On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

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Towards an Affordable and Reliable Grid with Energy Transition (TARGET)

An Evidence-based Comparative Assessment of Baseload Coal and Variable Renewable Generating Technologies

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Executive Summary

In the traditional sense, power, and the plants that produce it, can be categorized based on the type of demand they serve (baseload, intermediate, peaking). Baseload power is an energy resource that provides the minimum amount of electric power required by the load demand to remain operational 24/7. Intermediate and peaking power plants address the highly fluctuating needs of the load demand during peak hours. Despite the high variability in load requirements, heavy investments over the past decade have been poured mostly into baseload coal to support our country's economic development. This groundwork led to over half of the Philippine energy mix being coal and a reduced share of Renewable Energy (RE). This report compiled and analyzed energy data from various institutions of the Philippine energy sector and other research findings to determine the reliability and viability of coal and variable renewable energy sources from the past four years. The findings concluded that:

Baseload coal is no longer what the Philippines needs

Baseload coal has proven to be unreliable, in overcapacity, and is incompatible to what the Philippine power system needs today. What the grid needs now are more flexible power plants that can provide cheap, reliable, and secure power during times of peak demand.

Variable RE sources are reliable because of their high availability and predictability, and can be further realized with the appropriate system design and policies

Since variable RE plants are available at the time of high demand, they can conveniently provide power during this time. Moreover, data have shown that its availability rates are much better than coal plants, its hourly power dispatch are predictable, and its intrahour variability can be effectively managed.

Coal is not the most cost-effective and has hidden costs tied to it

The evidence clearly shows that coal has been intermittent and unreliable even before the pandemic– and this intermittency has direct implications on the system costs that are an added burden to the consumers. Moreover, since its operating costs are tied to the importation of its fuel, it is subject to the volatile prices at the global markets that also adds to this burden.

Variable RE sources are among the cheapest and have historically reduced the price of electricity

Since the power generation of variable RE plants is coincident with the peak demand, it has historically reduced the price of electricity during peak hours by 28% despite only having less than 3% share in the energy mix. Moreover, since it is indigenous, it is not prone to price volatility of the global markets.

Currently, the Philippines have envisioned achieving a 35% and 50% share of renewable energy in 2030 and 2040, respectively. The findings of this report confirm that the Philippines should take part in the Energy Transition by carrying out this target share as RE now proves to be economical, practical, and what our grid needs. Moreover, the current policies that are being implemented by the government proves to be in line with these findings as the RE-centric policies are being laid down in the previous years.

Ultimately, we must remember that while variable renewable energy cannot replace coal in its baseload capability – it does not have to replace baseload coal anyways. What is needed is to strike the balance between different types of power generating technologies – and evidences show that an energy transition utilizing variable renewable energy power generating technologies will aid in achieving the right mix towards achieving an affordable and reliable grid.

Contents

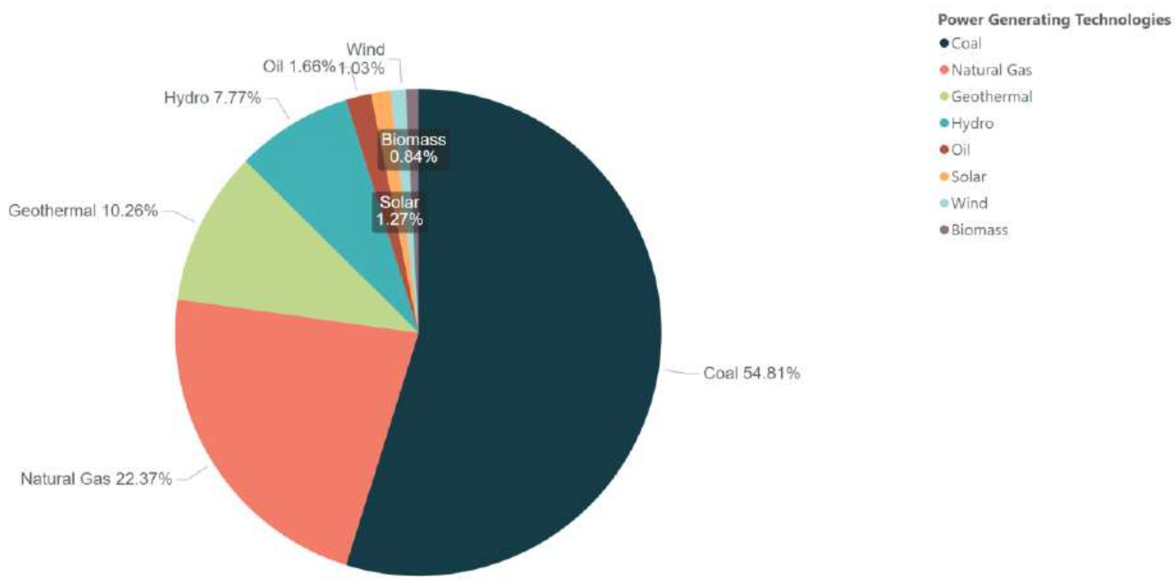
1. Introduction

Power Situation in the Philippines

In support for Renewable Energy, the Philippine government enacted the RA 9513 or the Renewable Energy Law of 2008 to accelerate the utilization of renewable energy in the Philippines [1]. The law was ambitious, and it targeted a 300% increase in renewable energy installed capacity in a span of 20 years. However, more than a decade has passed since the law was enacted, but we are still nowhere near this target, seemingly taking a turn in a different direction.

Before, the share of renewable energy in the Philippine power generation energy mix was about 35% in 2008. But today, the renewable energy share dropped to only 21% since our dependence to non-renewable energy sources increased rapidly throughout these years and due to the rapid construction of coal power plants in the past decade. In the 2019 energy mix, fossil fuel power generating technologies such as coal, natural gas, and oil accounted for almost 80% of the mix – with emerging power generating technologies such as solar and wind accounting for less than 3% of the power generation energy mix.

Figure 1: Philippine Energy Mix in 2019



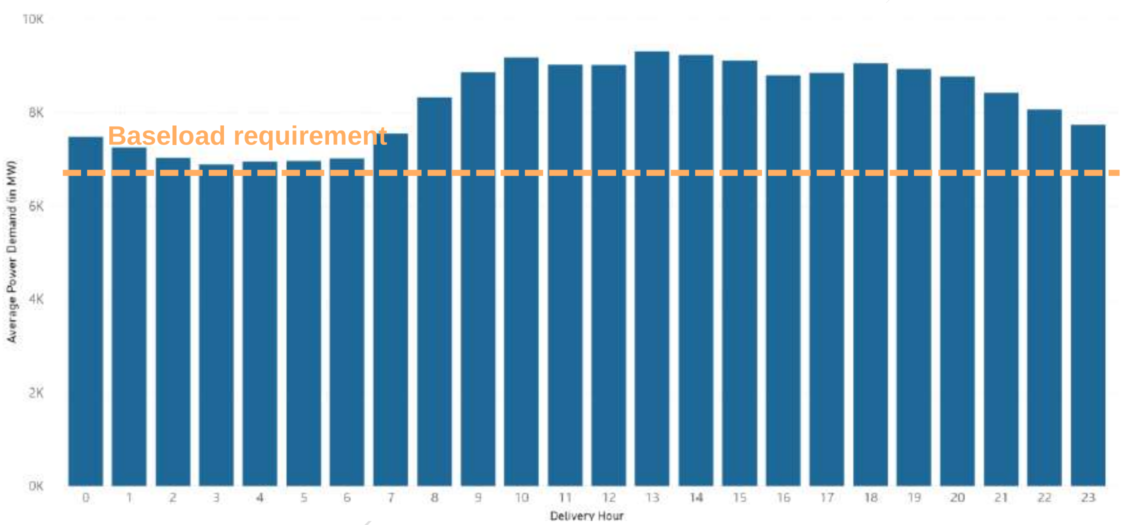
Coal, natural gas, and oil account to almost 80% of the gross power generation

The coal moratorium declared by the Philippine Department of Energy is a move in the right direction [2]. According to Dalusung III, a Technical Working Group member of the National Renewable Energy Board (NREB), the latest National Renewable Energy Plan (NREP) recommends no more new baseload coal power plants in the next 20 years [3]. However, despite halting the construction of future coal plants, the coal moratorium did not halt the construction of the coal power plants that are already in the planning and construction pipeline which were approved and committed prior to the coal moratorium on October 27, 2020. Based on the latest figures from the DOE Philippines, a total of 6,937MW committed baseload plants and 7,974MW indicative baseload power plants are currently in the works – in which the majority of these (4,421MW of committed plants and 2,190MW of indicative projects) are coal-fired power plants [4].

Matching Power Supply and Demand

Baseload is the minimum load level demand on a grid within a period, such as a day. As seen in Figure 2, the baseload amount requirement is often set during the off-peak hours of a day. Power, and the plants that produce it, can be categorized based on the type of demand they serve (baseload, intermediate, peaking). Baseload power is an energy resource that provides the minimum amount of electric power required by the load demand to remain operational 24/7. The plants designed to function as a baseload plant are rated to provide the minimum needed power; it is not economically feasible to operate them to produce the maximum needed power 24 hours of the day. In other words, the baseload plants' total output should amount to the baseload requirement (minimum or the lowest demand) seen in the figure and should stay constant [5].

Figure 2: Average Hourly Power Demand at Luzon in 2019



The baseload requirement can be set during the off-peak hours of the day

Furthermore, it must be noted that the Philippine load demand requirements fluctuate vastly throughout the day. As shown in the figure, it ramps up at 10 am, 1 pm, and later again at 6 pm. In the Luzon grid in particular, the power demand difference between peak and off-peak hours is roughly about 3,000MW. Intermediate and peaking power plants address the highly fluctuating needs of the load demand during peak hours. They are deployed to complement the baseload power plants and to match the required capacity demanded by the load.

Problem Statement

Despite the high variability of the load requirements, data shows that the power generation investments were poured heavily on coal-fired power plants because of the perceived cheap, affordable, and secure energy supplied by a baseload power plant.

With this in mind, the objective of this report is to provide evidence that shows how advancing the energy transition is the economic and practical way forward. This will be done by debunking coal's perceived reliability due to being a baseload power plant, and variable Renewable Energy's (vRE) perceived unreliability because it is intermittent.

Moreover, this paper will also debunk the claim that an energy transition is not viable and not practical in a developing country like the Philippines because coal is inherently cheap and vRE is expensive.

Scope and Limitations

The primary purpose of this paper is to disprove myths revolving around coal and variable renewables using historical information. Specifically, electricity market data from 2017 up to June 2021 was used where the dispatch is on an hourly basis.

New information from the DOE (as of November 2021) will be considered in future studies and reports. Simulations of future scenarios that will support the additions of more VRE will be done in future studies, as discussed further in the Future Studies section.

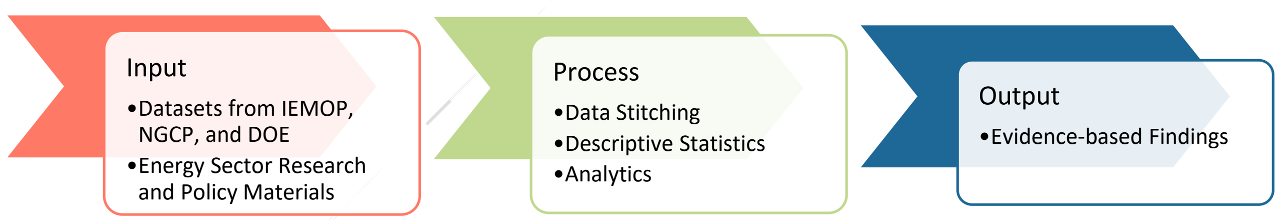
2. Methodology and Data Sources

In doing this study, the researchers have performed investigation on the various data sources from the Independent Electricity Market Operators of the Philippines (IEMOP), National Grid Corporation of the Philippines (NGCP), and the Department of Energy (DOE). The list of the datasets used in this study are listed below:

Table 1: List of Datasets Used

Dataset	Retrieval
WESM Market Prices and Schedules	Purchased
WESM Market Bids and Offers	Purchased
WESM Generation Offers	Purchased
WESM Generator Weighted Average Price	Purchased
WESM Marginal Plants	Purchased
WESM Market Clearing Prices	Purchased
WESM System Operator Advisory Logs	Purchased
NGCP Hourly Load Demand	Publicly available
NGCP System Peak Demand	Publicly available
NGCP Gross Generation Per Plant Type	Publicly available
DOE List of Existing Power Plants	Publicly available
DOE List of Committed Power Plants	Publicly available
DOE List of Indicative Power Plants	Publicly available

Figure 3: Conceptual Framework



This paper follows the conceptual framework described in the Figure 3. After gathering the datasets from various sources, the data were stitched together by appropriate attributes to observe the data in a much broader perspective and see the correlations and dependencies between parameters such as costs, power output, events, and many more. Research and reports by established institutions were also used as a point of reference or as supporting material.

Moreover, unless otherwise specified, all analyses are based on the historical and actual energy data that were processed using analytics and simple descriptive statistics measures such as taking its average over a relevant period. More details are elaborated in each of the sections of this paper.

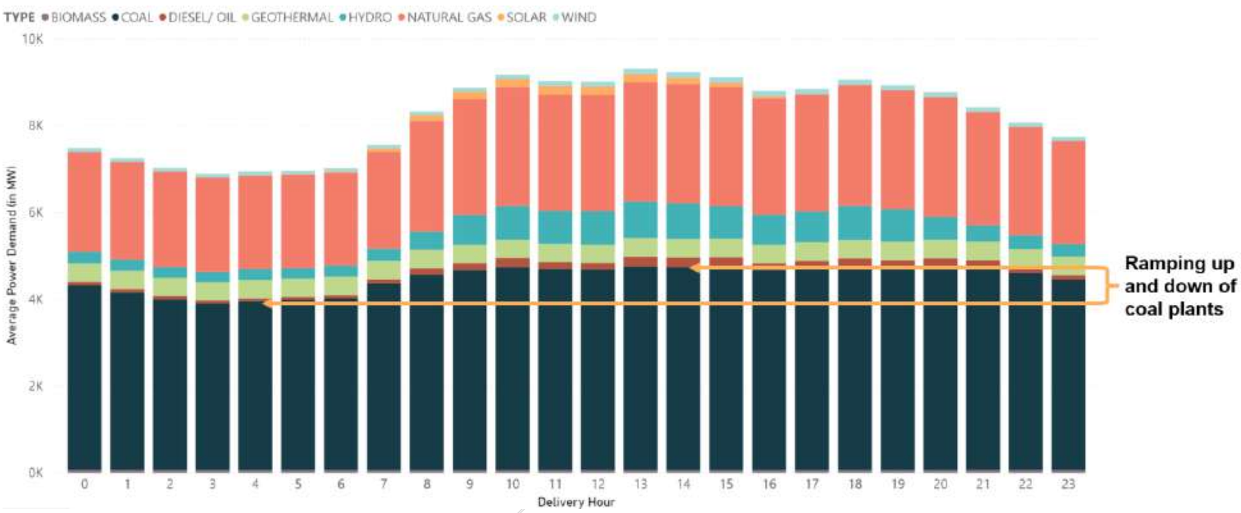
Finally, this paper aims to provide an evidence-based analysis by presenting the data and its findings as objectively as possible.

3. Coal is unreliable and not what is needed

3.1. Coal plants are operating as more than baseload, contrary to what they are designed for

To meet the baseload requirement in the Philippines, coal power plants are widely used – which now accounts for more than half of the Philippine energy mix. Heavy investments were poured into coal over the past decade because it advertises to provide cheap baseload capacity, and that it's available 24/7. However, these are not the only essential characteristics needed. Due to the nature of baseload requirement, these plants must run at that same level the whole day, every day during its operation [5]. And based on current data, this is not how they operate today.

Figure 4: Average Hourly Energy Mix in 2019

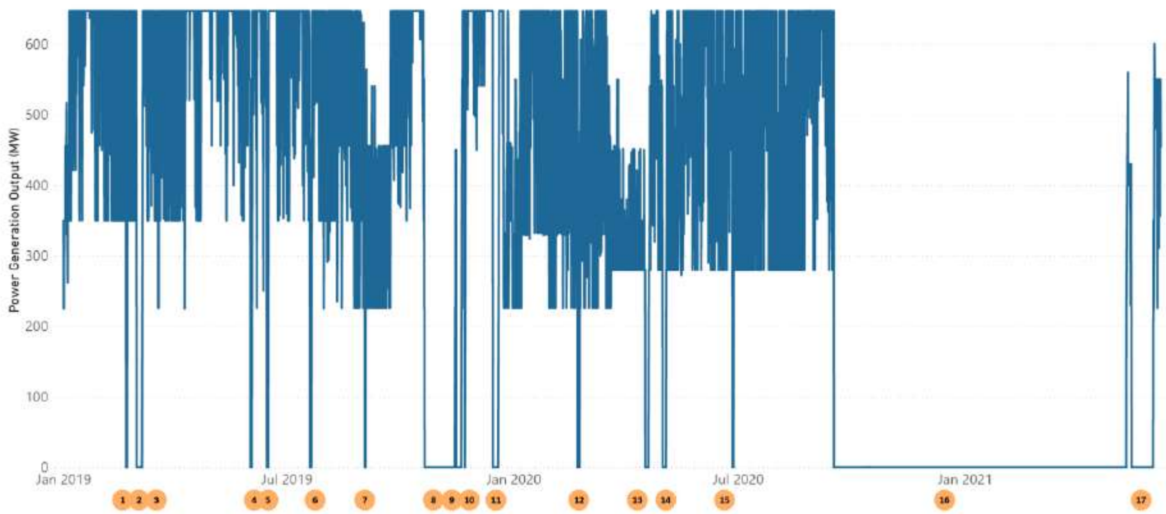


Coal-fired power plants accounts for the largest chunk and its contribution ramps up during peak hours

Looking at the current situation of the energy mix in the Philippine power industry, we can see that coal-fired power plants also ramp up during the daytime and ramp down during the nighttime. This ramping up and down are also pertained to as cycling. This cycling is an indication that the coal-fired power plants are operating as more than baseload power plants and providing intermediate loading as well.

The loading behavior can also be observed by viewing an individual coal plant's data (Figure 5). This section will analyze the frequency of cycling within a single plant and with most coal plants as a whole.

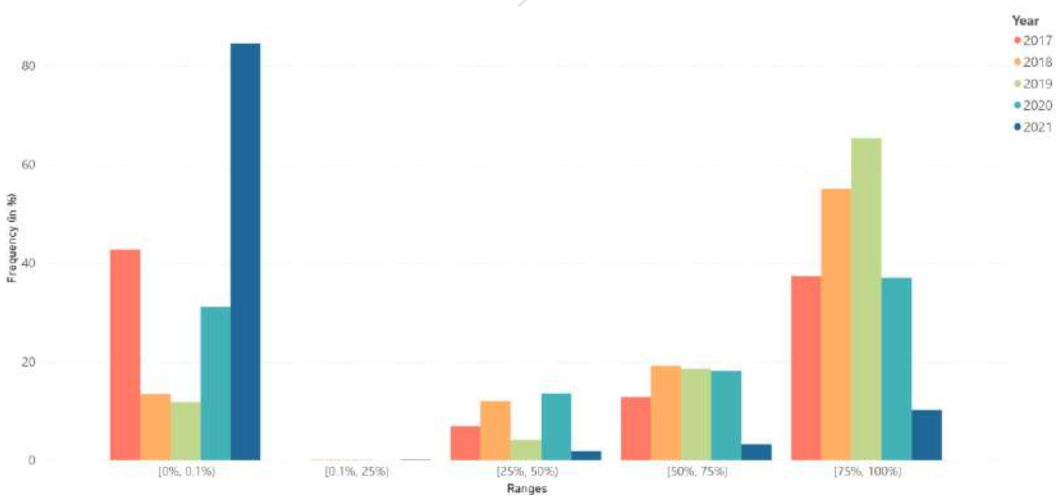
Figure 5: Power Output of Sual Coal-Fired Power Plant Unit 2 from January 2019 to June 2021



Historical data shows that this plant is frequently under cycling operation and has experienced 17 outages in this period

Based on the historical operating data of Sual Coal-fired Power Plant Unit 2 in Pangasinan, which is the largest coal power plant in the Luzon grid, we can observe two things. First, it did not run at a consistent loading level during its operation, and second, the plant experienced several outages. To simplify the historical power output data of the plant, we translate this into a histogram of its generation loading.

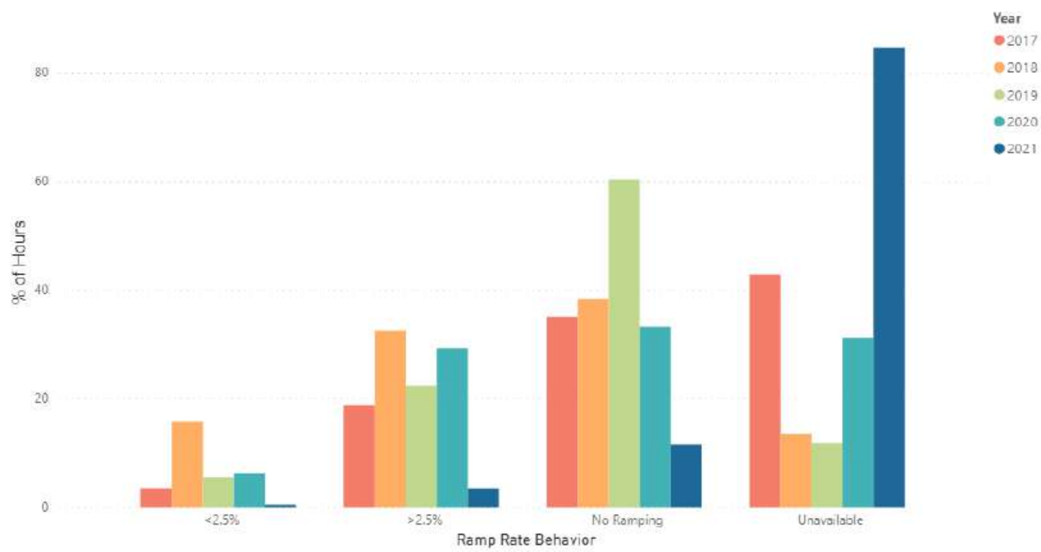
Figure 6: Histogram of Generation Loading for Sual Coal-fired Power Plant Unit 2



This plant operates under baseload operation, but also with cycling operations and frequent outages
Note: 2021 data is only up to June 2021

From this, we can see the frequency of the hourly instances when the generator operating level is at a certain loading level range. As discussed previously, an expectation for plants that serve baseload demand is that they must be running at a constant level throughout their operation. Despite the high frequency of the 75% to 100% generating levels, there is still a significant percentage between 25% to 75% loading. This spread may indicate that the plant may be cycling more frequently. To further investigate this loading behavior, we computed the percent hourly change of loading and placed the results in a distribution. This was done as means to analyze how often cycling occurs on an hourly interval [6].

Figure 7: Histogram of Hourly Ramp Rates for Sual Coal-fired Power Plant Unit 2

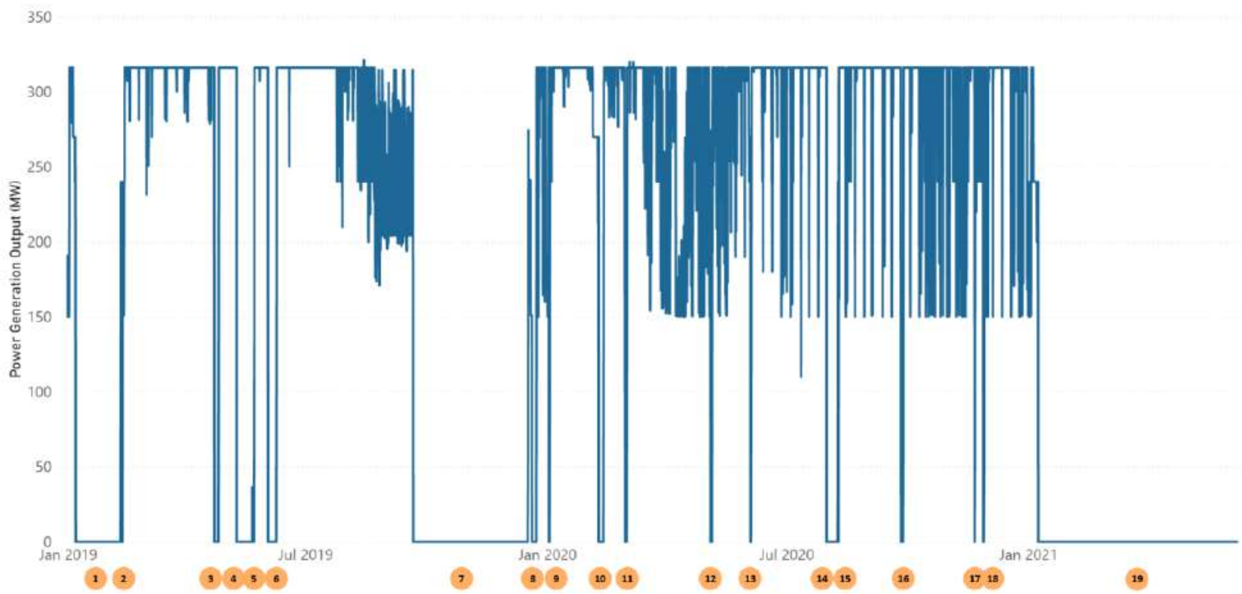


< 2.5% – Less than 2.5% change in loading from the previous hour
> 2.5% – More than 2.5% change in loading from the previous hour
No Ramping – No change in output from the previous hour
Unavailable – Intervals where the loading was 0-0.5 MW, or not operational
Note: 2021 data is only up to June 2021

The percent hourly change of loading for this case is the ramp rate. In context to the generation loading data, it is how much the loading level changed from the previous hour. The figure above exhibits the frequency of these variations binned into three groups with a fourth bin for periods where the plant was unavailable (planned or unplanned outage). A more than 2.5% change is considered significant ramping, a high frequency of which would indicate cycling occurring often. The data shows that Sual Unit 2 is cycling more than 20% of the year. Interestingly, it is only staying constant or not ramping less than half of the time. It suffered several outages as well in 2017, 2020, and 2021.

The same level of coal power plant cycling operation was observed in other coal power plants in the Philippines. Figure 8 shows the same cycling operation with frequency outages of GN Power Mariveles Unit 1 wherein it has experienced 19 outages in a span of 2.5 years. Note that this power plant uses the Circulating Fluidized Bed type of plant which is one of the latest technologies in coal power generation. Additionally, it has only been under operation for eight years as of 2021, which is considered one of the newer coal plants that are in operation.

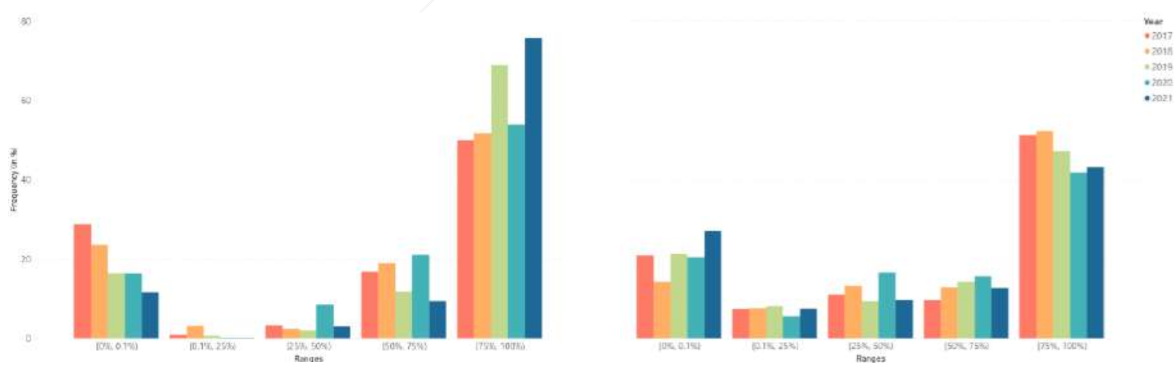
Figure 8: Power Output of GN Power Mariveles Unit 1 from 2019 to June 2021



Historical data shows that this plant has experienced 19 outages in this period

This recurring on and off operation or intermittent operation can be seen in the majority, if not all, coal plants. To view the prominence of cycling with coal plants as a whole, we take the average of the most commonly used technologies of the coal plants – such as the Circulating Fluidized Beds (CFB) and Pulverized Subcritical Coal (PSC).

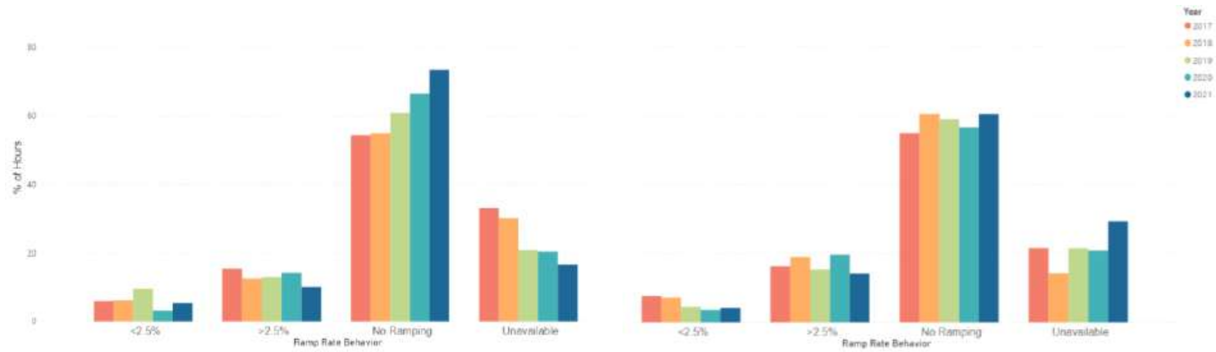
Figure 9: Histogram of Generation Loading for Circulating Fluidized Beds *(left)* and Pulverized Subcritical Coal *(right)*



The average plants operate under baseload operation, but also with cycling operations and frequent outages
Note: 2021 data is only up to June 2021

From these figures, both CFB and PSC operate at 75% to 100% generating levels around half of the time. However, the significant percentage between 25% to 75% generating level could indicate that plenty of these plants have been in a cycling condition more frequently. Moreover, the high frequency of the 0% loading levels (around 20% of the year) indicates a high occurrence rate of outages in these plants.

Figure 10: Histogram of Average Hourly Ramp Rates for Circulating Fluidized Beds *(left)* and Pulverized Subcritical Coal *(right)*



< 2.5% – Less than 2.5% change in loading from the previous hour
> 2.5% – More than 2.5% change in loading from the previous hour
No Ramping – No change in output from the previous hour
Unavailable – Intervals where the loading was 0-0.5 MW, or not operational
Note: 2021 data is only up to June 2021

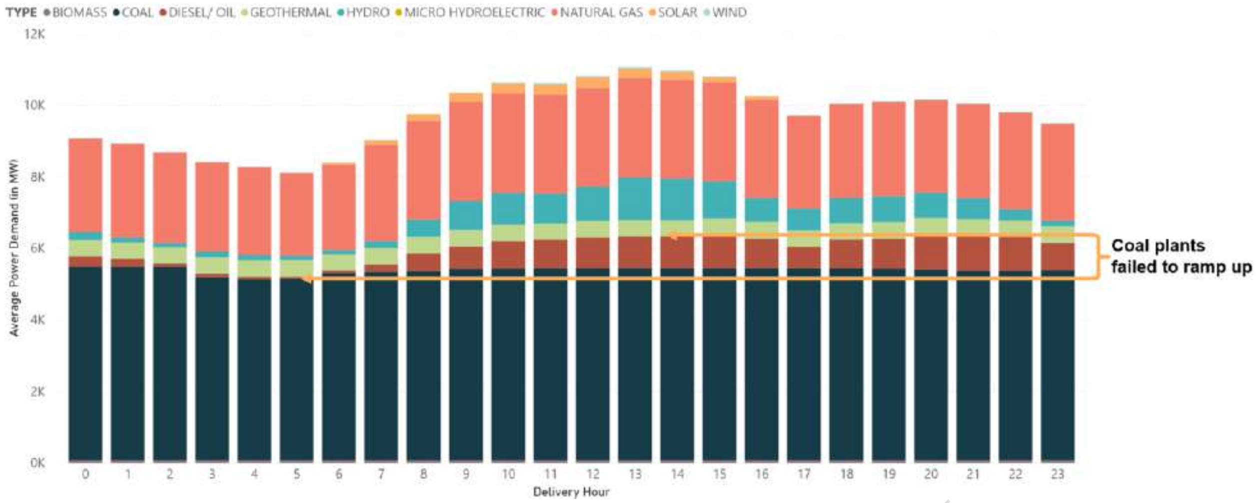
Observing the Histogram of Average Hourly Ramp Rates, the average coal plant operates better than Sual unit 2 in supplying baseload. However, the average coal plant in 2017-2020 was in baseload only 55% of the time while ramping significantly 15% of the time. This observation shows that Sual unit 2 is not an isolated case in terms of coal plants operating as more than baseload.

This ramping up and down in the operation of a coal-fired power plant comes with a cost. Since this type of plant is considered an inflexible plant, it can only adjust its power generation output to a limited degree. In fact, according to the study published by the U.S. National Association of Regulatory Utility Commissioners in January 2020, the increased cycling operations of coal-fired plants have a considerable impact on the reliability and cost of the plant [6]. Due to the more frequent cycling, the following effects may occur: wear-and-tear of plant equipment increases, shortened equipment lifespan due to thermal fatigue, thermal expansion, increased corrosion, and increased cost of start-up fuel. It was highlighted by the study that without proper maintenance of the plant during these operations, unexpected plant outages become more frequent.

3.2. Coal plants are experiencing intermittency

We have established that the cycling operation frequently occurs with these coal power plants, which can potentially degrade its operating condition. We now determine how much these cycling operations degrade their reliability. This question is very relevant because if a coal plant suddenly goes offline, there will be an energy shortage leading to other more expensive plants that must replace it in the energy mix, and this is what occurred during the Summer of 2021.

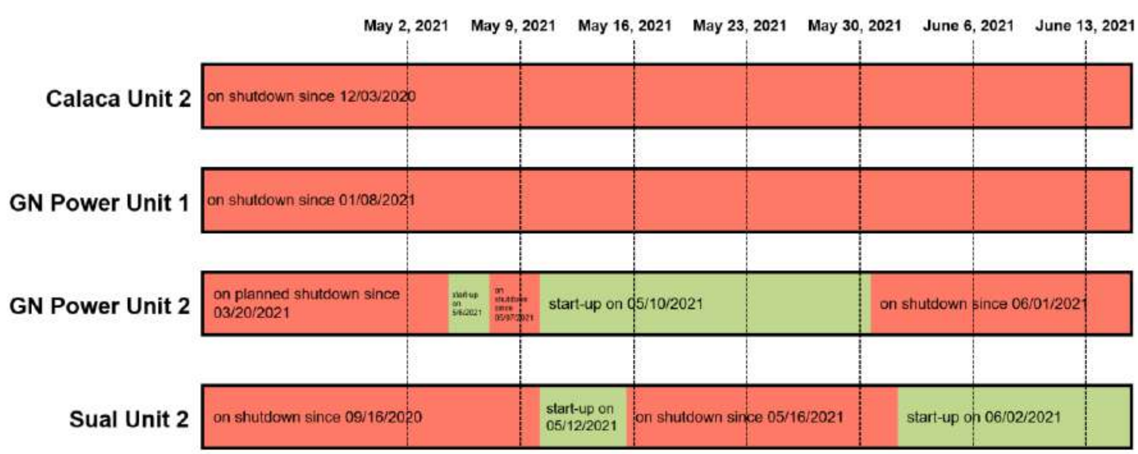
Figure 11: Hourly Power Demand from May 31 to June 1, 2021



During the outages in Summer 2021, the cumulative coal-fired power plants failed to ramp up accordingly. This necessitated the dispatch of expensive plants such as Diesel and Oil-based power plants.

From May 31 to June 1 of 2021, we can observe that a chunk of the coal in the energy mix failed to ramp up accordingly – unlike what it used to in the previous year as seen in Figure 4. This can be attributed to the simultaneous outages experienced by the coal-fired power plants in the country – namely, the GN Power Unit 1, GN Power Unit 2, Sual Unit 2, and Calaca Unit 2 – which resulted in a decrease of 1,500MW in electric power supply. Alongside this, there was a 40% supply gas restriction of Malampaya that derated the output of SLPGC Unit 1, Ilijan Unit 1, and Ilijan Unit 2 – which further resulted in almost 500MW of unused power capacity. The decrease in electric power supply during the unavailability of both the coal and natural gas plants had been offset using more expensive Diesel and Oil-based power plants.

Figure 12: Outage Timeline of Four Baseload Coal-fired Plants during Summer 2021



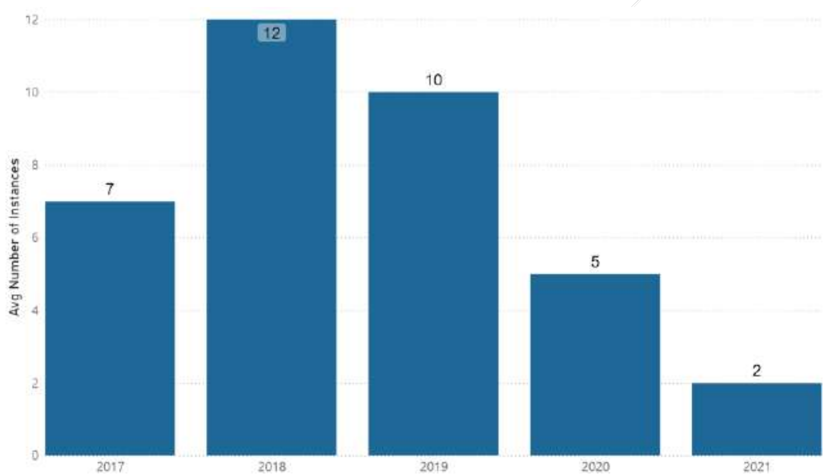
Red – Power plant on shutdown
Green – Power plant on start-up or running

Typically, coal-fired power plants undergo a planned outage every year for maintenance. Based on ERC Resolution no. 10, Series of 2020, effective 2021, the total allowed planned outages for Pulverized Subcritical Coal (PSC) and Circulating Fluidized Beds (CFB) are 27.9 days and 15.4 days, respectively [7]. However, the operational data of Sual Unit 2 shows that there are extended outages that span 6-to-8 months, which is very unusual and uneconomical to be a plant turnaround maintenance.

Additionally, besides these annual extended outages, we can observe several other outages from the 2.5-year operational data of Sual Unit 2 in Figure 5 and GN Power Mariveles Unit 1 in Figure 8. The short-duration outages are still observed in these coal-fired power plants even after extended outages. It is reasonable to expect that this should not happen since a planned and extended outage should have addressed all impending equipment failures in the plant. This recurring on and off operation, even after their planned and extended outage, had a significant effect during the Summer of 2021 – particularly with Sual Unit 2 and GN Power Mariveles Unit 2 that contributed to the expensive electricity and rotating blackouts experienced.

A drawback for coal-fired power plants since they operate in economies of scale is their susceptibility to breakdowns. The single unit of the power plant comprises several interdependent pieces of equipment – in which each one can experience its mechanism of failure. If one critical piece of equipment fails, this can cause a cascade that ultimately shuts down the entire unit resulting in an outage. In the case of these intermittent coal plants, it is a possibility that their various critical equipment (or parts thereof) experience their mechanism of failure at different rates – and that the existing preventive and predictive maintenance programs of the plant cannot reliably forecast the operating lifespan of the equipment. Thus, any random failure of any equipment can scale up and cascade to a total plant shutdown.

Figure 13: Number of Outage Instances for Sual Coal-fired Power Plant Unit 2



This plant experiences many other outages besides the annual planned outage.
Note: 2021 data is only up to June 2021. Additionally, for baseload plants a 0.5 MW output is considered negligible residual output due to its large capacity.

Looking at the number of plant outage instances, Sual Coal-fired Power Plant Unit 2 experienced several outages ranging from 5 to 12 instances annually and averaging to 8.5. We defined an outage instance as the number of occurrences where the power output of the power plant has been reduced to 0-0.5 MW (the plant is on shutdown), regardless of the duration of the shutdown. This indicates that besides the annual planned outage, the plant also experiences other outages annually.

Drilling down to the cause of the outages, we look at the system operator advisory event logs. From here, we can see that majority of these outages are in fact unplanned outages – in which one of the most common causes of these coal plant outages are boiler tube leaks This is particularly the case since the frequent cycling operation can produce thermal fatigue and thermal expansion as the operating temperature of the boiler fluctuates. This can cause increased wear-and-tear and elevated corrosion rates – which ultimately reduce its operating lifespan.

Figure 14: System Advisory Logs of the outages experienced by Sual Coal-fired Power Plant Unit 2

1 lrcc 2019-02-21 10:54:13: sual 2 (86mw) tripped at 1048h (**unplanned outage**). lowest freq = 59.685hz.
2 lrcc 2019-02-21 12:22:33: sual 2 (75mw) tripped at 1155h (**unplanned outage**). lowest freq = 59.72hz
3 lrcc 2019-03-05 19:56:00: sual 2 (124mw) tripped at 1943h (**unplanned outage**)
4 lrcc-06/01/2019 19:54: for info: sual 2 tripping at 1918h due to actuation of buchholz relay of generator transformer (**unplanned** outage)
5 lrcc-06/14/2019 21:40: sual 2 shutdown at 2139h (**planned** outage)
6 lrcc-07/19/2019 21:38: sual unit 2 shutdown at 2136h (**planned** outage)
7 lrcc-09/02/2019 22:15: sual 2 online at 2211h (**unplanned** outage).
8 lrcc-10/20/2019 23:49: sual unit 2 shutdown at 2348h. **planned** outage
9 lrcc-11/15/2019 07:55: sual unit 2 on emergency shutdown at 0750h. boiler tube leak. **unplanned** outage
10 lrcc-11/22/2019 19:27: sual unit 2(173mw) tripped at 1922h. lowest frequency=59.607hz (**unplanned** outage)
11 lrcc-12/15/2019 08:59: sual unit 2 on emergency shutdown at 0857h. boiler tube leak. **unplanned** outage
12 lrcc-02/21/2020 23:35: sual 2 shutdown at 2334h (**planned** outage)
13 lrcc-04/16/2020 23:43: sual unit 2 shutdown at 2336h. **unplanned** outage.
14 lrcc-04/30/2020 23:37: sual 2 offline at 2336h (**unplanned** outage).
15 lrcc-06/26/2020 23:44: sual unit 2 shutdown at 2342h. (**unplanned** outage)
16 lrcc-09/16/2020 15:02: system advisory: ald occurred at ngcp and meralco feeders at 1445h due to tripping of sual 2 at 639mw. lowest frequency=58.925hz (**unplanned** outage)
17 lrcc-05/16/2021 01:20: sual unit 2 shutdown at 0028h (**unplanned** outage)

This plant has experienced a lot of unplanned outages from 2019 to 2021

Unplanned outages are one of the factors that can halt the cost-effective and reliable operation of the grid; this is why predictability of the power plant operation is highly valued. With a predictable operation of a power plant, the grid operator can anticipate and effectively dispatch the most cost-effective power plants in replacement for the power plants that are expected to be down.

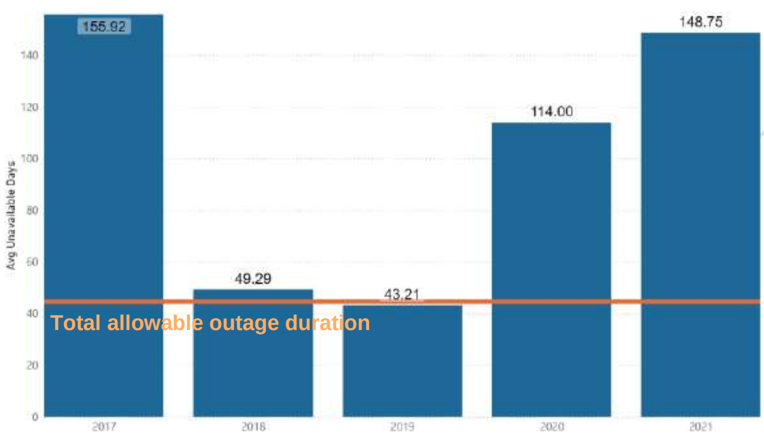
However, as shown in Figure 5, the downtime of these coal power plants is observed to be random in nature. This randomness makes it harder for the grid operator to dispatch the most cost-effective energy supply in time. Thus, more expensive power plants that are next-in-line to be dispatched are being used– like diesel power plants.

Now, to assess the 'intermittency' of these plants in the previous years – whether if these are still acceptable – we compared the total outage duration of the power plants to the maximum allowable outage duration limit established by the ERC effective 2021. According to ERC, the benchmark values prescribed are determined based on the computed Reliability Performance per Technology, as well as the Number of Outage Days per Year, by utilizing information from Actual Events Reports from 2015 to 2019 as submitted by generation companies in the Philippines [7]. Important to note that power plants that exceed this limit before 2021 will not be penalized since it was not effective previously this year. For this analysis, the threshold was used on the previous years since it still serves as a good benchmark to assess the historical performance of these plants.

Moreover, this paper took into consideration combined outage duration for planned and unplanned outages to simplify the analysis. Ultimately, if the power plant has exceeded the maximum planned and unplanned outage duration, it would mean that it has also exceeded either type of outage duration – both of which should be unacceptable. In addition, take note that this analysis only looked at the operational data and did not delve deeper on the specific reasons why these outages happened for each plant. There are certain instances wherein planned outages can exceed beyond the acceptable outage duration limits if deemed necessary by the System Operator and the Transmission Network Provider – but the reason for such extension shall be incorporated into the Grid Operations and Maintenance Program (GOMP) that is submitted quarterly to the ERC to assess whether these reasons are indeed acceptable [7].

For a Pulverized Subcritical Coal Plant, the maximum allowable outage duration for planned and unplanned outages is 44.7 days [7]. The Sual Coal-Fired Power Plant Unit 2 has exceeded this limit in 2021, registering 148 days of outages which is more than three times the allowable outage duration limit. Additionally, from a historical view (Figure 15), this plant consistently cannot meet the ERC-mandated total allowable outages for both planned and unplanned outages causing extended unavailability in the customers' perspective.

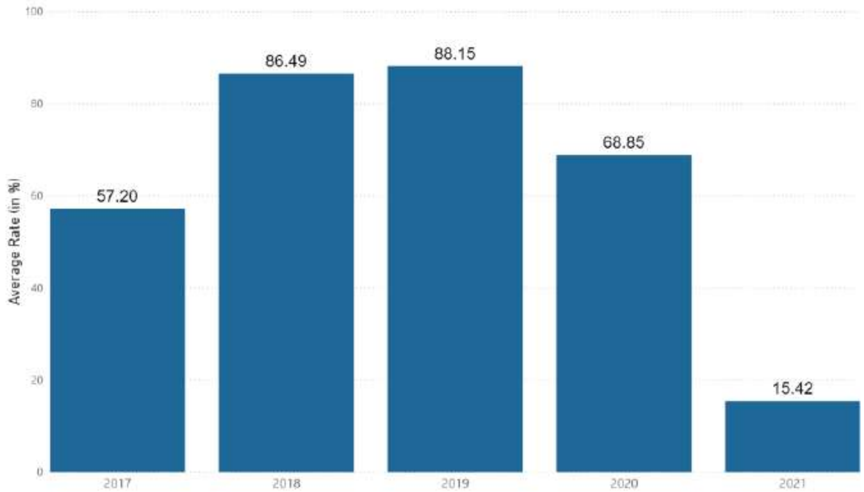
Figure 15: Outage Duration (in days) of Sual Coal-fired Power Plant Unit 2



This plant has historically exceeded the allowable limit mandated by ERC.
Note: 2021 data is only up to June 2021

Translating the outage durations into availability rates, we can see that this plant is unavailable for an average of 34% of the time annually. We defined the availability rate as the percentage of the number of hours that the plant is operating at any generation loading to the total number of hours in a year – which in the case of baseload power plants, it will be 8760 hours annually. All hours that the plant recorded a 0-0.5 MW power output have been considered as its unavailability time.

Figure 16: Availability Rates of Sual Coal-fired Power Plant Unit 2



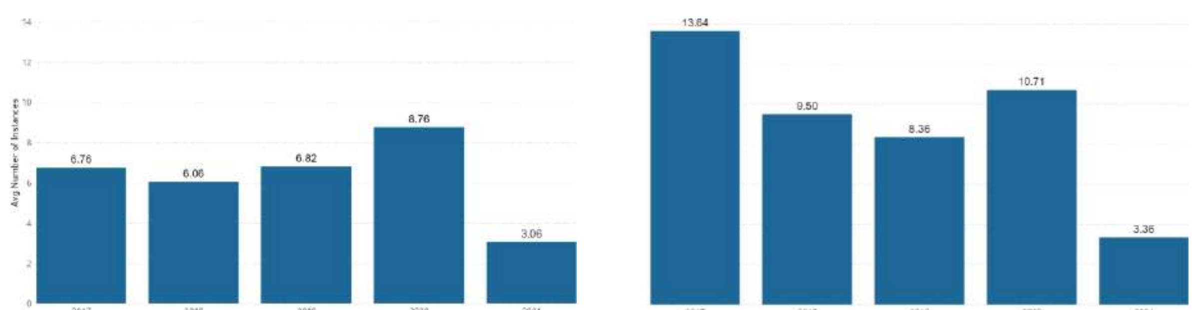
This plant has been unavailable about 31% of the time annually
Note: 2021 data is only up to June 2021

All of these operational data suggest that the outages frequently experienced by Sual Coal-fired Power Plant Unit 2 have been recurring year after year and have historically exceeded the maximum allowable limit even before the pandemic hit.

Now, are the outages experienced by Sual Coal-fired Power Plant Unit 2 an isolated case? Do other coal-fired power plants experience the same fate?

Focusing on the outage instances experienced by these types of plants (Figure 17), we can observe that they are numerous. For an average Circulating Fluidized Bed (CFB) coal fired-power plant, they experience 6 to 9 outage instances annually. This number is higher on PSC-fired power plants with 8 to 14 outages instances annually. Again, this indicates that besides the annual planned outage, the plant also experiences several other outages annually. This is not economical for any baseload power plant considering high startup costs and lower effective capacity factors.

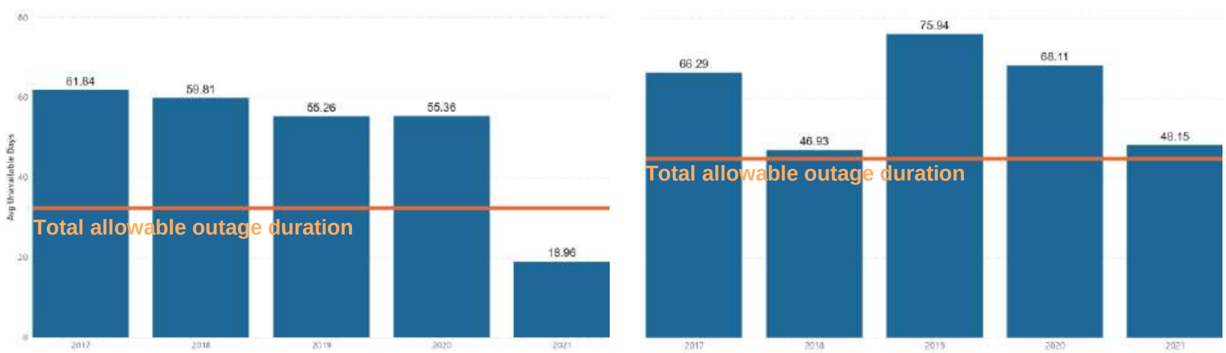
Figure 17: Number of Outage Instances for Circulating Fluidized Beds *(left)* and Pulverized Subcritical Coal *(right)*



The plants experience other outages besides the annual planned outage.
Note: 2021 data is only up to June 2021

In relation to the ERC Resolution [7] of maximum allowable duration of planned and unplanned outages, effective 2021, historical data shows that the average CFB and PSC power plants have consistently exceeded this limit of 32.3 days and 44.7 days, respectively. It is important to note that while the CFB-type power plants utilize the latest technology, they still exceed the ERC-mandated allowable outage duration even before the pandemic hit.

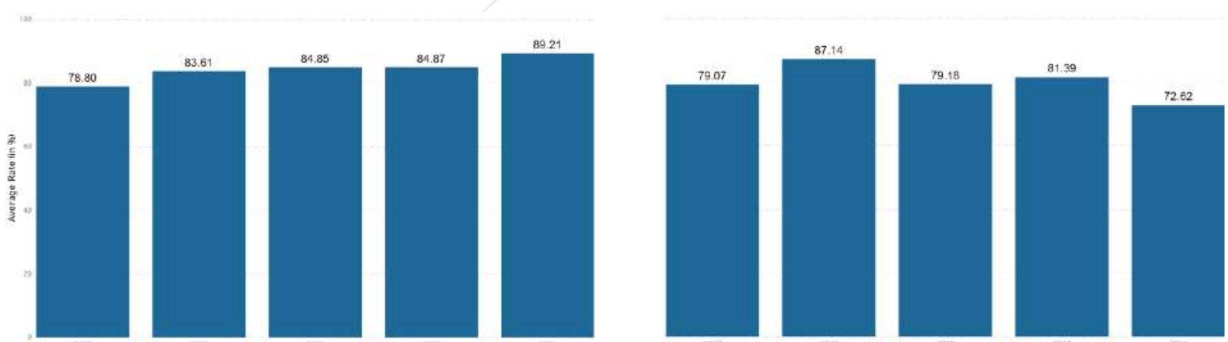
Figure 18: Outage Duration for Circulating Fluidized Beds *(left)* and Pulverized Subcritical Coal *(right)*



The different types of coal plants have historically exceeded the allowable limit mandated by ERC.
Note: 2021 data is only up to June 2021

Because of this long outage duration that exceeds the ERC-mandated limits, these coal-fired power plants are unable to provide power to the consumers. For both the CFB and PSC, these plants are unavailable for an average of 20% of the time annually.

Figure 19: Availability Rates for Circulating Fluidized Beds *(left)* and Pulverized Subcritical Coal *(right)*



The different types of coal plants are unavailable about 20% of the time annually.
Note: 2021 data is only up to June 2021

On a more granular basis, the heat map below shows the different power plants that have exceeded this maximum allowable planned and unplanned outage duration. Based on the data, the majority of these coal plants have exceeded the limit. Certain plants consistently did not meet this standard, while others had a more sporadic performance. However, note that not exceeding the outage limit does not mean they did not experience intermittency and unplanned outages as described before.

Interestingly, the newly commissioned plants (less than 3-4 years) have also shown to be exceeding the duration limit – which, for a newly constructed plant to exceed this level of unreliability is questionable and unacceptable.

Figure 20: Heat map of Outage Days for Circulating Fluidized Beds *(left)* and Pulverized Subcritical Coal *(right)*

Facility Name	Installed Capacity	2017	2018	2019	2020	2021
ANDA	83.70	Red	Red	Green	Red	Green
CEDC U1	83.70	Red	Green	Red	Red	Green
CEDC U2	83.70	Red	Green	Green	Red	Green
CEDC U3	83.70	Red	Green	Green	Green	Green
KSPC U1	103.00	Green	Red	Green	Green	Green
KSPC U2	103.00	Green	Green	Red	Green	Green
PCPC U1	135.00	Red	Red	Green	Red	Green
PEDC U1	83.70	Green	Red	Red	Green	Green
PEDC U2	83.70	Green	Red	Green	Green	Green
PEDC U3	150.00	Red	Red	Green	Red	Green
SCPC U1 (SMC LIMAY U1)	150.00	Red	Red	Red	Red	Green
SCPC U2 (SMC LIMAY U2)	150.00		Red	Red	Red	Green
SCPC U3 (SMC LIMAY U3)	150.00		Green	Red	Red	Green
SCPC U4 (SMC LIMAY U4)	150.00			Green	Red	Green
SLPGC U1	150.00	Red	Red	Red	Red	Green
SLPGC U2	150.00	Red	Red	Red	Red	Red
SLTEC PUTING BATO U1	135.00	Green	Red	Red	Red	Green
SLTEC PUTING BATO U2	135.00	Red	Red	Red	Red	Red
TVI U1	170.00	Green	Red	Red	Red	Green
TVI U2	170.00	Green	Red	Red	Red	Red
UPPC	30.00	Red	Red	Red	Red	Red

Facility Name	Installed Capacity	2017	2018	2019	2020	2021
APEC	52.00	Red	Green	Green	Red	Green
CALACA U1	300.00	Red	Green	Red	Green	Green
CALACA U2	300.00	Red	Red	Red	Red	Red
MARIVELES U1	345.00	Red	Green	Red	Green	Red
MARIVELES U2	345.00	Red	Red	Red	Red	Red
MASINLOC U1	330.00	Green	Green	Green	Red	Green
MASINLOC U2	344.00	Green	Red	Red	Green	Green
PAGBILAO U1	382.00	Red	Red	Green	Red	Green
PAGBILAO U2	382.00	Green	Green	Green	Red	Green
PAGBILAO U3	420.00		Green	Red	Green	Green
PETRON RSFFB	140.00	Red	Red	Red	Red	Green
QUEZON POWER	511.00	Red	Red	Green	Green	Green
SUAL U1	647.00	Red	Red	Red	Green	Green
SUAL U2	647.00	Red	Red	Green	Red	Red
TPC TG4 (Sangi Station)	26.30	Green	Green	Green	Green	Green

Red – Power plant has exceeded the maximum allowable outage duration
Green – Power plant has met the maximum allowable outage duration
Blank – Power plant has not started operating yet or is still in the commissioning stage
Note: 2021 data is only up to June 2021

Overall, the data have shown that outages experienced during Summer 2021 are a direct result of the unreliability of the coal plants – and that the outages are not an isolated case after all. The operational data of the average CFB and PSC power plants show that the outages they experienced are not at all random since the outages are frequently recurring year after year.

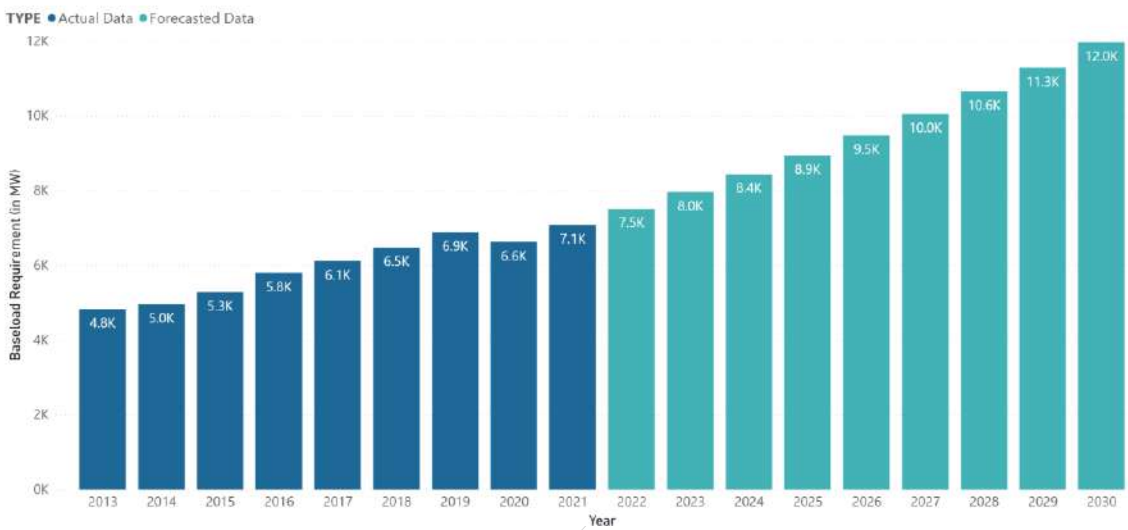
3.3. Additional capacity of coal plants is no longer needed

The notion that each power generating plant must be available for 24-hour power delivery for a grid system to be effective is flawed. It is the grid's ability as a whole to meet demand that is important [8]. We need the grid, as a whole, to have a reliable 24-hour power delivery which can be achieved by sourcing from various supply options. Supply options include variable renewable energy sources such as wind and solar, flexible power plants such as pump-storage hydro, distributed biomass power plants, simple cycle gas power plants, and even oil-fired engine generators. The basis of choosing capacities to add should not be on how it can provide a baseload requirement but on the most cost-effective combination of power generating technologies.

The previous sections have shown that baseload power plants are operating as more than baseload by cycling to provide intermediate power. Looking at our current baseload capacity in Luzon as of December 2020, the installed power capacity of baseload power plants such as coal, natural gas, and geothermal is 11,300MW. However, our Luzon's baseload requirement only ranges from 6,000MW to 7,500MW all year round. This signifies that we already have an overcapacity for baseload power plants and that we no longer need any additional baseload power plants in the Luzon grid today.

In terms of long-term planning, the 2030 baseload requirement for Luzon was forecasted by computing the average power demand during the off-hours of the day and projecting previous historical baseload demand growth into the future. Results show that the baseload requirement at Luzon in the year 2030 is about 12,000MW – which is only slightly above the existing baseload capacity of the grid today. However, note that 5,878MW of committed baseload capacity and 8,910MW of indicative baseload capacity are already in the pipeline in the next few years – which will further overinflate the already inflated baseload capacity of the grid.

Figure 21: Actual and Forecasted Baseload Requirements in Luzon



Projecting the baseload growth into the future and considering additional baseload capacities, we will still have an overcapacity of baseload power plants

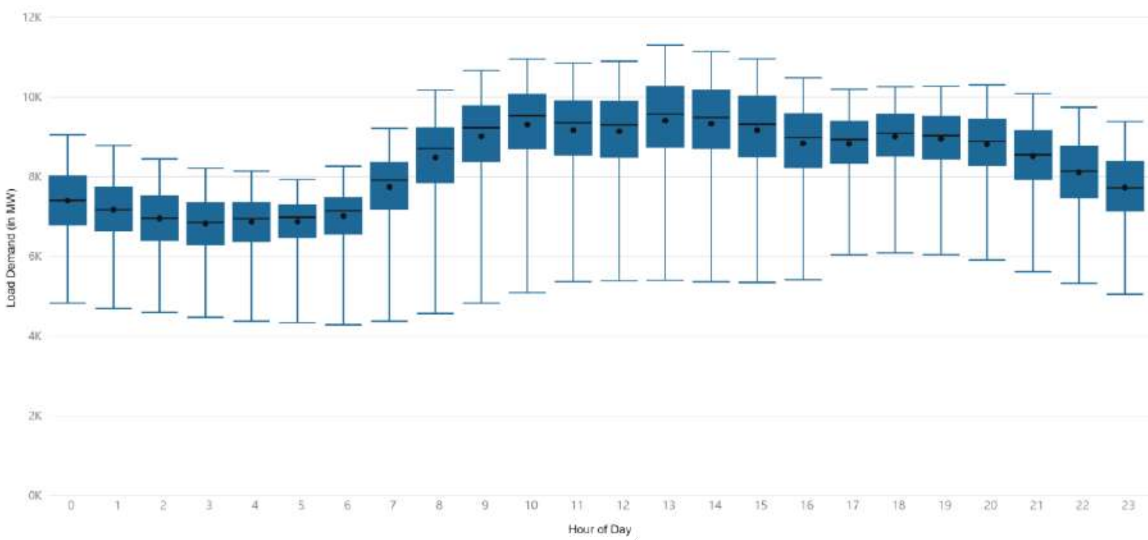
Note: Only the Luzon grid was used for this forecast to simplify the analysis, and it is the largest grid currently.

As presented above, the Philippines already has an overcapacity of baseload power plants, some being operated more as intermediate plants. This overcapacity is also reflected in the total installed capacity of the existing power plants in the grid. We currently have approximately 26,000MW of installed capacity in the grid, in which 54% share of this capacity accounts for coal and natural gas plants. Meanwhile, the system peak demand in the entire Philippines is only about 16,000MW. However, despite this huge overcapacity and more coal-fired power plants are in the pipeline, we still experience power shortages

Besides the unreliability and intermittency experienced by the coal power plants, another reason behind the power outages that we still experience is the limitations in the operation of these baseload power plants. These plants cannot ramp up and down easily and quickly. This limitation makes it impossible to dispatch coal during peak periods only – this is the time where we need the most power. In short, when we have too many baseload power plants, we will have too much power when we do not need it, and not enough when we do.

Another constraint in the grid is the risk that baseload power plant introduces to the grid. Since baseload power plants supply large chunks of energy to the grid – whenever they encounter problems, they have a large impact on the grid. For example, if Sual Coal-fired power plant, which is the largest baseload power plant in the Philippines at 647MW encounters a power outage, this large chunk needs to be replaced immediately. The system response for an outage this big would be to dispatch expensive power plants or drop loads – and in both scenarios, the consumers are on the losing side. In place of a single large power generating unit, it is more optimal to have distributed energy sources deployed to the grid. Because if a random outage occurs, it will be much easier for the grid to adjust if the grid is not solely relying on these centralized power generating technologies with large generating capacities.

Figure 22: Electricity Hourly Load Profile at Luzon in 2019



The Luzon load demand has a huge variability as evident on the wide span of each of the boxplots

Lastly, we must take note of the primary characteristic of the Philippine load profile – that it is inherently variable. It changes by the time of day, day of the week, and season of the year. As an example, looking at the body of the boxplot in Hour 13, we can see that the data points from the 1st quartile to the 3rd quartile vary by about 1,500MW. This capacity is about two to three of our largest coal power plants – which shows that the demand is dynamic. If more baseload coal power plants are constructed to meet this high variability of the load demand, it would entail the additional plants to still operate in a cycling condition. This would further aggravate the existing problems that coal power plants experience, such as their unreliability due to cycling operations.

Because of this, we need a heterogeneous mix of generators that can cope with the demand variability while still providing round-the-clock electricity, and this is not achievable by investing heavily in generators that can only provide baseload requirement. [5]. Thus, we no longer need additional baseload coal plants. What we require now are flexible power plants that match the variability of the demand instant by instant.

Existing policies by the DOE have affirmed the conclusion of no longer needing coal, as seen in the moratorium on greenfield coal power plants that took effect on October 27, 2020 [2]. The moratorium opens up the possibilities for increasing the share of variable energy sources in the supply mix.

4. Variable Renewable Energy (vRE) plants are reliable and can address our needs

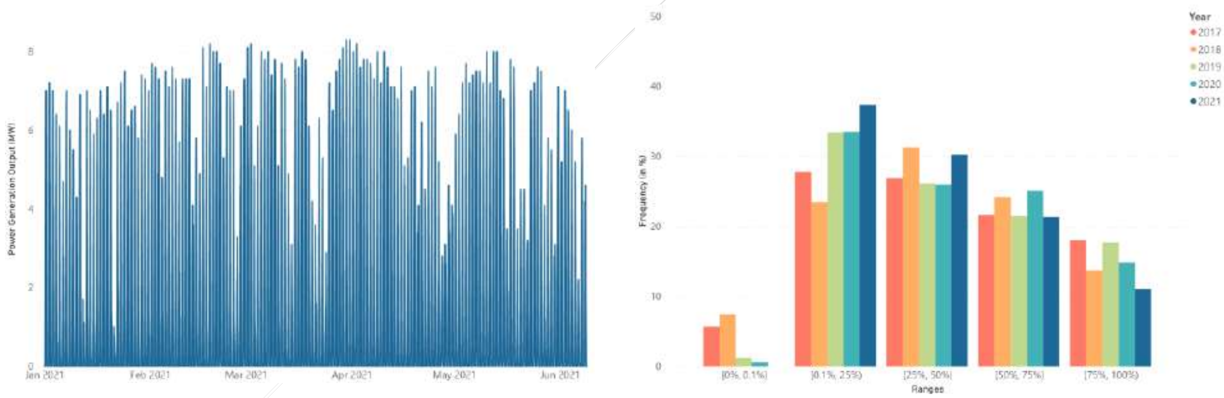
4.1. vRE is variable, not intermittent in a way that makes them unreliable

As the category name suggests, the power generation output of variable Renewable Energy (vRE) resources are variable in nature – thus, it can change depending on several factors. Unlike a conventional coal-fired power plant, whose output is controllable at will, wind speed and solar irradiance cannot – this lack of control is why people have branded it as an intermittent source of energy. However, this intermittency is often misinterpreted and rarely discussed from a practical perspective.

The Oxford dictionary defines “intermittent” as “stopping and starting, often over a period of time, but not regularly.” This definition suggests that an intermittent power plant experiences a recurring on and off situation. However, just because a power plant starts and stops in a manner that is not controllable does not immediately mean that they are unpredictable. While solar and wind RE outputs are not controllable, when and how much output they will generate is easily predictable through day and night cycles, weather, and seasonal forecasts. This predictability outweighs its intermittency as long as proper implementation of RE projects, necessary policies such as the Philippine Grid Code, and improvement in system design are done to harness these scheduled outputs.

Looking at the historical operation of a solar plant owned by First Cabanatuan Renewable Ventures Inc. in Cabanatuan, Nueva Ecija, Philippines, we can see that the power generation fluctuates daily based on the day and night cycle. Additionally, we can notice that the magnitude of the power generation changes daily due to the different atmospheric conditions – such as clouds.

Figure 23: 2021 FRCV Plant Power Generation Output *(left)* and Histogram of Generation Loading *(right)*

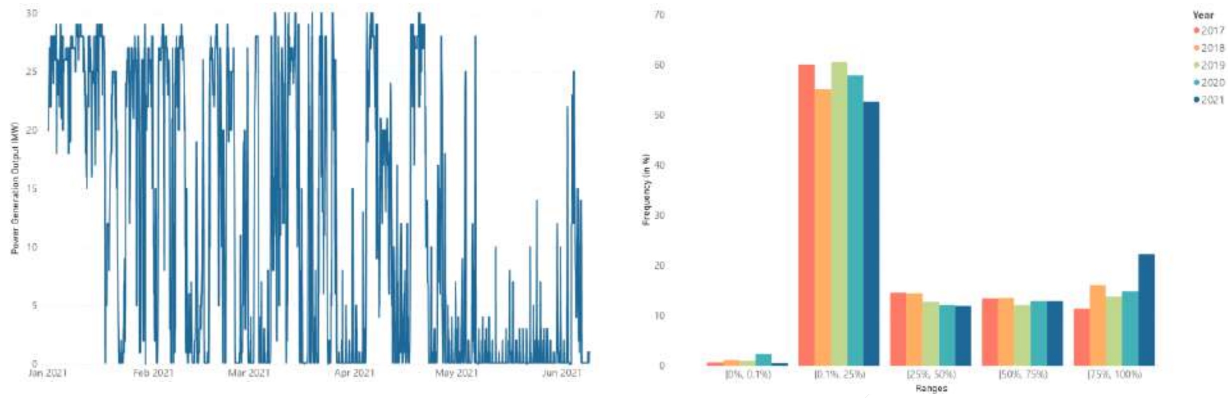


FRCV plant operates under variable generation since the frequency of generation loading is distributed.

Translating this solar historical generation output into the histogram of generation loading, we can see that there is a distributed frequency of generation loading – which suggests that it operates under variable generation. Note that we only consider its solar generation output from 7 am to 5 pm since these are the only times when a solar plant is expected to produce power. The 6 am and 6 pm time intervals were not included to limit the impact of varying sunrise and sunset times throughout the months of the year.

Looking at the historical operation of a wind plant of North Wind Power Development Corporation in Bangui, Ilocos Norte, Philippines, we can see that again – the power generation fluctuates much more than solar plants. This is because wind plants experience much greater variability due to their high dependence on the season. This dependence on the season can be observed in the power generation from January to April which is significantly higher than that in May and June.

Figure 24: 2021 NWIND-1 Plant Power Generation Output *(left)* and Histogram of Generation Loading *(right)*

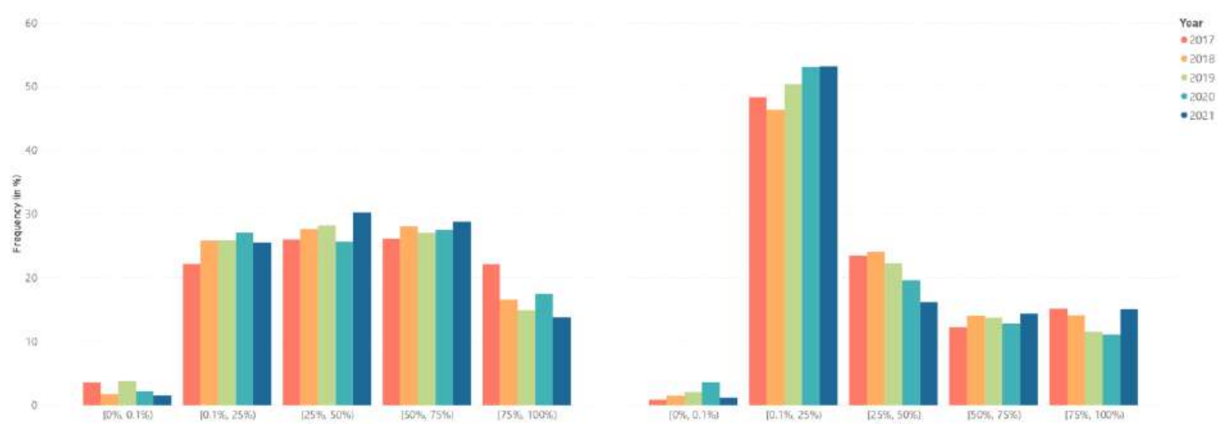


NWIND-1 plant operates under variable generation – but is highly dependent on the season

Translating this wind historical generation output into the histogram of generation loading, we can see that it outputs 0.1-25% loading around 55% of the time and above 25% the rest of the time. This variability is due to its high dependence on seasonality, which is expected of this technology.

To further confirm this variability, we take the representation of an average solar and wind power plant that is available on the Luzon and Visayas grid. The historical operation of an average solar and wind power plant shows that it does operate under variable generation. Moreover, the seasonality of the wind power plants is also observed on the average wind power plants.

Figure 25: Histogram of Generation Loading for Solar Plants *(left)* and Wind Plants *(right)*



This shows that the average solar and wind power plant operates under variable generation – however, wind power plants have a bias towards low generating levels due to their high seasonality
Note: 2021 data is only up to June 2021

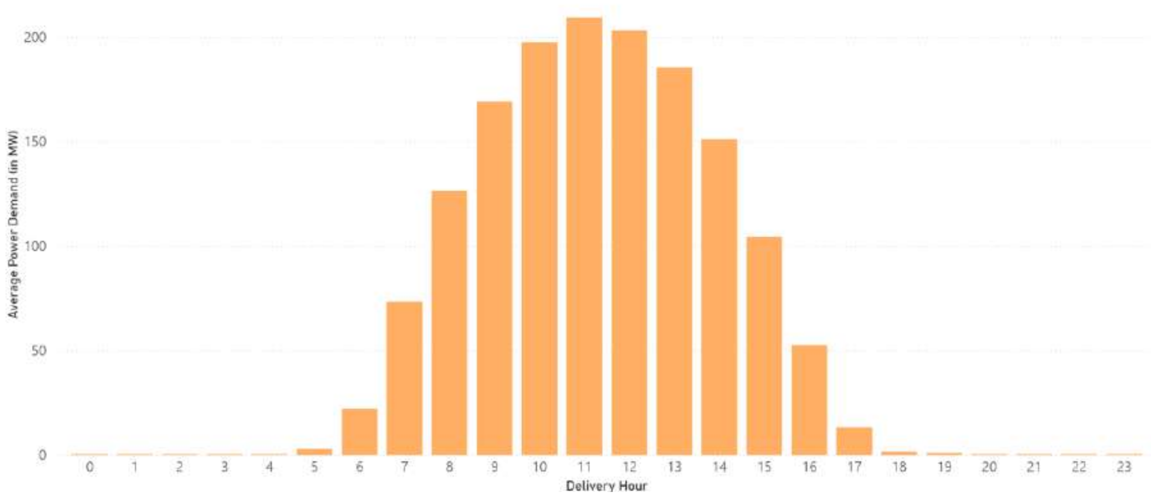
Based on the figure above, one thing to point out is the low levels of 0MW loading on both solar and wind power plants. This suggests that during the period we expect these sources to be running, they will reliably run. In other words, these power plants do not experience random starting and stopping of power generation output – they simply output variable generation. Understanding this variability lets us better plan their dispatch to the grid.

4.2. vRE can conveniently be dispatched and supply power during peak demand

While it is true that vRE cannot cover the baseload power demand round-the-clock – this was never the intended purpose of vRE. As presented above, the Philippines already have enough baseload power. What is needed today is to build a combination of different power plants that provide electricity cost-effectively and reliably – and to do that – we need flexible power plants that can address the variability of the load demand. In other words, baseload power plants' inability to provide flexible supply during peak hours when it is most needed is addressable by vRE as it is available at that time [5].

We know that solar power generation peaks during the daytime – and this generation profile coincides with the midday peak demand requirements of the grid (Figure 26). This makes it very amenable to be the source of power during these peak periods.

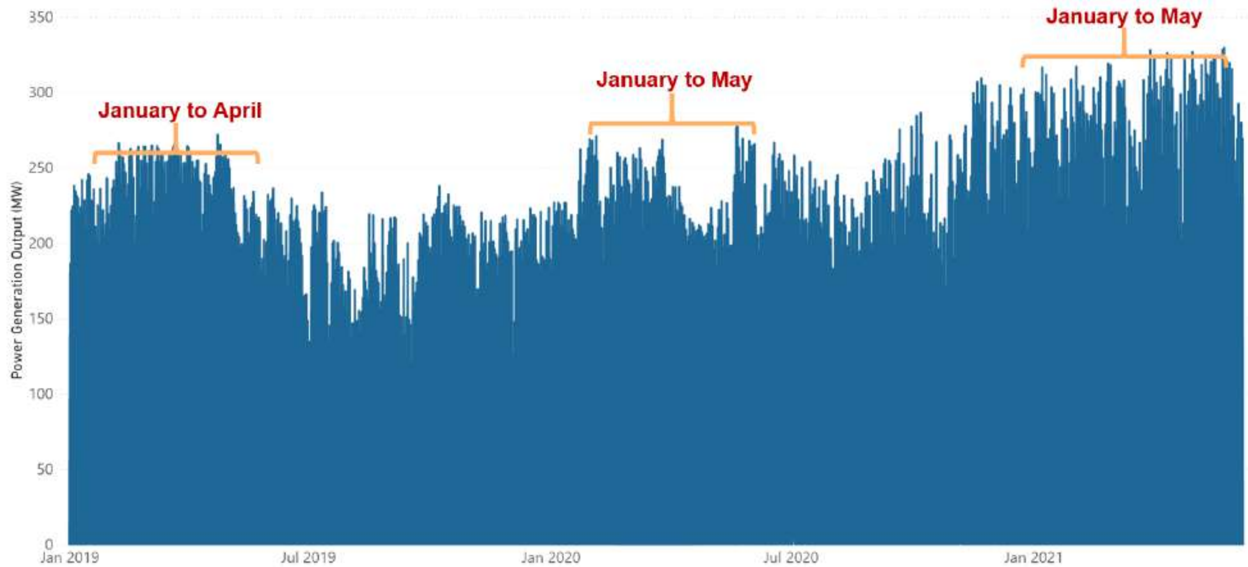
Figure 26: Average Daily Solar Generation Output at Luzon in 2019



The solar generation profile coincides with the midday peak demand requirements of the grid

Historical data shows that solar generation is available throughout the year – even with the rainy season experienced in some of the months. Another insight we can gather from Figure 27 is the variability of the solar plants, which peaks from January to May. All of these are what is expected for a solar power plant.

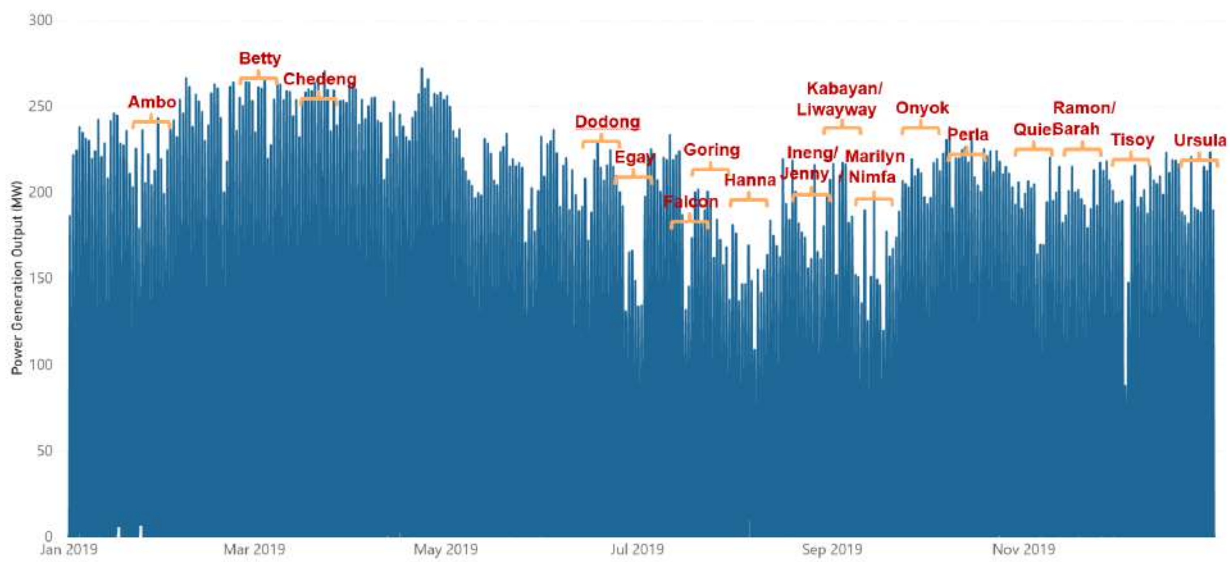
Figure 27: 2.5-year Generation Profile of Solar Plants at Luzon



Solar power generation is available throughout the year – even with the rainy season

Additionally, even with the frequent typhoons experienced in the Philippines, solar power generation is not completely disrupted. This is because since there are plenty of solar power plants that are installed on the grid, the intermittency and uncertainty experienced by an individual solar power plant are minimized when we look at it in an aggregated level.

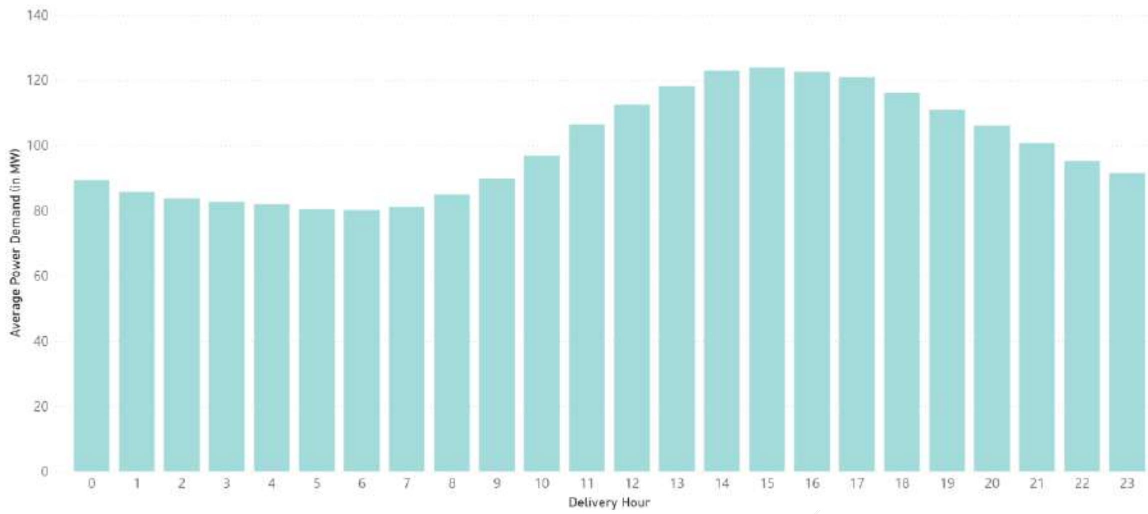
Figure 28: 2019 Generation Profile of Solar Plants at Luzon vs. Typhoons Experienced



Solar Generation is available even with the frequent typhoons experienced.

Now, for wind power plants, we can see in Figure 29 that the wind power generation peaks during the late afternoon. This generation profile also coincides with the peak demand requirements of the grid. This makes it amenable to be the source of power during these peak periods.

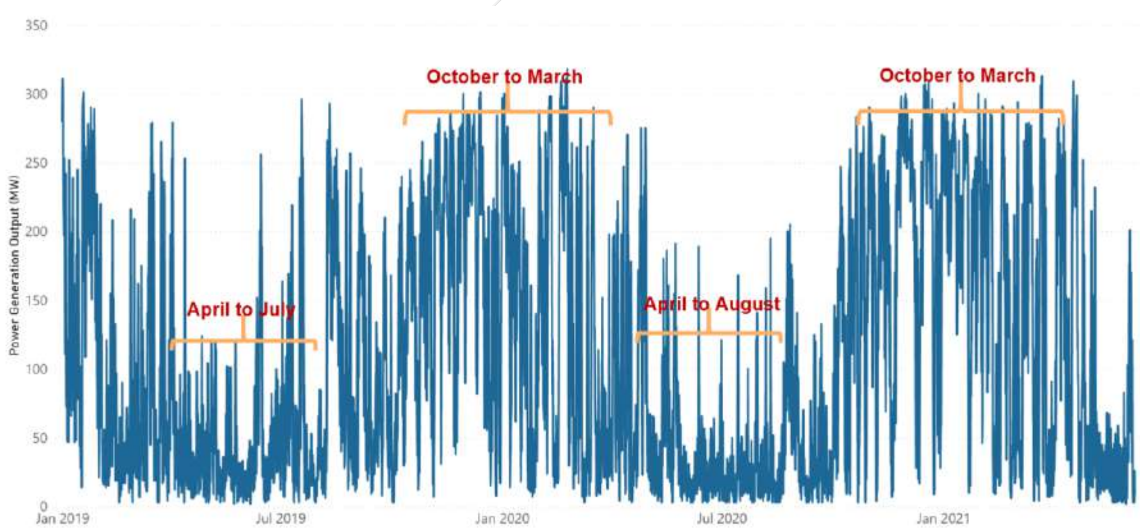
Figure 29: Average Daily Generation Profile of Wind Plants at Luzon in 2019



The wind generation profile coincides with the early evening peak demand requirements of the grid

Historical data of these wind power plants shows that it is variable, and it is also available throughout the year – however, its variability is highly seasonal. It ramps up from October to March, and ramps down during April to August – and this characteristic, is also what is expected of a wind power plant. Interestingly, the ramp-up coincides with the Northeast monsoon wind system during November to February. But take note that even when ramped down, wind power plants still produce power – just at a lower rate.

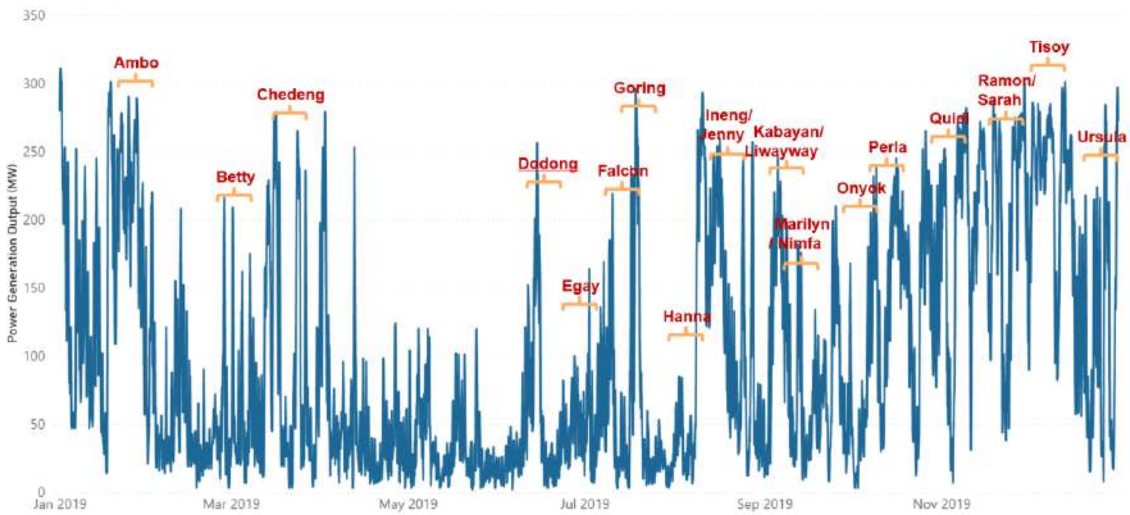
Figure 30: 2.5-year Generation Profile of Wind Plants at Luzon



Wind power generation is available throughout the year – but is highly seasonal

For wind power plants, we can observe that unlike in the solar plants, the variability and fluctuations did not cancel out for wind plants since we can still clearly see dips in the power generation (Figure 31). This is primarily due to the wind patterns in the Philippines that are dependent upon the same wind systems (Northeastern and Southwest Monsoon), they are not entirely diverse and independent from each other [8].

Figure 31: 2019 Generation Profile of Wind Plants at Luzon vs. Typhoons Experienced

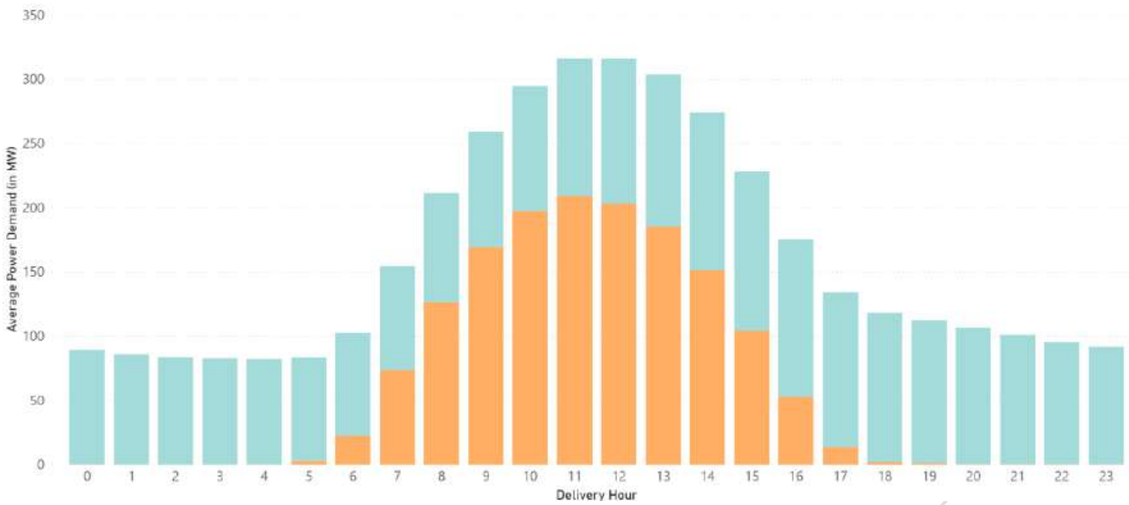


Wind Generation is available and can be affected by the frequent typhoons experienced.

Now, together, solar and wind generation adds to the electricity supply during peak hours. Take note that these variable renewable energy sources are also not flexible power plants – they cannot ramp up and down at the grid operator's will. Therefore, other flexible generators such as natural gas and hydroelectric power plants are also needed to complement the variable renewable energy sources.

Despite not being flexible, variable renewable energy sources coincidentally generate power during peak hours. If enough vRE plants were installed in the grid, existing coal plants would no longer need to ramp up and down significantly – thus, an increased RE penetration during peak hours could reduce the cycling operations of the coal plants which made them unreliable in the first place.

Figure 32: Average Daily Gen. Profile of Solar/ Wind Plants at Luzon in 2019



The combination of solar and wind power production can add to the supply during peak periods.

Therefore, the value of variable renewable energy to our existing electric grid is very promising because it can provide electricity generation at the right time. This will help us achieve an energy mix that is cost-effective and reliable – and reduce our dependency on much expensive Diesel power plants that run to complement the inflexibility of coal-fired power plants. This highlights again that variable renewable energy sources do not have to replace coal, but rather helps in achieving the right mix in our power system – a system in which different power generating technologies that complement each other [5].

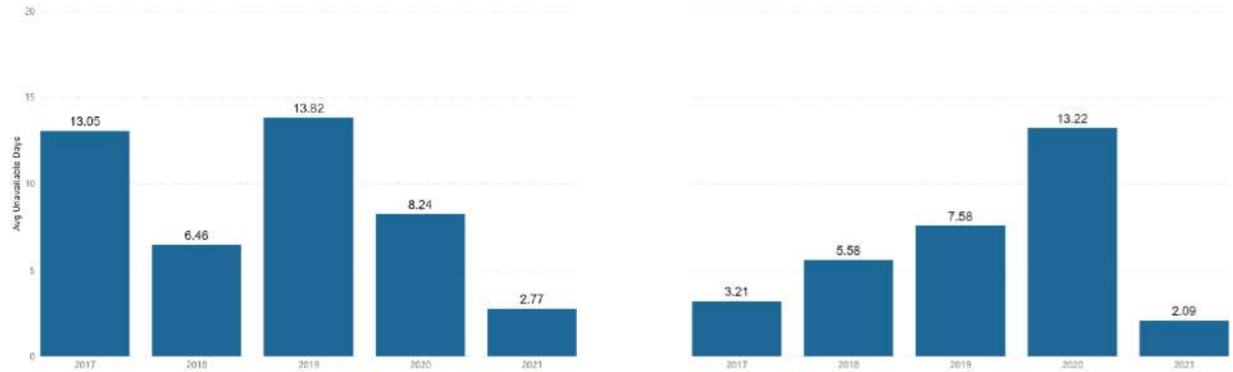
4.3. vRE has high availability rates and is accurately predictable

We have previously pointed out that if any power plant suddenly becomes unavailable, other power plants will have to step up and fill the void that is left by the unavailable power plant immediately. This highlights the need to have a power plant that is reliable and available when it is expected – to minimize the instances where other more expensive power plants would have to be dispatched as a replacement of the failed power plants.

Unlike the other power generation technologies, ERC did not mandate a total allowable planned and unplanned number of outage days that a solar or wind power plant can be on shutdown. But even so, we can see that the unavailability duration of these grid-connected solar plants is significantly lower than that of coal, geothermal, or biomass. The unavailability duration of a solar power plant is about 10 days (considering only operational hours 7 am to 5 pm), while the wind power plant is about 7 days. This shows that these variable renewable energy plants do not need extended outages to be maintained and does not experience recurring outages during their operations – which is in direct contrast to the baseload coal power plants.

Note that only grid-connected solar and wind power plants were considered for this analysis. Embedded plants were not considered as their outputs are consumed by their respective load centers before any excess goes to the grid. An embedded plant's downtime (or 0 MW output) may not mean it is on shutdown, but rather its load center may have higher consumption that reduced the total power exported to the grid to a lower value.

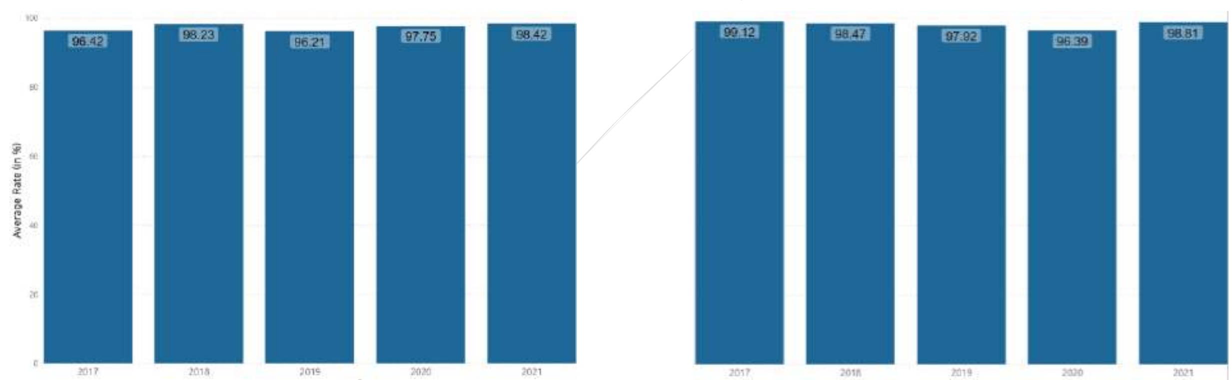
Figure 33: Unavailability Duration of Solar Power Plants *(left)* and Wind power plants *(right)*



Even without an ERC-mandated limit, the unavailability duration of solar and wind power plants are significantly less than that of other types of technologies.

Additionally, if we look at the unavailability rates of these solar plants from 7 am to 5 pm – we can see that these values are significantly lower than that of coal, geothermal, or biomass. This just shows that solar is much more available than these other types of plants.

Figure 34: Availability Rates of Solar Power Plants *(left)* and Wind power plants *(right)*



The availability rates of solar and wind power plants that are better than that of coal power plants

One factor that makes solar PV more reliable is its expected downtime during nighttime – wherein extensive preventive maintenance can be done when the power plant is not producing power. This avoids the need to have forced outages that can halt the power generating capability of the plant during daytime.

Another factor that adds to the reliability and availability of these vRE plants is modularity. The power generation for each module in a plant is independent of the other. Thus, when a module fails, no cascading failure will occur since they are running independently. A prime example of this is solar PV that comprises many small and modular panel circuits independent of each other. One circuit may undergo maintenance while the rest are still producing power.

To effectively utilize vRE, it is critical to gauge the uncertainty of the variable loading that is dependent on weather conditions. This uncertainty can cause a deviation of the vRE plant's actual generation to the forecasted value. Managing these deviations is vital since any deviations from the supply-demand balance will require a certain amount of reserves for regulating purposes.

With this, the WESM Rules require must dispatch generating units to comply with the forecast accuracy standards in respect of their submitted hourly projected outputs. Must-dispatch generating units are defined as qualified and registered renewable energy power plants such as wind, solar, run-of-river hydro, that are dispatched whenever its power generation is available.

The forecast accuracy requirement for these must-dispatch units is reflected on "Procedures for the Monitoring of Forecast Accuracy Standards for Must Dispatch Generating Units" which was established by the ERC and the Grid Management Committee on June 15, 2017 [9].

This manual provides that each must dispatch generating unit shall comply with the established standards for its Mean Absolute Percentage Error (MAPE) and Percentile 95 of the forecasting error (Perc95), as shown in Table 2. The two measures are set to 18% and 30%, respectively.

Table 2: Standard for Forecast Accuracy for Must Dispatch Generating Units

Technology	Standard	
	MAPE	PERC95
Solar	< 18%	< 30%
Wind	< 18%	< 30%
Run of River Hydro	< 9%	< 30%

Looking at the aggregated performance of all renewable energy units in the grid, we can see that the RE plants have consistently outperformed this metric. This result shows that the forecasting accuracy for RE plants is more than adequate. This high level of accuracy can be attributed to modern forecasting techniques which can make predictions based on factors that are highly dependent on natural systems.

Table 3: Aggregate Performance of Must Dispatch Generating units per Technology [10]

Technology	Region	Actual Performance					
		MAPE			PERC95		
		2019	2020	2021 YTD	2019	2020	2021 YTD
Run of River Hydro	**Luzon**	1.79%	2.42%	2.93%	6.68%	9.22%	5.94%
Solar		5.42%	3.67%	3.94%	15.34%	14.98%	16.81%
Wind		6.30%	6.18%	5.84%	17.43%	18.29%	17.80%
Run of River Hydro	**Visayas**	-	-	2.98%	-	-	16.24%
Solar		5.87%	3.48%	3.89%	17.99%	15.40%	17.93%
Wind		9.87%	8.52%	7.70%	28.15%	25.17%	21.86%

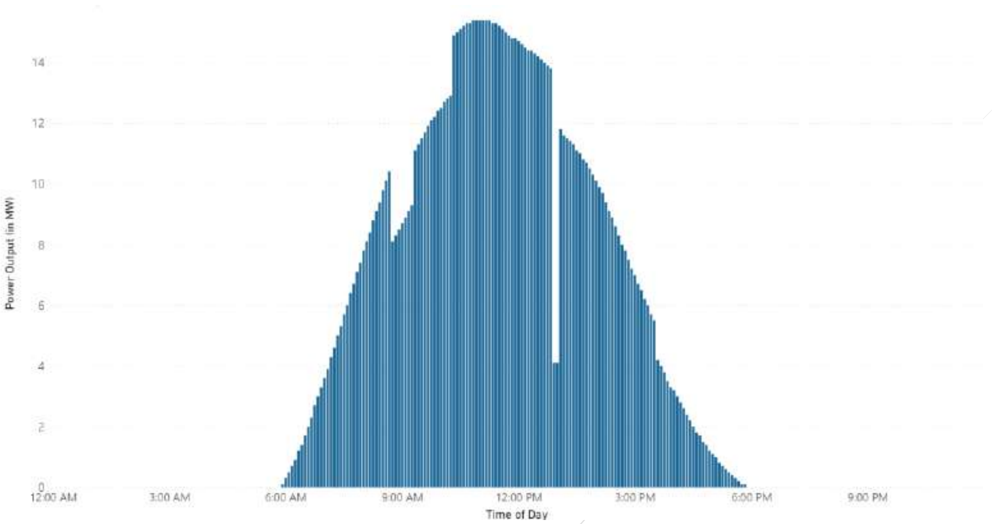
A good forecasting accuracy means that we are better able to determine the power generation loading of the vRE sources – and thus, we can better dispatch the right mix of the most cost-effective power generations at any point in time. As time progresses, more advanced models and algorithms will be developed that can better predict the vRE generation output. Additionally, more data recorded on these power plants will help us better understand their operation.

4.4. vRE's intrahour variable loading can be effectively managed

We've established the advantages of adding vRE in the grid in terms of its consistent availability (especially during peak demand) and high accuracy in forecasting its output. This section addresses how to manage the uncontrollable aspect of vRE that is its intrahour variability to effectively integrate them into the grid.

There could still be intra-hour variability and fluctuations from these vRE sources. This fluctuation is from natural events such as a short time change in solar irradiance due to the passage of a group of clouds that can cause deviations from its hourly dispatched power generation output.

Figure 35: Intra-hour Variability of Solar Power Plants in San Carlos Solar Energy, Negros Occidental



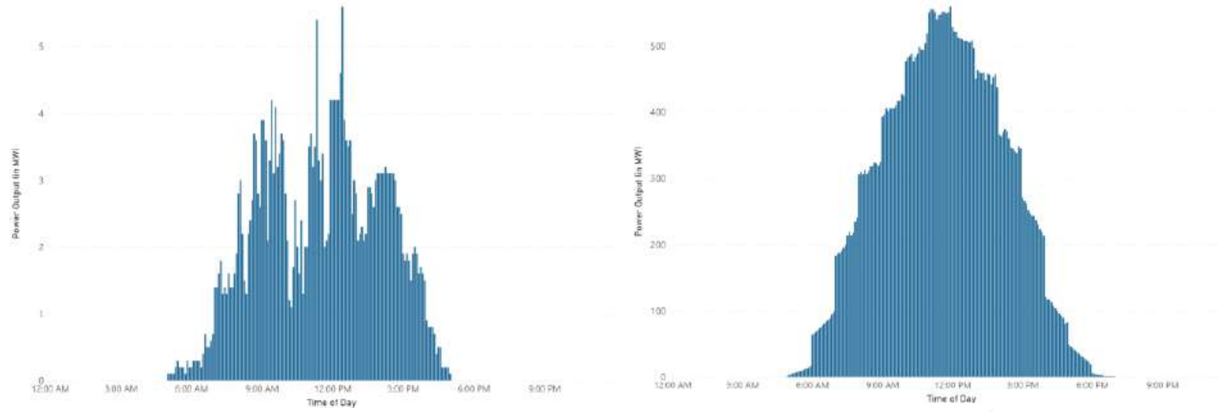
Due to passage of clouds and other natural events, individual solar plants can experience power fluctuations

While this concern is valid since any sudden reduction or increase in the power supplied to the system can cause the system frequency to deviate from its nominal level, these issues are not impossible to mitigate. These often arise when looked at the point of view of an individual plant or a local area – which is not the practical way of looking at it.

The power system is interconnected; thus, we need to view this issue on a system level. On this level, the Law of Large Numbers, utilizing geographic diversity, and technologies that allow more system flexibility like Battery Energy Storage Systems (BESS) or any other forms of energy storage could mitigate these deviations.

In probability theory, the Law of Large Numbers states that the aggregate result of several uncertain processes becomes more predictable as the total number of processes increases [11]. Applied to variable renewable energy sources, the Law of Large Numbers dictates that the combined output of every wind turbine and solar panel connected to the grid is far less volatile than the output of an individual generator. This is exhibited in the figure below.

Figure 36: Variable Power Output of an individual First Cabanatuan Solar plant *(left)* and the Aggregate Power Output of all solar plants in Luzon and Visayas Grid *(right)*



The intrahour variability of vRE plants tend to cancel out each other in an aggregated level

Simply put, as more VRE plants are added to the system, the intrahour variability and short-term fluctuations in output of different VRE plants located in different locations in a power system tend to cancel out, increasing its predictability [8]. This predictability is due to the power fluctuations of the multiple vRE generators being much less probable to occur at the same time.

Moreover, in terms of geographic diversity, different locations in the Philippines experience different weather conditions at any point in time. Because of this, there is great value in having this diversity of location sites of the various vRE plants. Therefore, grid planners should consider the concentration of vRE resources in the grid – so as to consider that there should not be an accumulating of multiple vRE power plants in one location to avoid risk in stability and reliability of the power system.

From the study of Mills and Wiser of the Berkeley National Laboratory (2010), the relative aggregate variability of PV plants sited in different locations across a wide area is six times less than the variability of a single site for variability [12]. Additionally, the level of variability is nearly identical over shorter and longer time scales. This signifies that by installing various vRE plants that are scattered across a wide area, the intra-hour variability and fluctuations of vRE plants can be managed.

Another measure that can help address the intrahour variability of vRE power plants are technologies that allow more system flexibility like, Battery Energy Storage Systems (BESS), which enables energy smoothing and short-term electricity balancing [13]. In the grid level, the utilization of BESS integrated with solar and wind farms has been proven to have good effects in the system security and reliability, mostly in smoothing the energy outputs and its economic effects in the energy markets. There are also other technologies that allow more system flexibility include reservoir hydroelectric power plants and open cycle natural gas power plants that can routinely manage the fluctuations experienced by the power system – both of which are already available in the Luzon grid. [8]

Aside from system flexibility and energy smoothing, BESS can store the power generated by VRE farms for time-shifting purposes that can be used later or during the peak hours. However, since this technology is a novel technology, it is not yet cost-effective to be implemented on a large-scale in the Philippines – but some pioneering BESS projects have already started here. According to the DOE summary of Committed Power Projects as of October 2021, a total 2,112.59 MW capacity for BESS has been committed with target commercial operation latest 2025 [4].

However, it must be noted that this intrahour variability of solar and wind power plants does not directly affect the hourly dispatch requirements to the grid. Rather, it affects the reserve requirements of the grid since it is the reserves or the ancillary services that manages the fluctuations and sudden changes from the hourly power dispatch in the grid. The need for ancillary services that can support the increased penetration of VRE resources in the grid was examined in a 2018 PEMC study which highlighted the need for the implementation of the reserve market [14].

The 2018 PEMC study also cited multiple case studies from different utility companies overseas. The first one is the New York Independent System Operator (NYISO) about the effects of 10% wind penetration in the New York Control Area and showed that there were only minor changes in the reserve capacity needed to accommodate wind generation. This study concluded that this minor change could be accommodated by the existing processes and resources in the NY Control Area without any new requirements. A similar finding was found in the second case cited, a 2006 Minnesota Wind Integration Study, wherein they have evaluated the penetration of wind in three levels, namely: 16%, 22%, and 27% - in which they calculated the regulating reserve requirement with the integration of wind. The Minnesota study also concluded that no additional contingency reserves would be required due to the wind because the largest contingency was unchanged [14] [15]. These findings confirm that the variability and uncertainty that vRE introduces in the system does not necessarily entail a higher reserve requirement.

Table 4: Summary of Results of the Integration Studies in Other Jurisdictions [14] [15]

Wind and Solar Integration Study	Peak Load	Penetration Level of vRE	Reserve Requirement (% of Peak Load)		
			Primary Reserve	Secondary Reserve	Following Reserve
NYISO	33,000MW	10% wind	No Additional Capacity Required	0.79% to 0.94%	No Additional Capacity Required
Minnesota	20,984MW	16% wind	No Additional Capacity Required	0.71%	0.52%
		22% wind	No Additional Capacity Required	0.73%	0.54%
		27% wind	No Additional Capacity Required	0.75%	0.59%

In other jurisdictions, the reserve requirements of the grid with vRE integration is minimal despite high vRE penetration

This is further supported by the 2018 study of Electric Reliability Council of Texas (ERCOT) entitled “Analysis of Wind Generation on ERCOT Ancillary Services Impact Requirements”. They have concluded that as the number of variable renewable generators connected to the grid increases, the amount of reserve capacity required to balance the variability of renewables to the grid becomes less than the reserve requirement needed by baseload power plants [16]. This is because uncertainty and variability are an inherent part of power system operations, and the addition of wind generation capacity increases both uncertainty and variability – but does not greatly change their nature. It should also be noted that the 2021 Texas power crisis is not an effect of the uncertainty and variability of these variable renewable generators – rather it is attributed to the failure of every power generating technology available in the region since they are not designed to withstand a winter that is as severe what they have encountered during that time.

Expounding on what ERCOT did, they found that an additional 15,000 megawatts of installed wind energy only require an additional 18 megawatts of new flexible reserve capacity to maintain the stability of the grid.

This additional 18 megawatts of reserve requirement are relatively inconsequential considering the massive amount of energy capacity that can be added with it. In other words, the impacts of the variability of the vRE sources can be addressed by existing technology and operational attention, without requiring any radical alteration of operation [17]. In fact, the spare capacity of an existing and fast-ramping natural gas power plant will be able to compensate for the variability introduced by 5,000 new wind turbines.

To sum, through appropriate system design and implementation of the right policy mechanisms, the intrahour variability of these variable renewable energy sources can be effectively managed.

4.5. vRE and Flexible generation complements each other

While vRE plants provide electricity at the time when it is most needed, vREs alone are still not enough to meet the requirements of the grid. This is because operators still do not have the controllability to fine-tune their power generation output. Thus, to meet these requirements of the grid, flexible generation sources are required. This was supported by a 2018 study by the United States Agency for International Development (USAID) which states that there is a need for system flexibility for the successful and cost-effective integration of variable RE in the grid [18].

Plant flexibility can take many forms, including the ability to start-up and shut down over short periods, be run at a low minimum load, rapidly change generation output, and offer ancillary services to support system reliability. This characteristic of a power plant can match the electricity supply to the variability of the load demand. Dam-based hydro, pump-storage hydro, simple-cycle gas turbines, and battery energy storage that offer fast ramping and fast reaction times all fall into this category. Moreover, the Luzon grid has existing installations of all these flexible generation sources.

As the Philippines envisions a higher RE penetration to 35% in 2030 and 50% in 2040, the ideal complement to this increased variable renewable energy share is flexible generation – and not baseload generation. The complement operation of vRE and flexible generation ensures that the grid as a whole can be able to adjust accordingly as the variable generation of the vRE and the high fluctuations of the load demand changes – and this is something that baseload power generation cannot accommodate. Moreover, as the vRE penetration in the grid increases, distinguishing between baseload/ intermediate/ peaking, and attributing power generating technologies to these types accordingly, is less meaningful and will no longer be necessary [5].

Moreover, the installation of more flexible generators is not the only means to achieve the flexibility that can support vRE integration. A recent 2020 USAID study highlighted another means of grid flexibility that can done is operational flexibility. Operational flexibility is the ability of the grid to respond to electricity demand and generation changes; these include improved market design and protocols, transmission strengthening, interconnected and extended balancing areas, flexible demand and storage, and advanced forecasting [19].

Additionally, innovative market regulations can be designed to incentivize operators to run flexible generation plants for balancing while also maintaining profits. As highlighted by the study of IRENA, a way to achieve this is by increasing the time granularity in the wholesale electricity spot market (WESM). An increased time granularity can better reflect the conditions at a particular time period and pays for efficient response from the existing generators. This development is because trading electricity with shorter intervals (or as close as possible to real-time) creates value for the flexible generation power plants that can respond in near-real-time by ramping up or down quickly [20].

These innovative market designs and regulations are already being initiated in the Philippines. As of June 26, 2021, the Wholesale Electricity Spot Market in the Luzon and Visayas grids has transitioned from a 1-

hour dispatch into a 5-minute dispatch – which significantly increased the time granularity of the electricity spot market. Additionally, the Philippine Electricity Market Corporation (PEMC) will soon open ancillary service markets that will enable the co-optimization of energy and dispatchable reserves scheduling. Because of this transition, the Philippine spot market is now more flexible, and the existing flexible power generators can better complement the variability that the solar and wind power plants introduce in the system.

To assess a power system's capability to further cope with the vRE penetration, the International Energy Agency (IEA) has defined four phases of VRE integration, which are differentiated by the effects on power system operation resulting from increasing shares of annual VRE generation [8] [19]. This is essential since as the effects of VRE become noticeable, operational practices can be upgraded and modified to integrate more VRE capacity and maintain smooth system operation. The four phases are described in the table below.

Table 5: International Energy Agency (IEA) Four Phases of vRE Integration

Characteristics	Attributes (incremental with progress through the phases)			
	Phase One	Phase Two	Phase Three	Phase Four
vRE share	Electricity Generation up to 3% share at any time	Electricity Generation from 3% to 15% share at any time	Electricity Generation from 15% to 25% share at any time	Electricity Generation from 25% to 50% share at any time
Characterization from a system perspective	VRE capacity is not relevant at the all system level	VRE capacity becomes noticeable to the system operator	Flexibility becomes relevant with greater swings in the supply/demand balance	Stability becomes relevant. VRE capacity covers nearly 100% of demand at certain times
Impacts on the existing generator fleet	No noticeable difference between load and net load	No significant rise in uncertainty and variability of net load, but there are small changes to operating patterns of existing generators to accommodate VRE	Greater variability of net load. Major differences in operating patterns; reduction of power plants running continuously	No power plants are running around the clock; all plants adjust output to accommodate VRE
Challenges depend mainly on	Local conditions in the grid	Match between demand and VRE output	Availability of flexible resources	Strength of system to withstand disturbances

In the Philippine Power System, the installed capacity of these vRE plants are about 6% of the total installed capacity – however, it must be noted that this installed capacity is not being fully dispatched due to the variable nature of these plants. Thus, the vRE penetration at any given dispatch interval is approximately 3% share in the energy mix. With this, it can be considered that the Philippines is still categorized under Phase One and is starting to transition to Phase Two.

The vRE capacity in Phase One has no noticeable impact on the system. Since other power plants have a much greater capacity than these vRE plants, its variability will go unnoticed. Meanwhile, in Phase Two, the impact of VRE becomes noticeable; but, by upgrading some operational practices to ensure the matching between demand and VRE output (as indicated in the challenges on the table), vRE capacity can be integrated quite smoothly. For the Philippines' case, the system design and policies that improves operational flexibility of the grid are already in place for such implementation. Policies and system designs include the transition from an hourly to a 5-minute dispatch, more advanced forecasting techniques, the planned reserves capacity market, more flexible generating plants, and many more.

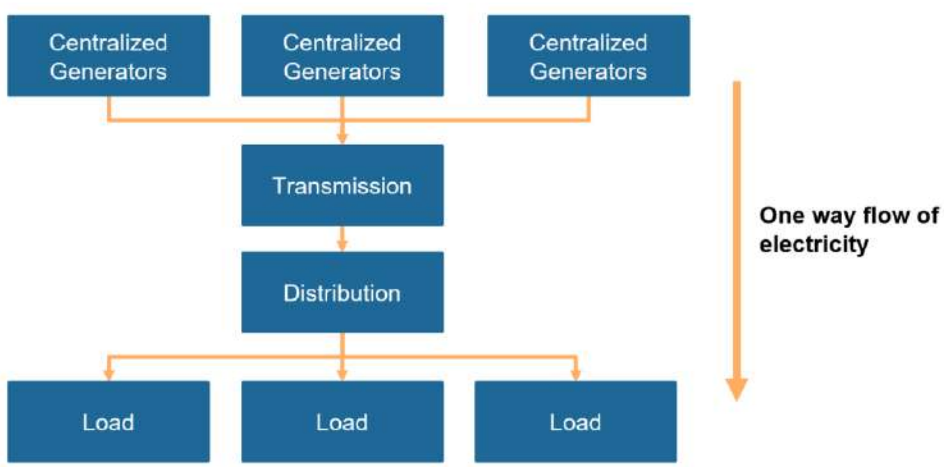
Thus, as the Philippines transition into Phase Two of the vRE integration framework, we would only need to implement these policies to help us realize a much greater vRE penetration in the system.

4.6. vRE paves the way to decentralized systems

In addition to the system-wide perspective, variable renewable energy technologies also support the transition from the traditional centralized generation configuration to a distributed generation configuration of the grid.

In the centralized generation configuration of the grid, we can notice that there is a one-way flow of electricity from the generators to the loads – in such a way that electricity must flow through the transmission and distribution sectors first. In this setup, the entire grid is dependent on large-scale generation of electricity at centralized facilities. These facilities are usually located away from end-users and connected through a network of transmission lines. This network is used to distribute to multiple end-users. Typical sources of centralized generation facilities include coal, natural gas, nuclear, and hydroelectric power plants.

Figure 37: Centralized Generation Block Diagram

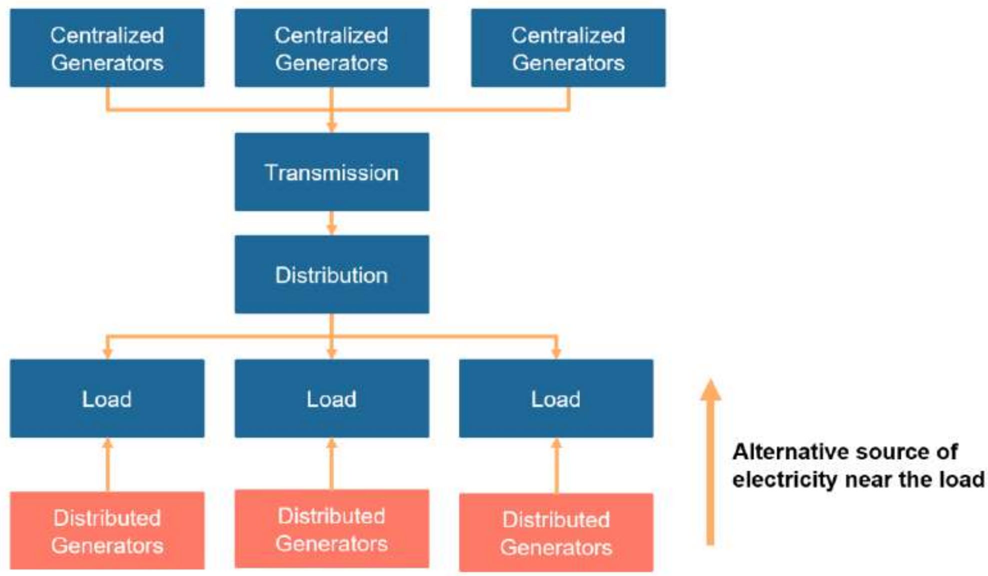


Major bottlenecks can be observed on the transmission and distribution system.

One vulnerability of this centralization is that one flow direction; this system is highly dependent on the transmission and distribution facilities to transmit the electricity from the generation to the load. Damage to any transmission facility can cause the flow of electricity from the generation sites to the load centers to halt. A disaster such as a typhoon that devastates a specific area with a transmission facility can result in electricity downtime to the load centers until the transmission facilities are reconstructed. Thus, with the increasing number and strengths of extreme weather events, the long transmission lines that go with centralized generation are prone to damages and generally take a long time and billions of Pesos to restore.

A solution that can address these fallbacks of centralized generation is through the utilization of a distributed generation system. Distributed generation refers to a variety of technologies that generate electricity at or near where it will be used, such as solar panels; it can either be utility or consumer-owned. Distributed generation may serve a single structure, such as a home or building, or it may be part of a microgrid.

Figure 38: Distributed Generation Block Diagram



Electricity can be generated at or near the loads, and its excess can be exported back to the grid

A microgrid is a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously. This set-up is advantageous because by bringing the power generators such as solar and wind plants closer to load demand, distributed generation can help deliver clean, affordable, and reliable power to its customers. Moreover, with shorter transmission and distribution line requirements, distributed generation would reduce electricity losses along these lines. Interestingly, this setup makes it possible for consumers to become suppliers as well. A distributed grid allows them to generate their own electricity and export excess to the grid. And when multiple microgrids and distributed generation systems are implemented, this would result in a more robust electric grid – one that is self-sustaining and serves as the back-up of one another.

Integrating RE technology, the characteristics of a distributed generation make it a favorable system design for the Philippines. Different island groups in the Philippines can benefit from a robust network of interconnected self-sustaining grids that supplies clean, affordable, and reliable power to the Filipino people.

This observation on VRE's potential in a distributed system is in line with the DOE's plans of increasing electricity accessibility for the country. Along with the moratorium, the department has expressed intentions to formulate policies deploying Distributed Energy Resources and Microgrids [2].

5. Coal is expensive

5.1. Fuel costs of imported coal directly affect electricity prices

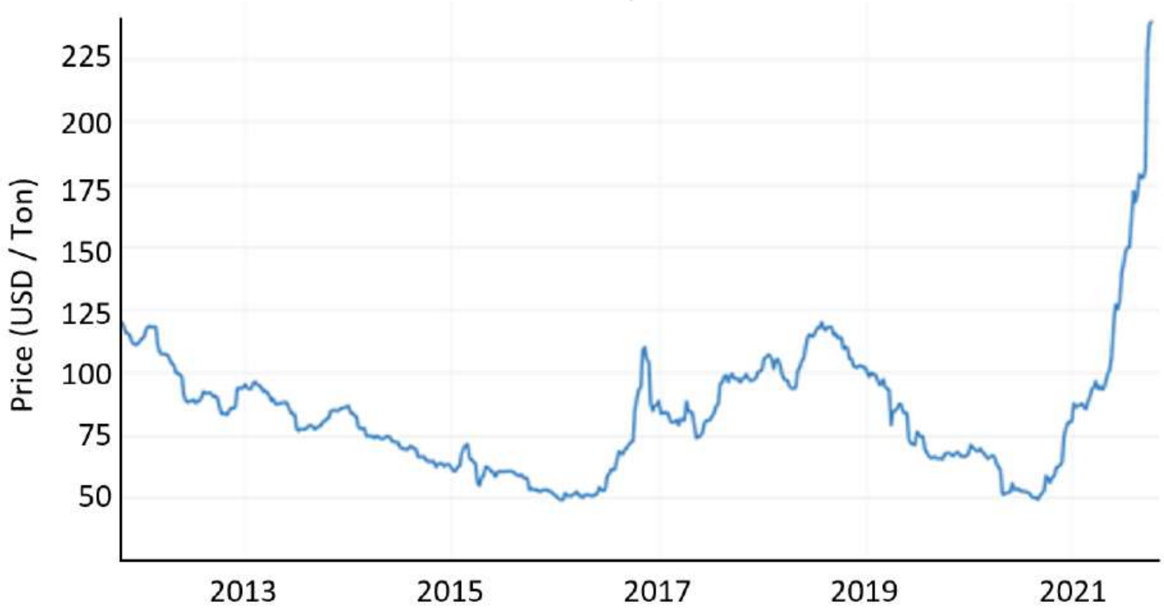
Traditional power plants like coal, natural gas, and diesel plants require fossil fuel to operate – and since the Philippines does not have enough fossil fuel reserves in its jurisdiction, it resolves by importing these energy sources. In fact, 81% of the coal consumed in the Philippines in 2019 is imported – and among these imported, 90% of them came from Indonesia [21]. With this high dependence on imported fossil fuel, there is a threat to the Philippines' energy security since the electricity price is tied to the volatility of the prices in global markets.

This volatility in prices can affect both the electricity that is sold thru the Wholesale Electricity Spot Market (WESM) and thru Power Purchase Agreements. For the WESM, the volatility is quite intuitive since the generation offers update in real-time and the price of electricity is known upon dispatch. However, this is not the case for the electricity that is traded thru the Power Purchase Agreements.

It is a common misconception that the price of electricity from the Power Purchase Agreements is fixed – it is not. The Philippines' energy regulatory practice allows automatic fuel pass-through in these power plants. This provision signifies that whenever the cost of fuel (coal) goes up in the world market, power producers and distributors, making use of this provision, could simply pass this higher cost on to consumers.

Since fuel costs are the highest cost item for these power plants, their impact on consumer costs of electricity is huge. In 2021 alone, the price of coal in the world market more than tripled due to higher demand as the pandemic restrictions ease in other countries [22].

Figure 39: Price of Coal (USD / Ton) in the Global Markets from 2009 to 2021 [22]



The price of coal has tripled from January 2021 to October 2021

This volatility can also be seen in the Natural Gas prices in the world market that have doubled in price since the start of the year.

Figure 40: Price of Natural Gas (in USD / MMBTu) in the Global Markets from 2011 to 2021 [23]

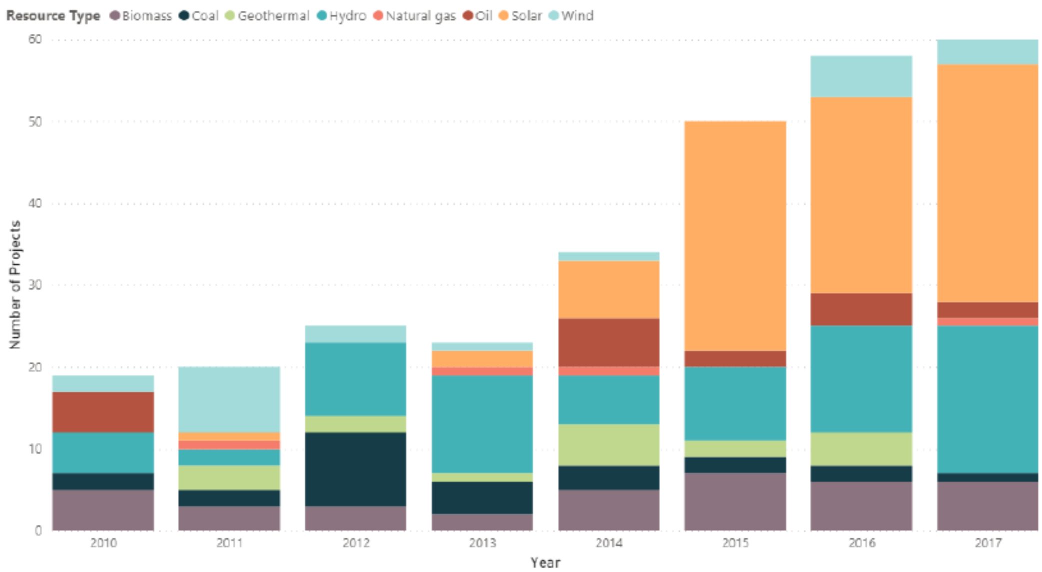
The price of natural gas has doubled in price from January 2021 to October 2021

Today, power producers are not incentivized to procure fuel for the power plants diligently and efficiently because all fuel costs and foreign exchange fluctuations can easily be passed through to the consumers. The current policies do not encourage power producers to look for cheaper alternative power sources. This results on the consumers to be burdened with higher electricity costs whenever the fuel costs increase.

5.2. Capital expenditures on Coal projects are high

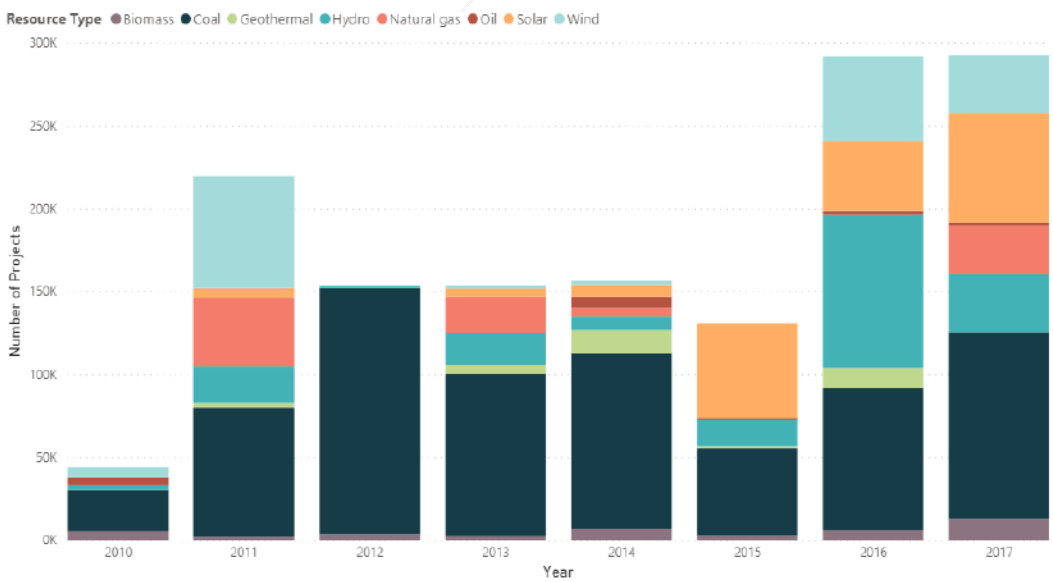
Coal power projects have received investment incentives under the Investment Priorities Plan (IPP) administered by the Board of Investments (BOI) under the Department of Trade and Industry (DTI). These incentives include tax holidays, tax and duty-free importation of equipment, etc. [24].

Figure 41: Number of Projects that are BOI Registered from 2010 to 2017 [25]



There are numerous Solar projects in the pipeline, while Coal projects are fewer

Figure 42: Investment Generated (in thousands) from 2010 to 2017 [25]



Coal projects generate more investments despite having fewer projects initiated

According to a report by the BOI in the December 2018 Energy Investment Forum, 25 coal projects have been registered to gain incentives from the IPP from the year 2010 to 2017 [25]. Despite having a fewer number of projects registered under IPP compared to RE, coal still dominates the share of investment costs. This indicates that coal projects require higher Capex than any other technology type but were still pursued due to the investment incentives under the IPP.

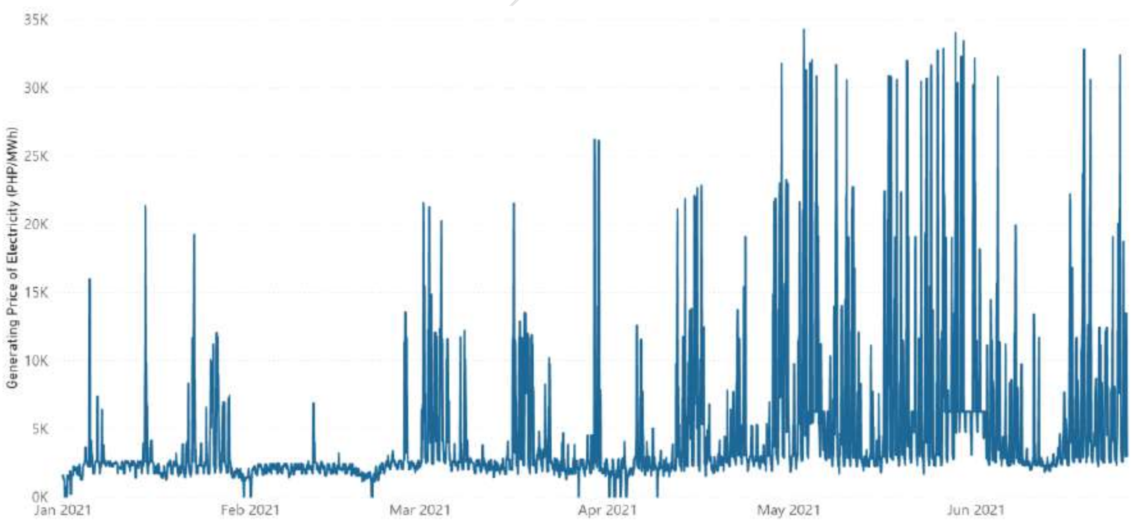
While economies of scale may apply to coal projects, unreliability in operation may prove them to be a poor investment. In terms of costs, it is important to consider whether these plants can deliver on their expected capacity and the additional expenses incurred as these plants experience unreliability issues. Given these considerations, the investments might no longer be as profitable as it may seem – and it could potentially result to more stranded assets on the part of the investors.

Ultimately, with the global initiatives towards more sustainable energy, coal is now seen to become stranded assets sooner – which can have significant financial consequences for corporates, banks and financial institutes with resources locked in coal assets. This has prompted many companies to reassess the long-term risks of investing in coal and exiting from coal investments [26]. Given the unreliability issues experienced, this can potentially hasten the stranding of these assets – which further highlights the need for long-term planning in the energy transition of the Philippines.

5.3. Outages by Coal plants directly causes prices spike

We have previously established that the unavailability of the four coal-fired power plants is the direct cause of the outages that were experienced in Summer 2021. To understand the effects of the outages on the price of electricity, we look at the GWAP or the Generator Weighted Average Price – which is the settlement price that the generators are paid in the spot market. This value is being regulated by the ERC thru the primary and secondary price caps.

Figure 43: Generator Weighted Average Price (GWAP) from January to June 2021

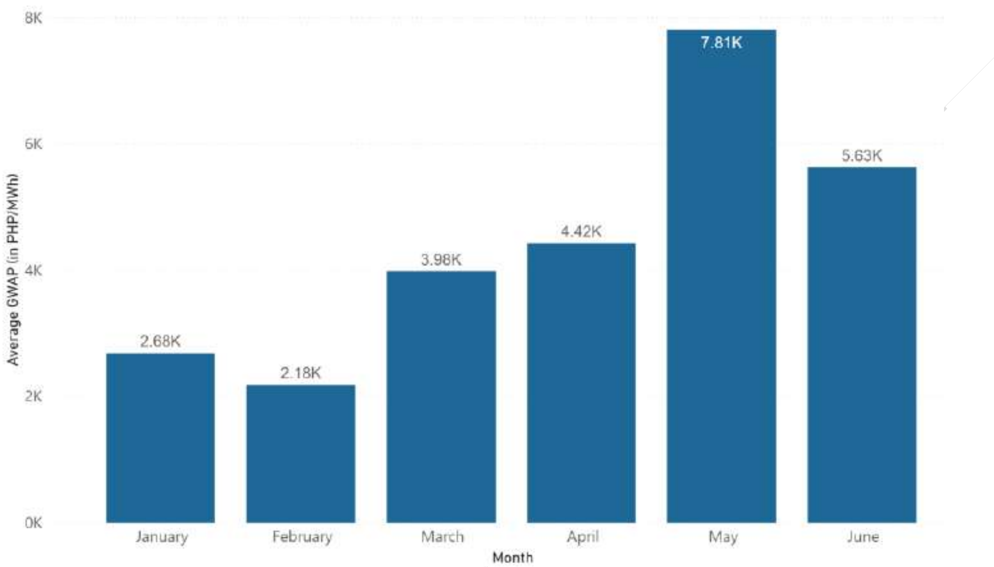


The price fluctuations are more frequent as the summer season approaches

From the figure, we can see here that the price of electricity is not constant – it changes throughout the day, weeks and months. However, one noticeable thing is that the fluctuation in price is much more frequent as the summer season approaches. This change is primarily because there is a much higher demand during the hot summer season leading to the supply of electricity getting thinner – and thus, the price of this electricity supply gets higher. However, due to the unavailability of these coal plants, the already lessened supply gets even thinner, then reaching the point that the price fluctuations aggravate.

By taking the monthly average price, we can see that the average generating price of electricity significantly increases. In particular, it triples in price from February 2021 to May 2021. This increase in the price of electricity indicates a looming and recurring problem – that there is a shortage in power supply.

Figure 44: Average Monthly Generation Prices in 2021

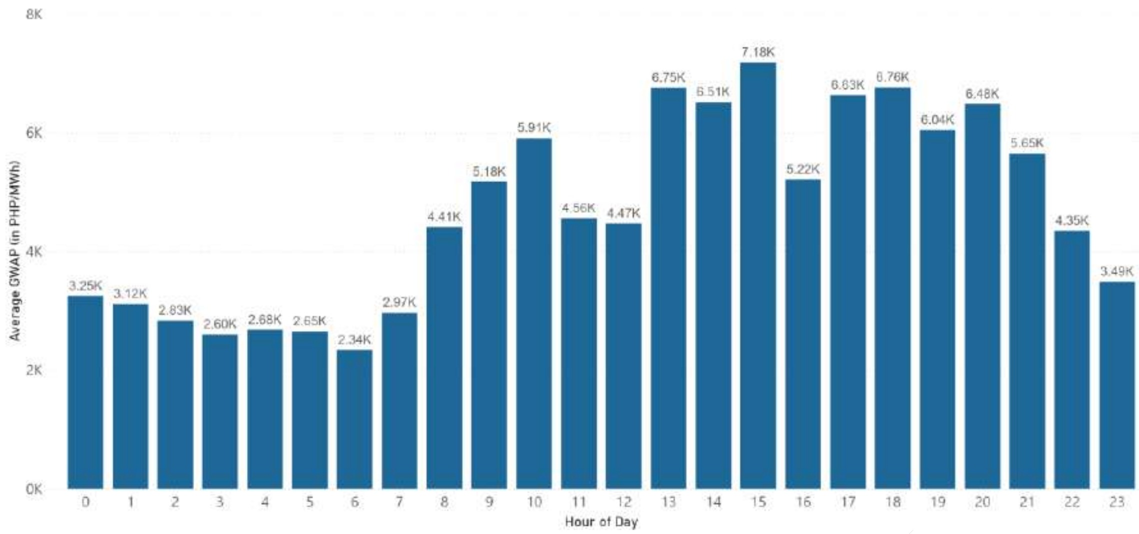


The generating price for electricity increases as the Summer approaches

Zooming into the daily basis, we notice that the hourly price of electricity in the spot market fluctuates depending on the demand for that hour of the day. Moreover, the price of electricity peaks at the same time as the load demand requirements peaks. The average hourly price of electricity in 2019 is reflected in Figure 45 – wherein the average price of electricity during off-peak hours is around 2 to 3 PHP/kWh and this ramps up to around 6 to 7 PHP/kWh during peak hours.

The data from 2019 was used for this observation as a benchmark case as it better resembles the typical demand in the power system than the year 2020 with the pandemic.

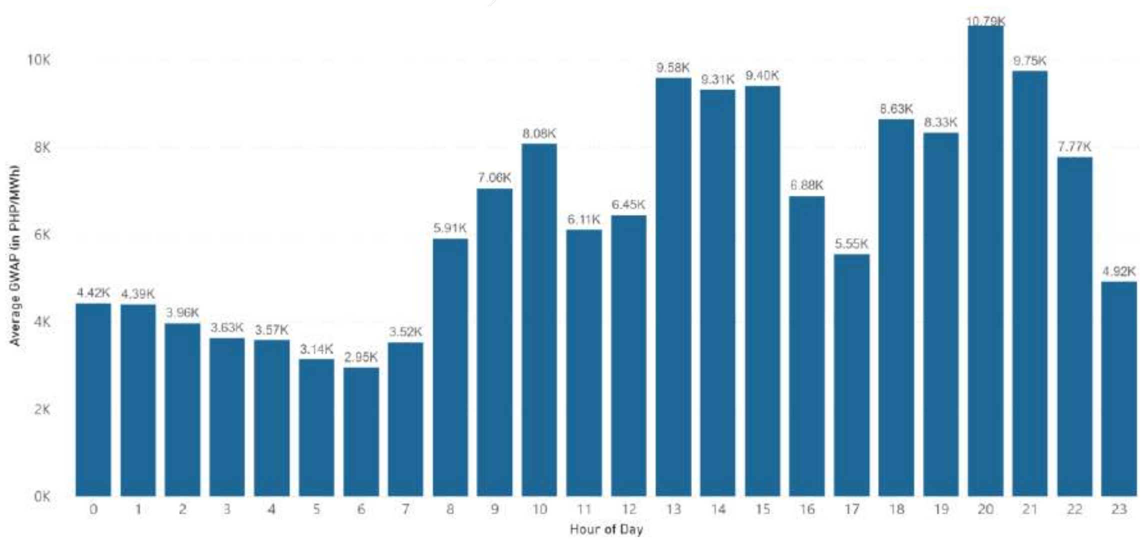
Figure 45: Average Hourly Prices in the Electricity Spot Market in 2019



The prices in the spot market fluctuate throughout the day – depending on the load demand requirements

Zooming into the summer season that is May to June of 2019, we can see the same trends, but with slightly higher magnitudes. The average hourly price of electricity in Summer 2019 is reflected in the figure below – wherein the average price of electricity during off-peak hours is around 3 to 4 PHP/kWh and this ramps up to around 7 to 10 PHP/kWh during peak hours. This suggests that there is a slight change in prices that is observed during the summer season.

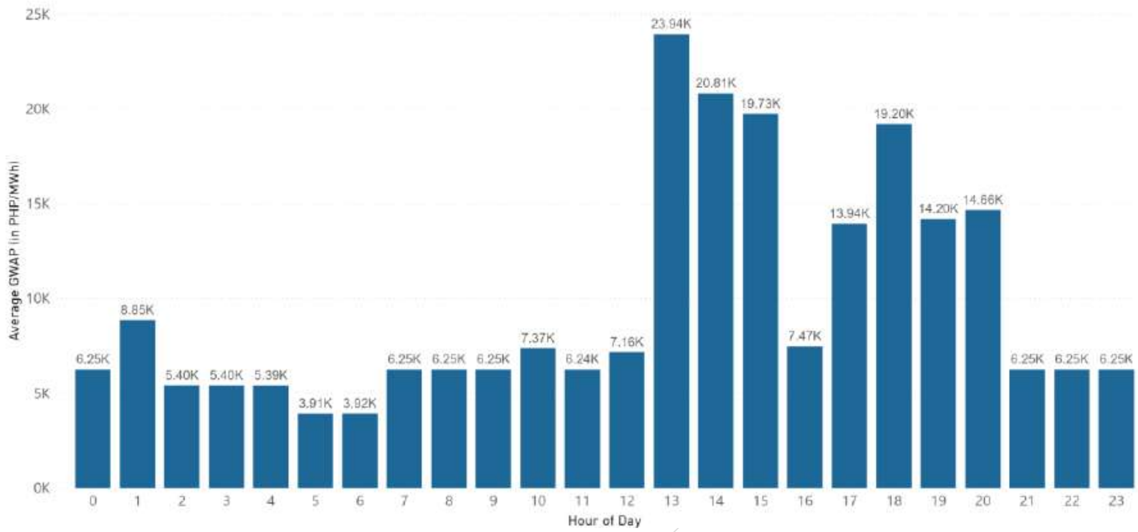
Figure 46: Average Hourly Prices in the Electricity Spot Market in May to June 2019



The prices in the spot market fluctuate throughout the day – depending on the load demand requirements

However, during the 2021 May 31 to June 1 outages experienced, this trend was intensified. During off-peak hours, the average price of electricity is around 5 to 7 PHP/ kWh and during peak hours, this price skyrocketed to around 24PHP/kWh. This is a significant increase in prices that can be attributed to the high electricity demand requirements during the summer season – and is aggravated by the outages of the baseload coal-fired power plants that we have depended upon.

Figure 47: Average Hourly Prices in the Electricity Spot Market from May 31 to June 1, 2021



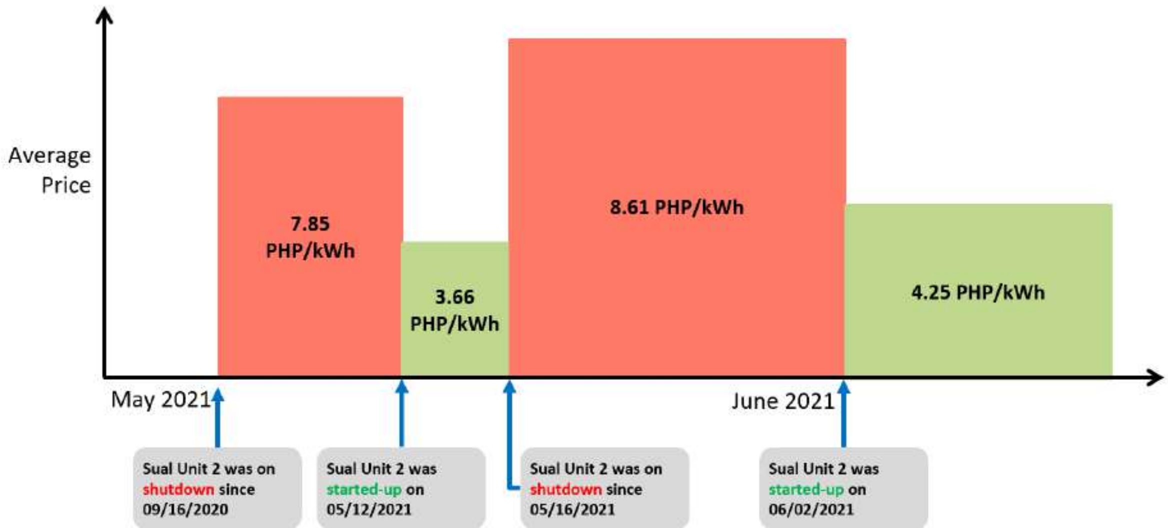
The prices in the spot market significantly changed from the baseline average cost of electricity

To explicitly show how the outages directly affect the prices of electricity, we present the operation of Sual Coal-fired Power Plant Unit 2. This plant is the largest power plant in the entire Luzon grid.

At the start of May 2021, the average settlement price of electricity in the spot market was at 7.82PHP/kWh; Sual Unit 2 was still on shutdown and has been for the previous 8 months. The shutdown ended on May 12 – and because of the added electricity supply to the grid, the average settlement price of electricity in the spot market during this time went down to 3.66 PHP/kWh. This shows that when there is enough electricity supply in the grid, the settlement price goes down. Moreover, it shows that a power plant this big can significantly affect the marginal electricity price of the deployed power plants.

However, the start-up of Sual Unit 2 was short-lived since it only ran continuously for 4 days and went on shutdown again despite having recently completed the 8-month shutdown just a few days before. Because of this, the price of electricity doubled to 8.60PHP/kWh. This shutdown went on for 2 weeks – and on June 2, this plant was put back into operation – in which the average settlement price of electricity in the spot market went down to 4.25 PHP/kWh.

Figure 48: Sual Unit 2 Timeline of Operation vs. Price of Electricity in the Spot Market during Summer 2021



The average generating cost in the spot market significantly increases whenever the power plant is unavailable

The correlation of the increase in electricity price to the unavailability of the power plant proves that when relatively big plants shut down, the price of electricity is significantly affected. Furthermore, the cost implications of these outages are considerable since the prices of electricity more than doubles during the sudden unavailability of this power plant.

Quantifying the increase in system costs brought about by the coal-fired power plant outages, an increase in system market costs of 1,071,826,786.74 pesos in just two days of outages was computed. This value is computed by multiplying the portion of the total energy generated that is settled in the spot market to its corresponding prices. Additionally, this was compared to a benchmark price that is set from the average GWAP in the previous month, April 2021.

With this evidence, we have established that the increase in prices during Summer 2021 was directly caused by the outages experienced due to the unreliable operation of these coal power plants – and that increase is an added burden to the electricity bills of the Filipino consumers.

6. Variable Renewable Energy (vRE) plants are cheaper

6.1. vRE resources are free, indigenous, and abundant

The Philippines is rich in indigenous resources such as solar and wind energy potential. Unlike fossil fuels that have volatile costs since this resource has to be found, extracted, traded, and transported to the power plants, renewable energy sources have a free fuel cost for the duration of the solar panel or the wind turbine's lifetime.

Because of the high potential for the solar and wind resource in the Philippines, the DOE have identified Competitive Renewable Energy Zones or CREZ [27]. These are geographic areas with high concentrations of cost-effective RE and strong developer interest. Data on CREZ informs the selection of new and enhanced transmission lines, encouraging new development toward the best RE resource areas.

There is a total of 25 identified CREZ areas across the Philippines with an estimated gross capacity of 152 GW of new on-shore wind and solar photovoltaics (PV). The zones also include an estimated 365 MW of geothermal, 375 MW of biomass, and over 650 GW of hydropower capacity distributed across the Luzon, Visayas, and Mindanao systems.

Table 6: Estimated CREZ Opportunity Capacity in MW

Grid	Solar PV	Wind (on-shore)	Geothermal	Hydropower	Biomass
Luzon	35,031	54,115	285	270,603	210
Visayas	11,876	25,429	40	1,917	71
Mindanao	11,203	14,443	40	382,514	93
Total	58,110	93,987	365	655,034	374

There are huge opportunities for renewable energy projects across the country

Additionally, recent data shows that there are huge potentials available for offshore wind in the Philippines. Only recently, The Department of Energy (DOE) announced that it partnered with the World Bank Group to craft a roadmap to harness the country's offshore wind energy as a potential source of clean power. Over 170 gigawatts (GW) of offshore wind potential was estimated in the Philippines, adding to the 93GW of wind potential from CREZ [28].

Data on offshore wind shows it has a consistent, balanced, and stable production pattern, making it the only variable baseload power generation technology with high capacity factors. Offshore Wind Farms operate with Capacity Factors of 40% to 50%. At these levels, offshore wind matches the capacity factors of efficient gas-fired power plants, coal-fired power plants in some regions, exceeds those of onshore wind, and is about double those of solar PV [29].

Like other vRE technologies, offshore wind output also varies according to the strength of the wind. However, its hourly variability is lower than that of solar PV. Offshore wind typically fluctuates within a narrower band, up to 20% from hour-to-hour, than is the case for solar PV, up to 40% from hour-to-hour. Offshore wind also contributes to electricity security with its high availability and seasonality patterns; it can make a stronger contribution to system needs than other variable renewables [29].

It is important to note that these potential energy resources can only be realized if the necessary transmission facilities are developed. Currently, the locations which showed great offshore wind potential are located in off-grid areas. Thus, the need for transmission line expansion to reach said areas. As an example, Mindoro and Batangas coast are among the locations that showed great potential. However, the existing transmission line backbone is on the right side of the country traversing region 4A, Bicol region, and going down to Region 8 and Cebu. Meanwhile, the offshore wind potential can be seen on the left side of the country, with transmission line connection in these locations is not yet available. From the Philippine Energy Plan 2020-2040, the Batangas-Mindoro Interconnection Project is already planned and is only pending approval to commence project implementation – thus, this could potentially open up the offshore wind potential to the main grid [30].

These findings suggest that the Philippines have more than enough potential to be self-sufficient in terms of energy security. Moreover, because of this characteristic of vRE plants that don't consume any fuel, they do not have to impose added fuel costs on their consumers. They then could better compete with fossil fuel power generation technologies in terms of the settlement price of electricity – and this aspect will be better realized by the consumers only if automatic pass-through provisions are removed in the power purchase agreements of generators.

6.2. vRE have cheaper capital and operating expenses today and tomorrow

From the 2018 study of USAID entitled "Building Low Emission Alternatives to Develop Economic Resilience and Sustainability Project (B-Leaders)", the capital and fixed operating expenses of variable renewable power generating technologies in the Philippines are already currently cheaper than coal-fired power technologies [31]. Additionally, the variable operating expenses of vRE plants are zero – which can be attributed to its free fuel costs – compared to the high operating costs of coal-fired power plants (Table 7).

Table 7: Cost Parameters of Different Power Generation Technologies in the Philippines [31]

	Capital Costs (USD/ kW)		Fixed O&M Costs (USD/ kW)		Variable O&M Costs (USD/MWh)	
	2016	**2030**	**2016**	**2030**	**2016**	**2030**
Circulating Fluidized Bed Coal	1809	1809	40	40	9.3	9.3
Subcritical Pulverized Coal	1607	1607	79	40	9	9
Supercritical Pulverized Coal	1921	1921	102	33	6.4	6.4
Ultra-supercritical Pulverized Coal	2300	2300	46	46	6.4	6.4
Solar PV (on-grid and off-grid)	1583	1040	44	8	0	0
Wind (on-grid and off-grid)	1996	1538	69	46	0	0

Renewable energy technologies are already cheaper than coal technologies, and will only go cheaper

This signifies that today, vRE sources are already the more cost-effective than coal-fired power plants. In addition to this, we can see that the forecasted costs of these vRE power plants are expected to go down further in 2030, compared to coal-fired technologies that are expected to maintain their price in the next decade. This shows that the technology of vRE plants are continuously improving, unlike that of coal-fired power plants that have already peaked and little-to-no cost improvements can be further extracted from it.

Another aspect to consider concerning the cost of the vRE integration is the claim that installing BESS is necessary to manage variability; since BESS are currently expensive, the integration is supposedly not feasible. While this claim is partially true since vRE integration calls for an increase in power system flexibility, it should be noted that battery storage is not the only form of flexibility, as mentioned in the previous section of this paper. Other cost-effective means of flexibility are available that can complement variable renewable energy sources such as reservoir pumped hydroelectric plants, open cycle natural gas plants can also provide this system flexibility [8]. Moreover, it should also be noted that BESS has been exhibiting similar downward cost trajectory as the solar PV. As technology advances and economies of scale applies, this could lead to even steeper declines in costs in BESS [32].

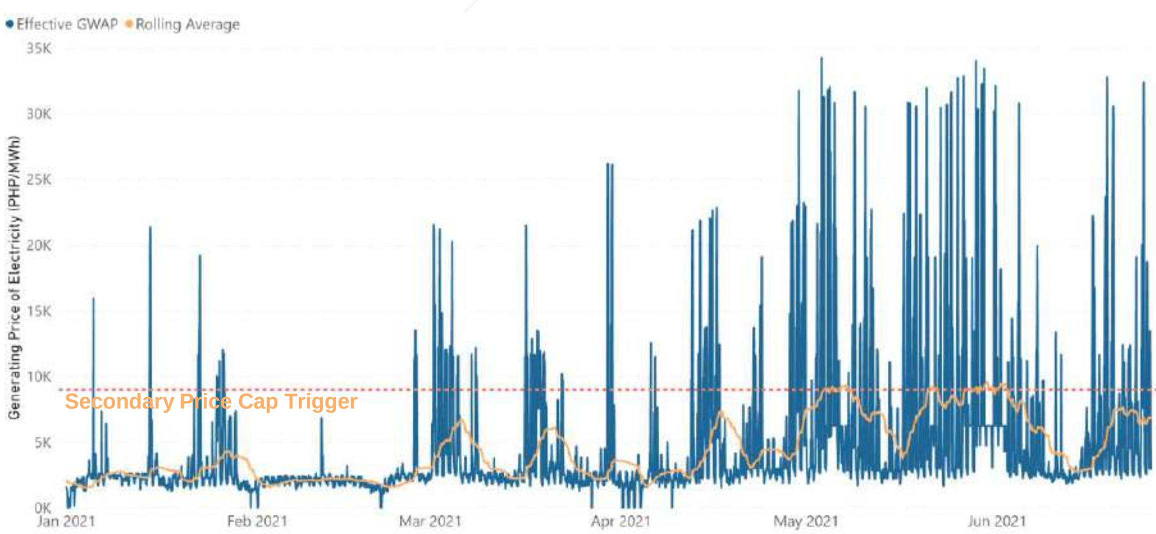
From a larger economic perspective, a financial metric that dictates the cost-competitiveness of an energy source is the Levelized Cost of Electricity (LCOE). The LCOE is essentially a measure that integrates all the relevant costs of electricity generation in a project's lifetime. In an October 2021 report by a financial management firm, Lazard, the LCOE of various energy technologies was done. Results show renewable energy technologies are financially integral to power systems complementary to conventional generation technologies predicting that investment in RE will become more prevalent [33].

In other words, RE projects are cost-competitive and will continue to be so because of their many benefits.

6.3. vRE achieved avoided market costs in its past years of operation

We have previously established that the price of electricity is not constant – it changes throughout the day, weeks, and months. The electricity price also peaks as the load demand also peaks throughout the day. Even with the loss of coal-fired power plants during the summer season, the price increase during peak hours was significantly high – at about 30 PHP/ kWh, but only to drop in price during the night. This is because expensive power plants were dispatched such as diesel during peak hours due to the high demand. The price surges during peak hours have resulted in the rolling average of the Generator Weighted Average Price (GWAP) reaching and exceeding the ERC secondary price cap trigger of 9,000 PHP / MWh.

Figure 49: GWAP and its Rolling Average in 2021



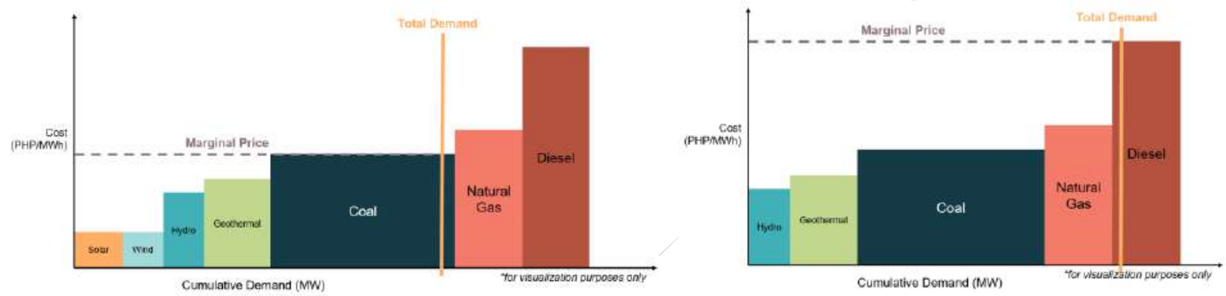
The GWAP rolling average reached the secondary price cap multiple times – which indicates the lack of power generators specifically during peak periods

The frequent triggering of the secondary price cap highlights the need for more power generators that can cater to peak hours specifically. And as previously mentioned, vRE sources have a great potential to meet this demand since they are available at times of high demand. Thus, vRE can greatly impact the price of electricity in the least cost generation dispatch mechanism of WESM.

Based on the WESM least cost generation dispatch mechanism, the order of the dispatch to meet the demand is based on the price of the different plants. Since renewable energy plants are among the cheapest plants, they are among the first in line to be dispatched during peak hours.

Since we have an overcapacity of coal-fired power plants, we might think that the capacity that are not in use can be utilized when we need it. However, due to the inherent limitation of a coal-fired power plant being inflexible – it simply cannot provide this. Therefore, with the same total demand, the next-in-line generators that are more expensive must be dispatched to meet the demand requirements in that time period – leading to an increase in the marginal price of electricity.

Figure 50: Least Cost Generator Dispatch Mechanism when RE is available (left) and when RE is unavailable (right)

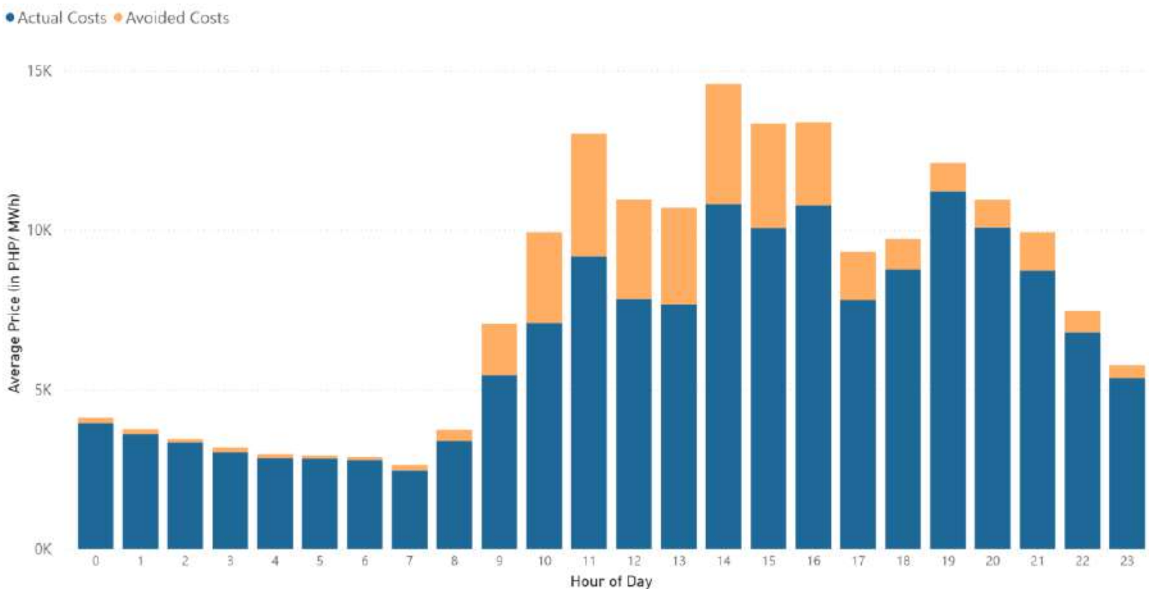


vRE can reduce the marginal price of electricity by introducing cheap power into the energy mix

Existing renewable energy plants help reduce the settlement price of electricity when the price is at its highest. A mathematically created scenario where these plants were not installed showed a dramatic change in the least cost generation dispatch compared to the current scenario.

Using actual data (Figure 51), the scenario with no RE installed experienced much greater peaks in prices due to the lack of cheaper generators in that period. This signifies that in the absence of the currently installed RE plants, there would not be enough power generators to cater to the peak hours specifically. Because of this, the WESM is forced to dispatch much more expensive power generators like Diesel power plants during this time.

Figure 51: Actual Settlement Price of Electricity vs. Avoided Cost due to RE in 2019



Renewable has reduced the settlement price of electricity by 28% during peak hours

The actual data shows that due to the existing RE sources that coincidentally generate power during the peak periods of the grid, we have effectively reduced the cost of electricity by 28% during peak hours. This is because vRE plants displaces expensive power plants like Diesel.This finding is consistent with a PEMC finding which states that from the standpoint of the country's electricity market, the increasing penetration level of VRE resources promotes lower market prices because the respective nominations from these resources are prioritized in the least cost generation dispatch model [14].

To conclude, it is important to note that VRE plants achieved this 28% reduction in price even with the share of VRE being under 3% of the energy mix. This shows the significant cost-saving potential of more VRE plants in the energy mix and that it has a large potential to further reduce the price of electricity at higher RE penetration in the energy mix.

7. Conclusion

The Philippines position on climate change issues has always been on climate justice – considering that the country is a victim rather than the initiator of all of these climate impacts [34]. However, while the Philippines is only a small contributor to Greenhouse gas emissions, this report shows that the energy transition is still beneficial to the country since the renewable energy technologies now proves to be economical, practical, and what our grid needs. These are elaborated on the following key points:

Baseload coal is no longer what the Philippines needs

Evidences show the incompatibility of coal plants for the current needs of the Philippine energy system. Currently, the Philippines already has an overcapacity of baseload power plants – but even so, we still experience power outages because of its inherent limitations. Data have shown that coal-fired power plants are unreliable, intermittent, and not what is technically needed by our existing power grid. The conventional thinking that we only need baseload power plants to supply power continuously 24/7 is flawed. The Philippine load demand is variable, and we should develop the power grid to adapt and meet the varying needs of the load demand. We need to push for the right energy mix in our power generating sources – and currently, what we need to achieve the right energy mix is a power source that is cheap, reliable, available during peak demand hours.

Variable RE sources are reliable because of their high availability and predictability, and can be further realized with the appropriate system design and policies

Data has shown variable renewable energy sources can help support the variability of the Philippine load demand requirements. A key reason is its availability when the energy demand is the highest. Not only that, but data has also shown that vRE can reliably be dispatched into the electricity spot market because they are predictable and do not experience outages as conventional power plants do. Even though there are still some inherent variability and fluctuations with these power plants, these issues can be minimized to a manageable level through an improved system design and implementation of appropriate policies.

With these points in mind, vRE sources do not have to replace coal but rather help in achieving the right mix in our power system – a system in which different power-generating technologies complement each other. If enough vRE plants were installed in the grid, existing coal plants would no longer need to ramp up and down significantly. Thus, an increased RE penetration during peak hours could reduce the cycling operations of the coal plants, which made them unreliable in the first place.

Coal is not the most cost-effective and has hidden costs tied to it

Due to the intermittency and unreliability of these coal-fired power plants, significant increases in the electricity price occurred when they were unavailable. We have seen that the electricity price more than doubles from the previous months due to the unavailability of these coal-fired power plants – but even with the increased prices, we still experience rotating blackouts during the Summer of 2021. We have also presented hidden costs to coal-fired power plants due to the policies here in the Philippines that allow automatic fuel pass-through, which makes the price of electricity volatile to the global markets. This issue is a clear threat to the energy security of the Philippines.

vRE sources are among the cheapest and have historically reduced the price of electricity

Data shows that vRE power plants are already cheaper than coal-fired power generating technologies – and they are projected to get cheaper in the coming years. This projection is primarily due to the advancing technologies in producing these power generating units and the abundance of the fuel for these energy sources. To add to this, these power plants have shown that they are available during the highest demand – that is peak hours. Because of this availability, vRE has reduced the price of electricity by 28% on average during these peak hours even with the share of vRE being under 3% of the energy mix. This just shows its potential to further reduce the price of electricity at higher RE penetration in the energy mix.

Actions undertaken by the Philippines

The findings in this paper confirm existing initiatives undertaken by the government. One of these initiatives is in the latest edition of the Philippine Energy Plan, stating the country envisions achieving a 35% and 50% share of renewable energy by 2030 and 2040, respectively [30]. Wherein clean and indigenous energy production paves the way for socio-economic progress and Energy Efficiency & Conservation (EE&C) developing into a national way of life.

This move is further supported by the RE-centric policies and mechanisms spearheaded by the DOE, which aim at facilitating greater private sector investments in renewables. Policies and programs include the participation of electricity consumers in renewable energy (RE) development, enabling them to produce their electricity requirements or choose RE as their supply. Other RE development measures include the Renewable Portfolio Standards policy, Green Energy Option Program policy, and Enhanced Net-Metering System, among others, which gear towards achieving a 35 percent RE share by 2030 [34].

The existing policies on baseload coal are also in line with the findings of this paper. Currently, the Philippines is pushing for the transition from fossil fuel-based technology utilization to cleaner energy sources to ensure more sustainable growth for the country – as seen in the moratorium on greenfield coal power plants that took effect in October 2020. The moratorium aims to improve energy sustainability, reliability, and flexibility by reducing dependency on unreliable and intermittent coal power [2].

Ultimately, evidence has shown that advancing the energy transition is the economic way forward - that it can pave the way for affordable and reliable energy for the Philippines. Its compliance with the environmental concerns are just an added co-benefit to this initiative.

8. Research Priorities in 2022

The Clean, Affordable and Secure Energy for Southeast Asia (CASE) project aims to drive the energy transition in the Philippines towards a new, economically successful, and environmentally friendly power sector. To achieve this, we plan to undertake future research priorities that will tackle:

1. Long Term Energy Scenario (LTES) for the Philippine Energy Plan

   Energy is one of the key inputs in each sector and industry in the Philippines, highlighting the importance of energy for the Philippine economy. However, the energy sector is also pointed out as one of the main contributors of GHG emissions that contribute to climate change. Because of this, in order for the Philippines to prepare for a just energy transition, comprehensive modeling of the energy sector must be done in parallel with all of the sectors that are affected.

   The CASE Philippines team aims to develop and model the energy and non-energy sectors in the Philippines in order to account for the GHG contribution of each industry group today and in the future. Moreover, we also seek to develop the least cost expansion for the energy transition in order to determine the attributed costs that are tied to the energy transition. The team will do this by using the data from the DOE PEP and synergizing with various DOE bureaus – such as the REMB, EPIMB, EPPB, EUMB, and many more – to streamline the processes and computations necessary for the PEP.

2. Impact Studies

   As the Philippines gradually undergoes an energy transition through renewable energy sources, various impacts would be inevitable. Because of this, the CASE Philippines team aims to study the technical, physical, and market policy aspects of the grid that are currently being planned or implemented in achieving grid flexibility. The goal is to assess whether the effectiveness of existing or future technologies & policies are enough to economically and practically meet the demands of the Philippines while still achieving climate mitigation agreements.

   Some of the key projects that the CASE Philippines team are aiming is to:

- Assess the impact of the existing and additional BESS facilities on the price and the entire grid
- Assess the impact of moratorium on greenfield coal projects on the GHG
- Assess how Waste-to-Energy (WTE) could replace coal in minimizing GHG emissions,
- Assess how the Green Energy Auction Program will affect the energy mix, in terms of policy presentation.
- Assess Power Procurement Processes for Distribution Utilities in terms of cost-competitiveness and RE integration

CASE Philippines team would like to jointly collaborate with the DOE in the conduct of these research studies. Moreover, we will also be open to collaborate with other development agencies and partners to synergize the research efforts towards advancing energy transition in the Philippines.

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About CASE

The programme "Clean, Affordable and Secure Energy for Southeast Asia" (CASE) is jointly implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and international and local expert organisations in the area of sustainable energy transformation and climate change: Agora Energiewende and NewClimate Institute (regional level), the Institute for Essential Services Reform (IESR) in Indonesia, the Institute for Climate and Sustainable Cities (ICSC) in the Philippines, the Energy Research Institute (ERI) and Thailand Development Research Institute (TDRI) in Thailand, and Vietnam Initiative for Energy Transition (VIET) in Vietnam. The DOE is the political partner of CASE in the Philippines and REMB is its main implementing partner bureau.

Funded by the German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU), CASE aims to support a narrative change in the region's power sector towards an evidence-based energy transition, in the pursuit of the Paris Agreement goals. The programme makes use of available research initiatives while generating new evidence grounded in local realities that can influence economic managers, power sector decision makers, industry leaders and electricity consumers to support early, speedy, and responsive strategic reforms in the power sector. To reach this objective, the programme applies a joint fact-finding approach involving expert analysis and dialogue to work towards consensus by converging areas of disagreement.

Furthermore, CASE is an aligned programme of the Energy Transition Partnership (ETP), an alliance of international donors, philanthropies, and partner governments established to accelerate energy transition and to support sustainable development goals in Southeast Asia.

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About ICSC

The Institute for Climate and Sustainable Cities is an international climate and energy policy group based in the Philippines advancing climate resilience and low carbon development. Based in the Philippines, it is engaged with the wider international climate and energy policy arena, particularly in Asia. It is recognized for its role in helping advance effective global climate action and the Paris climate agreement.

CASE
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