On behalf of:

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Toward 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 on the basis of 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 the Philippines' economic development. This groundwork has led to over half of the Philippine energy mix being coal and to a reduced share of renewable energy (RE). This work compiles and analyzes 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 (vRE) sources in the past four years. The following findings are derived:

Additional baseload coal is no longer what the Philippines needs

Baseload coal has been proved to be unreliable, in overcapacity, and 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 maximized with the appropriate system design and policies

Variable RE plants are available during times of high demand and can thus conveniently provide needed power. Moreover, data have shown that the availability rates of these plants are much better than those of coal plants, their hourly power dispatch are predictable, and their intrahour variability can be effectively managed.

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

The evidence clearly shows that coal has been intermittent and unreliable even before the pandemic. This intermittency has direct implications on system costs, which become an added burden to consumers. As the operating costs of coal plants are tied to fuel importation, coal is affected by the volatile prices in global markets that also add to the burden of consumers.

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

As the power generation of variable RE plants is coincident with peak demand, these plants have historically reduced the price of electricity during peak hours by 28% despite only having less than 3% share in the energy mix. Moreover, variable RE sources are indigenous and are thus not prone to price volatilities in global markets.

Currently, the Philippines envisions achieving a 35% and 50% share of RE by 2030 and 2040, respectively. The findings of this report confirm that the Philippines should take part in the energy transition by meeting target share, especially with RE proving to be economical, practical, and necessary for our grid. Moreover, current government policies are in line with the findings as RE-centric policies have been laid down in recent years.

Ultimately, we must remember that variable RE cannot and need not replace coal in terms of baseload capability. The urgent need is for us to strike a balance between different types of power generating technologies. Evidence shows that an energy transition utilizing variable RE power generating technologies will aid in achieving the right mix toward an affordable and reliable grid.

Contents

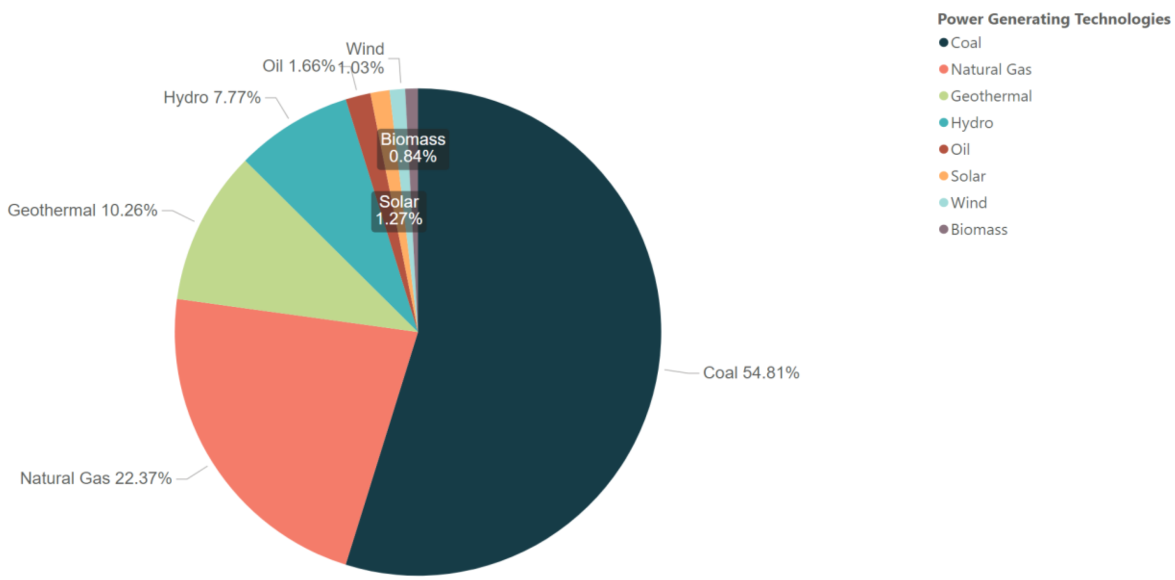
1. Introduction

Power Situation in the Philippines

In support of renewable energy (RE), the Philippine government enacted RA 9513 or the Renewable Energy Law of 2008 to accelerate the utilization of RE in the Philippines [1]. The law was ambitious, and it targeted a 300% increase in RE installed capacity in a span of 20 years. More than a decade has passed since the law was enacted, but we are still nowhere near this target, and the current scenario seems to have taken a turn toward a different direction.

The share of RE in the Philippines' power generation energy mix was about 35% in 2008. Today, the RE share has dropped to only 21% because our dependence on nonrenewable RE sources has increased rapidly and coal power plants have been rapidly constructed in the past decade. In the 2019 energy mix, power generating technologies based on fossil fuels, 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



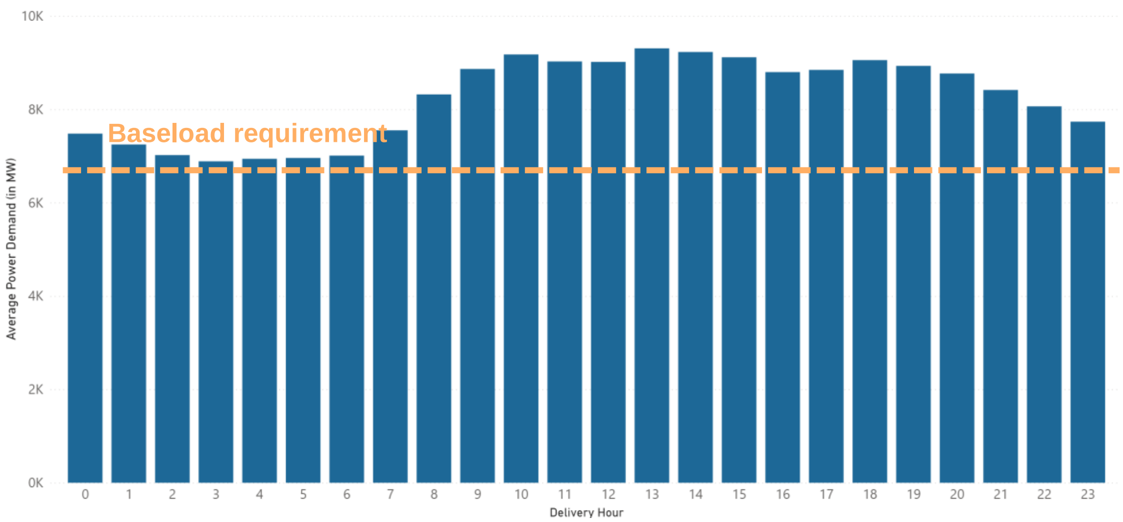
Coal, natural gas, and oil account for almost 80% of the gross power generation

The coal moratorium declared by the Philippine Department of Energy (DOE) is a move toward the right direction [2]. According to Dalusung III, a Technical Working Group member of the National Renewable Energy Board, the latest National Renewable Energy Plan no longer recommends new baseload coal power plants in the next 20 years [3]. However, despite such coal moratorium, construction has continued for coal power plants that were already in the planning and construction pipeline and were approved and committed to prior to the coal moratorium on October 27, 2020. According to the latest figures from DOE Philippines, a total of 6,937 MW committed baseload plants and 7,974 MW indicative baseload power plants are currently in the works, and most of them (4,421 MW of committed plants and 2,190 MW 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 required baseload amount is often set during the off-peak hours of a day. Power, and the plants that produce it, can be categorized on the basis of 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 baseload plants are rated to provide the minimum needed power; it is not economically feasible to operate them 24/7 to produce the maximum power required. In other words, baseload plants' total output should match the baseload requirement (minimum or the lowest demand) seen in Figure 2 and should stay constant [5].

Figure 2: Average Hourly Power Demand in Luzon in 2019



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

Furthermore, the Philippine load demand requirements fluctuate vastly throughout the day. As shown in Figure 2, 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 3,000 MW. 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 load requirements, data show that power generation investments are poured heavily into coal-fired power plants because of the perceived cheap, affordable, and secure energy supplied by baseload power plants.

Given such scenario, this report aims to provide evidence that shows how advancing energy transition is the economic and practical way forward. Specifically, this work debunks the perceived reliability of coal-fired power plants due to being baseload power plants and the perceived unreliability of variable renewable energy (vRE) plants due to their intermittency.

Moreover, this work debunks 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 the myths revolving around coal and vRE on the basis of historical information. Specifically, electricity market data dispatched hourly from 2017 to June 2021 are used.

New information from DOE (as of November 2021) will be considered in future studies and reports. Simulations of future scenarios that will support the addition of vRE will also be conducted in future studies, as discussed in the CASE Research Priorities section.

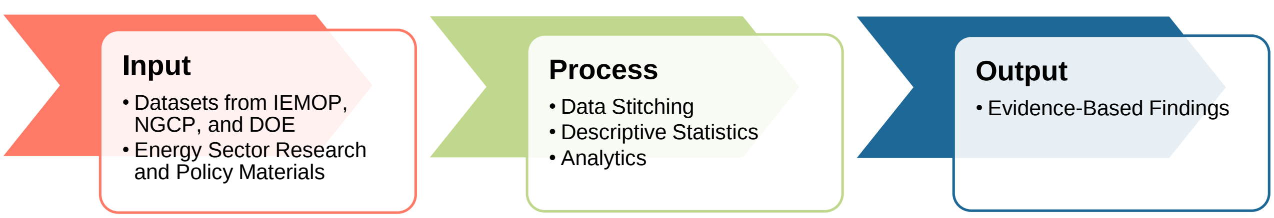
2. Methodology and data sources

The researchers have evaluated various data sources from the Independent Electricity Market Operators of the Philippines (IEMOP), National Grid Corporation of the Philippines (NGCP), and DOE. The list of the datasets used in this study is shown in Table 1.

Table 1: List of Datasets Uses

Dataset	Retrieval
Wholesale Electricity Spot Market (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 work follows the conceptual framework described in Figure 3. After gathering the datasets from various sources, the researchers stitched the data together by appropriate attributes to observe them from a broader perspective and establish the correlations and dependencies between parameters such as costs, power output, and events. Research and reports by established institutions were also used as a point of reference or as supporting materials.

Unless otherwise specified, all analyses are based on historical and actual energy data that were processed using analytics and simple descriptive statistic measures such as taking the average over a relevant period. The details are elaborated in each section of this paper.

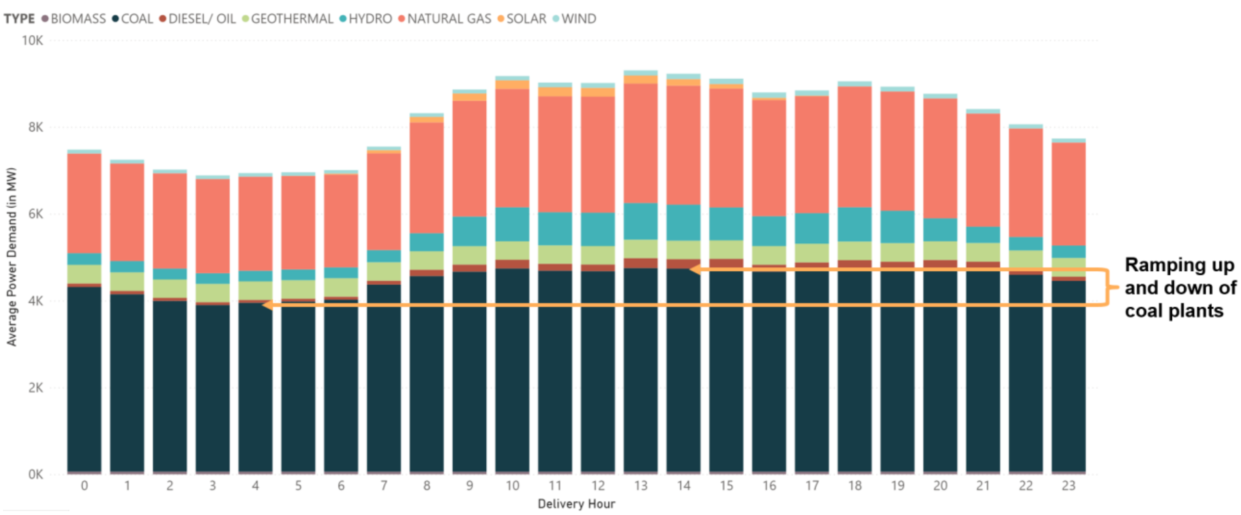
Finally, this report aims to provide an evidence-based analysis by presenting the data and the relevant findings as objectively as possible.

3. Coal is unreliable and is not what is needed

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

Coal power plants are widely used in the Philippines to meet the country's baseload requirement, and they now account for more than half of the Philippines' energy mix. Heavy investments have been poured into coal over the past decade because it is advertised to provide cheap baseload capacity and 24/7 availability. However, these features are not the only ones required. Given the nature of baseload requirements, coal power plants must run at that same level across all periods every day during their operation [5]. According to current data, such mode of operation is not aligned with how these plants operate today.

Figure 4: Average Hourly Energy Mix in 2019

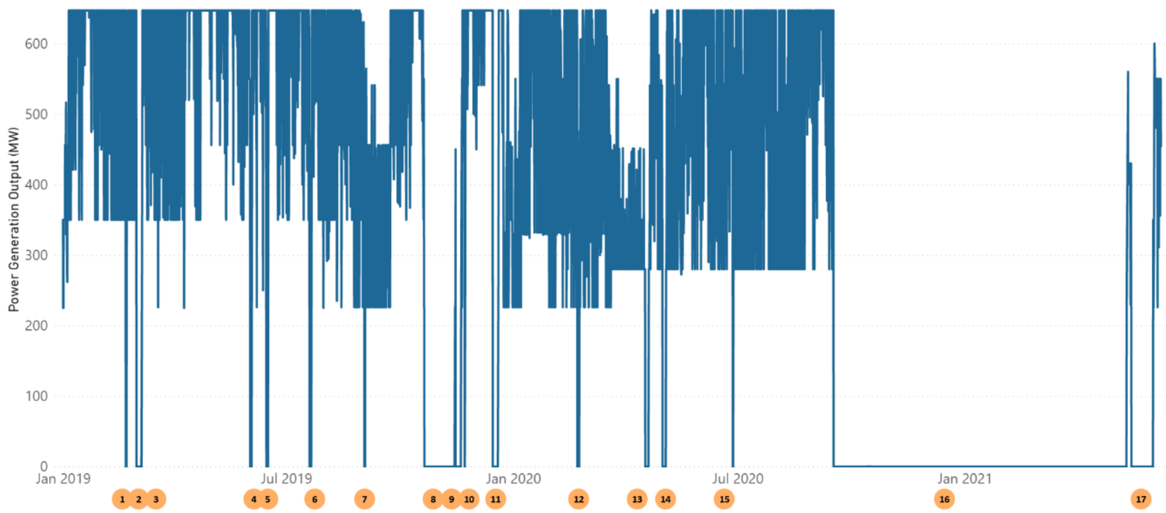


Coal-fired power plants account for the largest chunk, and their contribution ramps up during peak hours.

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 is also referred to as cycling. This cycling is an indication that coal-fired power plants are operating as more than baseload power plants and that they also provide intermediate loading.

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

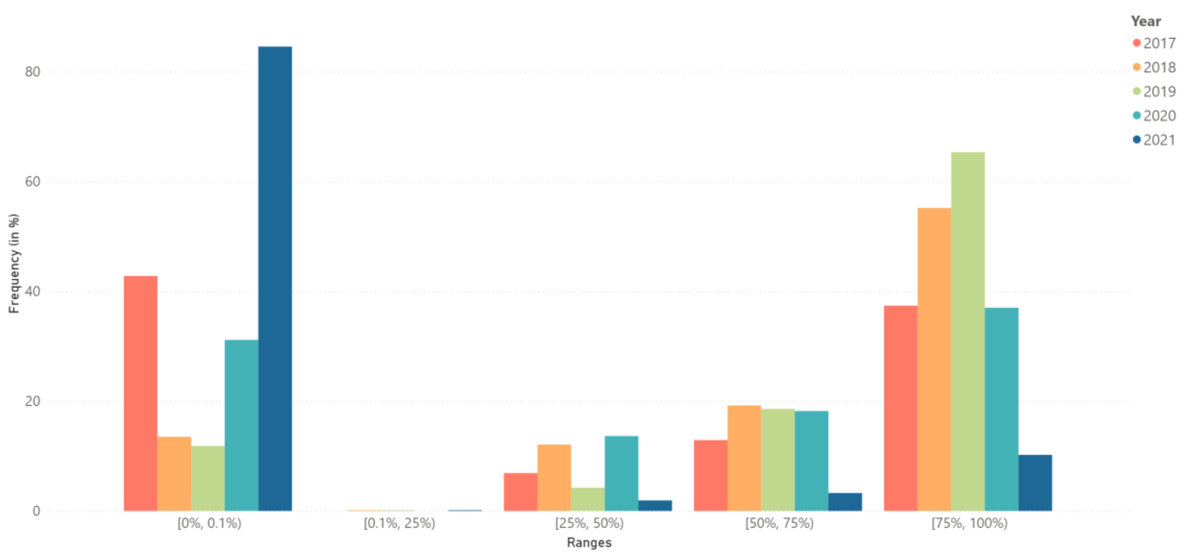
Figure 5: Power Output of Sual Coal-Fired Power Plant Unit 2 from January 2019 to June 2021



Historical data show that this plant is frequently under cycling operation and that it experienced 17 outages in this period.

On the basis of 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 make two observations: first, it did not run at a consistent loading level during its operation; second, the plant experienced several outages. To simplify the historical power output data of the plant, we provide a histogram of its generation loading.

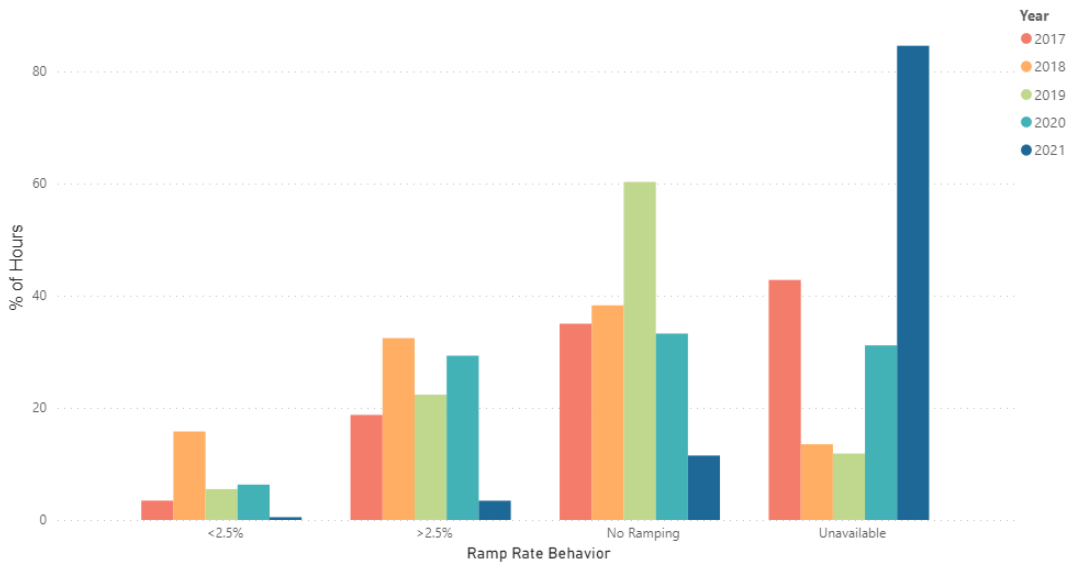
Figure 6: Histogram of Generation Loading for Sual Coal-Fired Power Plant Unit 2



This plant operates under baseload operation, but it also adopts cycling operations and experiences frequent outages.
Note: The 2021 data are only up to June 2021.

Figure 6 reflects the frequency of the hourly instances when the generator operating level was at a certain loading level range. As discussed previously, plants that serve baseload demand are expected to run at a constant level throughout their operation. Despite the high frequency of the 75%–100% generating levels, there is still a significant percentage between 25% and 75% loading. This spread may indicate that the plant may be cycling more frequently. To further investigate this loading behavior, we compute the percent hourly change of loading and placed the results in a distribution. In this way, we can 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

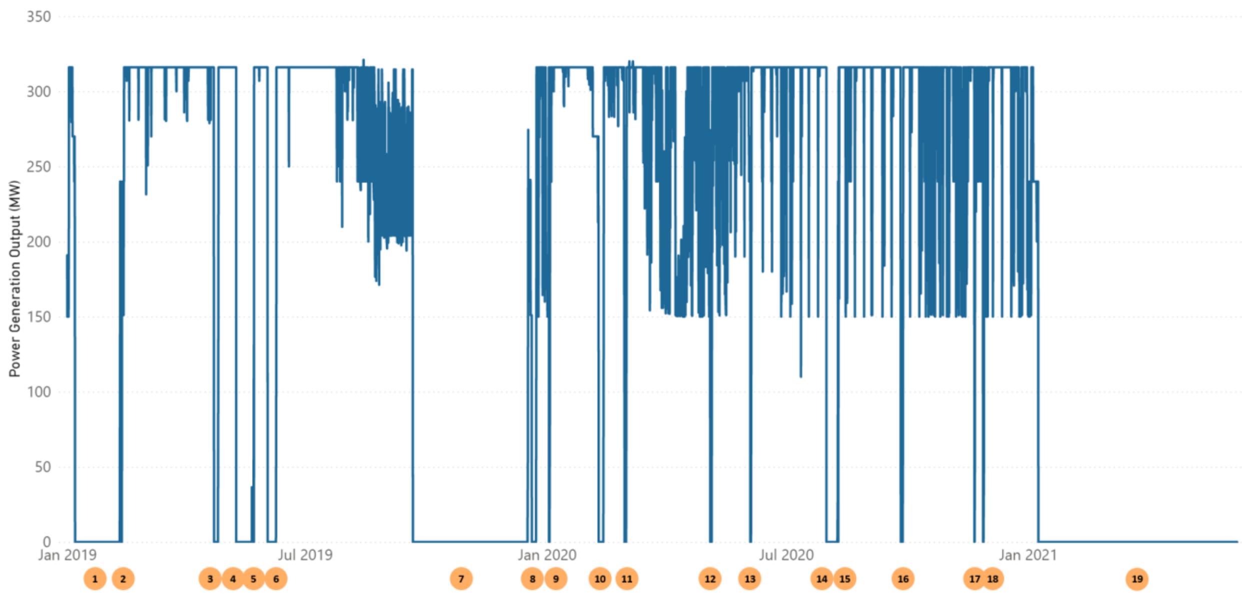


< 2.5% – Less than 2.5% change in loading from the previous hour
> 2.5% – More than 2.5% change in loading from the previous hour
No Ramping – No change in output from the previous hour
Unavailable – Intervals where the loading was 0–0.5 MW or there was no operation
Note: The 2021 data are only up to June 2021.

The percent hourly change of loading for this case is the ramp rate. In the context of the generation loading data, the percent hourly change of loading refers to how much the loading level changes from the previous hour. Figure 7 shows 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 change of more than 2.5% is considered to indicate significant ramping, a high frequency of which would indicate frequent cycling. The data show 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 can be observed in other coal power plants in the Philippines. Figure 8 shows the same cycling operation with frequency outages for GN Power Mariveles Unit 1, which experienced 19 outages in a span of 2.5 years. Note that this power plant uses a circulating fluidized bed (CFB), which is one of the latest technologies in coal power generation. Additionally, it has only been in operation for eight years as of 2021 and is thus considered as one of the newer coal plants operating in the country.

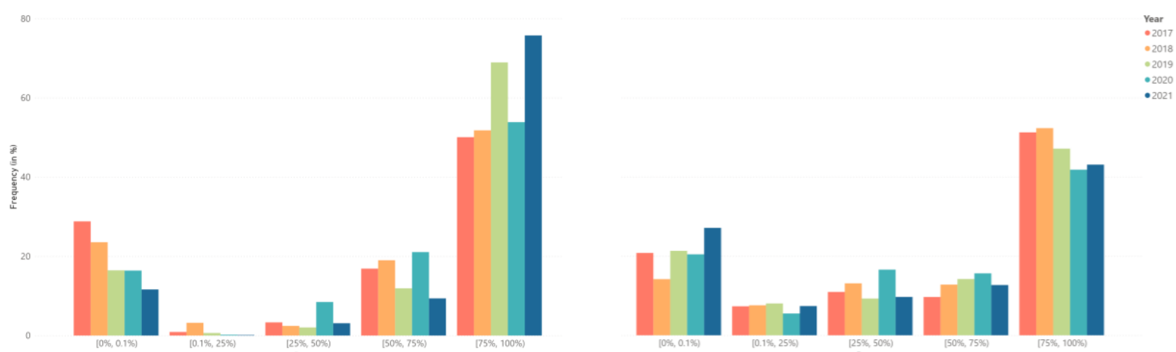
Figure 8: Power Output of GN Power Mariveles Unit 1 from 2019 to June 2021



Historical data show that this plant experienced 19 outages in this period.

This recurring on-and-off operation or intermittent operation can be observed in most, if not all, coal plants. To view the prominence of cycling in coal plants as a whole, we take the average of the most commonly used technologies in coal plants, such as the CFB and pulverized subcritical coal (PSC).

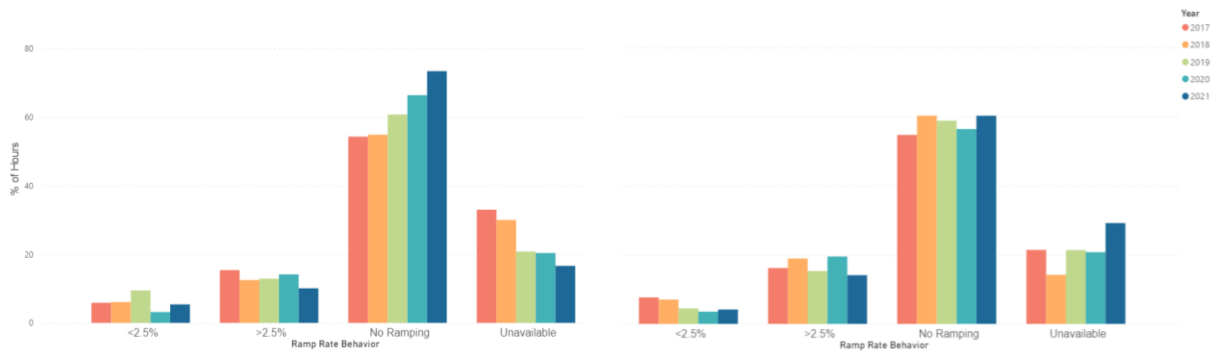
Figure 9: Histogram of Generation Loading for Circulating Fluidized Beds *(left)* and Pulverized Subcritical Coal *(right)*



The average plants operate under baseload operation, but they also have cycling operations and frequent outages.
Note: The 2021 data are only up to June 2021.

As shown in Figure 9, the CFB and PSC operate at the 75%–100% generating levels around half of the time. However, the significant percentage between the 25% and 75% generating levels could indicate that many of these plants are in a cycling condition more frequently. Moreover, the high frequency of the 0% loading levels (around 20% of the year) indicates the 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 there was no operation
Note: The 2021 data are only up to June 2021.

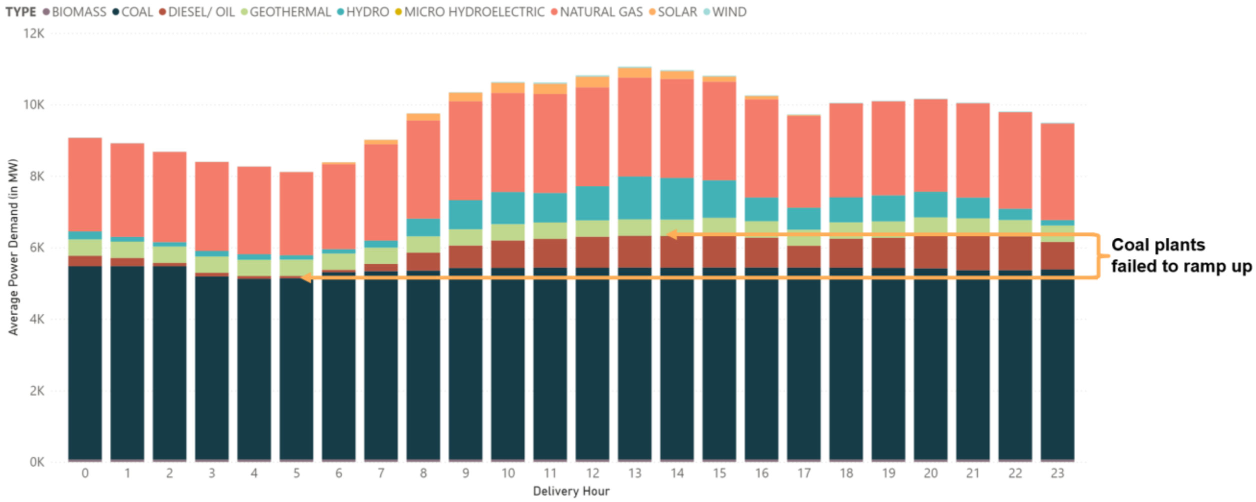
Observing the histogram of average hourly ramp rates (Figure 10), the average coal plant operates better than Sual Unit 2 in terms of baseload supply. However, the average coal plant in 2017–2020 was in baseload only 55% of the time while ramping significantly 15% of the time. This observation shows that Sual Unit 2 is not an isolated case in terms of coal plants operating as more than baseload plants.

This ramping up and down in the operation of a coal-fired power plant comes with a cost. As 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 their reliability and cost [6]. As a result of frequent cycling, the following effects may occur: increased wear and tear of plant equipment, shortened equipment lifespan due to thermal fatigue, thermal expansion, increased corrosion, and increased cost of start-up fuel. The study emphasized that without a proper maintenance of plants during these operations, unexpected outages become frequent.

3.2. Coal plants experience intermittency

We have established that cycling operations frequently occur in coal power plants, thereby potentially degrading operating conditions. We now determine how much these cycling operations degrade the reliability of coal power plants. This question is very relevant because if a coal plant suddenly goes offline, an energy shortage occurs and leads to the need for other more expensive plants as a substitute in the energy mix. Such a case occurred in the summer of 2021.

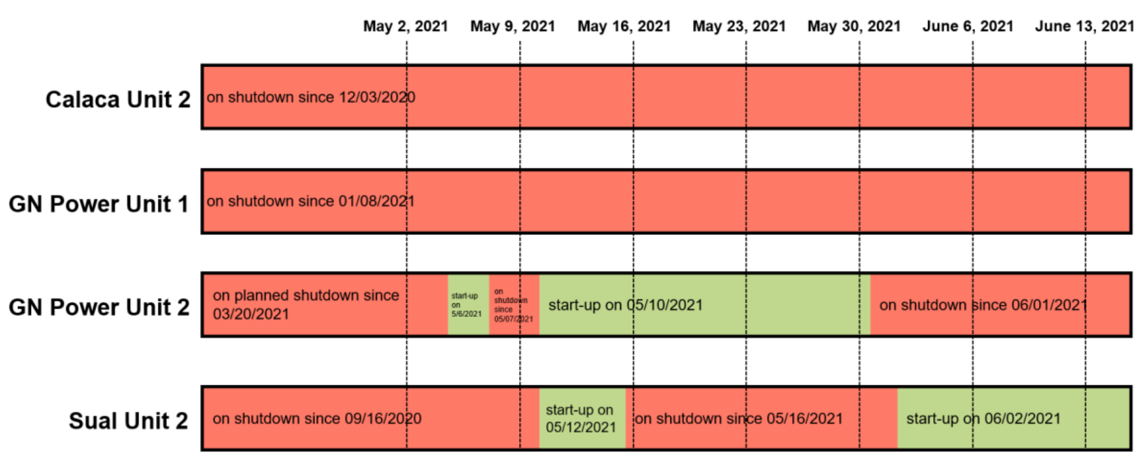
Figure 11: Hourly Power Demand from May 31 to June 1, 2021



During the outages in the summer of 2021, the cumulative coal-fired power plants failed to ramp up accordingly. This failure necessitated the dispatch of expensive plants, such as diesel and oil-based power plants.

From May 31 to June 1, 2021, a chunk of coal plants in the energy mix failed to ramp up accordingly; this scenario differed from that in the previous year (Figure 4). This result 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. These outages resulted in a decrease of 1,500 MW in the electric power supply. At the same time, the 40% supply gas restriction of Malampaya derated the outputs of SLPGC Unit 1, Ilijan Unit 1, and Ilijan Unit 2, thereby resulting in almost 500 MW of unused power capacity. The decrease in electric power supply during the unavailability of coal and natural gas plants was offset using more expensive diesel and oil-based power plants.

Figure 12: Outage Timeline of Four Baseload Coal-Fired Plants in Summer 2021



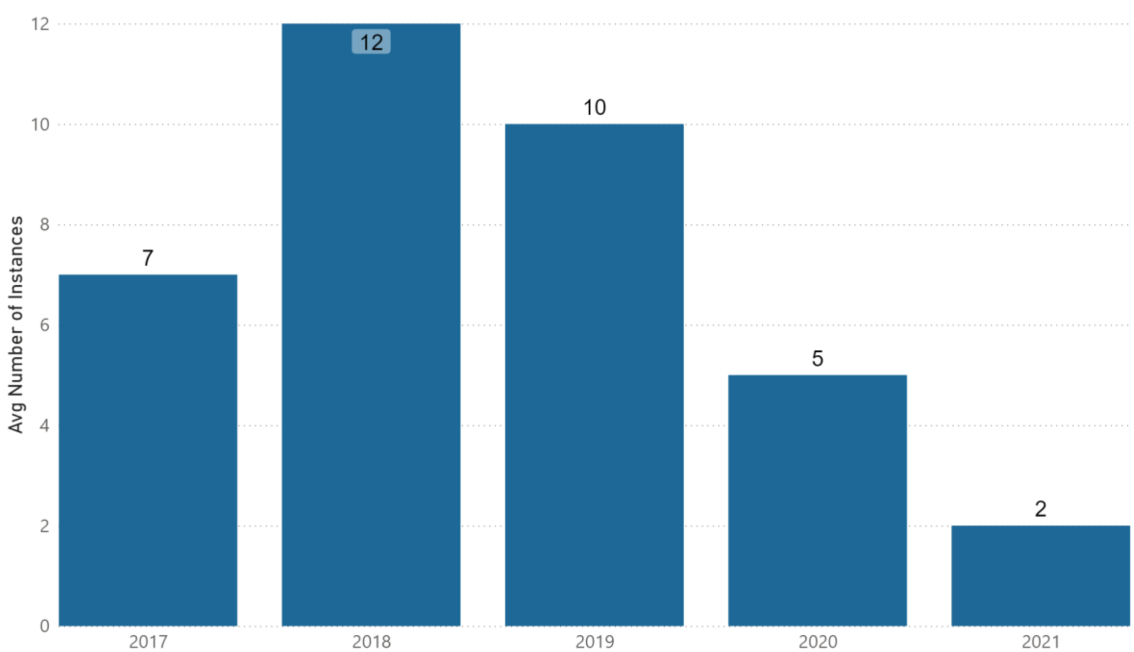
Red – Power plant on shutdown
Green – Power plant on start-up or running

Typically, coal-fired power plants undergo a planned outage every year for maintenance. According to Energy Regulatory Commission (ERC) Resolution No. 10, Series of 2020, effective 2021, the total allowed planned outages for PSC and CFB are 27.9 and 15.4 days, respectively [7]. However, the operational data of Sual Unit 2 show extended outages that span 6–8 months, which are very unusual and uneconomical to be a plant turnaround maintenance.

Aside from these annual extended outages, we can observe several other outages from the 2.5-year operational data of Sual Unit 2 (Figure 5) and GN Power Mariveles Unit 1 (Figure 8). 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 because planned and extended outages should have addressed all impending equipment failures. This recurring on-and-off operation, even after planned and extended outages, had a significant effect during the summer of 2021, particularly for Sual Unit 2 and GN Power Mariveles Unit 2. The resulting impact contributed to the expensive electricity and rotating blackouts experienced in this period.

As coal-fired power plants operate in economies of scale, they are susceptible to breakdowns. A single unit of a power plant comprises several interdependent pieces of equipment, each of which can experience a mechanism of failure. The failure of one critical piece of equipment may exert a cascading effect and ultimately shut down the entire unit, which leads to an outage. In the case of intermittent coal plants, their critical equipment (or parts thereof) could experience mechanisms of failure at different rates. At the same time, their existing preventive and predictive maintenance programs cannot reliably forecast the operating lifespan of 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: The 2021 data are only up to June 2021. Additionally, for baseload plants, a 0.5 MW output is considered negligible residual output because of its large capacity.

According to the number of plant outage instances, Sual Coal-Fired Power Plant Unit 2 experiences 5 to 12 outage instances annually or 8.5 on average. We define an outage instance as the number of occurrences wherein the power output of the power plant drops to 0–0.5 MW (the plant is on shutdown) regardless of the duration. It indicates that in addition to the annual planned outage, the plant experiences other outages annually.

Drilling down to the cause of outages, we look at the system operator advisory event logs. From here, we can see that most of these outages are in fact unplanned outages, with the most common cause being boiler tube leaks. Such scenarios are plausible because frequent cycling operations can cause thermal fatigue and thermal expansion as the operating temperature of the boiler fluctuates. These conditions can increase wear and tear and corrosion rates, which ultimately reduce the operating lifespan of equipment.

Figure 14: System Advisory Logs of 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 experienced many 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; hence, the predictability of power plant operations 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 to replace the power plants that are expected to be down.

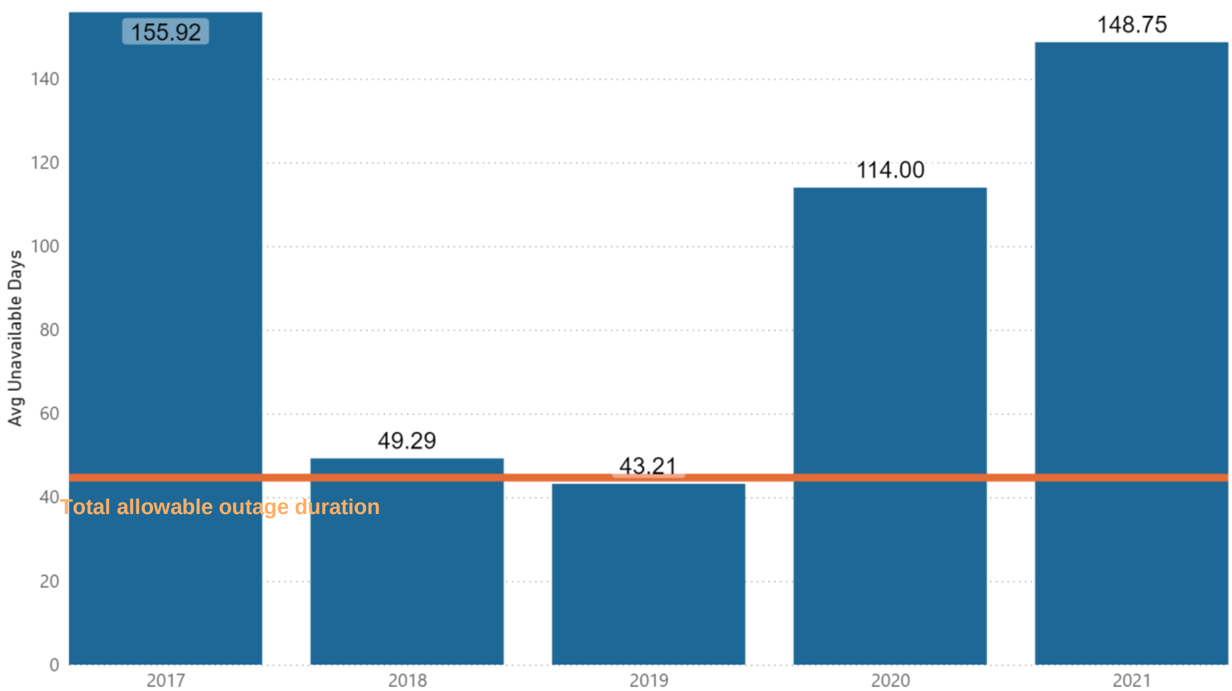
However, as shown in Figure 5, the downtime of these coal power plants is random by nature. This randomness makes it harder for the grid operator to dispatch the most cost-effective energy supply in a timely manner. In such cases, more expensive power plants, such as diesel power plants, are dispatched.

To assess the intermittency of these plants in previous years and determine whether it is still acceptable, we compare the total outage duration of the power plants with the maximum allowable outage duration limit established by the ERC effective 2021. According to ERC, the benchmark values prescribed are determined on the basis of the computed reliability performance per technology, as well as the number of outage days per year, by utilizing information from the Actual Events Reports from 2015 to 2019 submitted by generation companies in the Philippines [7]. We should note that power plants that exceeded this limit before 2021 will not be penalized because such limit was not effective prior to the current year. For this analysis, the threshold is applied to the previous years because it still serves as a good benchmark to assess the historical performance of these plants.

Moreover, this work considers the combined duration for planned and unplanned outages to simplify the analysis. Ultimately, if a power plant exceeds the maximum planned and unplanned outage durations, then it also exceeds either type of outage duration; none of these cases are acceptable. Note that this analysis only refers to the operational data and does not delve deeper into the specific reasons why these outages happened for each plant. In certain instances, planned outages can exceed beyond the acceptable outage duration limits if deemed necessary by the system operator and the transmission network provider. However, the reason for such extension shall be incorporated into the Grid Operations and Maintenance Program that is submitted quarterly to ERC to assess whether these reasons are indeed acceptable [7].

For a PSC plant, the maximum allowable outage duration for planned and unplanned outages is 44.7 days [7]. Sual Coal-Fired Power Plant Unit 2 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 has been consistently unable to meet the ERC-mandated total allowable outages for planned and unplanned outages, thereby causing extended unavailability among customers.

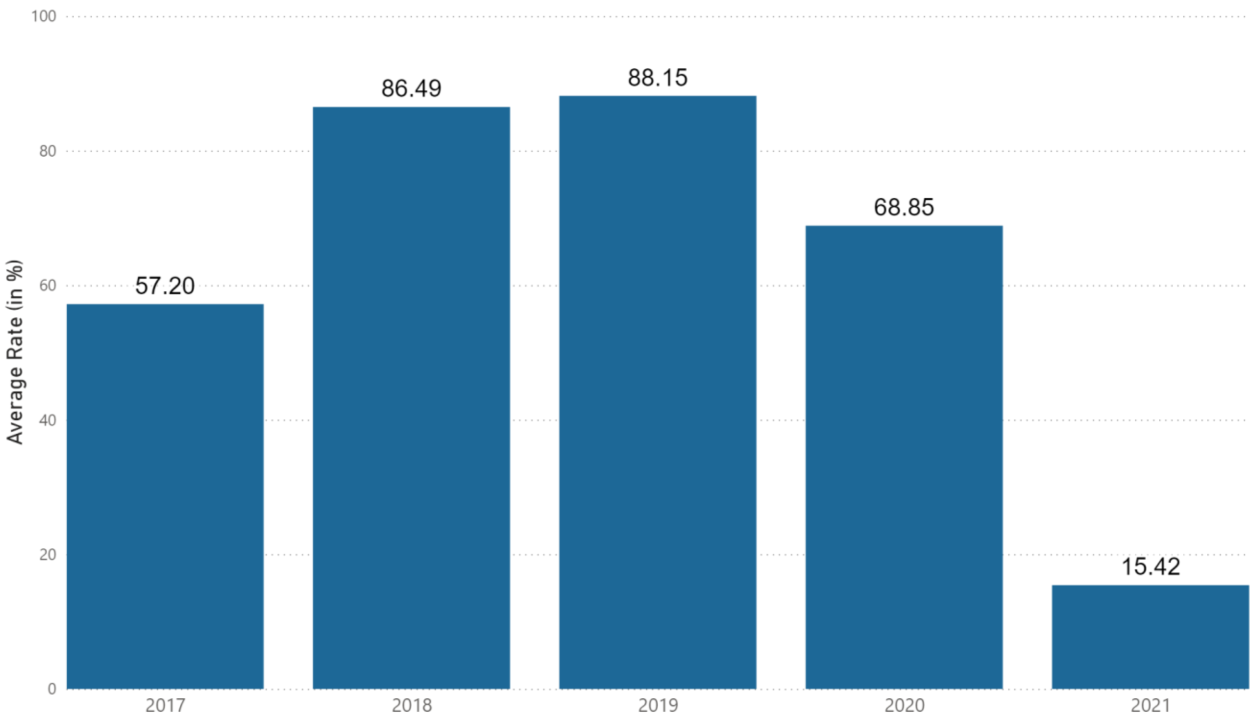
Figure 15: Outage Duration (In Days) of Sual Coal-Fired Power Plant Unit 2



This plant has historically exceeded the allowable limit mandated by ERC.
Note: The 2021 data are 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 define the availability rate as the percentage of the number of hours that the plant is operating at any generation loading relative to the total number of hours in a year. In the case of baseload power plants, the total number of hours is 8,760 hours annually. All hours that the plant records a 0–0.5 MW power output are considered as its unavailability time.

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



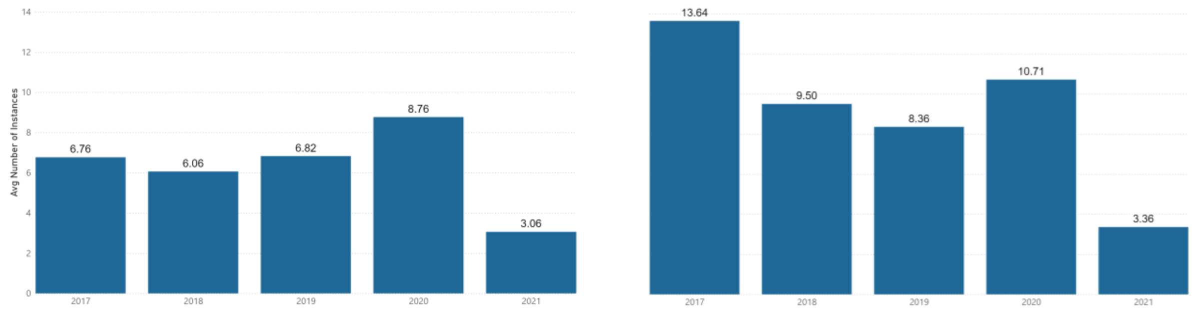
This plant has been unavailable about 31% of the time annually.
Note: The 2021 data are only up to June 2021.

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.

Are the outages experienced by Sual Coal-Fired Power Plant Unit 2 isolated cases? Do other coal-fired power plants experience the same?

Focusing on the outage instances experienced by these types of plants (Figure 17), we can observe that they are numerous. For an average CFB coal fired-power plant, it experiences 6–9 outage instances annually. This number is higher for PSC-fired power plants, which experience 8–14 outage instances annually. Such data indicate that aside from annual planned outages, plants also experience several other outages annually. These instances are not economical for any baseload power plant with high startup costs and low effective capacity factors.

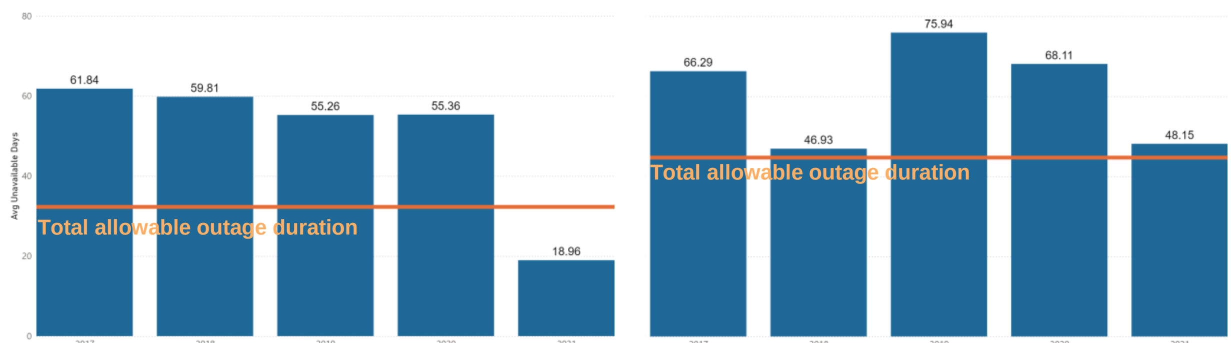
Figure 17: Number of Outage Instances for Circulating Fluidized Beds *(left)* and Pulverized Subcritical Coal *(right)*



The plants experience other outages aside from annual planned outages.
Note: The 2021 data are only up to June 2021.

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

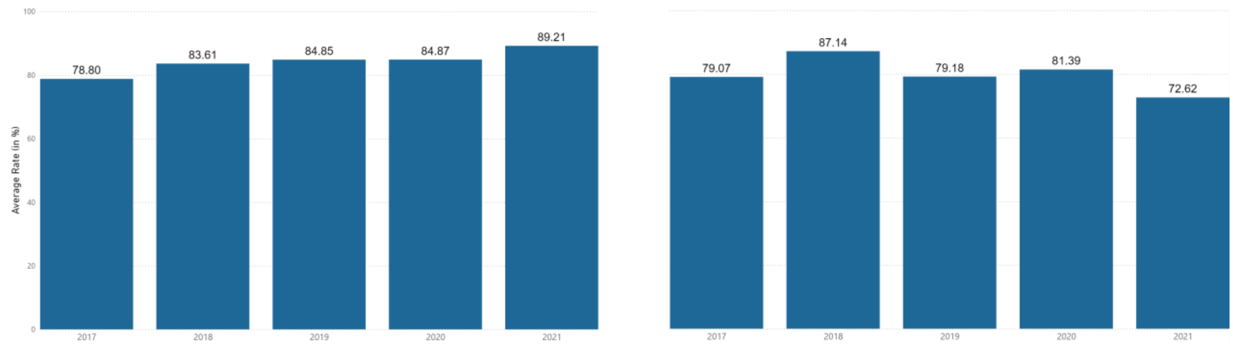
Figure 18: Outage Duration for Circulating Fluidized Beds *(left)* and Pulverized Subcritical Coal *(right)*



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

Because of this long outage duration that exceeds the ERC-mandated limits, coal-fired power plants are unable to provide power to consumers. For CFB- and PSC-type plants, they 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)*

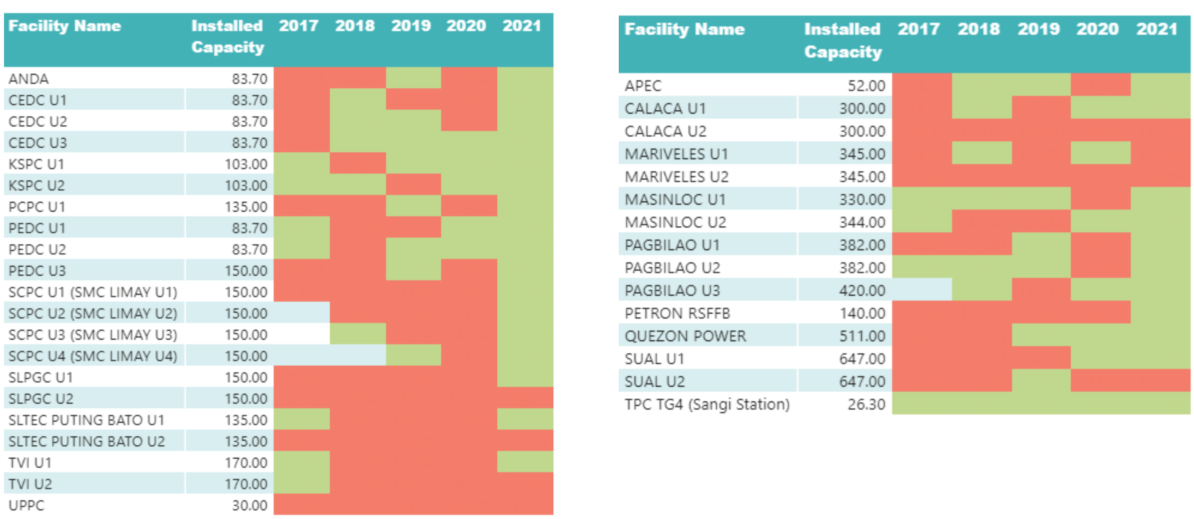


The different types of coal plants are unavailable about 20% of the time annually.
Note: The 2021 data are only up to June 2021.

On a more granular basis, the heat map in Figure 20 shows the different power plants that exceeded the maximum allowable planned and unplanned outage durations. The data show that most of these coal plants exceeded the limits. 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 that they did not experience intermittency and unplanned outages as described before.

Interestingly, the newly commissioned plants (less than 3–4 years) also exceeded the duration limits. 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)*



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

Overall, the data show that the outages experienced during the summer of 2021 directly resulted from the unreliability of the coal plants and that the outages were not isolated cases. The operational data of the average CFB and PSC power plants show that the outages they experienced were not at all random because the outages frequently recurred year after year.

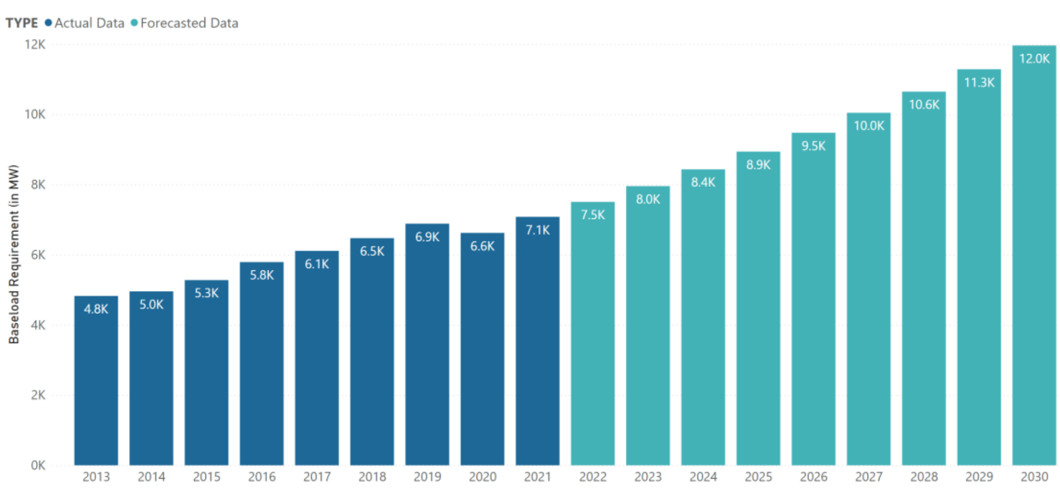
3.3. Additional capacity of coal plants is no longer needed

The notion that each power generating plant must be available for a 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, and such target can be achieved by sourcing from various supply options. Supply options include vRE sources, such as wind and solar; and flexible power plants, such as pump storage hydro, distributed biomass power plants, simple cycle gas power plants, and even oil-fired engine generators. Choosing capacities to add should not be based on how they can meet baseload requirements but should be grounded in the most cost-effective combination of power generating technologies.

The previous sections have shown that baseload power plants operate as more than baseload plants 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 power plants, is 11,300 MW. However, our Luzon's baseload requirement only ranges from 6,000 MW to 7,500 MW all year round. Hence, we are facing overcapacity for baseload power plants, and 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 has been forecasted by computing the average power demand during the off-peak hours of the day and projecting previous historical baseload demand growth. Results show that the baseload requirement in Luzon in 2030 will be about 12,000 MW, which is only slightly higher than the existing baseload capacity of the grid today. However, note that 5,878 MW of committed baseload capacity and 8,910 MW of indicative baseload capacity are already in the pipeline for the next few years; these values will further overinflate the already inflated baseload capacity of the grid.

Figure 21: Actual and Forecasted Baseload Requirements in Luzon



Projecting the baseload growth in the future and considering additional baseload capacities, we will still experience an overcapacity of baseload power plants.

Note: Only the Luzon grid was used for this forecast to simplify the analysis. This grid is the largest one currently.

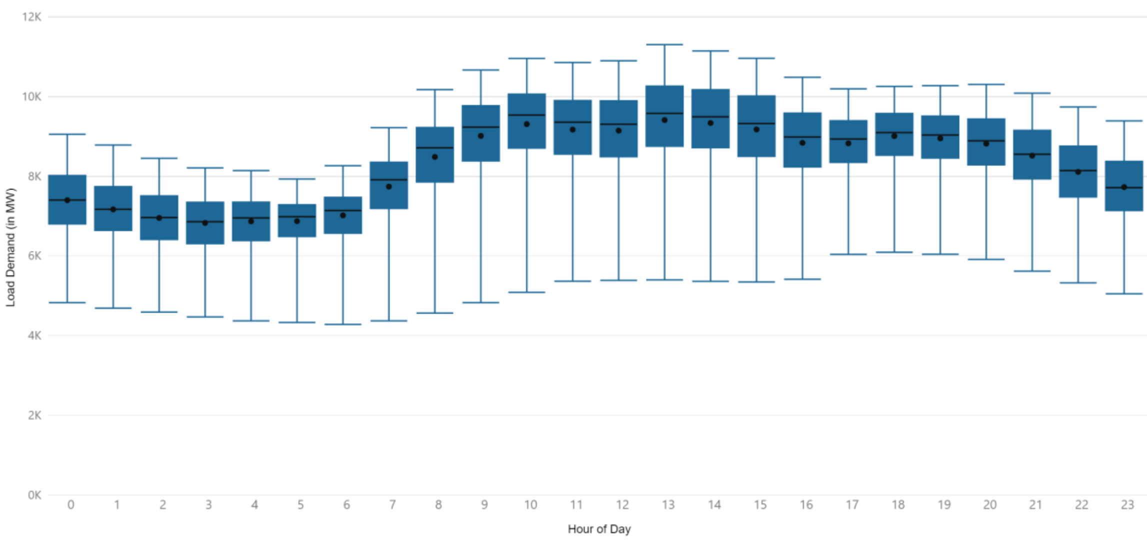
As presented above, the Philippines already has an overcapacity of baseload power plants, with some plants being operated more as intermediate plants. This overcapacity is also reflected in the total installed capacity of the existing power plants in the grid. We currently have approximately 26,000 MW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

Aside from the unreliability and intermittency experienced by coal power plants, another reason behind the power outages that we still experience is the limitation in the operation of 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, at which we need the most power. In sum, when we have too many baseload power plants, we will have too much power when we do not need it and not have enough when we do.

> *In sum, when we have too many baseload power plants, we will have too much power when we do not need it and not have enough when we do.*

Another constraint in the grid is the risk that baseload power plants introduce to the grid. As baseload power plants supply large chunks of energy to the grid, they exert great impact on the grid whenever they encounter problems. For example, if the Sual Coal-Fired Power Plant, which is the largest baseload power plant in the Philippines at 647 MW, 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; in both scenarios, the consumers are on the losing side. It is more optimal to have distributed energy sources deployed to the grid in place of a single large power generating unit. Specifically, if a random outage occurs, it will be much easier for the grid to adjust if it is not solely relying on these centralized power generating technologies with large generating capacities.

Figure 22: Electricity Hourly Load Profile in Luzon in 2019



The Luzon load demand has huge variability, which is evident in the wide span of each of the boxplots.

Lastly, we must take note of the primary characteristic of the Philippine load profile, that is, it is inherently variable. It changes any time of the day, day of the week, and season of the year. Take for example the body of the boxplot in Hour 13 (Figure 22). The data points from the 1st quartile to the 3rd quartile vary by about 1,500 MW. This capacity is about twice or thrice that of our largest coal power plants. This difference indicates that the demand is dynamic. If more baseload coal power plants are constructed to meet this highly variable load demand, then additional plants will 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.

Therefore, we need a heterogeneous mix of generators that can cope with demand variability while still providing round-the-clock electricity; this objective cannot be achieved by investing heavily in generators that can only provide baseload requirements [5]. Thus, we no longer need additional baseload coal plants. What we require now are flexible power plants that match demand variability instant by instant.

The existing policies by DOE affirm our conclusion that we no longer need coal, as indicated 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

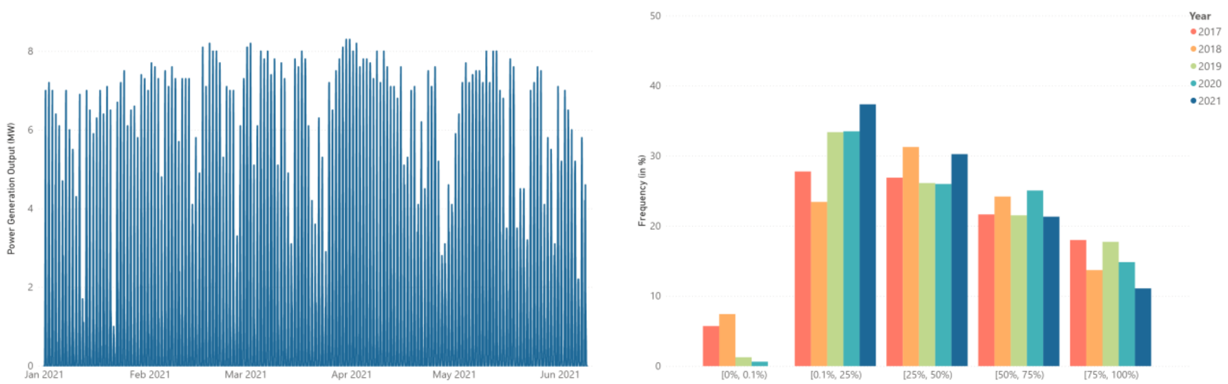
4.1. vREs are variable and not intermittent in a way that makes them unreliable

As the category name suggests, the power generation output of vRE resources is variable in nature; thus, it can change depending on several factors. Unlike conventional coal-fired power plants, power plants dependent on wind speed and solar irradiance have uncontrollable output; this lack of control explains why vREs have been branded 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 it is unpredictable. Although solar and wind RE outputs are not controllable, when and how much output they will generate can be easily predicted through day and night cycles, weather, and seasonal forecasts. This predictability outweighs the intermittency of vREs as long as the proper implementation of RE projects, necessary policies such as the Philippine Grid Code, and improvements in system design is ensured to harness these scheduled outputs.

Referring to 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 cycles. Additionally, we can notice that the magnitude of the power generation changes daily because of the different atmospheric conditions, such as clouds.

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

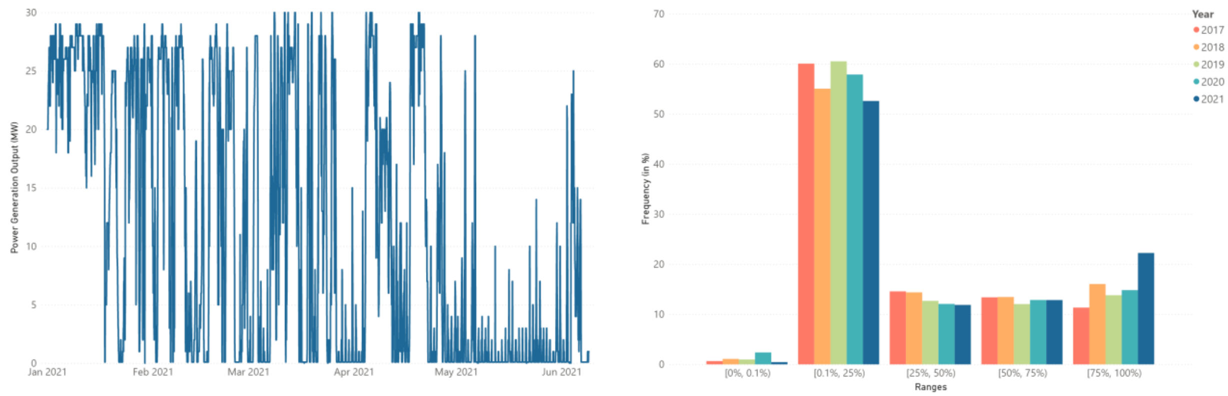


FRCV plant operates under variable generation as the frequency of generation loading is distributed.

Translating this solar historical generation output into the histogram of generation loading, we can see that there is a distributed frequency of generation loading. This observation suggests that the plant operates under variable generation. Note that we only consider its solar generation output from 7 am to 5 pm because these are the only times when a solar plant is expected to produce power. The 6 am and 6 pm time intervals are 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 the power generation fluctuates much more than solar plants. This is because wind plants experience much greater variability as result of their high dependence on seasons. This dependence on seasons 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)*

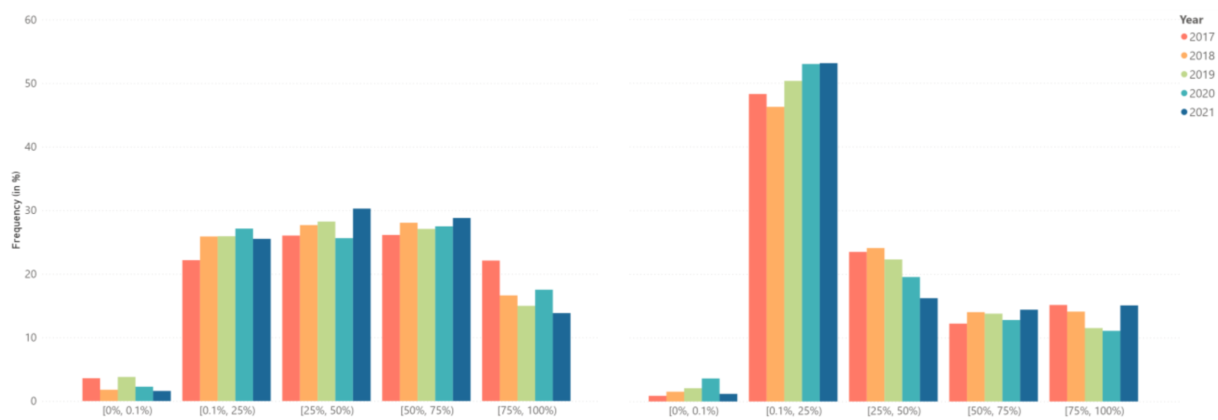


NWIND-1 plant operates under variable generation, but it is highly dependent on seasons.

Translating this wind historical generation output into the histogram of generation loading, we can see that the plant 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 grids. 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 observed in the average wind power plants.

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



The average solar and wind power plant operates under variable generation. However, wind power plants have a bias toward low generating levels because of their high seasonality.
Note: The 2021 data are only up to June 2021.

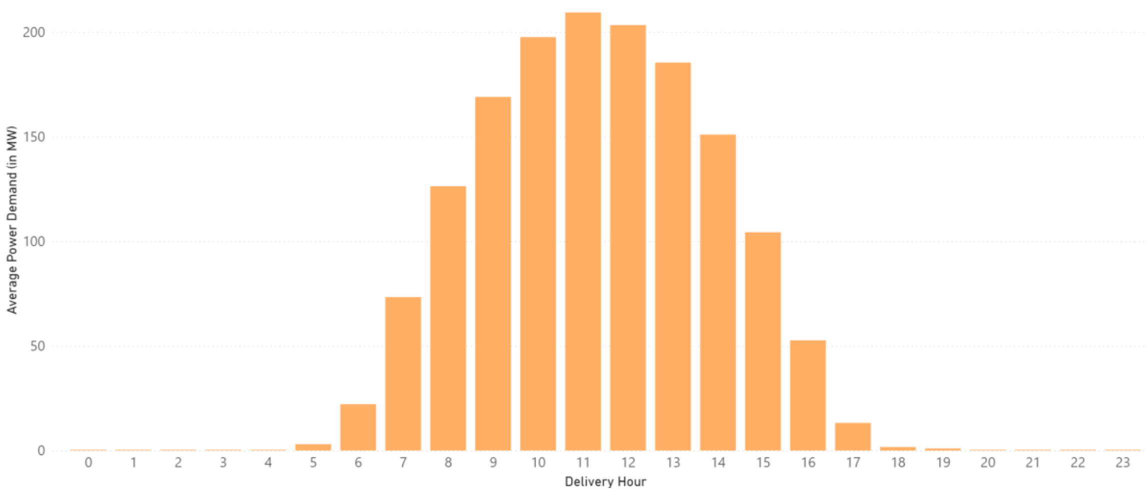
Figure 25 shows the low level of 0 MW loading on both solar and wind power plants. This result suggests that during the period we expect these sources to be running, they will reliably run. In other words, these power plants do not experience random starting and stopping of power generation output; they 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

Although it is true that vREs cannot cover the baseload power demand around the clock, this was never the intended purpose of vREs. As presented above, the Philippines already has enough baseload power. What is needed today is a combination of different power plants that can provide electricity cost-effectively and reliably. To realize this objective, 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 can be addressed by vREs as they are available at that time [5].

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

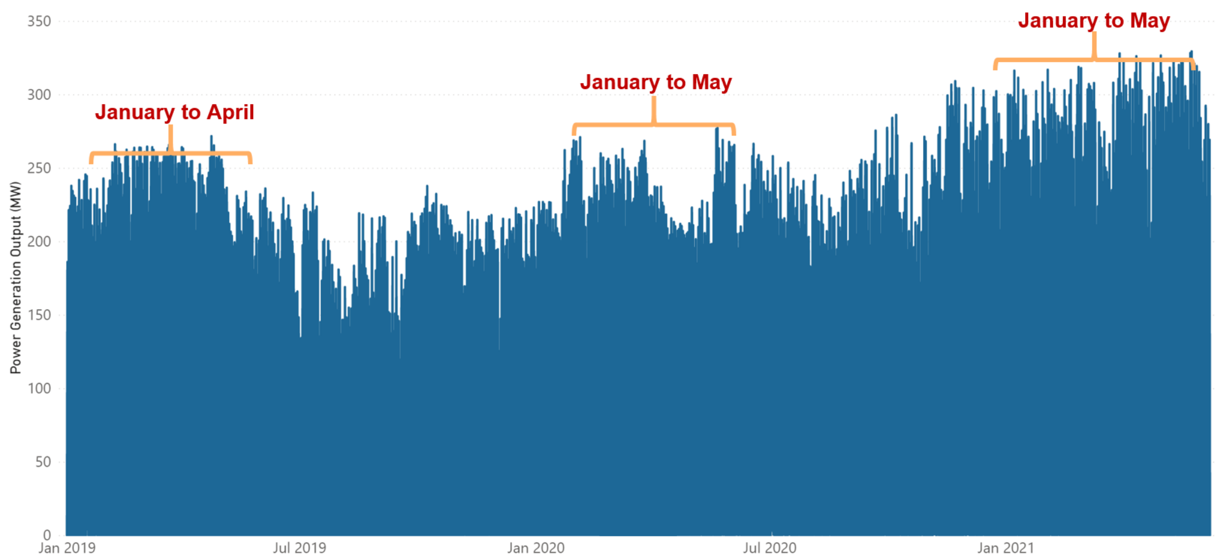
Figure 26: Average Daily Solar Generation Output at Luzon in 2019



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

Historical data show that solar generation is available throughout the year, even during the rainy season experienced in some months. Figure 27 also shows the variability of solar plants, which peaks from January to May. All of these characteristics are expected from solar power plants.

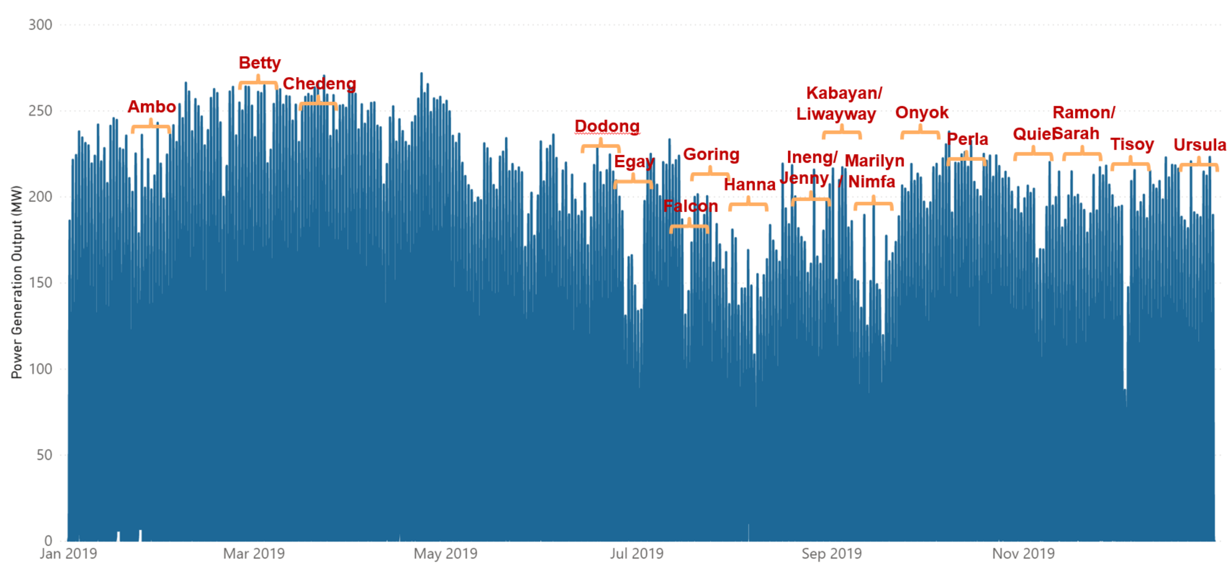
Figure 27: 2.5-Year Generation Profile of Solar Plants in Luzon



Solar power generation is available throughout the year, even during rainy season.

Additionally, even with the frequent typhoons experienced in the Philippines, solar power generation is not completely disrupted because of the large number of solar power plants installed on the grid. The intermittency and uncertainty experienced by an individual solar power plant are minimized when we look at them at an aggregated level.

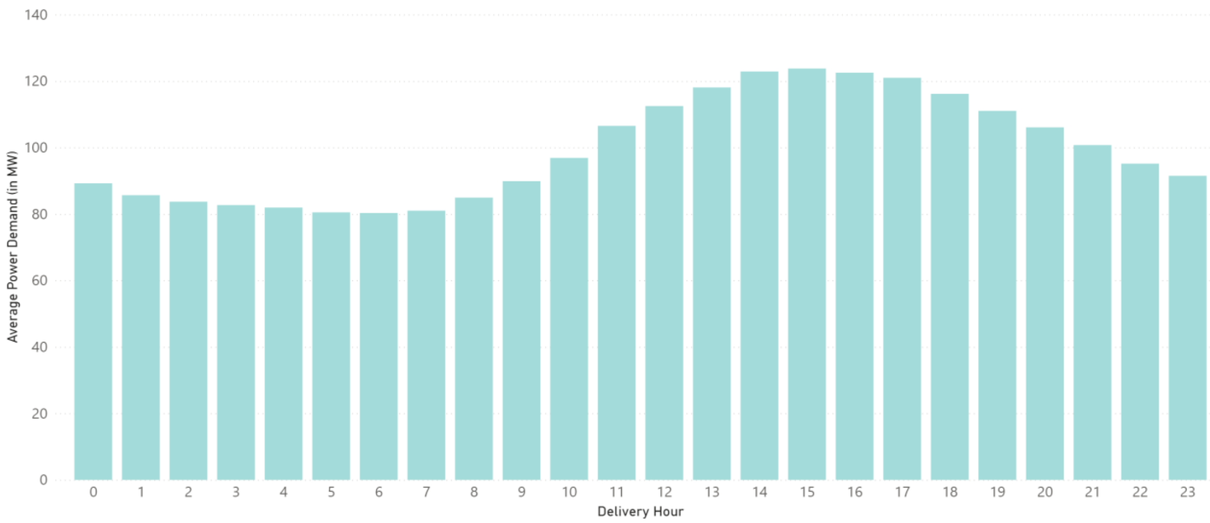
Figure 28: 2019 Generation Profile of Solar Plants in Luzon vs. Typhoons Experienced



Solar generation is available even with frequent typhoons.

For wind power plants, Figure 29 shows that wind power generation peaks during the late afternoon. This generation profile also coincides with the peak demand requirements of the grid. Hence, wind power is feasible to serve as the source of power during these peak periods.

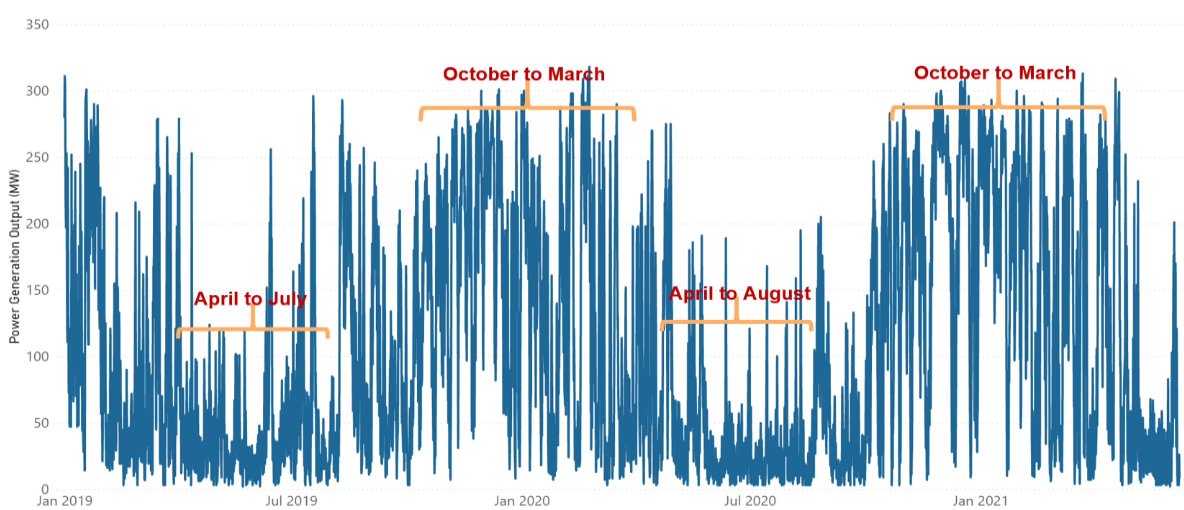
Figure 29: Average Daily Generation Profile of Wind Plants in Luzon in 2019



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

The historical data (Figure 30) of these wind power plants show that they are variable and that they are available throughout the year; however, the variability is highly seasonal. The variability ramps up from October to March and ramps down from April to August. This characteristic is expected from wind power plants. Interestingly, the ramping up coincides with the Northeast monsoon wind system from November to February. However, take note that even when ramped down, wind power plants still produce power but at a lower rate.

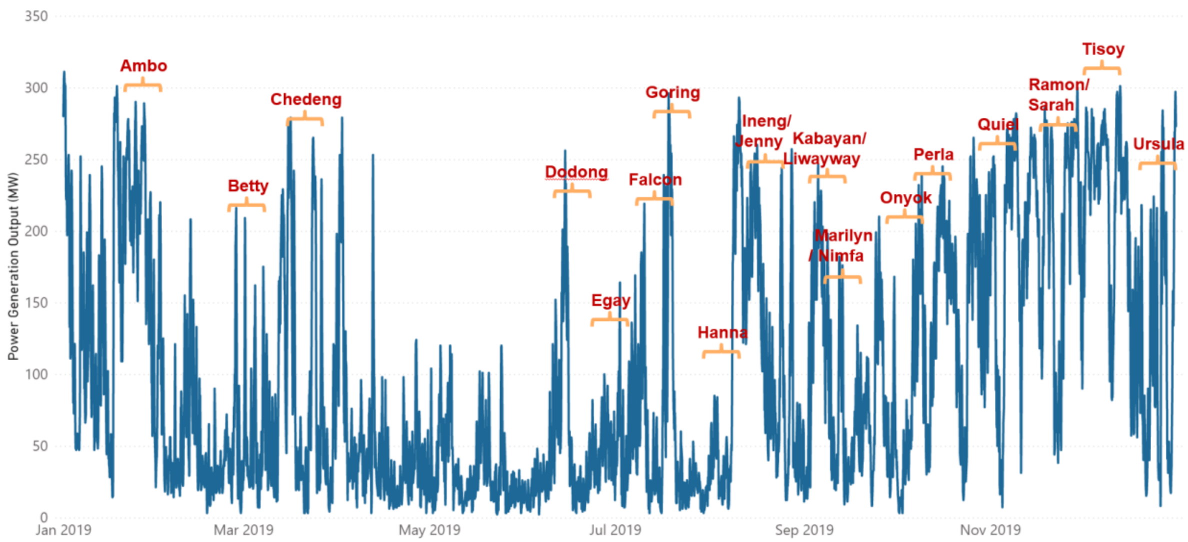
Figure 30: 2.5-Year Generation Profile of Wind Plants in Luzon



Wind power generation is available throughout the year, but it is highly seasonal.

We can observe that unlike those in solar plants, the variability and fluctuations in wind power plants are not cancelled out, as observed in the dips in the power generation (Figure 31). This result is primarily due to the wind patterns in the Philippines that are dependent upon the same wind systems (Northeastern and Southwest monsoon) and are not entirely diverse and independent from each other [8].

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

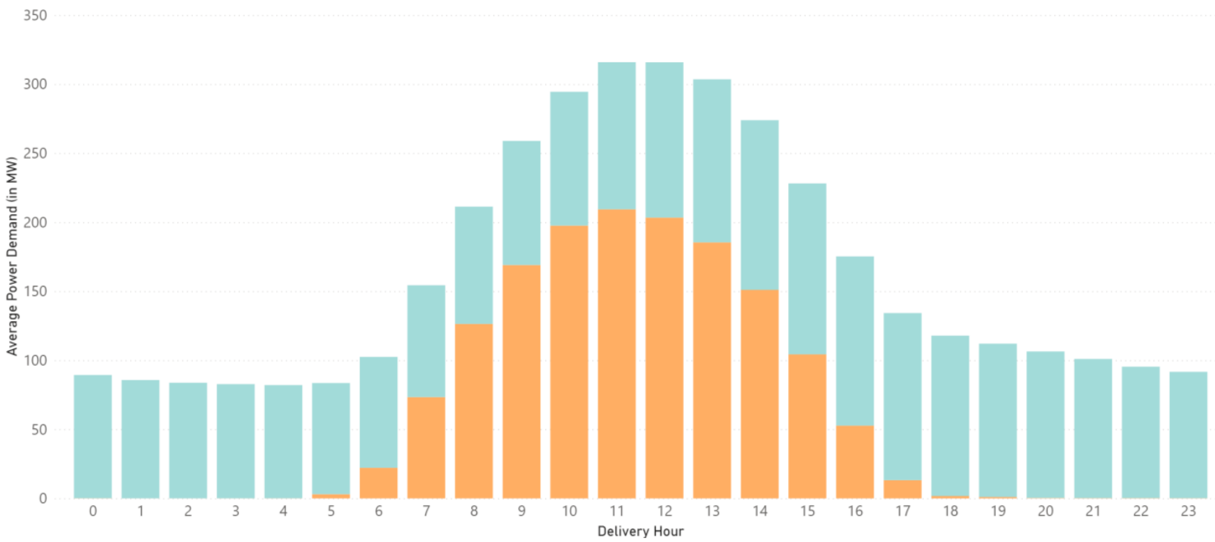


Wind generation is available and can be affected by the frequent typhoons experienced.

Collectively, solar and wind generation adds to the electricity supply during peak hours. Take note that these vRE sources are also not flexible, that is, 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 vRE sources.

Despite not being flexible, vRE 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. In such a case, an increased RE penetration during peak hours could reduce the cycling operations of the coal plants that made them unreliable in the first place.

Figure 32: Average Daily Generation Profile of Solar/Wind Plants in Luzon in 2019



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

Therefore, the value of vRE for our existing electric grid is very promising because it can provide electricity generation at the right time. Essentially, the use of vREs will help us achieve an energy mix that is cost-effective and reliable and reduce our dependency on much expensive diesel power plants that are run to complement the inflexibility of coal-fired power plants. As emphasized previously, vRE sources need not replace coal, but they can help achieve the right mix in our power system, in which different power generating technologies complement one another [5].

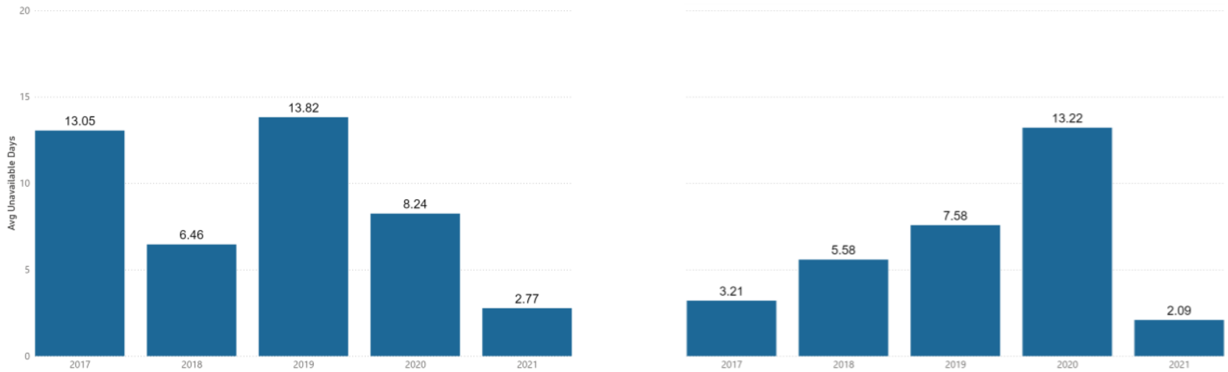
4.3. vRE has high availability rates and is accurately predictable

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 scenario highlights the need to have a power plant that is reliable and available when expected to minimize the instances wherein other more expensive power plants would have to be dispatched as a replacement of failed power plants.

Unlike other power generation technologies, solar or wind power plants are not mandated by ERC to meet an allowable planned and unplanned number of outage days. Nevertheless, the unavailability duration of these grid-connected solar power plants is significantly lower than that of coal, geothermal, or biomass power plants. The unavailability duration of a solar power plant is about 10 days (considering the operational hours from 7 am to 5 pm) while that of a wind power plant is about 7 days (Figure 33). Hence, these vRE plants do not need extended outages to be maintained, and they do not experience recurring outages during their operations. This characteristic is in direct contrast to that of baseload coal power plants.

Note that only grid-connected solar and wind power plants are considered for this analysis. Embedded plants are 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 that it is on shutdown as its load center may have higher consumption that reduces the total power exported to the grid.

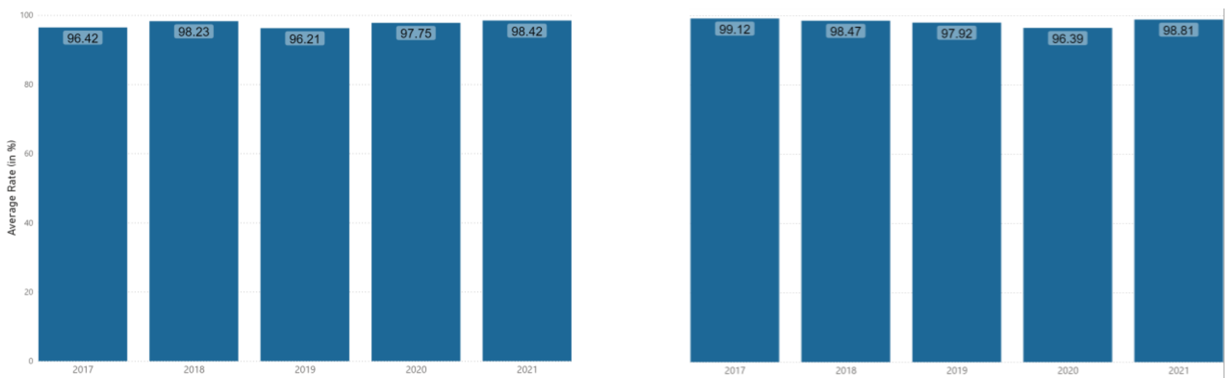
Figure 33: Unavailability Duration of Solar Power Plants *(left)* and Wind Power Plants *(right)*



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

By referring to the availability rates of solar power plants from 7 am to 5 pm, we can see that these values are significantly higher than those of coal, geothermal, or biomass power plants (Figure 34). This result shows that solar power plants offer greater availability than 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 are better than those of coal power plants.

These solar plants are commonly comprised of solar photovoltaic (PV) panels, panels which are designed to convert sunlight to electricity. One factor that makes solar PV more reliable is their expected downtime during nighttime, at which point extensive preventive maintenance can be performed. This setup avoids the need to have forced outages that can halt the power generating capability of these plants during the daytime.

Another factor that adds to the reliability and availability of vRE plants is modularity. The power generation for each module in a plant is independent of other components. Thus, when a module fails, no cascading failure occurs because each module runs independently. A prime example is solar PV that comprises many small and modular panel circuits that are independent of one another. One circuit may undergo maintenance while the rest may still produce power.

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

The wholesale electricity spot market (WESM) rules require must-dispatch generating units to comply with the forecast accuracy standards on the basis of their submitted hourly projected outputs. These must-dispatch generating units are defined as qualified and registered RE power plants, such as wind, solar, and run-of-river hydro power plants, which are dispatched whenever power generation is available.

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

As described in this manual, each must-dispatch generating unit shall comply with the established standards for the mean absolute percentage error (MAPE) and 95th percentile of forecasting error (PERC95), as shown in Table 2. The two measures are set to 18% and 30%.

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 RE units in the grid (Table 3), 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 on the basis of 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%

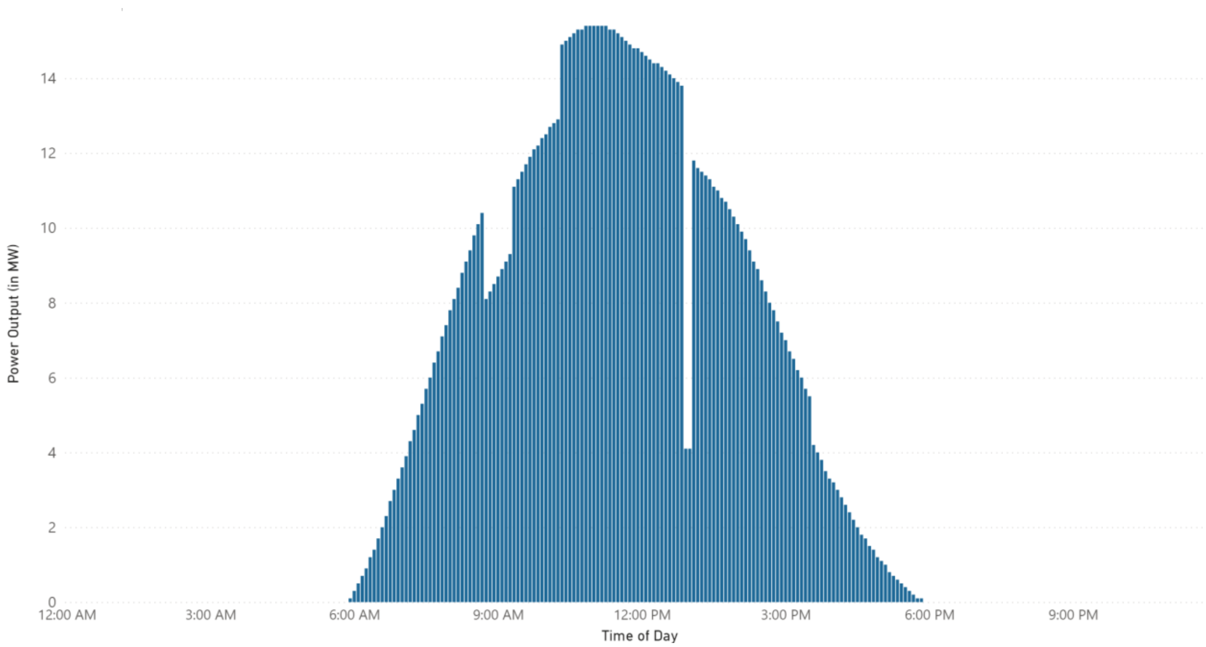
A good forecasting accuracy means that we are better able to determine the power generation loading of vRE sources. Thus, we can effectively dispatch the right mix of the most cost-effective power generations at any point in time. As time progresses, more advanced models and algorithms will be developed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

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

We have established the advantages of adding vRE to 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 vRE into the grid.

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

Figure 35: Intrahour Variability of Solar Power Plants in San Carlos Solar Energy, Negros Occidental



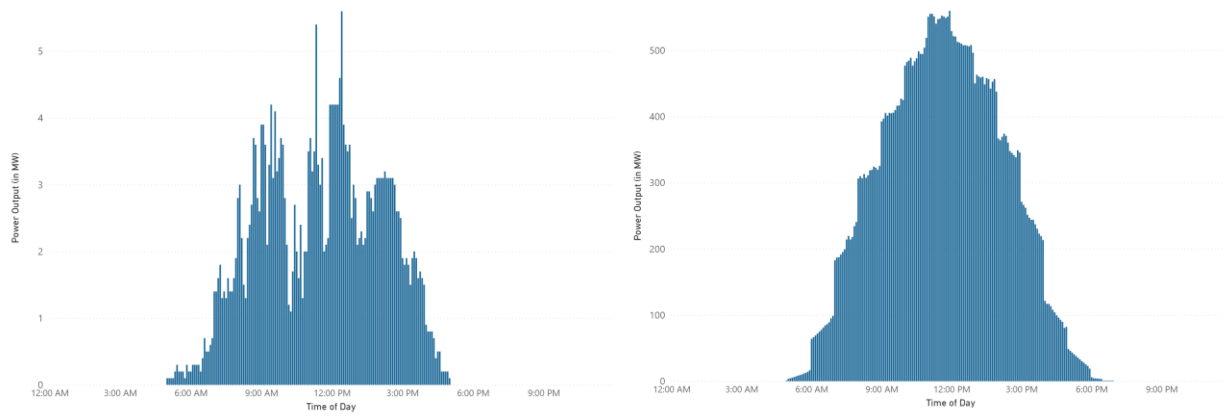
As a result of the passage of clouds and other natural events, individual solar plants can experience power fluctuations.

Although this concern is valid because 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. They often arise when viewed from the aspect 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, the utilization of geographic diversity, and technologies that allow more system flexibility (e.g., 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 vRE 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 feature is exhibited in Figure 36.

Figure 36: Variable Power Output of an Individual First Cabanatuan Solar Plant *(left)* and the Aggregate Power Output of all Solar Plants in the Luzon and Visayas Grids *(right)*



The intrahour variabilities of vRE plants cancel out each other in an aggregated level.

As more vRE plants are added to the system, the intrahour variabilities and short-term fluctuations in the output of different vRE plants located in different locations in a power system cancel out, increasing their 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. Hence, the diverse locations of the vRE plants have great value. Therefore, grid planners should consider the concentration of vRE resources in the grid. In specific, multiple vRE power plants should not accumulate in one location to avoid risk in the stability and reliability of the power system.

As more vRE plants are added to the system, the intrahour variabilities and short-term fluctuations in the output of different vRE plants located in different locations in a power system cancel out.

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

The intrahour variability of vRE power plants can also be addressed using technologies that increase system flexibility, such as Battery Energy Storage Systems (BESS), which enables energy smoothing and short-term electricity balancing [13]. At the grid level, the utilization of BESS integrated with solar and wind farms exerts positive effects on system security and reliability, particularly on smoothing the energy outputs and its economic effects in energy markets. Other technologies that increase system flexibility include reservoir hydroelectric power plants and open cycle natural gas power plants that can routinely manage the fluctuations of 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. The stored energy can be used later or during peak hours. However, BESS is a novel technology. Thus, its large-scale implementation in the Philippines is not yet cost effective, although some pioneering BESS projects have been initiated in the country. According to the DOE summary of Committed Power Projects as of October 2021, a 2112.59 MW capacity for BESS has been committed with target commercial operation latest 2025 [4].

However, 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 because the reserves or the ancillary services manage 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 case was the New York Independent System Operator (NYISO) about the effects of 10% wind penetration in the New York Control Area and showed that only minor changes are needed in the reserve capacity to accommodate wind generation. 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. They evaluated wind penetration at three levels, namely, 16%, 22%, and 27%, and calculated the regulating reserve requirement with the integration of wind. The Minnesota study concluded that no additional contingency reserves are required due to the wind because the largest contingency is unchanged [14] [15]. These findings confirm that the variability and uncertainty introduced by vRE in the system do not necessarily entail a higher reserve requirement.

The variability and uncertainty introduced by vRE in the system do 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	33,000 MW	10% wind	No Additional Capacity Required	0.79% to 0.94%	No Additional Capacity Required
Minnesota	20,984 MW	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 are minimal despite high vRE penetration.

This result 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." This study 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 uncertainty and variability but does not greatly change their nature. Moreover, the 2021 Texas power crisis cannot be attributed to the uncertainty and variability of these variable renewable generators but rather to the failure of every power-generating technology available in the region to withstand a winter that is as severe what they have encountered during that time.

ERCOT also 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 can compensate for the variability introduced by 5000 new wind turbines.

In sum, appropriate system design and implementation of the right policy mechanisms are necessary to manage effectively the intrahour variability of these vRE sources.

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 insufficient 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, flexible generation sources are required to meet these requirements of the grid. A 2018 study by the United States Agency for International Development (USAID) reported that system flexibility is necessary for the successful and cost-effective integration of variable RE sources 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 increasing RE penetration to 35% in 2030 and 50% in 2040, the ideal complement to this high vRE share is flexible generation and not baseload generation. The complement operation of vRE and flexible generation ensures that the grid as a whole can adjust accordingly as the variable generation of the vRE and the high fluctuations of the load demand change, and such adjustment cannot be accommodated by baseload power generation. Moreover, as the vRE penetration in the grid increases, distinguishing between baseload/intermediate/peaking and attributing power generating technologies to these types accordingly are less meaningful and will no longer be necessary [5].

As the Philippines envisions increasing RE penetration to 35% in 2030 and 50% in 2040, the ideal complement to this high vRE share is flexible generation and not baseload generation.

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

In addition, innovative market regulations can be designed to incentivize operators to run flexible generation plants for balancing while maintaining profits. A study by IRENA highlighted that this goal can be achieved by increasing the time granularity in the WESM. An increased time granularity can better reflect the conditions at a particular time period and pay for efficient response from the existing generators. This development is because trading electricity with short 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. Furthermore, the Philippine Electricity Market Corporation (PEMC) will soon open ancillary service markets that will enable the co-optimization of energy and dispatchable reserves scheduling. With this transition, the Philippine spot market is now more flexible, and the existing flexible power generators can better complement the variability introduced by the solar and wind power plants in the system.

To assess the capability of a power system to cope with 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 because 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: Four Phases of vRE Integration in the International Energy Agency (IEA)

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 all system levels	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 small changes occur in 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 is approximately 6% of the total installed capacity. However, this installed capacity is not being fully dispatched because of 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, 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. Given that other power plants have a much greater capacity than these vRE plants, its variability becomes negligible. Meanwhile, in Phase Two, the impact of VRE becomes noticeable; however, vRE capacity can be integrated smoothly by upgrading some operational practices to ensure the matching between demand and VRE output (as indicated in the challenges on the table). For the Philippines' case, the system design and policies that improve the 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, planned reserves capacity market, more flexible generating plants, and so on.

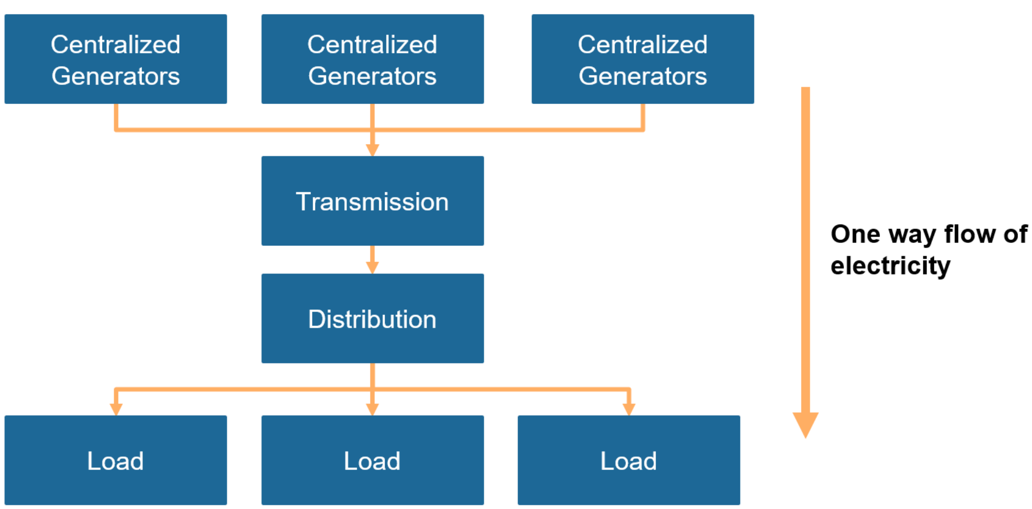
Thus, as the Philippines transition into Phase Two of the vRE integration framework, these policies must be implemented to realize a much greater vRE penetration in the system.

4.6. vRE paves the way to decentralized systems

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

The centralized generation configuration of the grid features 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 the 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

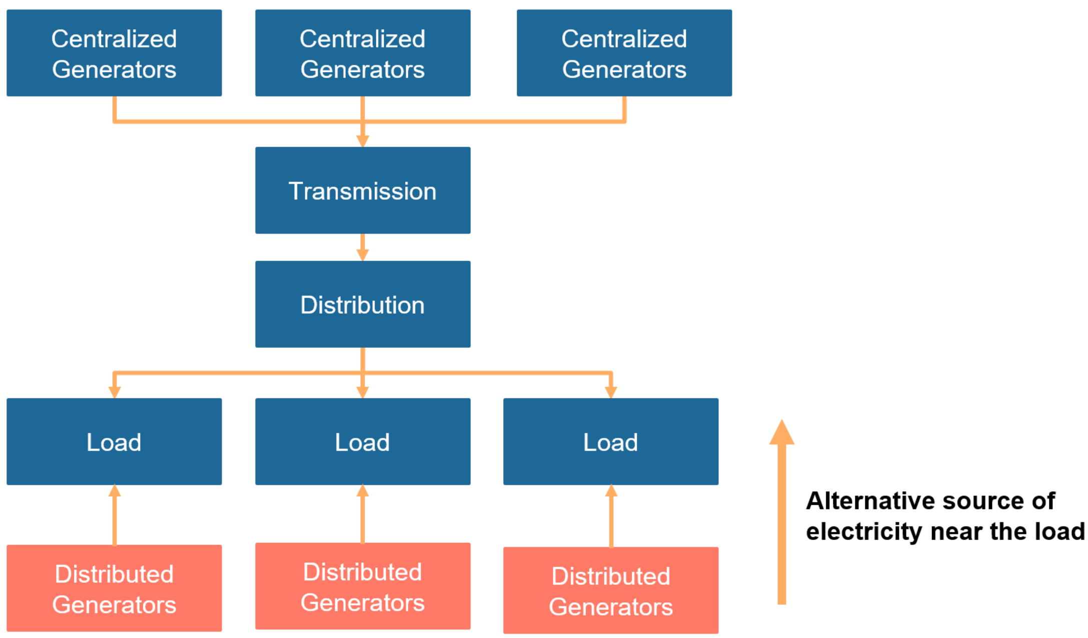


Major bottlenecks can be observed on the transmission and distribution system.

One vulnerability of this centralization is the one flow direction; this system is highly dependent on the transmission and distribution facilities to transmit electricity from the generation to the load. Damage to any transmission facility can halt the flow of electricity from the generation sites to the load centers. 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.

Utilization of a distributed generation system can address these fallbacks of centralized generation. 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 allows consumers to become suppliers as well. A distributed grid allows consumers to generate their own electricity and export excess to the grid. Implementation of multiple microgrids and distributed generation systems would result in a robust electric grid 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 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 such as coal, natural gas, and diesel plants require fossil fuel to operate. The Philippines lacks sufficient fossil fuel reserves in its jurisdiction and thus imports these energy sources. In fact, 81% of the coal consumed in the Philippines in 2019 was imported, and 90% of those imported originated from Indonesia [21]. This high dependence on imported fossil fuel is a threat to the Philippines' energy security because the electricity price is tied to the volatility of the prices in global markets.

This volatility in prices can affect the electricity that is sold thru the WESM and thru Power Purchase Agreements. For the WESM, the volatility is intuitive because the generation offers update in real time and the price of electricity is known upon dispatch. However, the case is different for electricity that is traded thru Power Purchase Agreements.

A common misconception is that the price of electricity from Power Purchase Agreements is fixed. The Philippines' energy regulatory practice allows automatic fuel pass-through in these power plants. This provision signifies that whenever the cost of fuel (coal) increases in the world market, power producers and distributors using this provision could simply pass this higher cost on to consumers.

Given that fuel costs are the highest cost item for these power plants, their impact on the consumer costs of electricity is huge. In 2021 alone, the price of coal in the world market more than tripled because of increased 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 tripled from January 2021 to October 2021.

This volatility can also be observed in the natural gas prices in the world market that have doubled since the start of the year.

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

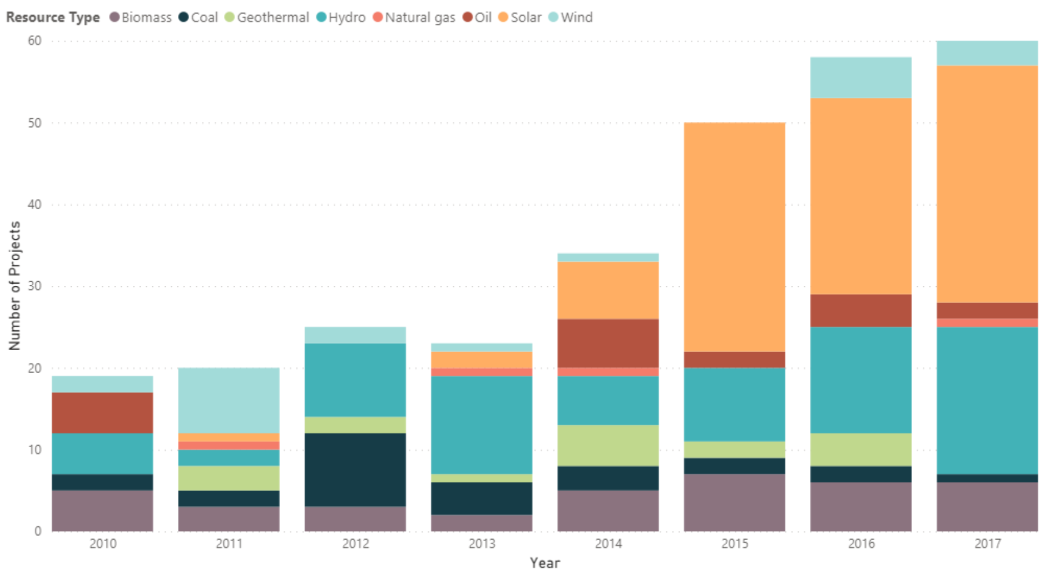
The price of natural gas doubled in price from January 2021 to October 2021.

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

5.2. Capital expenditures on coal projects are high

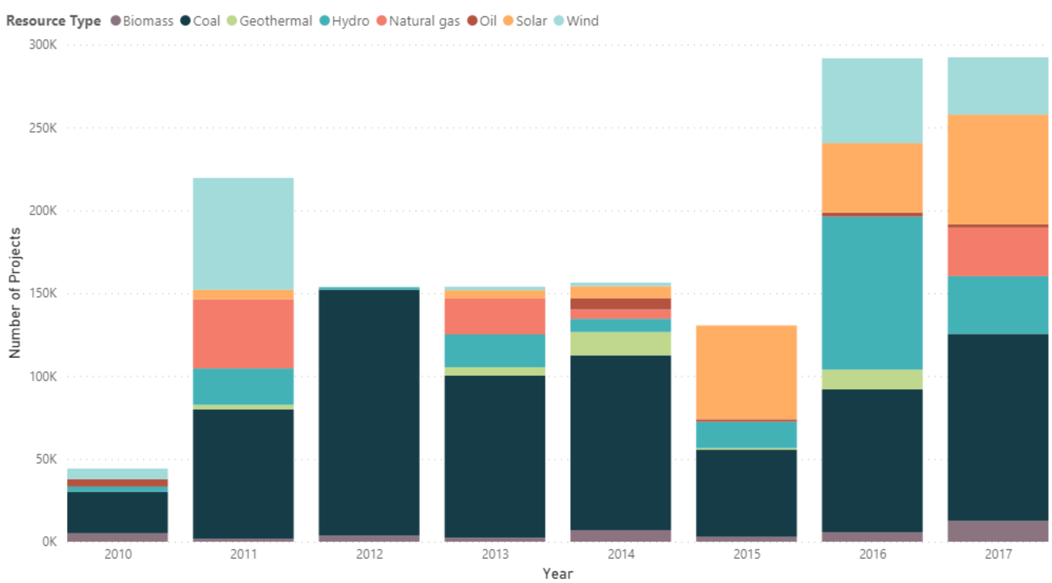
Coal power projects have received investment incentives under the Investment Priorities Plan (IPP) administered by the Board of Investments (BOI) under the Department of Trade and Industry (DTI). These incentives include tax holidays, tax and duty-free importation of equipment, and so on [24].

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



There are numerous solar projects in the pipeline while coal projects are few.

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 2010 to 2017 [25]. Despite having a fewer number of projects registered under IPP compared with RE, coal still dominates the share of investment costs. This finding indicates that coal projects require higher Capex than any other technology but are still pursued because of the investment incentives under the IPP.

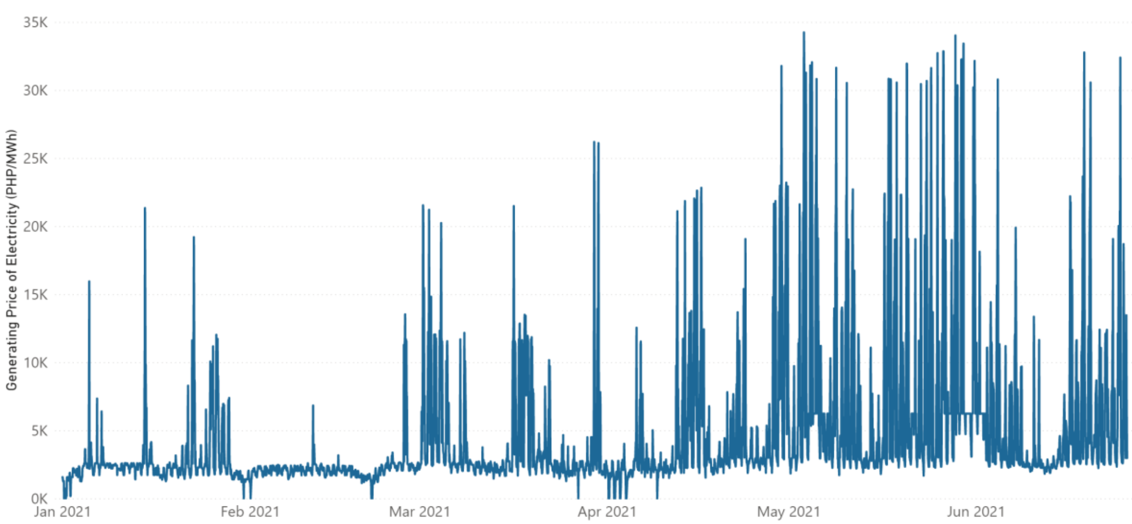
While economies of scale may apply to coal projects, unreliability in operation may prove them to be a poor investment. In terms of costs, it is important to consider whether these plants can deliver on their expected capacity and the additional expenses incurred as these plants experience unreliability 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 toward more sustainable energy, coal power plants will become stranded assets sooner, which can have significant financial consequences for corporates, banks, and financial institutes with resources locked in coal assets. Hence, many companies have reassessed the long-term risks of investing in coal and exiting from coal investments [26]. Given the unreliability issues experienced, this scenario 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 cause price 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

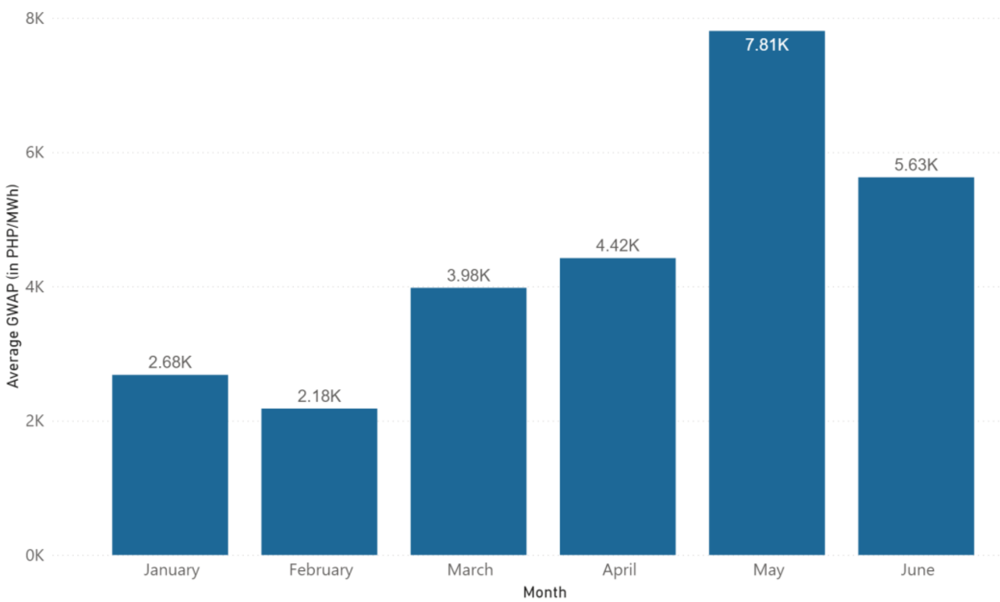


The price fluctuations are more frequent as the summer season approaches.

Figure 43 shows that the price of electricity is not constant. It changes throughout the day, weeks, and months. However, the fluctuation in price is much more frequent as the summer season approaches. This change is primarily because of the much higher demand during the hot summer season, causing the supply of electricity to become thinner and the price of this electricity to become higher. However, due to the unavailability of these coal plants, the already lessened supply becomes even thinner, reaching a point where 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 tripled in price from February 2021 to May 2021. This increase in the price of electricity indicates a looming and recurring problem of power supply shortage.

Figure 44: Average Monthly Generation Prices in 2021

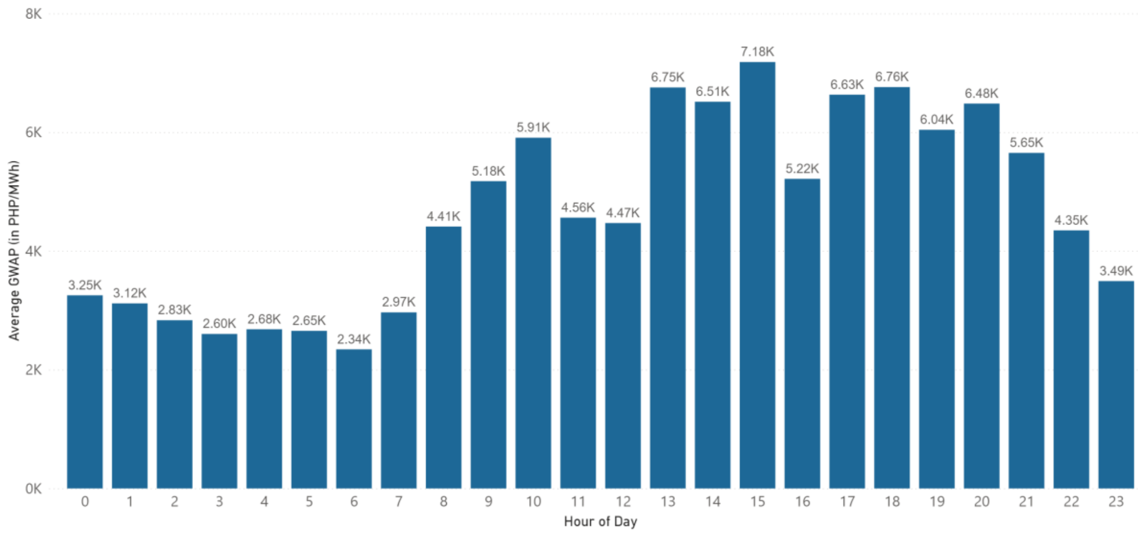


The generating price for electricity increases as the summer approaches.

Zooming into the daily basis (Figure 45), 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 peak. The average hourly price of electricity in 2019 is reflected in Figure 45, wherein the average price of electricity during off-peak hours was approximately 2–3 PHP/kWh, which increased to approximately 6–7 PHP/kWh during peak hours.

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

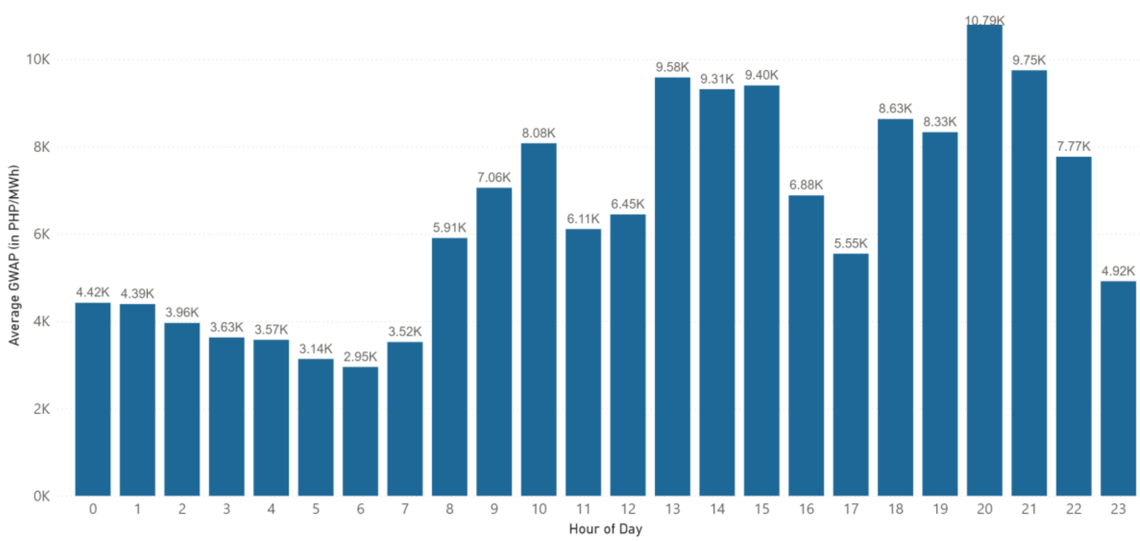
Figure 45: Average Hourly Prices in the Electricity Spot Market in 2019



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

Zooming into the summer season (May–June 2019), we can observe the same trends but with slightly higher magnitudes. The average hourly price of electricity in Summer 2019 is reflected in Figure 46, wherein the average price of electricity during off-peak hours was approximately 3–4 PHP/kWh, which increased to approximately 7–10 PHP/kWh during peak hours. This result suggests a slight change in prices during the summer season.

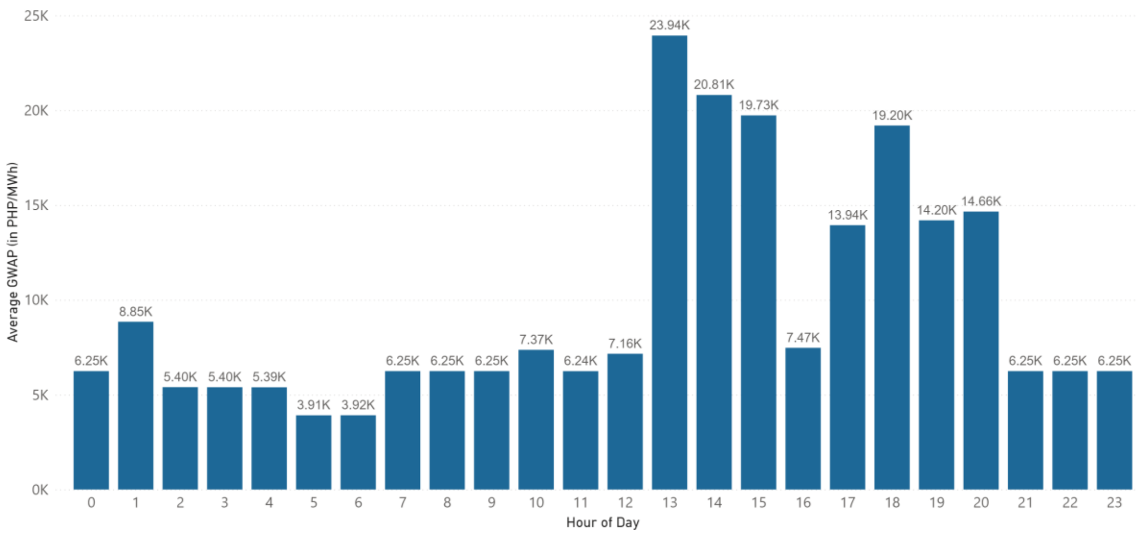
Figure 46: Average Hourly Prices in the Electricity Spot Market in May to June 2019



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

However, this trend was intensified during the 2021 May 31 to June 1 outages. During off-peak hours, the average price of electricity was approximately 5–7 PHP/ kWh, which skyrocketed to approximately 24 PHP/kWh during peak hours. This significant increase in price can be attributed to the high electricity demand requirements during the summer season and was 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



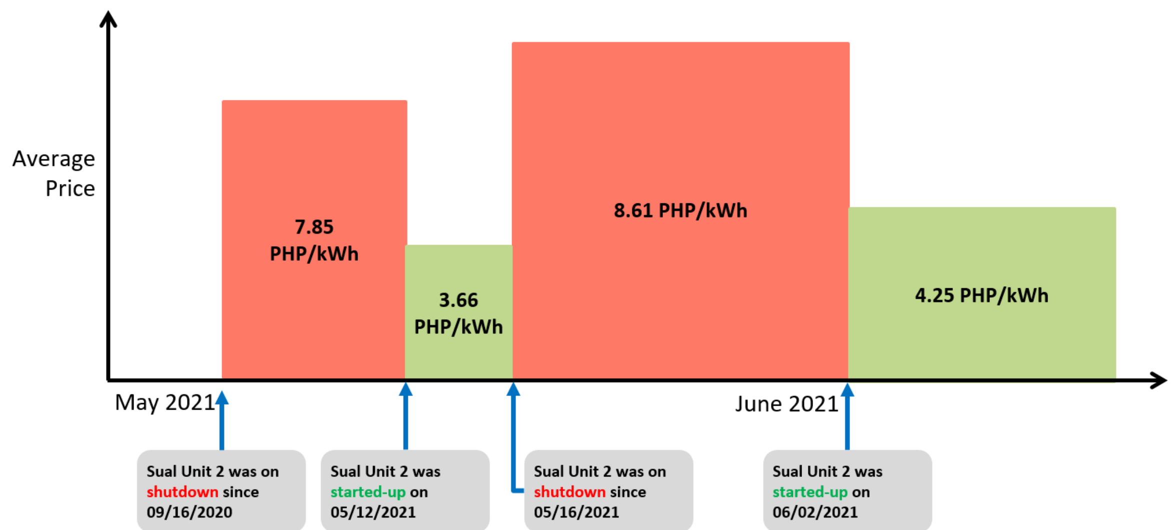
The prices in the spot market significantly changed from the baseline average cost of electricity.

To explicitly show how the outages directly affect the prices of electricity, we present the operation of Sual Coal-fired Power Plant Unit 2 (Figure 48). 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 7.82 PHP/kWh; Sual Unit 2 was still on shutdown and has been for the previous 8 months. The shutdown ended on May 12, and the average settlement price of electricity in the spot market during this time went down to 3.66 PHP/kWh because of the added electricity supply to the grid. This finding indicates that the settlement price goes down when the electricity supply in the grid is sufficient. Moreover, 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 because 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. As a result, the price of electricity doubled to 8.60 PHP/kWh. This shutdown continued for 2 weeks before the plant was put back into operation on June 2, 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 because the prices of electricity more than double 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 2 days of outages was computed. This value was computed by multiplying the portion of the total energy generated that is settled in the spot market to its corresponding prices. In addition, this result 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. This increase is an added burden to the electricity bills of 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 because this resource has to be found, extracted, traded, and transported to the power plants, RE 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 resources in the Philippines, DOE has identified Competitive Renewable Energy Zones (CREZ) [27], which are geographic areas with high concentrations of cost-effective RE and strong developer interest. Data on CREZ inform the selection of new and enhanced transmission lines, encouraging new development toward the best RE resource areas.

A total of 25 CREZ areas were identified 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 RE projects across the country.

Recent data show huge potentials available for offshore wind in the Philippines. Only recently, DOE has 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 93 GW of wind potential from CREZ [28].

Data on offshore wind show that 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%–50%. At these levels, offshore wind matches the capacity factors of efficient gas-fired power plants and coal-fired power plants in some regions, exceeds those of onshore wind, and is approximately double those of solar PV [29].

Similar to 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].

These potential energy resources can only be realized if the necessary transmission facilities are developed. Currently, the locations that show great offshore wind potential are located in off-grid areas.

Thus, transmission line expansion is needed to reach said areas. As an example, Mindoro and Batangas coasts show 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 observed on the left side of the country, and the 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 project could potentially open up the offshore wind potential to the main grid [30].

These potential energy resources can only be realized if the necessary transmission facilities are developed. Currently, the locations that show great offshore wind potential are located in off-grid areas.

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

6.2. vRE has 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]. In addition, the variable operating expenses of vRE plants are zero, which can be attributed to their free fuel costs, compared with 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

RE technologies are already cheaper than coal technologies and will only go cheaper.

Today, vRE sources are already more cost effective than coal-fired power plants. In addition, the forecasted costs of these vRE power plants are expected to go down further in 2030, compared with coal-fired technologies that are expected to maintain their price in the next decade. This result shows that the technology of vRE plants is 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 vRE integration is the claim that installing BESS is necessary to manage variability. Given that 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, battery storage is not the only form of flexibility, as mentioned in the previous section of this paper. Other cost-effective means of flexibility that can complement vRE sources include reservoir pumped hydroelectric plants; open cycle natural gas plants can also provide this system flexibility [8]. Moreover, BESS exhibit 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].

This result shows that the technology of vRE plants is 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.

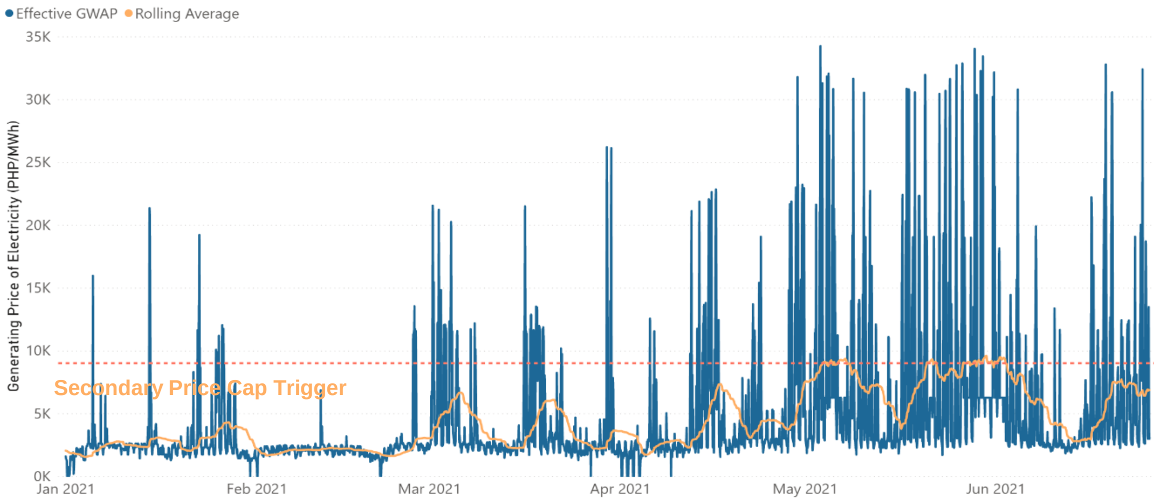
From a larger economic perspective, a financial metric that dictates the cost-competitiveness of an energy source is the Levelized Cost of Electricity (LCOE). The LCOE is essentially a measure that integrates all the relevant costs of electricity generation in a project's lifetime. In an October 2021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

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

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

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 (i.e., at approximately 30 PHP/kWh) but only to drop in price during the night. This result is because expensive power plants, such as diesel, were dispatched during peak hours because of the high demand. The price surges during peak hours have resulted in the rolling average of the GWAP reaching and exceeding the ERC secondary price cap trigger of 9000 PHP / MWh.

Figure 49: GWAP and Its Rolling Average in 2021



The GWAP rolling average reached the secondary price cap multiple times, thereby indicating the lack of power generators specifically during peak periods.

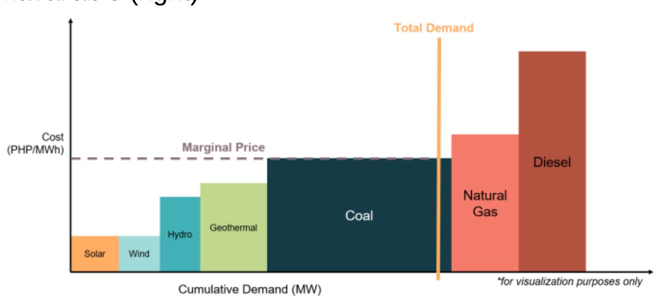
The frequent triggering of the secondary price cap highlights the need for more power generators that can cater to peak hours specifically. As previously mentioned, vRE sources have a great potential to meet this demand because they are available at times of high demand. Thus, vRE can greatly impact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

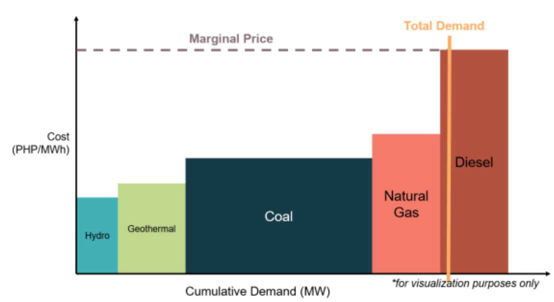
The frequent triggering of the secondary price cap highlights the need for more power generators that can cater to peak hours specifically.

In accordance with 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. RE plants are among the cheapest plants and thus are 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)



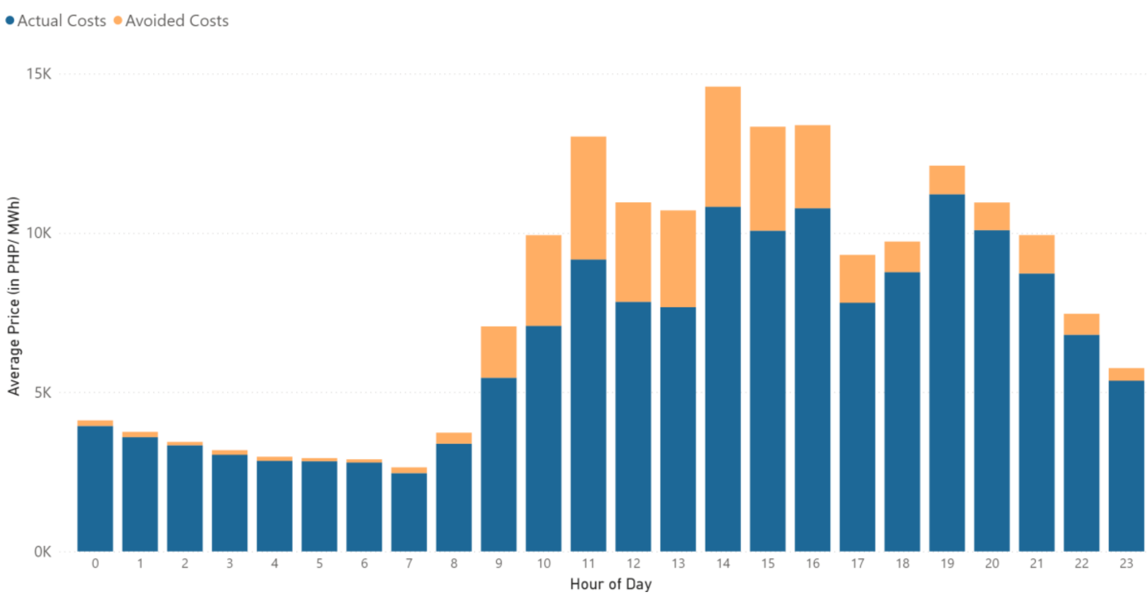


vRE can reduce the marginal price of electricity by introducing cheap power into the energy mix.

Existing RE 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 with the current scenario.

Using actual data (Figure 51), the scenario with no RE installed experienced much greater peaks in prices because of the lack of cheaper generators in that period. This result signifies that in the absence of the currently installed RE plants, power generators to cater to the peak hours specifically would be insufficient. Thus, the WESM is forced to dispatch much more expensive power generators, such as Diesel power plants, during this time.

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



RE reduces the settlement price of electricity by 28% during peak hours.

Considering 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 such as Diesel. This finding is consistent with a PEMC finding stating 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, 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 because the RE technologies now prove to be economical, practical, and what our grid needs. These are elaborated on the following key points:

Additional baseload coal is no longer what the Philippines needs

Evidence shows 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. However, even so, we still experience power outages because of its inherent limitations. 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. Currently, a power source that is cheap, reliable, and available during peak demand hours is needed to achieve the right energy mix.

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

Data has shown vRE 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. Data have 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. Despite 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. Rather, vRE can 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. The electricity price more than doubles from the previous months because of the unavailability of these coal-fired power plants. However, even with the increased prices, we still experienced rotating blackouts during the summer of 2021. We have also presented hidden costs to coal-fired power plants because of 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

vRE power plants are already cheaper than coal-fired power-generating technologies, and they are projected to become 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. In addition, these power plants are available during the highest demand, i.e., during peak hours. Given 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 result 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% RE share by 2030 and 2040, respectively [30]. Clean and indigenous energy production paves the way for socio-economic progress and Energy Efficiency and Conservation developing into a national way of life.

This move is further supported by the RE-centric policies and mechanisms spearheaded by DOE, which aim at facilitating greater private sector investments in renewables. Policies and programs include the participation of electricity consumers in 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 toward achieving a 35% RE share by 2030 [34].

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 sustainable growth for the country, as evidenced 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 is 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 toward a new, economically successful, and environmental-friendly power sector. To achieve this, we plan to undertake future research priorities that will tackle the following:

1. **Long-Term Energy Scenario for the Philippine Energy Plan**

   Energy is a key input 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 a major contributor of GHG emissions that promote climate change. Thus, for the Philippines to prepare for a just energy transition, comprehensive modeling of the energy sector must be performed in parallel with all affected sectors.

   The CASE Philippines team aims to develop and model the energy and non-energy sectors in the Philippines to develop the least cost expansion for the energy transition to determine the attributed costs tied to it. Moreover, we also seek to account for the GHG contribution of each industry group today and in the future. 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 RE sources, various impacts would be inevitable. Thus, 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 and policies are sufficient to economically and practically meet the demands of the Philippines while still achieving climate mitigation agreements.

   Some of the key projects of the CASE Philippines team are to:

- Assess the impact of 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 Biomass and other Waste-to-Energy (WTE) technologies could replace coal to minimize 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 toward advancing energy transition in the Philippines.

9. References

[1] "Republic Act No. 9513 An act promoting the development, utilization and commercialization of renewable energy resources and for other purposes," Congress of the Philippines, Manila, 2008.

[2] "Advisory on the Moratorium of Endorsements for Greenfield Coal-Fired Power Projects In Line with Improving the Sustainability of the Philippines' Electric Power Industry," 22 December 2020. [Online]. Available: https://www.doe.gov.ph/announcements/advisory-moratorium-endorsements-greenfield-coal-fired-power-projects-line-improving?ckattempt=1. [Accessed 16 November 2021].

[3] A. R. Dalusung, Interviewee, *Technical Working Group RE Developer of National Renewable Energy Board.* [Interview]. November 2021.

[4] DOE, "Summary of Committed Power Projects as of 31 October 2021," 2021.

[5] IRENA, From Baseload to Peak: Renewables Provide a Reliable Solution, 2015.

[6] National Association of Regulatory Utility Commissioners, "Recent Changes to U.S. Coal Plant Operations and Current Compensation Practices," 2020.

[7] Energy Regulatory Commission Res 10, *Annex A – Rules for the Interim Reliability Performance Indices and Equivalent Outage Days per Year of Generating Units,* 2020.

[8] OECD and IEA, Getting Wind and Sun onto the Grid: A Manual for Policy Makers, 2017.

[9] Energy Regulatory Commission, Grid Management Committee, "Procedures for the Monitoring of Forecast Accuracy Standards for Must Dispatch Generating Units," Wholesale Electricity Spot Market, 2017.

[10] IEMOP, Monthly Report on the Monitoring of Forecast Accuracy Standards for Must Dispatch Generating Units, 2019-2021.

[11] F. Dekking, C. Kraaikamp, H. Lopuhaä and L. Meester, A Modern Introduction to Probability and Statistics, Springer-Verlag London, 2005.

[12] A. D. Mills and R. H. Wiser, "Implications of Wide-Area Geographic Diversity for Short- Term Variability of Solar Power," in *2011 IEEE Power and Energy Society General Meeting*, Detroit, 2010.

[13] R. Kempener and E. Borden, "Battery Storage for Renewable: Market Statues and Technology Outlook," IRENA, 2015.

[14] Philippine Electricity Market Corporation, "Increasing Penetration of vRE Resources and The Reserve Market," 2018.

[15] NREL, E. Ela, M. Milligan and B. Kirby, Operating Reserves and Variable Generation: A comprehensive review of current strategies, studies, and fundamental research on the impact that increased penetration of variable renewable generation has on power system operating reserves, 2011.

[16] Electricity Reliability Council of Texas, "Analysis of Wind Generation on ERCOT Ancillary Services Impact Requirements," 2008.

[17] R. Fares, "Renewable Energy Intermittency Explained: Challenges, Solutions, and Opportunities," 2015.

[18] USAID, DOE, "Greening the Grid: Solar and Wind Grid Integration Study for the Luzon Visayas System of the Philippines," USAID, 2018.

[19] USAID, Grid Integration Series: Impact of Variable Renewable Energy on System Operations, 2020.

[20] IRENA, "Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables," International Renewable Energy Agency, Abu Dhabi, 2019.

[21] DOE, "2019 COAL IMPORTATION based on the ETAs of submitted CoC applications as of 31 December 2019," 2019.

[22] Trading Economics, "Coal 2021 Data | 2022 Forecast | 2008-2020 Historical," 2008. [Online]. Available: https://tradingeconomics.com/commodity/coal. [Accessed 19 October 2021].

[23] Trading Economics, "Natural gas 2021 Data | 2022 Forecast | 1990-2020 Historical," 1990.

[24] DOE, "Executive Order No. 226 The Omnibus Investments Code of 1987," 1987.

[25] Board of Investments, Department of Trade and Industry, "Incentives for Energy Sector," in *Energy Investment Forum*, Taguig City, 2018.

[26] N. Sarma, "Future of Coal: The stranded asset problem," Observer Research Foundation, 2020.

[27] NREL, DOE PH, NGCP, USAID, "Grid Planning and Competitive Renewable Energy Zones (CREZ) in the Philippines," 2020.

[28] "DOE launches offshore wind roadmap project," Philippine News Agency, 2021.

[29] "Offshore Wind Outlook 2019: World Energy Outlook Special Report," International Energy Agency, 2019.

[30] DOE, "Philippine Energy Plan (PEP) 2020-2040," DOE, 2021.

[31] USAID, "Building Low Emission Alternatives to Develop Economic Resilience and Sustainability Project (B-Leaders)," 2018.

[32] Asian Development Bank, "Handbook on Battery Energy Storage System," Mandaluyong, 2018.

[33] Lazard, Lazard's Levelized Cost of Energy Analysis - Version 15.0, 2021.

[34] "Cusi Reiterates DOE Position on Climate Justice, Energy Transition and Order in the Power Industry," DOE, Taguig, 2021.

[35] DOE, "Summary of Indicative Power Projects as of 31 October 2021," 2021.

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, ICSC 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.

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