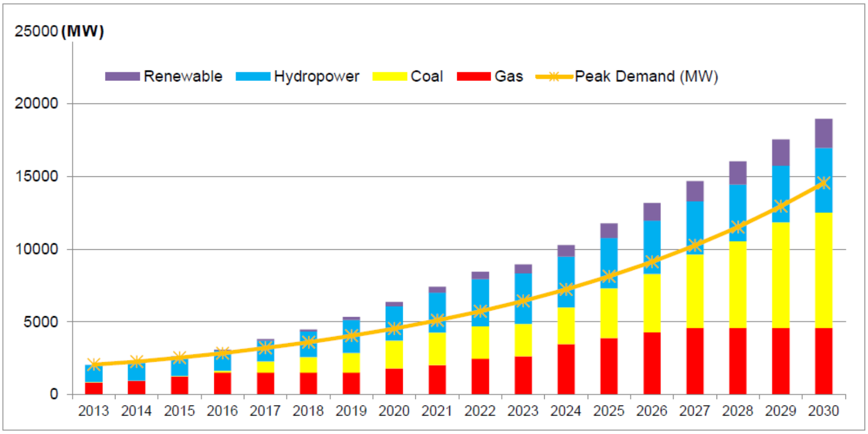


Source: Reliefweb (2018) (online access)

Figure 8 Monsoon Floods in Myanmar

The major source of power generation business is mainly based on hydro-power projects. In Myanmar, currently, there are almost 200 large dams built from 1990 to 2015. Several large dams are planned on increasing the future hydro-power utilization. In their final report for the implementation of the Master Plan, JICA Survey Team said: "Existing power generation development plans had been oriented on large-scale hydro-power projects and were revised to balance power resources composition appropriately. It was a turning point for policies of the electric power sector in Myanmar. It is also a remarkable aspect to include environmental and social considerations like Strategic Environmental Assessment (SEA) to set the criteria for the environmental impacts of decision making and policies." The best combination of power resources is shown in Figure 9. The feasibility of project implementation and the primary energy demand forecast can be guessed by this figure. According to the survey, JICA found that this would be the most effective and efficient while it is balancing the power resources in term of energy security.

This section will be focused on applying the Bayesian inference to draw conclusion and find the best solution to flood disaster effects on the construction of dams for hydro-power projects since hydro-power plants will be selected as a high priority to maintain power resource balance in the future.



Source: Final report summary on power sector development in Myanmar by JICA

Figure 9 Power supply for power resources balance

1.2 Data and Problem Statement

Figure 10 shows the dataset of flood disaster occurrences due to the flooding in the monsoon season during the years covered by the study. It appears that the rate is high in the later part. We are truly interested in locating the change-point during the study period of the time series, which may be related to building of the dams and consequent climate change/natural environment. Thus, to know whether the disaster occurrences have really changed over time, the Bayesian MCMC data analysis will be applied here.

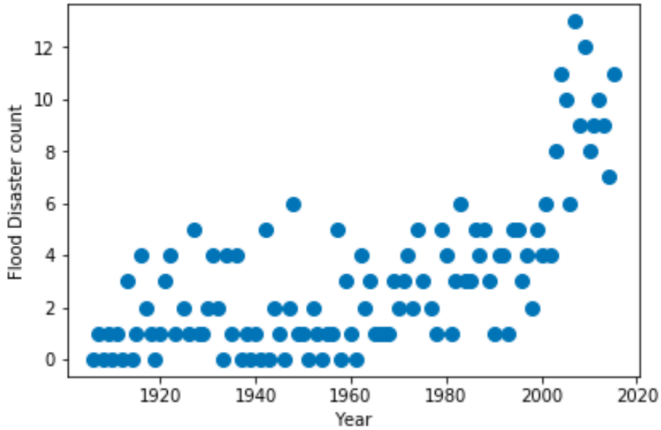


Figure 10 Flood disasters in Myanmar

1.3 Conceptual Model Building

"$(D_t|s, e, l) \sim$ Poisson (r_t), $rt = \begin{cases} e \text{ if } t < s \\ l \text{ if } t \geq s, \ t \in [t_l, t_h] \end{cases}$

$s \sim$ Discrete Uniform(t_l, t_h)
$e \sim$ Exponential(r_e)
$l \sim$ Exponential(r_l)

Dt: The number of disasters in year t
rt: The rate parameter of the Poisson distribution of disasters in year t
s: The year in which the rate parameter changes (the switchpoint)
e: The rate parameter before the switchpoint s
l: The rate parameter after the switchpoint s
tl, th: The lower and upper boundaries of year t
re, rl: The rate parameters of the priors of the early and late rates, respectively"

The expected (mean) values of early and late rates with Poisson and exponential distributions are:

$$E[e|r_e] = 1/r_e \text{ and } E[l|r_l] = 1/r_l$$

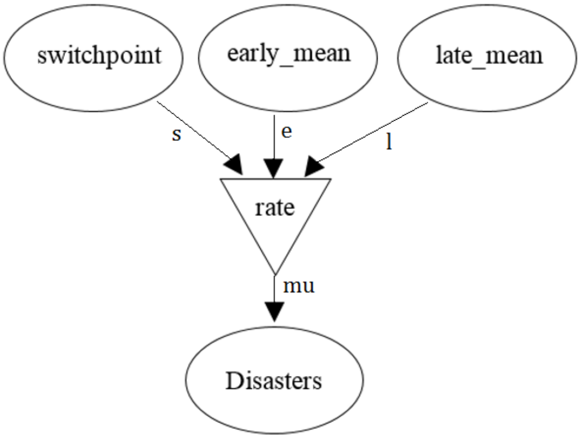


Figure 11 Graphical model for the parameters generated in the observations

After constructing our model, specifying our priors, setting our observing data, run in the PyMC programming. Iterations are 15,000 samples, discarded burn-in samples are 5, 000 and thinning is 5.

```
>>> from pymc.examples import disaster_model
>>> from pymc import MCMC
>>> mcmc = pm.MCMC(model)
```

```
>>> mcmc.sample(iter=15000, burn=5000, thin=5)
```

```
 [-----------------100%-----------------] 15000 of 15000 complete
in 3.6 sec
```

```
early_mean_samples = mcmc.trace('early_mean')[:]
late_mean_samples = mcmc.trace('late_mean')[:]
switchpoint_samples = mcmc.trace('switchpoint')[:]
```

```
>>> from pymc.Matplot import plot
>>> plot(mcmc)
```

1.4 Result and Inferences

The final results can be checked in Figure 12 and the Bayesian inference on our unknown parameters can be drawn. The usefulness of the trace plot is the evaluation and diagnosing the algorithm's performance of the program. All traces express our strong belief in posterior distribution.

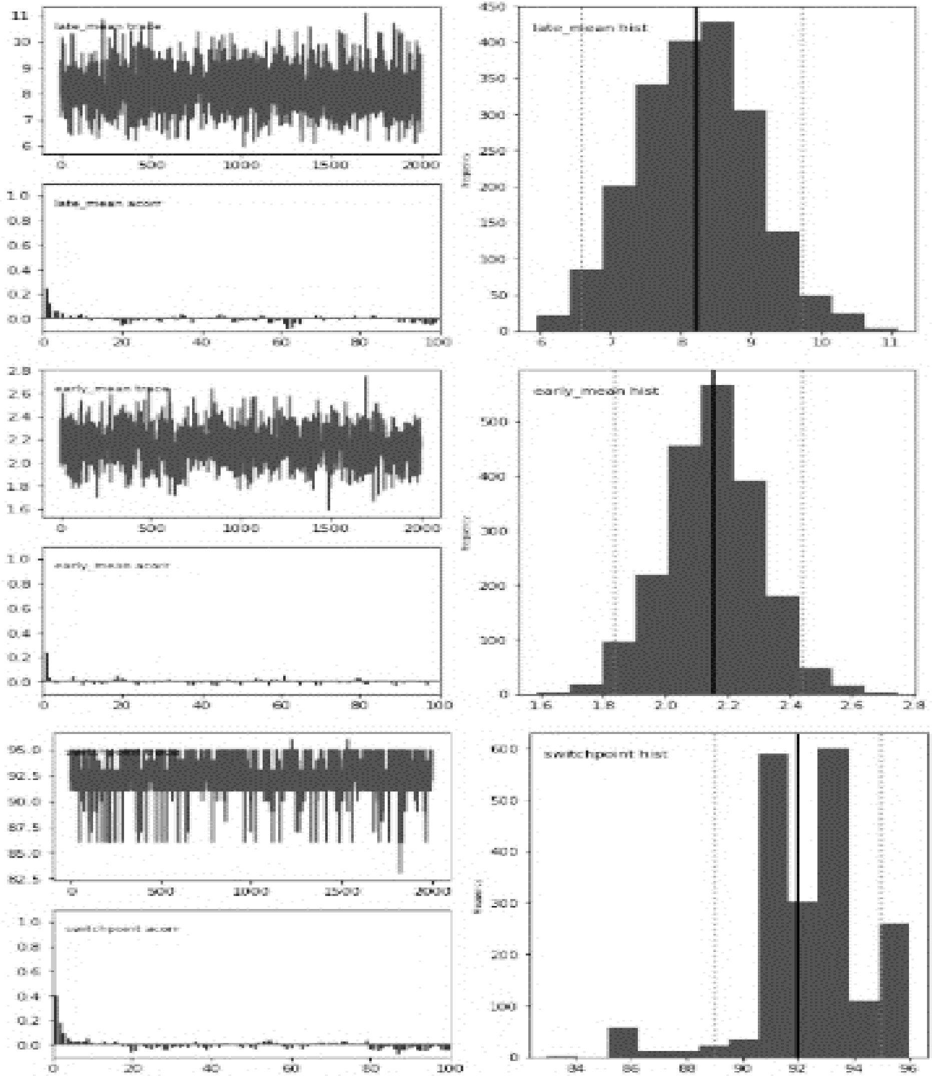


Figure 12 Output of PyMC internal MCMC plotting tool

The autocorrelation plots state that there is no correlation between variables because of data noisiness. It means flood disaster occurrences are not connected to each other because of data noisiness as heavy rains, storms or others.

The right-hand panels show a histogram of visualizing the posterior distribution. The thick vertical lines represent the posterior mean. The intervals between the two dash lines represent the 95% credible interval (95% CI) that can see 95% uncertainty area and values within CI have a total probability of 95%.

Posterior distributions of the two rates are clearly distinct, e's value, early rate is around 2 indicating that little chance of occurrences before switchpoint and l's value is around 8 which reveals to have more frequency of occurrences after switchpoint.

In switchpoint plot after the large-scale construction of dams started from the year 1990, there was a maximum possibility of change in flood disaster occurrence. Potential switchpoints might occur only three or four times during the observation period.

In conclusion, the proposal is that it is necessary to study a development plan against the types of hydro-power stations such as reservoirs, regulation-pond and run-of-river. Additionally, it is also needed to have enough capacity to store the large quantities of water during the heavy rain season in order to avoid flood disasters and prevent people's losses. Reforms and progress will have to be made on the core issues of (i) uncertainty and lack of policy over planning of the dam's construction projects; (ii) outdated/absent legal rules and regulations for the whole sector; (iii) introduction of new policy frameworks, regulation and commercial performance; (iv) concerns about sector sustainability; and (v) weak capacity of government and institutions.

1.5 Model's Goodness of Fit

Comparison between the actual data and an artificial dataset that we simulate is one way to measure the model's goodness of fit. These graphs in Figure 13 and 14 represent how well data simulated from the prior model and posterior parameters reflects the raw data. From the figures, we can see that the actual data show no appearance to deviate from our constructed model although randomness makes them appear different.

There are high rates of change in disaster occurrences in the late parts that reflect our prior belief that it is highly probable it is due to the large-scale dam constructions and consequent climate/natural environmental changes.

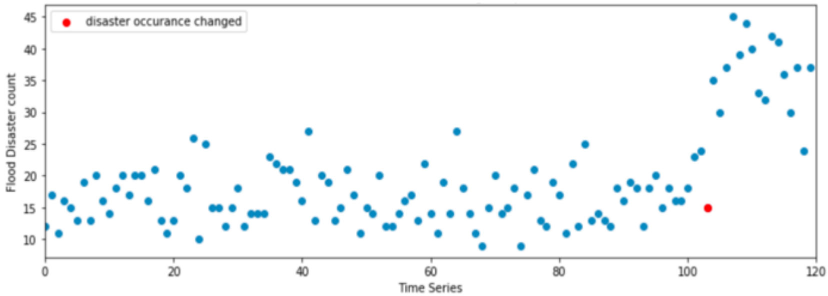


Figure 13 Artificial dataset from the priors

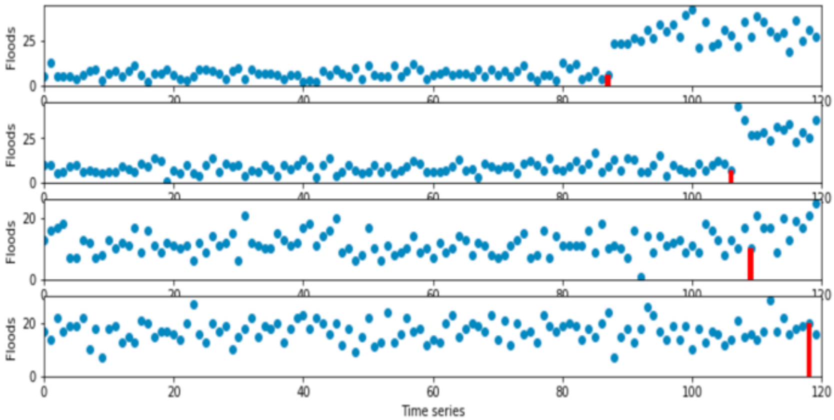


Figure 14 Simulated dataset using posterior parameters

2. Bayesian Inferences on Power Business

In Myanmar, climate change is expected, with a high forecast, to become a major impact on causing continuous increased flooding, increased temperature variations and sea levels rises due to its low industrial development and predominantly hydro-based power generation. Therefore, the priority concern for Myanmar is to consider facilitating climate change adaptation (Myanmar Energy Sector Assessment, ADB, 2016). According to JICA and ADB, it was proposed to develop the solar-powered electricity generation together with the hydro-power for the optimal energy mix in commercial electricity supply. Myanmar has rich hydro-power potential as well as "it has a strong solar radiation level, reaching more than 6.5 kWh/ square meter and collecting up to 1.9 megawatt-hours annually on a square meter, and 60% of the land area appears suitable for photovoltaics. Due to its mountainous terrain and protected areas, Myanmar's maximum solar power potential is estimated at about 40 terawatt-hours per year" according to ADB's online source (Myanmar Energy Sector Assessment, ADB, 2016). A preliminary investigation for the construction of solar power plants with the help of foreign direct investment is conducted by MOEE in some regions of Myanmar. Here the comparison table of strong and weak points between hydro and solar power generation projects can been seen in Table 1.

Table 1 Strong and weak points of hydro and solar power projects

	Hydro	Solar
Strong Point	Easy to use production technology	Comfortable for environment without natural disaster effects
Weak Point	Environmental impacts like deforestation, floods and consequent climate change	Difficult to get technology and cost more

Nevertheless, the energy industry is one of the most capital intensive high-tech industries. Using the Bayesian MCMC Analysis on the revenue side will make the economic evaluation on such kind of capital investment project. To carry out the tasks of Master Plan, JICA prepared the overall development cost depending on the year of project phases of operational for power resources balancing. This can be seen in Table 2. In this section, we will focus on Japan's electric power business to search for the possibility of efficient and secure energy generation and supply in Myanmar.

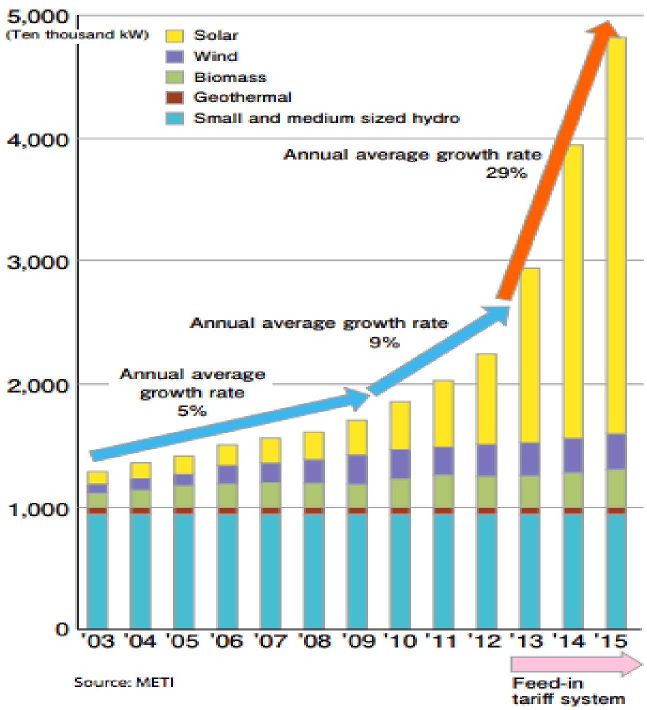
Table 2 Main indicators power resources balance scenario

Indicators			2013	2020		2030	
				High	Low	High	Low
Power Demand Forecast	Power Consumption		8,613GWh	22,898GWh	19,514GWh	77,730GWh	48,639GWh
	Maximum Power Demand		1,969MW	4,531MW	3,862MW	14,542MW	9,100MW
Primary Energy	Hydropower		2,361 MW	4,721 MW		8,896 MW	
	Gas		247 bbtud	348 bbtud		679 bbtud	
	Coal		300,000 ton	5,795,000 ton		23,373,000 ton	
	Renewable Energy		0 MW	200 MW		2,000 MW	
Power Supply Composition for Myanmar	Hydropower		2,361 MW (65.0%)	4,721 MW (53.6%)		8,896 MW (37.7%)	
	Gas		1,152 MW (31.7%)	1,969 MW (22.3%)		4,758 MW (20.2%)	
	Coal		120 MW (3.3%)	1,925 MW (21.8%)		7,940 MW (33.6%)	
	Renewable Energy		0 MW (0.0%)	200 MW (2.3%)		2,000 MW (8.5%)	
	Total		3,633 MW (100%)	8,815 MW (100%)		23,594 MW (100%)	
Power System Facility	Transmission (km)	500kV	0 km	1,029 km		2,659 km	
		230kV	3,047 km	7,434 km		9,624 km	
		132kV	2,109 km	2,389 km		2,511 km	
	Substation (MVA)	500kV	0 MVA	50,000 MVA		17,500 MVA	
		230kV	3,760 MVA	11,500 MVA		16,030 MVA	
		132kV	1,323 MVA	2,153 MVA		2,873 MVA	
Overall Development Cost	Power Generation		–	13.8 Billion USD		55.2 Billion USD	
	Transmission		–	2.7 Billion USD		5.6 Billion USD	
	Total		–	16.5 Billion USD		60.8 Billion USD	

Source: Prepared by JICA survey team for final report summary on master plan

2.1 Electricity Review for Japan

In the website www.fepc.or.jp, it is stated that "Electric power companies in resource-poor Japan are committed to developing an optimal combination of power sources including renewable energy, thermal and nuclear power in order to provide electricity, which is essential for modern living, in a stable manner at the lowest prices. Hydroelectric, geothermal, solar, wind, and biomass energy are all clean and renewable, and the electric utilities are striving to develop them for the decarbonization of energy on the supply-side." Especially, Japan is developing mega-solar power generation on a large scale. According to Chubu Electric Power business, Japan stands in the world's No. 3 in solar power (Renewable Energy, Chubu Electric Power, 2018). The amount of generating capacity of renewable energy and its annual growth rate can be seen in Figure 15 (Electricity Review Japan, 2017).

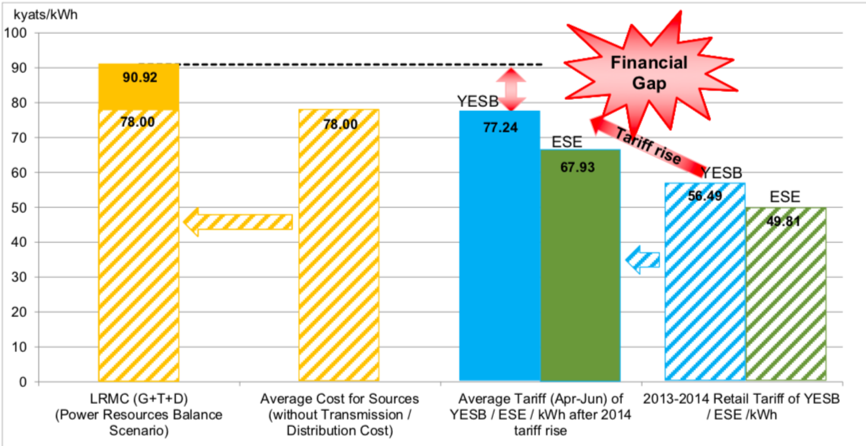


Source: Electricity review Japan, 2017

Figure 15 Amount of generating capacity (Renewable Energy) in 2017

2.2 Expected Revenue Analysis for Power Business in Myanmar

The Myanmar Times said that the government's net income shows K284 billion losses per year at current rates (Electricity Price Hike Set for April 1, Myanmar Times, 2014). The annual transition of power supply as well as the financial gap between electricity tariffs and Long Run Marginal Cost (LRMC) are finalized by JICA and shown in Figure 16.



Source: JICA report summary for electricity master plan

Figure 16 Financial gap between power tariffs and LRMC

In an effort to reduce state spending, there was a proposal in the Parliament in 2014 to increase the price of electricity usage for the households by as much as 42.8 percent on the electricity units which are used over a certain threshold. On the other hand, increasing rates will push up the cost of business and impact commodity prices. Some economists suggested that the government should subsidize through tax collection for the future development of industry instead of raising rates. It also should try to extend power access to other off-grid regions and expand to more households. At the present time, Myanmar government is carrying out all basic reforms, and the development of infrastructure resources, technologically and financially, by the international assistance for the transmission and distribution of electricity that will effectively reduce the rate of loss through power leakage. As a result, it will cover annual financial losses to some amount.

In its report, JICA writes "although financial issues in the electric power sector were of concern to stakeholders, it had been suggested that, due to the lack of systematic scheme, they should be expressed by qualitative opinions and the electricity tariffs by quantitative analysis. It indicates that it should formulate and adjust the appropriate tariff level which corresponds to the realistic power generation and transmission costs by the development and fund procurement scheme."

The current electricity tariffs are shown in Table 3. And the current exchange rate from MMK (Myanmar Kyat) to USD is 1MMK = 0.0006USD. If the electricity supply can extend locally, it will also enable raising revenue. Based on the current electricity tariffs for households and the percentage of households that can use electricity, we will make analyze revenue using the Bayesian A/B test for an economic assessment to endure and overcome financial deficit period.

Table 3 The electricity tariffs in Myanmar

Present Price	
Household	
1 unit to 100 units	35 kyats
101 units to 200 units	40 kyats
201 units and above	50 kyats
Industries/Commercial	
1unit to 500 units	75 kyats
501 units to 10,000 units	100 kyats
10,001 units to 50,000 units	125 kyats
50,001 units to 200,000 units	150 kyats
200,001 units to 300,000 units	125 kyats
300,001 units and above	100 kyats

Source: Current status of oil and gas sector, MOEE

Company's expected revenue can be calculated from:

$$E[R] = 35p35+ 40p40 + 50p50 + 0p0$$

The analysis is made for before (Plan A) and after (Plan B) expanding the electricity access to more households by the Bayesian MCMC analysis by Python Programming. By the use of Dirichlet/Multinomial model, we can see the result of the revenue analysis in Figure 16 and their differences between two plans in Figure 17.

```
def expected_revenue(P):
    return 35*P[:,0] + 40*P[:,1] + 50*P[:,2] + 0*P[:,3]

N_A    = 5000
N_A_35 = 2500
N_A_40 = 1050
N_A_50 = 550
N_A_0  = N_A - (N_A_35 + N_A_40 + N_A_50)
observations_A = np.array([N_A_35, N_A_40, N_A_50, N_A_0])


N_B    = 7000
N_B_35 = 3500
N_B_40 = 2370
N_B_50 = 600
N_B_0  = N_B - (N_B_35 + N_B_40 + N_B_50)
observations_B = np.array([N_B_35, N_B_40, N_B_50, N_B_0])


prior_parameters = np.array([1,1,1,1])

posterior_samples_A = dirichlet(prior_parameters + observations_A,
                                size=10000)
posterior_samples_B = dirichlet(prior_parameters + observations_B,
                                size=10000)

posterior_expected_revenue_A = expected_revenue(posterior_samples_A)
posterior_expected_revenue_B = expected_revenue(posterior_samples_B)
```

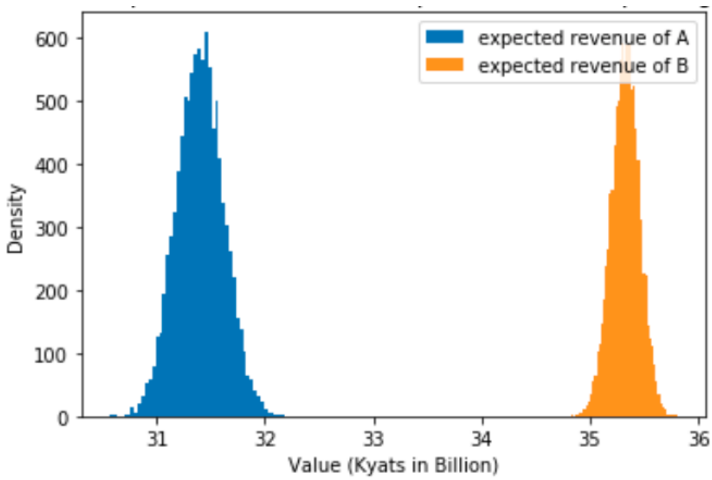


Figure 16 Posterior distribution of the expected revenue

Two posteriors of revenues have a significant difference between them. The probability that Plan B has higher revenue than Plan A is high enough. So, the business should choose Plan B going forward to overcome the financial deficit period. Another interesting plot to look at is the posterior difference in revenue between the two plans, which we can see it in Figure 17.

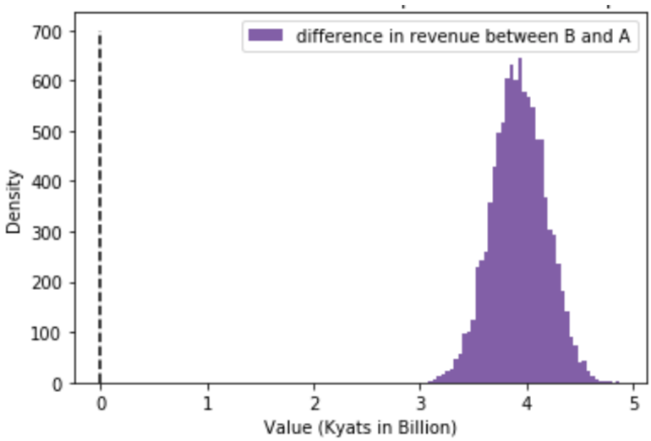


Figure 17 Posterior distribution of the differences between expected revenues by B side

In this figure, we see that there is a 50% chance that the difference is more than 4 billion Kyats to nearly 5 billion, and shows at least larger than 3 billion. The analysis found that the energy industry could continue its business development investments in 'Valley of Death' as negative financial period under such financial crisis.

At that time, firm's revenue as the sort of real options can be a guideline to facilitate the risky, but promising investments. This analysis is expected to be the basis for studying the electricity tariff to set the appropriate level and future development scheme based on the number of households or electricity users.

In practice, there are other core variables and influencing factors that must take into consideration and measured critically market uncertainty and demand forecast with some degree of risk to facilitate the irreversible capital investment. In our previous research, we used the combination of real options analysis and game theory for the assessment of investment strategies with managerial flexibility against rival companies to enter the market. In this paper, the Bayesian analysis is the preliminary stage and it needs further deeper and more effective analyses in connection with the power supply side by the government, and generation side by the private companies. Finally, we will have to integrate all kinds of analyses harmoniously to sum up our research objectives.

3. Conclusion and Implications

Solar electricity is an interesting renewable energy source in a dry zone like Myanmar as a backup to hydroelectricity and for the risk management of disasters from the building of dams, that have some negative impacts on the natural environment according to the power balance scenarios drawn by JICA that points to the best energy mix in electricity supply. Especially, the implementation of a solar power project is totally possible if it is available for financing alternatives with low interest rates from international development banks and national Export-Import banks or foreign investments keen to invest in renewable power projects and eager to support their manufacturers. Currently, Myanmar government has already commenced the infrastructure development and huge capital investment in the electricity sector. But it is still necessary to clarify the difference between electricity productivity and infrastructure investment cost by the scale of firm's net income for long-term survival probability. In addition, ongoing and expedited progress is also a necessity to ensure the sector's performance is improved and the required scale of investments is met, such that an efficient, adequate and sustainable energy distribution and supply to the entire population are met in line with the government targets.

Japan electricity business says on its web page that they are striving for strengthening international communication and cooperation for environmental conservation in the aspect of electric power generation and supply. Moreover, they said, "they are also sharing Japan's top-level environmental technologies with the World". On the other hand, JICA is supporting aids and loans to Myanmar for her development including the power sector. As mentioned in previous sections, we can clearly see such effective and efficient supports by the Japanese government and JICA. We propose to cast the result, through cooperation between Japan and Myanmar, to appear as strategic energy productivity and supply from a perspective of ecology and quality of life in Myanmar as a pioneer.

In the new dynamic competitive landscape that high-tech and other industries are facing today, it becomes essential for firms to be more flexible in their investment programs, allowing management to change the amount, rate, timing or scale of investment in response to new, unexpected developments and competitive moves (Nyein and Fujiwara, 2014) that are connected with our previous research methods in the master course. The integration of real options analysis, game theory and Bayesian method can be important and play a major role for evaluating the merits of investment under uncertainty, competition, and information asymmetry (Fujiwara, 2016; Schwartz and Trigeorgis, 2001). This is the next challenge for our research.

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