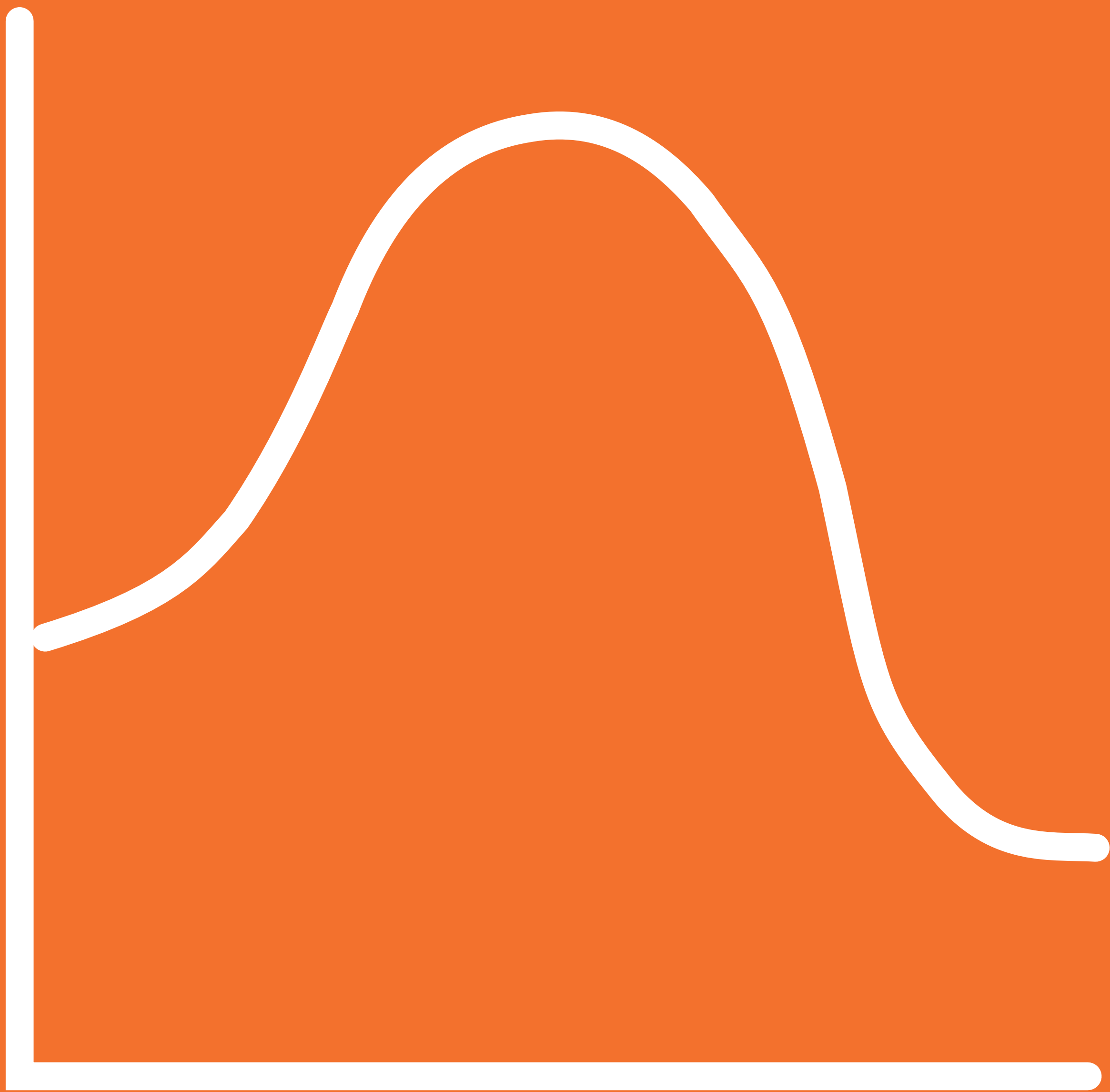

From 'baseload' to flexible generation: meeting the power generation requirements of the future

'Baseload' is a characteristic of power demand, not of a specific supply technology. The demand for baseload electricity can actually be met by any combination of generation sources, including variable renewable energy.

From 'Baseload' to Flexible Generation

For a power grid to run smoothly and without outages, demand (load) and supply (generation) have to be constantly balanced. Even though load may vary over the 24 hours in a day, it never falls below a certain minimum threshold[1]. This minimum threshold is often called 'baseload'. Baseload is thus a characteristic of power demand.

Baseload exists because certain loads constantly require an electricity supply, e.g. industrial processes or refrigerators in households. In larger grids, such as the Luzon, Visayas and Mindanao grids, there are also statistical reasons for the existence of a minimum load: whenever someone switches off an appliance, it is likely that somewhere else in the system someone is switching on an appliance at that same moment.[2] Besides baseload, there is a distinction to be made between intermediate or mid-merit load and peak load. Peak load is the maximum power requirement at a given time or over a given period, and intermediate load refers to the load between baseload and peak load. In typical power systems, baseload makes up more than 50% of peak electricity demand; this value was 56% for the Luzon and Visayas grids in 2016[3].

How power is supplied to cover these different load classes is a very different question. Traditionally, nuclear, lignite and hydro power plants cover the baseload every hour of the year (see figure 1[4]), whereas hard coal and gas-fired power plants provide intermediate load, usually from the morning to the evening. Peak load is provided by gas and diesel plants for a few hours during the day.

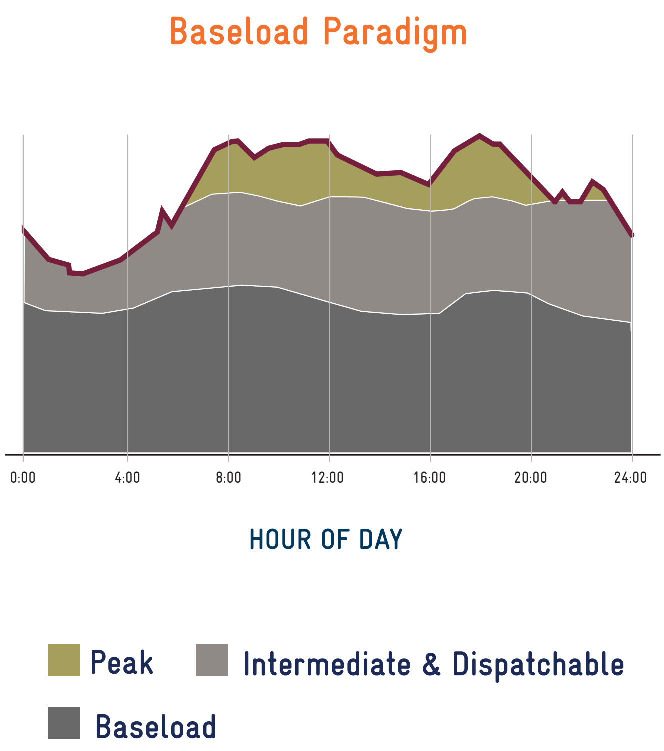

Figure 1. The Baseload Paradigm: nuclear, coal, biomass, geothermal and hydro provide the baseload, whereas natural gas is used for intermediate load and peak load together with oil-fired plants. The generation mix was often optimized to correspond to these 'load classes'. (Source: REN21, 2017)

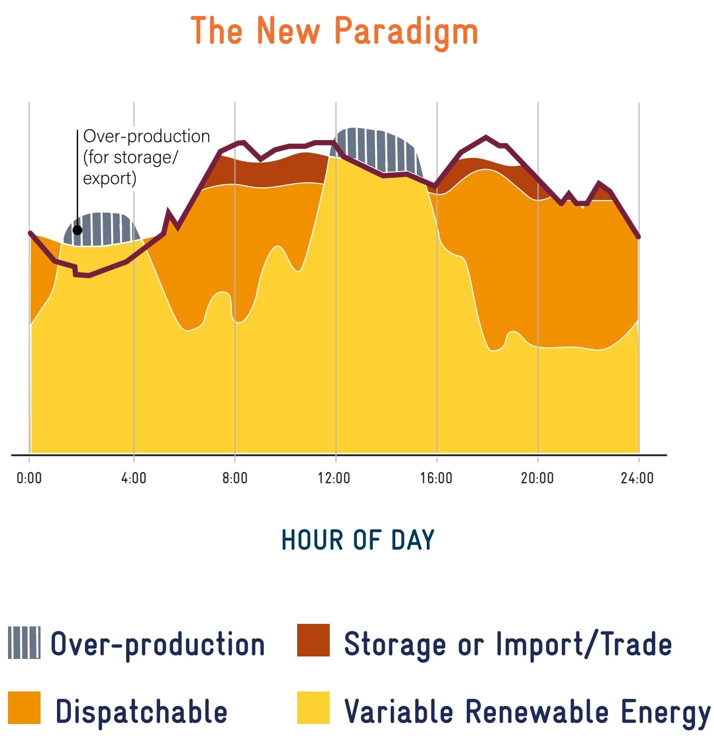

Figure 2. The New Paradigm: load is entirely supplied by renewable energies. When electricity from solar PV is abundant, other more expensive technologies, such as biomass, hydro and geothermal, are curtailed. In the evening, they are ramped up quickly. (Source: REN21, 2017).

The rapid evolution of variable renewable energy sources, such as solar and wind, over the last decade challenges this traditional composition. As variable energy sources depend on natural factors, such as sunshine and wind, they contribute to any load class requiring supply at the time of availability of the respective resource. For example, in the Philippines, if solar generation is strong at midday, it will contribute to peak load and replace expensive diesel fuel, while wind power generated in the middle of the night will contribute to supplying the baseload and replace generation from coal plants. Variable renewable energy generation cannot therefore be classified according to the traditional system of load classes. This means that baseload does not have to be covered solely by the same conventional plants with constant generation output; variable renewable energy can easily cover significant parts of this minimum energy demand whenever a given natural resource is available. Figure 2 depicts a possible power mix of the future where load is entirely supplied by a mix of renewable energies and natural gas. Figure 3 illustrates that this is indeed a realistic vision of the future since its main features can already be seen today. During a stormy day in Germany in 2017, traditional baseload technologies were pushed out of the market and even had to be curtailed.

Hence, the concept of 'baseload generation' describing individual plants that provide 24/7 constant generation output to cover baseload demand is not applicable for modern power systems with higher shares of variable renewable energies.

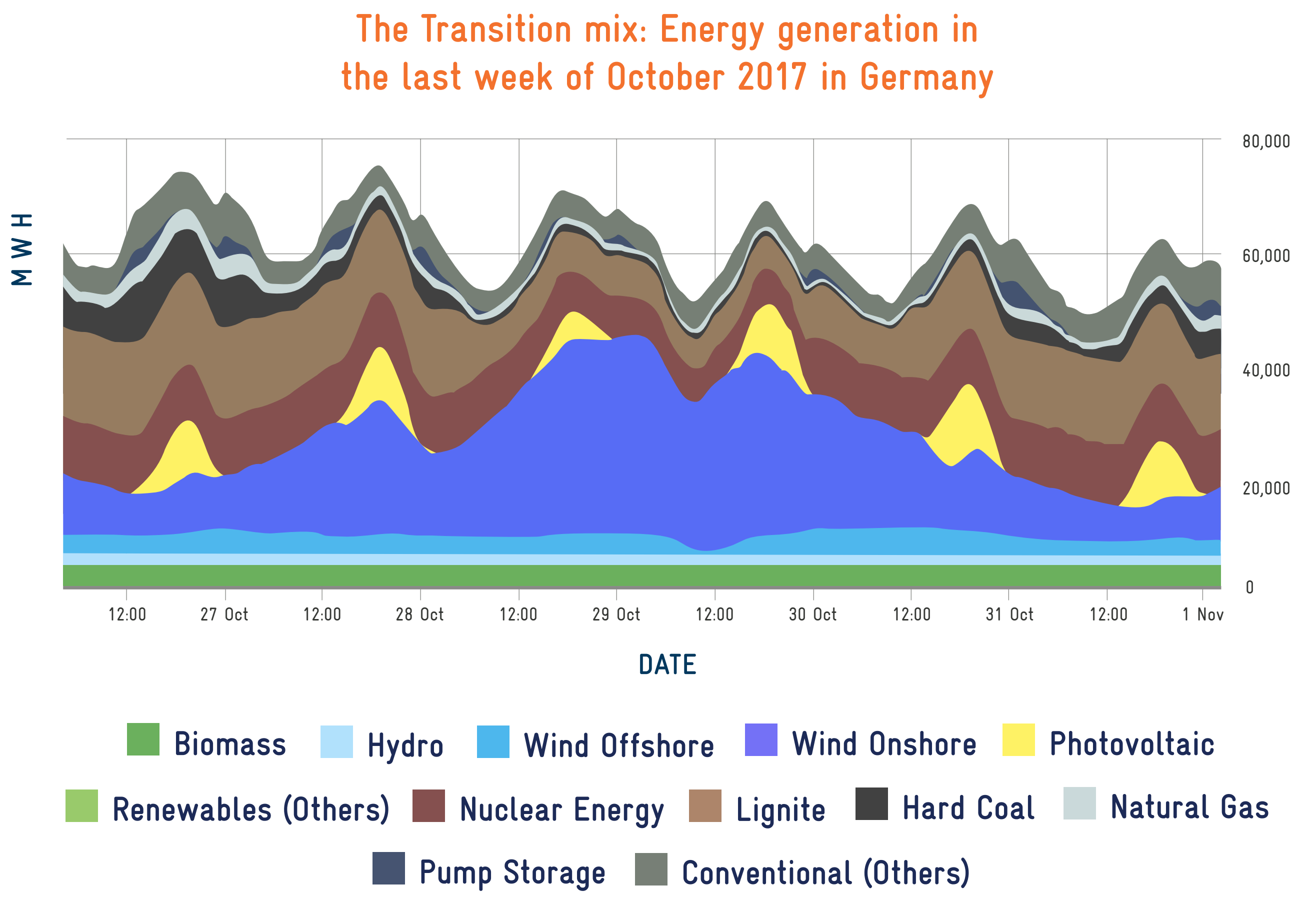

Figure 3. The Transition mix: So-called 'baseload' technologies are being pushed out by cheaper renewables. This graph shows energy generation in the last week of October 2017 in Germany. The high share of onshore wind and solar PV increasingly replaces traditional baseload technologies. Both nuclear and lignite had to be curtailed; generation from hard coal was curtailed to below 1.5 GWh on three consecutive days. Flexible pumped storage and hard coal are used to follow demand. Source: Smard.de

FUTURE POWER SYSTEMS WILL REQUIRE MORE FLEXIBLE GENERATION TO FOLLOW THE GENERATION PROFILE OF CHEAPER VARIABLE SOURCES.

Over previous decades, many power systems were dominated by fossil fuel or nuclear power plants. These power plants have very high investment costs and must therefore rely on high utilisation rates to recover the initial investment costs. They are usually run constantly throughout the year, supplying a major share of a country's baseload, and have thus become known as 'baseload power plants'.

Since the marginal costs of variable renewable energy (vRE) generators, such as wind or solar PV, are negligible, they always produce power at lower marginal costs than conventional plants. This power should therefore always be fed into the grid whenever weather conditions allow. The remaining power plants will be left to cover the so-called 'residual load'.

The residual load is what is left after subtracting those generators that have to produce electricity (e.g. plants that cannot be shut down because they provide crucial grid services) and those that generate with (almost) no marginal costs, such as vRE. The characteristics of this residual load differ strongly from traditional 'baseload', 'intermediate' or 'mid-merit load' and 'peak load'. Ramp rates to serve the residual load are often steeper and non-uniform and may exhibit higher variability, so that more flexible plants are required to cover it[5].

A power plant is considered flexible if it can adjust the power it feeds into the grid quickly and easily. This includes fast ramp rates and low minimum load and/or start-up times. Many baseload power plants were not designed for any other purpose than providing constant power outputs and therefore lack the ability to quickly ramp their power output up or down.

A high degree of flexibility in the power plant fleet is more than a goal in itself; it is a necessary precondition for operating and reaping the benefits of an efficient power system in the future. A flexible operation decreases the frequency of curtailments and negative market prices. As a result, plant revenue streams become more plannable, which improves the investment climate in new generation, and consumer prices decrease because of optimized overall system costs[6].

While in the past electricity systems valued steady, plannable output, the future system with large amounts of cheap variable energy sources puts more value on flexibility. The value of baseload will further decrease as flexibility and the ability to complement other sources become much more valuable.

Reliability of baseload power plants

Reliability refers to the ability of a power plant to respond to unforeseen events. While the need for baseload power plants is often explained in terms of their higher reliability compared to variable sources, they are not necessarily more reliable than other plants. In 2016, the outage factor due to unplanned and forced outages of coal power plants in Luzon was 7% (presentation on the National Policy Review on Energy (NPRE) by Alberto Dalusung). On the other hand, variable sources, such as solar and wind, are hardly unpredictable, as modern forecasting systems have lowered error margins significantly, making variable renewable energy very predictable.

THE PHILIPPINES' POWER SYSTEM IS DOMINATED BY INFLEXIBLE POWER PLANTS OPERATING IN BASELOAD MODE. THE CURRENT REGULATORY FRAMEWORK DOES NOT INCENTIVIZE PRIVATE INVESTMENT IN MORE FLEXIBLE GENERATORS. THIS WILL FURTHER RESTRICT THE GRID'S CAPACITY TO ABSORB CHEAPER VARIABLE RENEWABLE ENERGY SOURCES AND MAY THEREFORE INCREASE CONSUMERS' FUTURE POWER BILLS.

Due to the further strong projected decline in the cost of technologies, such as solar PV, wind turbines, and power storage, renewables are already, or will soon become, the least-cost option in most power systems. The changes in value carry considerable risk in terms of 'stranded costs'[6] from over-contracted coal capacities and may result in even higher rates for consumers. A predominance of baseload plants could also hinder the development of new efficient technologies if utilities and consumers are locked into inefficient long-term contracts with such plants.

Current regulation in the Philippines allows private investors in fossil fuel plants to pass fuel and foreign exchange costs on to captive consumers. This transfers the risk of international fuel price fluctuations from the power producers to consumers, who are left to bear the cost of potential future fuel price increases. This makes investing in coal plants a low-risk, profitable option for the private investor. The currently planned coal expansion projects totalling 10,423 megawatts (MW)[7] are an indication of the attractiveness of such investments. However, continued investments in inflexible baseload plants will leave the power system incapable of subsequently integrating larger shares of variable renewable energy sources in a cost-effective manner. To mitigate this, regulators can take care to include higher flexibility requirements in power purchase agreements, refrain from approving agreements with high full-load hours and consider lower plant load factors for future coal power plants.

Flexibility of coal power plants in the Philippines

By the end of 2017 the Philippines had around 7,500 MW of coal power installed and in operation, with an additional 4,000 MW to go online by 2020 and 7,500 MW in advanced planning stages. An average US pulverized coal combustion (PCC) power plant has a ramp rate of 1-2%/minute.[1] Assuming that the Philippine plants mimic their US counterparts, a total of 19,000 MW of installed coal capacity would permit a maximum change in output of 190-380 MW/minute. Further studies would need to assess whether this figure is enough to cope with the challenges of future flexible power systems, especially since the Philippines is not a single system with free power exchanges and some power plants are built in isolated areas or in smaller grids, such as the Mindanao grid. Technological and operational retrofit options for increased flexibility exist, but they are most efficient when incorporated in the initial planning phase.

TO PREPARE FOR A FUTURE WITH HIGH SHARES OF LOW-COST RENEWABLE ENERGY, THE PHILIPPINES WOULD HAVE TO FOCUS ON ENHANCING SYSTEM FLEXIBILITY. THERE ARE MANY DIFFERENT OPTIONS – SOME OF THEM RELATIVELY LOW-COST AND QUICK – THAT CAN BE IMPLEMENTED TO INCREASE FLEXIBILITY.

One way to increase flexibility is by physical alterations to the system, such as retrofitting conventional power plants, strengthening grid connections and introducing large-scale energy storage. Hard coal plants in particular can provide much more flexibility than commonly assumed – in Germany and Denmark, these technologies are now used to follow load. Augmenting the flexibility of conventional coal-fired power plants is a major strategy to increase flexibility in the system. Through lower minimum load requirements, higher ramp rates and faster start-up times, they can contribute to a more flexible power system[8]. State-of-the-art hard coal power plants can operate at minimum load levels of 25-40% of minimal load[9].

Gas-fired power plants are an additional important flexibility option, since their ramp rates and start-up times are significantly below those of even state-of-the-art coal-fired power plants. Further, natural gas emits about 40% less CO_2 per kWh of electricity produced than hard coal.[10] Thus, natural gas can serve to transition to greener power generation, a fact the DOE has already recognized. The market potential for generation capacity from natural gas may be as high as 11,900 MW for Luzon (up from 3,500 MW in 2017) alone, and plans to diversify the supply of gas and replace the supply from Malampaya are being developed.[11] While private companies have already started investments in further facilities and capacity, one of the means of diversifying the gas supply included in official plans is the establishment of a LNG (liquefied natural gas) hub in Luzon. For this process, new policy initiatives and legislation are also expected. Significant flexibility potentials can also be realized through improved and more responsive market design and new incentives. Some of these changes may require little capital investment and will therefore be considerably cheaper than physical alterations to the system. Institutional changes, such as the amendment of grid codes to encourage new renewable energy (RE) generators to provide a variety of grid services, better RE forecasting and sub-hourly scheduling of load or dispatch, can serve as further sources of flexibility.[12] The timely enactment of the planned transition from a one-hour dispatch interval and one-hour gate closure in the Wholesale Electricity Spot Market (WESM) towards five-minute dispatch intervals, economic scheduling of P_{min}, and < 30 seconds gate closure are a significant step in this direction.

This trend could further reduce utilisation of inflexible coal-fired plants and provide more space for variable RE generation in a future power system.

This factsheet is part of a series on energy issues relevant to current policy discussions in the Philippines. The factsheets aim to provide policymakers and sector practitioners with a rapid overview of some of the most pressing issues in this dynamically evolving sector.

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END NOTES AND RESOURCES

[1] This holds for any larger grid. In very small grids with a limited number of consumers and no big customers requiring constant power supply, demand may drop to zero.

[2] International Renewable Energy Agency (IRENA, 2015), 'From baseload to peak: Renewables provide a reliable solution'. Retrievable online from: http://www.irena.org/publications/2015/Jun/From-Baseload-to-Peak-Renewables-provide-a-reliable-solution.

[3] Philippine Department of Energy (DOE, 2017), 2016 Philippine Power Situation Report. Retrievable online from: https://www.doe.gov.ph/sites/default/files/pdf/electric_power/power_situationer/2016_power_situation.pdf.

[4] Renewable Energy Policy Network for the 21st Century (REN21, 2017), Renewables 2017 Global Status Report. Retrievable online from: http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf

[5] US National Renewable Energy Laboratory (NREL, 2015), Advancing System Flexibility for High Penetration Renewable Integration. Retrievable online from: https://www.nrel.gov/docs/fy16osti/64864.pdf.

[6] M. Miller, L. Bird, et al. (2013), RES-E-NEXT: Next Generation of RES-E Policy Instruments, International Energy Agency's Implementing Agreement on Renewable Energy Technology Deployment (IEA-RETD).

[7] Stranded costs are the part of a public utility's existing infrastructure investments that may become redundant due to substantial changes in market conditions or the regulatory framework.

[8] DOE (2016), 'List of existing power plants as of December 2016'. Retrievable online from: https://www.doe.gov.ph/electric-power/list-existing-power-plants-december-2016.

[9] NREL (2015), Advancing System Flexibility for High Penetration Renewable Integration. Retrievable online from: https://www.nrel.gov/docs/fy16osti/64864.pdf. These options have been studied by Agora Energiewende (2017), Flexibility in thermal plants. Retrievable online from: https://www.agora-energiewende.de/fileadmin/Projekte/2017/Flexibility_in_thermal_plants/115_flexibility-report-WEB.pdf.

[10] Retrofitting older plants can reduce minimum loads even further – minimum loads as low as 12% for hard coal plants were achieved in Germany.

[11] US Energy Information Administration (EIA, 2017), 'FAQ: How much carbon dioxide is produced when different fuels are burned?'. Available online at: https://www.eia.gov/tools/faqs/faq.php?id=73&t=11.

[12] DOE (2017), 'Natural Gas: Introduction'. Available online at: https://www.doe.gov.ph/natgas.

[13] Flexibility options have been extensively studied in various reports, for example by ECOFYS (2015), Power System Flexibility Strategic oadmap. Retrievable online from: https://www.ecofys.com/en/publications/power-system-flexibility-strategic-roadmap/; and NREL (2015), Advancing System Flexibility for High Penetration Renewable Integration. Retrievable online from: https://www.nrel.gov/docs/fy16osti/64864.pdf.

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