



# Non-intermittency and Sustainability in Renewable Energy Generation: The Case Study of a Renewable Energy and Energy Storage System for Mae Moh Power Plant Substitution

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## ABSTRACT

The objectives of this research are to study applications of energy storage systems for enhancing the non-intermittency and sustainability in renewable energy generation as well as to propose plan for developing renewable power plants and an energy storage system for substitution of the Mae Moh Power Plant in Lampang Province of Thailand after its retirement in 2051. This research was conducted in a qualitative approach by gathering information from various sources including literature review, secondary data collection and experiences of researcher and experts. Subsequently, gathered information was analysed to define configurations of the renewable power plant and energy storage system as well as the analysis of the economic feasibility, energy security, environment and social benefits.

The main problem focused in this research is that power generated from renewable energy resources such as solar and wind are intermittent and varying. The amounts of power generated from these energy sources depends strongly on weather conditions. As a result, it is impossible to control the amounts of power generated from intermittent renewable energy and to balance with amounts of power required by the load at any time. One promising solution to tackle this problem is to store power generated at one time in energy storage systems and use it at another time when renewable energy cannot be generated.

The problem of the intermittency of renewable energy is the main impediment of increasing penetration of renewable energy in the Thailand grid system in the near future. It is therefore, necessary that the country execute an energy storage development plan as soon as possible to mitigate any difficulties related to this problem.

According to the research, after the retirement of the Mae Moh Power Plant and Mine, areas of the power plant and mine are highly recommended to be developed to the system of a 1,500-megawatt Solar Power Plant and a 1,000-megawatt Pumped Hydro Storage. The Pumped Hydro Storage in the system could serve as an energy storage that charges energy from the solar power plant during the day and discharges energy during the night when the solar power plant cannot generate electricity and when power demand is relatively high. Capital investment of the system is estimated to be around 82,000 million THB. Projected internal rate of return (PIRR) is as high as 12.29%. In addition, the system could help to reduce emissions at the rate of 1.03 million tons of carbon dioxide equivalent per year compared to convention electricity generation from fossil fuels. Due to the aforementioned reasons, this system has the potential to be the model of 100% renewable energy generation, able to generate non-intermittent and sustainable power in the gigawatt range.

**Keywords:** Sustainability, Renewable, Energy, Generation.

## Introduction

According to the Thailand Power Development Plan 2015-2036 (PDP2015), Thailand is trying to increase the proportion of renewable and alternative energy power plants to 30 percent by 2036, which is equivalent to the energy generation capacity of 19,684 MW of all renewable energies. Of this figure, solar and wind energies account for 9,002 MW (PDP, 2015: 9). It is worth noting that solar and wind energies are fluctuating energies. To clarify, the generation volume largely depends on weather conditions such as the

amount of sunlight and wind speed at a certain period of time. Therefore, it is hard to control the production volume to be constant or sufficient for the demand.

However, in the grid system, stability can be assured when it is possible to control the volume of power generation and the supply to the transmission system in of a supply-demand matching manner. Should there be high fluctuations in power supply from the renewable energy generation, there will be instability

problems in the grid system.

This research explores a technology that stores renewable energy to address such problems and promote the constant production of renewable energy. In the meantime, Mae Moh Power Plant with the capacity of 2,400 MW will be shut down in 2051, the power plant and the mine areas will not be used from then (EGAT, 2016: 10). Therefore, this research also proposes the development of the Mae Moh power plants and mine after the shutdown in order to promote non-intermittent and sustainable energy for Thailand.

### **Objectives of the Research**

1. To study renewable energy generation and the trend for renewable energy plants, and fluctuation problems in electricity generation
2. To investigate the mechanism of an energy storage system, the trend of energy storage system technology and the usage of an energy storage system to enhance electricity generation from fluctuating renewable energy in a non-intermittent and sustainable manner
3. To present a case study and the analysis of the approach for founding renewable energy plant and energy storage system for the Mae Moh power plant substitution in 2051.

### **Scope of the Research**

1. Scope of content
  - 1.1 Investigate the mechanism of renewable energy plants, problems from fluctuations in electricity generation and

mechanisms of an energy storage system.

- 1.2 Explore the data of Mae Moh power plants and mine in Lampang province and propose the model of renewable energy plant and an energy storage system for Mae Moh power plant substitution at conceptual level.

2. Scope of area

This research covered the study area of the Mae Moh power plants and coal mine in Mae Moh District, Lampang, which is the power supply scope in the northern region of Thailand.

3. Scope of time

This research time frame was during 2015 – 2016.

### **Research Methodology**

This research is a qualitative research. The procedures are as follows:

1. The research starts with investigating electricity generation from renewable energy, the common problems caused by fluctuating renewable energy, the mechanism of an energy storage system and the approach for introducing an energy storage system to promote efficient electricity generation from renewable energy based on literature review, collection of secondary data and knowledge of the researcher.
2. The second stage of the research concerns collecting data about a case study of energy the storage system of Mae Moh power plant and coal mine based on literature review, secondary data, knowledge of the researcher and interview with experts at EGAT.
3. The third stage involves the an energy

storage method and system as well as the type of renewable energy plant suitable for Mae Moh power plant and coal mine substitution.

4. The final stage of the research discusses the economic preliminary feasibility analysis, feasibility analysis for energy, environmental and social security for developing an energy storage system.

### Benefits

1. This research will provide knowledge about the mechanism of a renewable energy plant and anticipate problems due to the increased proportion of electricity generation from fluctuating renewable energy in Thailand.

2. The research will reveal the mechanism of the energy storage system and explain the importance of introducing using an energy storage system constantly to enhance electricity generation from renewable energy for sustainability.

3. This research will elucidate the approach, capacity and worthiness of developing a renewable energy plant and an energy storage system as a substitute for Mae Moh power plant which will be shut down in 2051. The data will be used as the guideline for using the areas of the power plant and coal mine as well as relevant equipment for electricity generation and supply of Mae Moh after its shutdown.

### Results

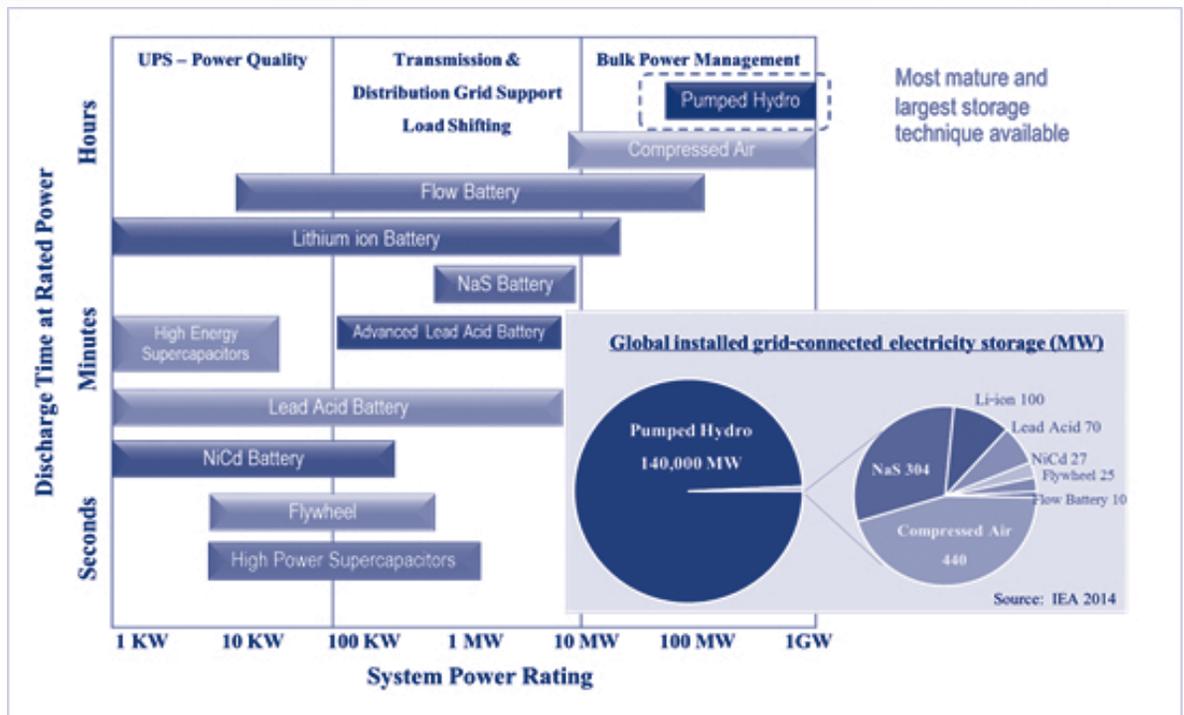
The Alternative Energy Development Plan 2015 - 2036 (AEDP 2015) determines that Thailand

will increase the proportion of renewable energy plants with low carbon dioxide emissions. As of 2015, its proportion has been 20% of the total electricity generation capacity of the country. The plan is to increase it to 30% by 2036 which is equivalent to 19,684 MW for electricity generation from all types of energy. The same plan determines the goal to generate electricity from solar energy and wind energy to 6,000 MW and 3,002 MW, respectively (AEDP 2015: 7-9)

According to previous studies, both solar and wind energies are of high fluctuations. Their disadvantage is that the production volume depends on the weather. For example, solar energy can be generated only during daytime with the availability of sunlight. Similarly, wind energy can only be produced while the wind speed is faster than 2-3 meters per second, but not without wind. As a result, electricity generation from these renewable energies are not continuous and not constant so it is impossible to control the production volume as intended. This phenomenon in turn affects the stability of the grid system which requires a good grip of electricity volume produced and supplied to meet the consumption demand during different times. An energy storage system is a system introduced to reduce the problem caused by fluctuations of renewable energy generation. The system stores the energy that is produced more than needed during a certain time to substitute for other times with higher consumption demands but failing to produce due to such fluctuation.

At the moment there are a number of

Diagram comparing discharge capacity and time at maximum discharge capacity and different installation requirements of each type of energy storage system



Source: DOE and EPRI, 2013: Page 29; IEA, 2014: Page: 17.

energy storage technologies such as pumped hydro energy storage, compressed air energy storage, lead acid battery, lithium ion battery and vanadium redox flow batteries.

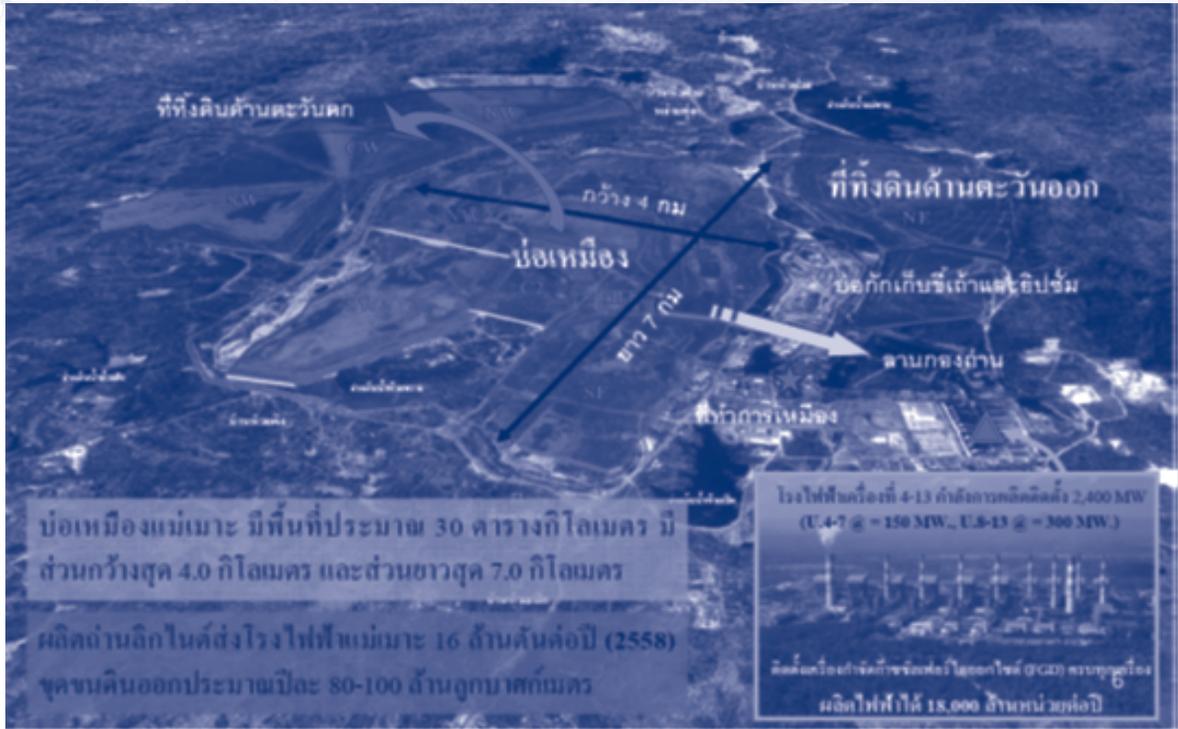
Each type of energy storage system have different mechanisms and properties as demonstrated in the diagram below. To choose an energy storage system, it is important to consider varied factors such as the maximum generation capacity, the electricity storage capacity, duration and frequency of power supply and spatial limitation for installation so that one has the suitable type of energy storage system.

The pumped hydro energy storage system

is suitable for energy backup for large utility scale with a maximum discharge capacity from 100 MW and 1 GW. It is less costly compared to other systems. However, the system needs 2 large water resources or reservoirs situated at different levels. To be precise, it requires a specific location to build e.g. on the mountains (DOE and EPRI, 2013: 30-36).

The compressed air energy storage system has high storage capacity. It is suitable for energy backup for a large utility scale with a maximum discharge capacity from 100 MW and 1 GW like the above type. However, the compressed air type requires an underground air storage area

The site plan around Mae Moh coal mine



Source: EGAT, 2016: pp. 10.

such as the hole between halite layers or natural gas wells that ran out of gas. Like the previous type, the compressed air type has limitations of installation locations (DOE and EPRI, 2013: 37-40).

There are a variety of batteries used today. Most of them are used for the maximum storage capacity of 100 MW. The storage employs a chemical reaction process. Each type of battery works differently depending on the properties of the chemicals used to make the poles. Many types of battery are still costly. However, the lithium ion battery is gaining popularity as its weight is lighter and the size made smaller compared to other batteries. Also, the lithium ion battery is likely to be of lower cost and a higher

life (Hadjipaschalis, Poullikkas & Efthimiou, 2009: 1514-1517; DOE and EPRI, 2013: 96-108).

This research discovered that after the shutdown in 2036, Mae Moh power plant and its coal mine space can be developed into a solar farm with the energy generation capacity of 1,500 MW and the application of pumped hydro energy storage with the capacity of 1,000 MW. The area that can be made into a solar farm is the coal mine on the east while that which can be transformed into the pumped hydro energy storage is the existing coal mine and settling well on the southwest. What needs to be done is land alteration to form 2 large reservoirs at different levels of around 475 meters.

The diagram showing mechanism of pumped hydro energy storage system



Example of the approach for developing pumped hydro energy storage system and solar cell farm at Mae Moh project area, Lampang province



Source: DOE, Online, 2011; Guim, Online, 2017.

The pumped hydro energy storage system stores energy by the water transfer between 2 reservoirs with different altitudes. First of all, the electricity generated from the renewable energy will be supplied to the pump which pumps the water from the lower reservoir to the higher one. When electricity is needed, the water from the higher reservoir will be discharged to the lower one through the turbine which functions as the generator.

With this principle, this system is capable of discharging electricity to the grid system during the time that the solar farm cannot generate electricity. This will also address the fluctuations from dependence upon renewable energy. However, it requires careful production planning and storage of energy in the system at different times. That is to say, during daytime when solar farm can generate electricity, some proportion of the electricity will be supplied to the grid

Picture of coal mine at Glenmuckloch, Scotland, in preparation for 400 MW pumped hydro energy storage system



Source: Glenmuckloch Pumped Storage Hydro Ltd., 2015: Page 7

system to fulfil high demand during the day. The rest of the volume will be used for pumping the water to the higher reservoir. At night when the solar farm cannot generate electricity, the system will resume its work and take the turn of solar farm to generate electricity.

According to the initial analysis, the construction of a pumped hydro energy storage system will cost around 82,000 million baht. The current value of the project has a 10% discount, worth 14,878 million baht. The turnover rate of the investment is around 12.29%, which is cost-competitive compared to coal, thermal or natural gas power plants.

If such a project comes to reality, Thailand will be able to generate electricity from renewable energy and the country will achieve higher energy

stability. From the environmental aspect, with this project, the annual carbon dioxide emission will be reduced by 1.03 tons of carbon dioxide compared to the power generation from fossil fuels. From the social and economic aspect, this project will create a lot of job positions for local people and become a tourist attraction. However, it is crucial to prevent contamination in the reservoirs and further study of the spatial conditions for designing properly. Also, EIA needs to be conducted.

This project has the potential to generate electricity from renewable energy without fluctuation. It is therefore suitable to become the pilot project for 100% renewable electricity generation at GW level that can constantly and sustainably produce electricity in Thailand. When the project is in place, it can be the guideline for

developing other energy storage system projects that will help reduce fluctuation of renewable energy and improve the generation capacity of such power plants in the future.

It is also learned in this research that some other countries have started developing the similar projects in the mining areas that have been shut down, becoming the construction site for pumped hydro energy storage system. For example, the Glenmuckloch Project was once an open surface coal mine near Kirkconnel town in Dumfries and Galloway of Scotland. At the end of 2016, the project was approved by the Scottish government to develop a pumped hydro energy storage system with capacity of 400 MW. Similarly, Glyn Rhonwy Project revived the slate quarry in Llanberis of Gwynedd in the northwest of Wales to establish the same type of energy storage system with a production capacity of 99.9 MW [Glenmuckloch Pumped Storage Hydro Ltd., 2015: 7; Hydro Review, 2017].

### Suggestions

1. It is advisable to study further about the development of pumped hydro energy storage systems and solar from while the Mae Moh Power plant is still operational. This might start from a solar farm with a capacity around 300-500 MW before subsequently installing more.

2. This study can be applied to other open surface mines in Thailand with large wells such as gold mines or dolomite mines in order to develop a pumped hydro energy storage system when these mines stop operation.

3. It is also possible to study further with

the dams of EGAT, other large reservoirs of the Royal Irrigation Department or Sub-district Administrative Organisation and Provincial Administrative Organisation for the possibility to develop additional pumped hydro energy storage systems.

4. It would be useful to study the compressed air energy storage system, which is another technology with large storage and generation capacity in case the pumped hydro storage system cannot be developed.

5. This research presents the general potential analysis. There should be deeper investigations on other topics necessary for design such as soil layer structure survey, water discharge direction, levelling and soil density. There should also be optimal analysis for energy storage and discharge for the maximum benefit of the project.

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