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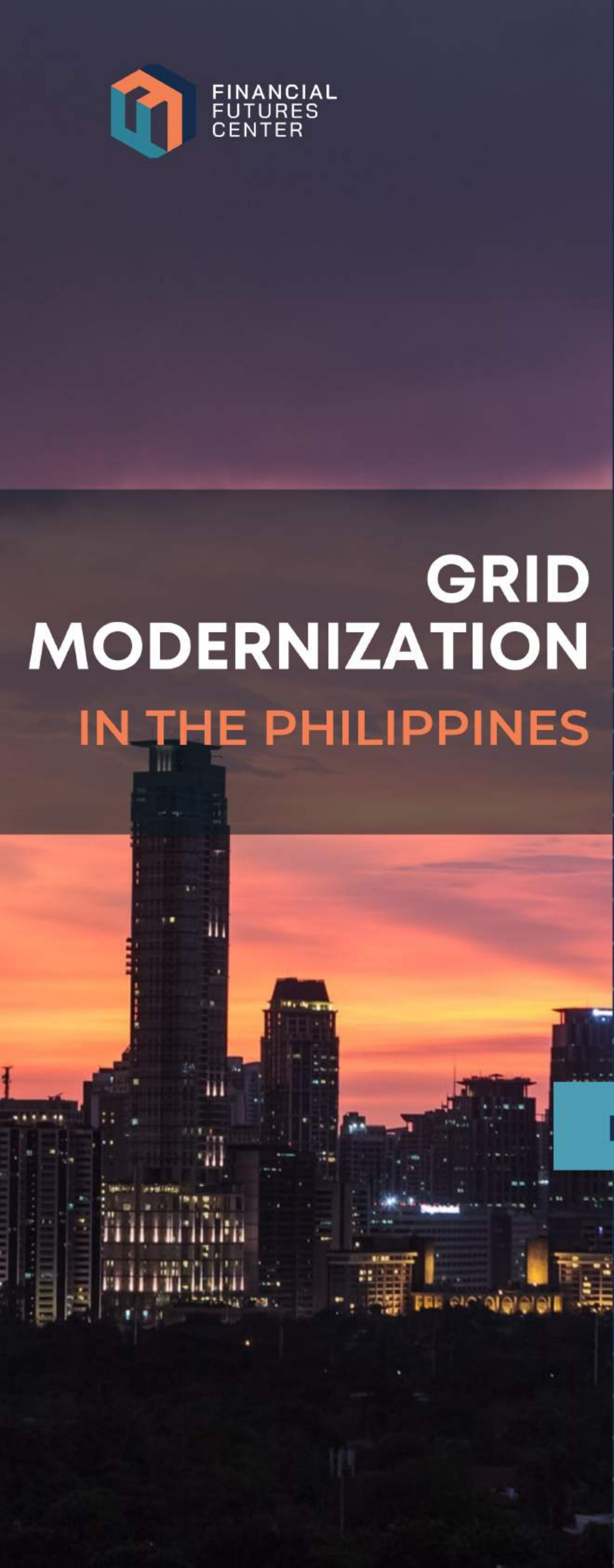

GRID MODERNIZATION IN THE PHILIPPINES

Top-down Cost-Effective Resilience as Policy Drivers

Financial Futures Center

July 2022

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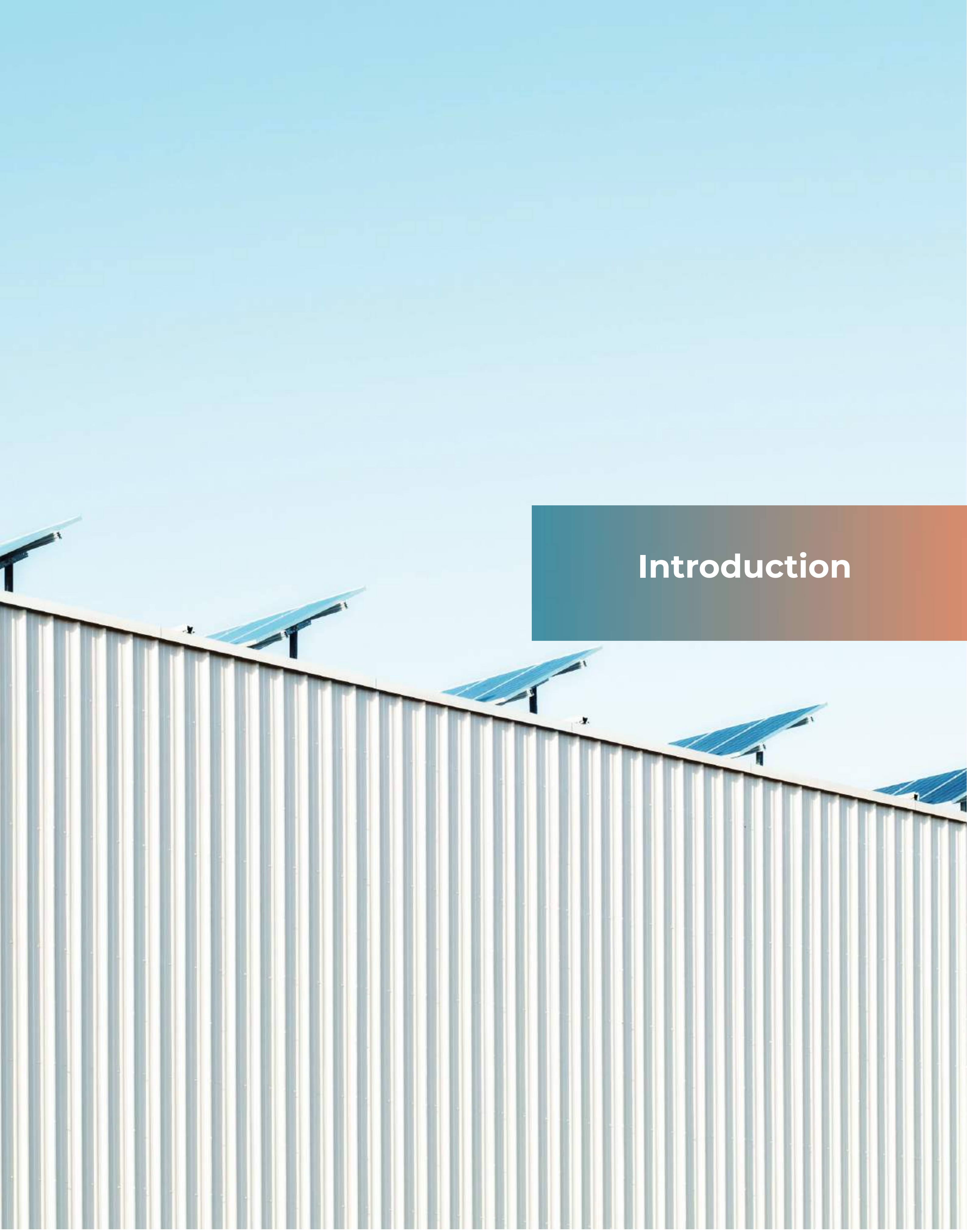


Introduction

Philippine energy policymakers, and their global counterparts, are facing a new era of policy and technology choices. The era of generation-centric power system planning, where every problem could be answered by building large-scale baseload units, has come to an end. Policymakers will now be called upon to adapt to a more dynamic world where fossil fuel price volatility tilts the balance toward modular renewables and storage, while new market solutions will define new solution portfolios that support actually resilient and cost-effective power systems. Countries that embrace this shift with flexible grid-focused strategies will be able to avoid fossil fuel lock-in while benefiting from a far broader and more responsive range of new technology options.

The pivot away from baseload generation- to grid-centric planning has been necessitated by three developments that increase the urgency of re-positioning policy in relation to the Philippine electricity grid. The first is the country's commitment to accelerated emissions reduction targets at the COP 26 meetings last year. During the event, the Philippine delegation committed to reduce its greenhouse gas emissions by 75% by 2030 through actions of which all but 2.75% were conditional. Philippine Secretary of Finance Carlos Dominguez III, who led the country delegation to Glasgow, said "We shifted from theorizing about climate change to executing practical adaptation and mitigation projects on the ground." Although a new policy direction has been endorsed, gaps remain between the government's new climate commitments and existing market policies in relation to a modernized grid.

The second development is the emergence of ongoing conflict between generation-centric power supply goals and regulatory and market implementation policies related to the design of a power system that can benefit fully from cost-effective renewables. For instance, although the Department of Energy (DOE) has stopped accepting new applications for coal power plant construction, the agency has nonetheless allowed previously approved coal projects – projects that have struggled to reach financial close and failed to meet project timelines -- to move ahead.

To fill the supply gap and reposition the Philippine's power market, policies to support technology transfer, modernized market design and financing structures must now be put in place. This is critical to the government's ability to meet targeted power supply gaps with cost-effective modular renewables solutions. While the DOE has made much of its shift to renewables, it has done little to enable the delivery of renewable solutions that depend on changes in the design and operation of the grids. The net effect of this policy dissonance has been a situation where the market is prepared to offer solutions to meet government policy goals, but is stymied by the lack of progress on grid issues, creating a setting where the market ends up struggling to provide cost-effective solutions that can be funded quickly.

While there are elements of a transition in Philippine energy policy, unlocking the potential of renewables will require new grid and system management initiatives such as storage.

The lack of coherent policy and effective regulation in recent years has held back investments in the infrastructure needed to quicken the transition. For example, it is not yet clear from the rulings of the Energy Regulatory Commission how developers of essential grid storage may be compensated. The concept of mini-grids has long been in the toolkit of the DOE and has even made its way to the legislature and yet these so-called “mini-grids” refer only to areas outside the current distribution grids and are better known as "off-grid" areas. They do not refer to mini-grids within current distribution systems that are meant to facilitate supply from local, often renewable, sources while still connected to the grid, thereby reinforcing the overall resiliency of supply.

The third development that should shape energy policy planning is the need for a more resilient power system. Damage from Typhoon Rai once again highlighted the Philippines’ vulnerability to the increasing frequency of adverse weather events. On December 14, 2021, typhoon Rai (local name: Odette) made its first landfall as a Category 5 typhoon in Siargao located in the Southern Philippines. It continued to cut across the entire area, inflicting severe losses on life and property. Power grids were taken down and, in some affected areas, restoration of service was estimated to take 6 months. While many of the initial reports on the damage and estimates of repair referred only to the local distribution grids, the transmission grid and the entire power system were likewise adversely impacted.

The disaster brings to the fore the question of whether a business-as-usual approach to grid development is still appropriate. The cost of maintaining the grids have soared, while rebuilding them has become even more expensive. More important, where catastrophe insurance is still available, the premium expected by carriers has become so unaffordable to many grid owners their assets are left uncovered. Only continuing subsidies contained in the costs charged by the grids have allowed them to continue to rebuild and operate. It is an untenable situation.

To address these developments, and present a roadmap for new policy development, this Report focuses on the infrastructure needed to implement the transition so the Philippines can meet its COP 26 commitments and, far more importantly, adopt a cost-effective and more resilient system design that will open new clean energy technology pathways that can only enhance affordable, reliable, and secure supply that meets demand and the load profile of the country. While it is true that policy is the starting point of concerted action and that regulation directs that action toward the policy goal, it is also true that both policy and regulation are developed within the horizon of already existing technologies. Efforts should be made to open the system for future technology options. To address this situation, the Report has focused on the technological elements of the power delivery system that will enable the modern grid.

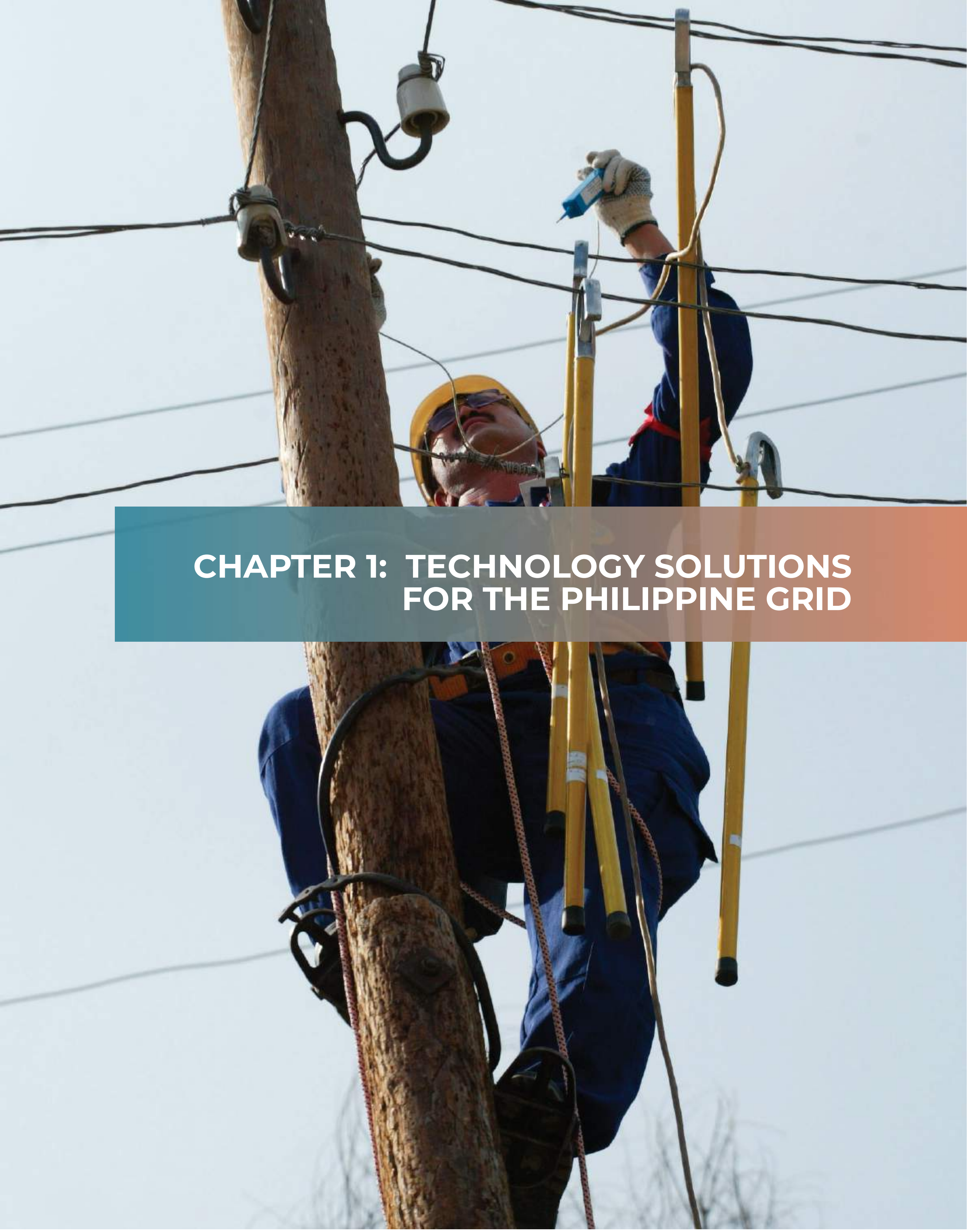
Policymakers are in a fortunate position despite the challenges. It is important to note many of the critical technologies already exist and have been deployed successfully in global markets. As a result, an enhanced grid strategy can increase functionality and help the Philippines meet the objectives of a more flexible and resilient power system. An example of this can be seen when new rooftop solar units become a catalyst for accelerating bi-directional flows of information and energy that can help system operators find new solutions to urgent system needs. Another example is the way new approaches to managing extreme weather events have prompted increased deployment of sensors that can then be used to increase grid responsiveness. While the Report is detailed in respect of technology in order to widen the field for policy and regulation to develop and enable a modern power system, it also embraces a new role for customers that go beyond restrictive, narrow goals of dependable supply and lower prices that still too many energy specialists confine their proposals to.

Philippine commitments during COP26, the disjointed policies of the DOE, and the damage inflicted by Typhoon Rai, as well as the global conflict in Ukraine highlight the incoherence of the country's energy policy framework when confronted with the colossal challenges imposed by climate change, extreme weather events, and energy security. It also highlights the need to develop an energy system that can build greater resilience without requiring actions that undermine that very effort.

The Report focuses on the often-missing piece in the energy and power policy transition that the Philippines must address between 2022 and 2027: the technological requirements of an enhanced delivery system. Aware that technology develops quickly especially when an urgent need exists, the Report aspires only to be directional rather than prescriptive. While technical, its appeal is to the planning imagination because, if the effort to change is wanting, its root is likely in the lack of imagination.

While the idea of a transition and a design for its realization may be widely accepted, it is the effect on the public of its implementation that will ultimately spell success or failure. Already, there are signs of hesitancy on the part of policymakers and business leaders. These can be counteracted, however, by advancing four key points complemented by policy development:

1. Broad technology partnerships through the promotion of innovative business models and technology transfer;
2. Project preparation support from inception to evaluation;
3. Bring down the cost of capital through credit strengthening, long-term financing, and local currency financing; and
4. Shift fossil fuel subsidies (whether direct or indirect) to building and operating resilient grids and storage.



CHAPTER 1: TECHNOLOGY SOLUTIONS FOR THE PHILIPPINE GRID

In the Philippine Energy Plan 2018-2040, the Department of Energy laid out a clear set of objectives consistent with the country's ambition to become a prosperous, predominantly middleclass society by 2040 as contained in Executive Order 5 of the Duterte administration, AmBisyon Natin 2040. These are:

a. Increase the production of clean and indigenous energy sources to meet the country's growing economic development.
b. Decrease wasteful energy use through energy efficiency tools and strategies.
c. Ensure a balance between the provision of reliable and reasonably priced energy services, support for economic growth, and protection of the environment.

While clear, these objectives are easy to achieve. With respect to the power system, objective (a) refers to renewable power generation while objective (c) refers to the reliability of that system. What is central to those objectives, although not explicitly stated in the plan, is the grid that will deliver clean electricity to consumers.

The Philippine electric grid was designed to carry large amounts of power in one direction from central power stations to large loads through high-voltage transmission wires. As late as 1992, a large percentage (49.84%) of that power came from large baseload renewable energy plants, specifically hydroelectric and geothermal ones. Of the share of fossil fuel (53.63%), the mix was coal (4.82%), crude (41.93%), regasification (0.11%), diesel (2.95%), fuel oil (2.95%) and LPG (0.85%).[1]

Excess power, especially in the evenings, was saved in large pump storage hydroelectric plants that provided regulation as well as adequate resources to the system. Today, 76.25%[2] electricity in the country is generated from fossil fuels, with coal alone providing 50%[3] of the total. While the amount of variable wind and solar generation has increased, the grid that delivers that power to load centers has remained fundamentally the same, that is, one that does well in delivering baseload (mostly fossil fuel) power, but which does far less so with variable (mostly renewable) power. If the Philippines is to meet its energy provision objectives, the grid should be modernized in a way that ensures the integration and delivery of variable renewable energy in a cost-effective way.

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Resilience must also be a planning priority. In terms of vulnerability to severe weather events, the Philippines ranked ninth in the 2020 World Risk Index (WRI), with a score of 20.96. While that marks a significant improvement over 2018 when the country ranked third among all countries, it remains very vulnerable as the scale of extreme weather events increases. Damage to the power system from such events has resulted in large financial losses to the grid because of lost revenue and repair costs. More important, those losses have risen every year as the increase in the frequency and severity of extreme weather events has taken an even greater toll on a rapidly aging grid.

How can a modern grid with smart or intelligent technologies create a more dynamic network for real-time information, with enhanced measurements and data transformation for timely and appropriate response to system events? With digitalization, the modern grid can tap into new sources of functionality that support both high voltage bulk transmission and local distribution systems. More importantly, it helps raise market efficiency because it brings real-time sharing of generation, transmission and distribution information on pricing and use with standardized templates.[4] Much emphasis must be placed on the distribution network as regards embedded renewable resources. For example, to manage distributed energy resources (generators) and demand control resource (customer load), it is expected that the distributor will be allowed to take greater dispatch control on distributed energy resources or utilize its demand control on customer loads. This will require increased investments in facilities that enable coordinated and dispersed operations. The distribution network must also invest in load shedding capabilities in the event of demand controls and should be able to implement demand control by shedding customer load through commercial contracts.

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The two-way communication infrastructure linking the distributor and the customer in a modern grid environment would cut transaction costs, increase market transactions, and contribute to the strong expansion of wholesale and retail energy markets. In many markets, it's common to see a new range of players providing value-added services to customers. For example, the retailer's role is likely to grow as they meet new market needs located between the distribution network service provider and the end-use customer. Energy service companies could also have a roll in the electricity supply chain with demand control commercial contracting. These companies will also be able to engage in supply contracting, providing clients with electrical equipment designed to function at the predetermined quality level of supply standards.

There are other types of new market players as well. Aggregators—intermediaries who form many small consumers into large groups—can play a role by supporting small commercial customers dispersed within a contiguous area, or households willing to play an active role in energy supply and consumption. This model works where there is the potential to create economies of scale. Peer-to-peer energy[5] trading which supports buying and selling of energy between two or more gridconnected parties, often in solar energy, can develop where any excess power can be transferred and sold to other users via a trading platform. Consumers can choose who they buy electricity from, and to whom they sell it. This is often preferable to net metering policies.

Because these services may affect network operations, the distributor with ultimate responsibility for local network reliability must always be kept informed on market player actions and grid dynamics. New roles for the distributor may include (a) actively purchasing system services from distributed resources to manage their flexibility needs, (b) overseeing data handling in smart grids, and (c) remaining in charge of metering due to their dependence on the data for secure and reliable grid operation.

To ensure fair and equal access to the distribution network, the new entrant participants and the new roles of the distributor will need regulatory reforms. Regulatory frameworks for distributors currently do not always reflect the immense need for investment in grid development and upgrades. To remedy this situation, regulators can shift their framework away from prioritizing cost reductions to top-down cost-effective resilience, incentivizing innovation and consumer engagement. This will result in improved service quality and, as efficiencies work their way through the system, in a reduction in prices. For instance, the ERC can approve an investment recovery mechanism for the use of energy storage systems to provide ancillary services such as frequency and control and voltage support. Storage systems can also act as reserves providing resource adequacy thereby improving grid stability and system reliability.

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Grid operators assume a certain level of redundancy in both transmission capacity and supply capacity. These capacity margins in transmission should give the grid the capability to withstand an unexpected outage of a single system component in the grid. The same criteria on the outage of any generating unit online apply to generation supply capacity. Such a supply capacity margin must at least match the largest generating unit online even as the same margin is needed to quickly balance and match electricity usage. Supply margins that commit generation capacity to balance supply and demand also help the system recover from an adverse event. Generation that functions in this manner provide ancillary services. Systems with significant variable renewables penetration will require additional ancillary services. It is important to note that while ERC and DOE use common norms for setting reserve capacities, no review of actual performance is made to check if such capacities are effective.

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Using supply margins means committing generation capacity to address imbalances between supply and demand and to help the system recover after an adverse power system event. Functions that help grid operators maintain a secure grid operation are called ancillary services. In systems with significant variable renewables penetration, additional ancillary services may be required to manage renewable energy generation. Another challenge of integrating renewable resources is the bidirectional power flow brought about by distributed generation, affecting system protection, operation, and power quality.

While transmission and distribution networks share the fundamental function of transporting electricity, they are very different in design and operation. Transmission grid operators have a limited view of the distribution network and only see embedded distributed generation as a reduction in system demand. Allowing the transmission grid to see all generation especially from distributed renewables will enable the system operator to better forecast the need for ancillary services. In this way, current analytical tools enhanced with new sensor technology can facilitate the integration of renewable energy.

These and other smart grid solutions have the potential to better integrate diverse generation technologies, enabling the integration of both distributed renewable generation and large-scale renewable generation into the grid.

It is important to note the Philippines has enjoyed energy storage as early as 1982 through the Kalayaan Pump-Storage Hydro Power Plant. The project was integral to the intention to use nuclear -- an inflexible power source. The large storage hydro capacity was also meant to provide intermediate and peaking capacity. The same grid resources may thus help absorb new capacity. Considering fossil fuel price hikes due to exposure to international volatility, NAPOCOR may consider to update existing studies on hydropower projects in Luzon to see if they can be part of a new initiative to integrate more RE capacity. There are also recent announcements from the private sector to develop 1,400MW of pump-storage hydro to support the Philippine'' Clean Energy Scenario.[6]

International Experience 1. Integrating Renewable Energy - Example from Brazil

An element of a modern grid is its ability to integrate larger amounts of renewable sources to increase flexibility. In 2020, Brazil produced 84.23% renewable energy out of its total electricity generation, with 64.58% hydroelectric power, 9.36% wind, and 1.25% solar. Despite this already high share of renewable energy, the Brazilian government has committed to increase the non-hydro renewable energy sources in the mix, like solar, wind and geothermal, to reduce dependence on hydro power, which could be affected by drought.[7]

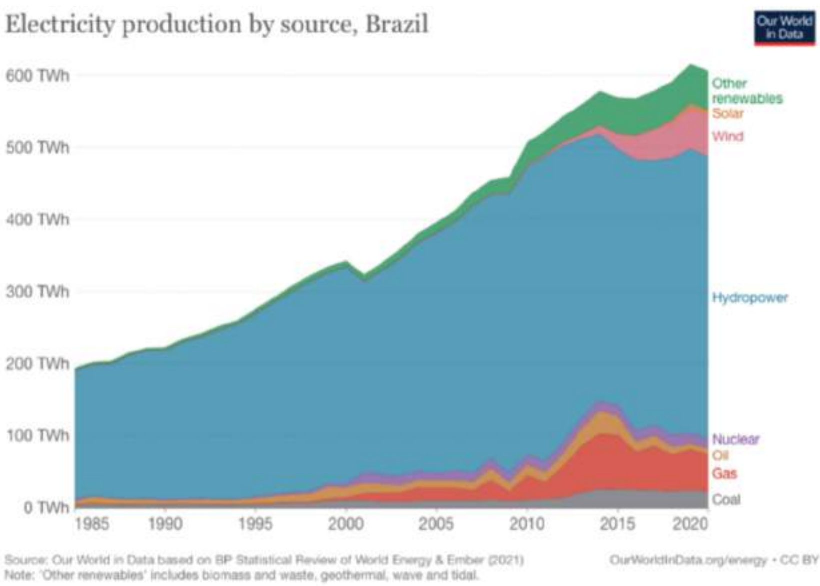

Figure 1: Electricity Production by Source in Brazil from 1985 to 2020 Source: Our World in Data

In 2019, Phase 1 of the Belo Monte Hydropower UHV DC Transmission Project in Brazil was completed. It consists of 2,518km of ±800kV ultra high voltage (UHV) DC power transmission lines to deliver large amounts of renewable energy to distribution stations.[8] The UHV allows integration of large amounts of renewable energy to the grid. However, it does not ensure flexibility because of the source, which is still large-scale hydroelectric.

TRANSMISSION NETWORK

Transmission infrastructure investments for resilience and increased energy load management must be complemented by smart solutions that support the integration of renewable energy resources. New levels of functionality are provided by a range of new technologies including:

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- Substation automation, including voltage control, synchronism, load and bus transfer, load curtailment, and fault detection
- Intelligent electronic devices (IED) such synchrophasors
- AMI and smart meters
- Wide-area measurement
- Energy management systems (EMS) and supervisory control and data acquisition system (SCADA)
- High-voltage direct current (HVDC) transmission and static VAR compensators (SVC)
- Power transmission analysis software
- Outage management systems (OMS)
- Energy storage systems.

One of the most important smart grid technologies for integrating renewable energy into the grid is the synchrophasor, a technology that measures conditions on transmission lines through the assessment of voltage, phase angle, and frequency. Systems with synchrophasors working with state estimators give grid operators more information and help them conduct advanced scrutiny such as disturbance analysis, stability analysis, and fault monitoring. The results are used to prepare emergency recovery procedures and automatic adjustments when disruptions are identified. Software for power transmission analysis that enables system engineers to model, design, and manage transmission networks is similarly important.

EMS are used by utility companies to better visualize, operate, optimize, and maintain transmission networks. Key components of the systems include the SCADA, which supports the monitor and control components of the grid, and the outage management systems (OMS) which is designed to track, group and display outages to safely manage service restoration activities.

Technologies such as Synchrophasors, Energy Management Systems and Outage Management Systems increase the wide area awareness of the grid.

It was mentioned earlier that storage technologies enhance grid flexibility and resilience by providing ancillary services. On the other hand, smart grid technologies, in addition to performing the conventional functions of grid operation and management, do so with enhanced monitoring which enables greater anticipation and faster response. In sum, these technologies increase the wide area awareness of the grid.

International Experience 2. Real Time Pricing – Example from Australia

This brings us to the last element of a modern grid, which is the importance of enabling consumers to choose suppliers, and providing real-time pricing, making the market more competitive. The National Electricity Market (NEM) covers five of the eight states and territories of Australia.

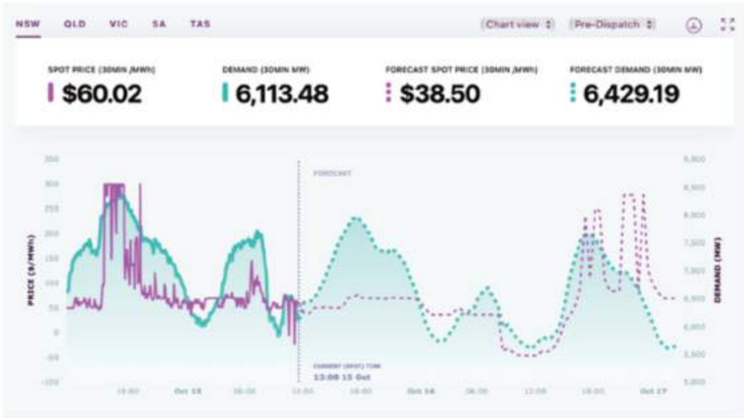

Figure 2: New South Wales Electricity Market Dispatch Dashboard
Source: Australian Energy Market Operator

The Australian Energy Market Operator (AEMO) is responsible for the operation of systems "that allow energy to be generated, transmitted and distributed, and the financial markets that allow energy to be sold and bought."[9] Originally created to manage the fossil gas market, AEMO's role has expanded to include the electricity spot market. Their technology allows viewing of five-minute and 30-minute intervals of dispatch, as well as pre-dispatch, to give consumers a better understanding of the market price.[10] They also provide a real-time fuel mix breakdown to allow consumers to make an informed decision about their energy consumption.

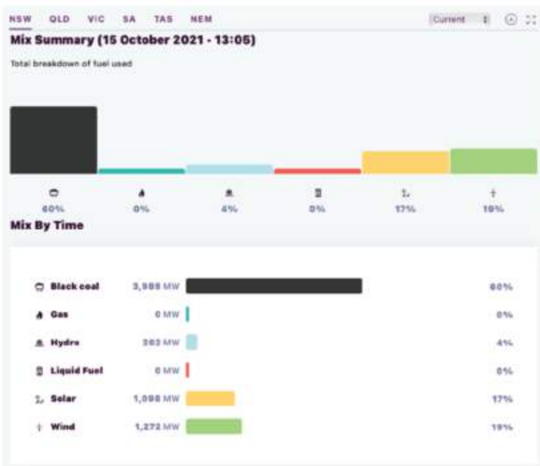

Figure 3: New South Wales Energy Mix Summary
Source: Australian Energy Market Operator

SMART TRANSMISSION NETWORK SOLUTIONS

Smart grid technologies will replace traditional systems, allowing for the integration of renewable generation through advanced information exchange of networked sensors and big data technology. Some of these are:

- **Energy storage systems.** Energy storage will become increasingly vital for smoothing out energy supply from variable distributed energy resources, helping ensure that generation supply matches demand. Advanced vehicle battery charger inverter technology will expand the usage of these batteries for grid service, as it charges or discharges power.

- **Advanced prediction tools for renewable energy sources.** Improving short-term variable renewables generation forecasting improves generating unit operation scheduling and operational planning and helps reduce the number of operating reserves required in the system. Over longer timescales, forecasting tools can aid in better planning system development, including both generation and network transmission capacity.

- **More observations and methods for congestion management.** Generation scheduling, network reconfiguration, and load shedding are the legacy systems options. The current approach is generation rescheduling and demand response. Electric car charging infrastructure will play a critical role in transmission congestion management.

- **Generation, load balancing, and other system services such as frequency control and voltage control.** Because renewable resources have no rotational inertia, frequency control from conventional generation becomes more costly. Smart inverters that can provide grid services such as voltage and frequency regulation are a way to integrate distributed renewable energy resources.

- **Advanced power automation technology** helps to increase system observability and monitoring. Smart sensing, communications, and automation control components detect and give guidance to grid dispatchers, and automatically perform the appropriate actions in emergencies for swift restoration.

- **Modern state estimators with phase measurement devices.** State estimators (SE) use remote measurements of bus voltage magnitude and line active and reactive power flow to generate static estimates of system conditions. Even though significant progress has been made in detecting poor data from polled data from the remote terminal units, there is still a need for better “bad data” detection and correction. A smart sensor measurement device called the phasor measurement unit is helping improve SE accuracy, allowing grid operators to prepare for quicker recovery procedures from power loss events.

- **Island operation.** Distributed generation can respond quickly to line faults by separating into islanded sub-networks. To enable this, the control system must be able to detect island formation and regulate internal frequency and voltage by controlling the connected distributed generation.

- **Photovoltaic plants with advanced inverters.** Typical solar PV inverters worked at unity power factor. But now, advanced inverters can inject reactive power to the grid to support voltage by reactive power control.

- **Cybersecurity of SCADA and WAMS.** The SCADA system currently provides the grid with supervisory control and data acquisition capabilities. The Wide Area Measurement System (WAMS) is a set of advanced measurement technologies, information tools, and an operational infrastructure that enables complex networks to be planned, operated and managed. It is a real-time situational awareness system that also supports the post-event study of large system events and complements the SCADA system. Because of their critical functions, these systems require enhanced cyber-security protection.

Smart grid technologies such as Advanced prediction tools for renewable energy sources, smart inverters, and the Wide Area Measurement System (WAMS) should be considered as opportunities for government to secure climate finance where developed countries cover acquisition, training, and deployment costs in exchange for estimated emission reduction outcomes, because of the ways such tech can help accelerate the transition.

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DISTRIBUTION NETWORK

Transmission and distribution operations and management are separate tasks. With variable renewable energy resources, coordinated actions on demand and power injections in the network are required for secure operations. One of the main benefits of smart grid technologies is that it can be deployed at the distribution level to facilitate integration and control. It will become necessary to have the following items in Box 1.

Box 1. Smart Technologies

- Substation automation. This is about enhancing remote management with the attendant communication infrastructure of the distribution system. The technologies in automation include the SCADA platform that provides real-time monitoring and control software applications, outage detection, and power quality management on distribution networks. Altogether, this is referred to as distribution automation and FDIR (fault detection, isolation, and recovery). Also included as smart technology is the advanced on-load tap-changer (OLTC), which is used for enhanced voltage regulation.

- Smart meters, also referred to as advanced metering infrastructure (AMI). The resulting improvements in communication enables utilities to respond faster to service problems and communicate real-time costs enabling customers to alter their electricity consumption habits based on real-time usage and pricing data.

- Microgrids. Microgrids are a type of grid configuration with a power system constituted by distributed energy resources. They provide self-sufficiency and enable “islanding”.

Other smart grid technologies include Geographic Information Systems (GIS). Together, these technologies improve distribution operations by making the network more visible to its operators and enabling them to anticipate and correct situations before they become problematic.

- Real power control over distributed generation to balance the variable power injections with the demand
- Monitoring and control of network voltage at the connection points of renewables plants
- Monitoring network loading when electric vehicles are charging
- Maintaining the reliability of supply even with rapid change in network conditions
- Distribution automation, network automation and remote control
- Re-closers, feeder automation/smart re-closers
- Distribution management software, SCADA, and GIS
- Meter data management system
- Outage management system

Smart Distribution Network Solutions

- Advanced Metering Infrastructure and Smart Meters. Key to realizing the modern grid is an advanced metering infrastructure based on smart meters. AMI is a 2-way communication system that collects and analyzes data from smart meters. It is the first step in digitizing electric grid controls. Installed at consumers’ premises, smart meters measure energy consumption and transmit essential other key information to the control center.

- Metering back-office system. The meter data management system collects consumption data. In an AMI setup, it will also collect consumption profiles and use this alongside the tariff information in the billing system to draw up invoices for customers.

- Enhanced distribution protection. This is an adaptive protection system that mitigates the effects of high penetration distributed generation on the protection coordination for varied operating conditions such as bi-directional power flows and islanding mode. Current solutions include the use of directional overcurrent relays and the deployment of fault current limiter technologies to restrict circuit current during fault occurrence. Future smart protection systems would be able to adapt to changes in network architecture, power generation and consumption. It will also be able to monitor the protection scheme and apply suitable protective settings in response to changes in the network.

- Electric storage systems. Networks with distributed generation are increasingly incorporating battery energy storage systems. With the advancements in inverter technology, BESS can provide spinning reserve service to compensate for the fluctuations in distributed generating output and reactive power reserve service for voltage control.

- Electric vehicle charging management. The envisioned future of widespread adoption of electric vehicles, along with the development of battery charging infrastructure will cause an increase in electricity demand. Using "managed charging" by controlling charging time, duration, and intensity will reduce charge during peak load hours.

- Enhanced ICT. This technology must penetrate the distribution systems down to the end customers' network level. Current SCADA systems cannot provide all the functions needed to realize the goals of the modern distribution network.

Each technological component of an evolving modern grid has its own importance. For most, the AMI/smart meter solution is the initial step. The smart meters and the requisite information and communications systems will provide added data acquisition functions for the enhanced SCADAs and the planning software for system management and operations. Strategically located, BESS enables quick integration of distributed generation into the grid.

Other smart technologies can also bring about significant changes in the system. The critical task is that important work of linking these smart technologies to the legacy system. Improvements in network monitoring, congestion management tools and renewables generation prediction are steps toward integrating more renewables into the transmission network. They can be aided in that task by distribution automation, GIS into SCADA and meter management and outage management systems.

There is an old axiom that states "trade follows the flag". In the power sector, this can be interpreted as *developments taking direction from policy*. While a framework for a modern grid is lacking, the policy environment for crafting one is limited by the technological horizon which is often defined by those who currently operate the grids. What is not easily recognized is that the horizon moves in lockstep with current business models for electricity provision that perpetuate a *business-as-usual* (BAU) approach to changes in the power system. Indeed, what happens more often is the opposite of the axiom, where "the flag follows trade". A clearer understanding of the relationship between policy and monopoly businesses may help better navigate the advocacy for a modern grid.

CHAPTER 2: HOW CAN NEW TECHNOLOGIES BE USED TO MODERNIZE THE PHILIPPINE GRID?

The Philippine transmission grid was designed, built, owned, and operated by the National Power Corporation, a government-owned corporation for decades before enactment of the Electric Power Industry Reform Act (EPIRA) of 2001. Pursuant to the law, the grid was spun off into a separate corporation, National Transmission Corporation (Transco), also a government corporation and its operation was awarded by concession agreement to a private company, National Grid Corporation of the Philippines (NGCP). The agreement also delegated the planning and development of the transmission grid to NGCP. In theory, those plans and programs for the grid should be coordinated with Transco and aligned with those of the Department of Energy.

Market reality is more complicated, however. Vague provisions in the concession agreement have weakened its enforcement, enabling wider discretion on the part of NGCP to increase its profits in ways that are not always for the benefit of power consumers. While NGCP is overseen by the DOE and the Energy Regulatory Commission (ERC), its actions and their effects on service delivery and electricity prices escape the scrutiny of most consumers. Its plans and programs thus develop absent meaningful public participation or accountability. As such, there is a need to strengthen DOE's oversight of NGCP's performance to address delays in grid expansion and the inability to quickly process applications for interconnection by RE projects through the SIS. This weakness comes from the centralized grid planning paradigm where only a few large projects are needed in generation.

The Transmission Development Plan (TDP) is the key document for the development of the electric transmission network. It contains specific plans and programs of the NGCP for improving the reliability of the grid and ensuring security of supply as demand for power grows. Its goal is to provide an increasing number of customers with dependable quality service. The current plan contains the following components:

- Addition of transformers in several substations to handle load growth.
- Addition of new transmission lines and upgrading of existing transmission lines to improve service delivery with the long-term goal of creating multiple transmission pathways that will increase the overall reliability and operational flexibility of the network.
- Voltage improvement to improve the quality of electric service.
- Interconnection of more islands to extend reliable service delivery in part by creating a pool of reserve power that can be more widely shared.

Compliant with the DOE Circular 2018-01-0001 titled, "Adoption of Energy Resilience in the Planning and Programming of the Energy Sector to Mitigate Potential Impacts of Disasters", NGCP developed a resilience plan in 2018 to improve the capacity of the transmission system to withstand and recover quickly from the impacts of adverse environmental conditions such as extreme weather events as well as disruptive human actions such as sabotage in order to ensure uninterrupted or minimally interrupted service to its customers (refer to Box 2 for the key components).

Box 2. Key Components of the Resilience Plan

- Better selection of transmission line routes and substation sites. Changes in weather patterns and the increases in the severity and frequency of extreme weather events driven by climate change pose additional hazards to the transmission network. Selection of routes and sites away from these hazards protect its integrity and reliability ensuring security of supply.
- Reinforcement of proper selection of transmission line routes and substation sites.
  i. Transmission lines will be routed to avoid areas prone to flood and soil erosion.
  ii. Substations will be sited away from floods, possible sources of pollution, flammable materials such as bulk oil storage tanks and oil/fossil gas pipelines, and saltwater corrosion on insulators of substation equipment.
  iii. High voltage underground cables on critical lines will be removed from areas vulnerable to typhoon and storm surges.
  iv. Sites that have minimal effect on human settlement and that require minimal removal of plants and trees will be prioritized for future facilities.
- Strengthening of Transmission Towers [Note: The maximum wind velocity design of overhead transmission lines' (OHTL) support structures is based on three wind zones: Zone 1 (270 kph), Zone 2 (240 kph), and Zone 3 (160 kph).]
  i. New OHTLs to be erected in Luzon should be able to hold out against wind speeds of 300 kph to withstand the effects of super typhoons.
  ii. Existing transmission towers. As support structures for overhead transmission lines, the towers were designed to withstand probable maximum wind speeds. Climate change has increased wind speeds beyond their design tolerance requiring reinforcement to new standards.
  iii. Configuring transmission line loops. The redundant routes enabled by loops ensure delivery of power when more established routes fail.
  iv. Strictly implementing asset replacement programs. Often cost considerations extend the deployment of a transmission asset beyond its service life increasing the risk of system failure. Replacing an asset in a timely fashion mitigates that risk.
- Adoption of smart grid technologies
  i. These systems enable better grid management through enhanced control and data acquisition strategically distributed over the network. They also include added protection from cyber-attacks.

The DOE Circular 2018-09-0027 titled, "Establishment and Development of Competitive Renewable Energy Zones in the Country" seeks to harmonize and direct the many energy plans to support renewable energy by identifying and developing strategically located zones where renewables projects may be built with ease. In effect, it directs the NGCP to build transmission facilities to areas rich in renewable energy resources in advance of generation plants to accelerate the availability of cost-effective renewables power. This development speaks to the aspirations of consumers for clean energy by enabling access to sites that have potential for commercial renewables power generation.

The Transmission Development Plan and the Resilience and Renewable programs of the NGCP affect electricity consumers who cannot fully comprehend its effects on them, shrouded as they are in highly technical language. While public consultations on the grid run by the ERC are public, consumers have effectively no means to participate meaningfully because much of the discussion is framed in technical language. One critical step to take – perhaps a minimum – is to utilize benchmarks in pricing matters, and to ensure full disclosure of PSA provisions that affect customer costs. This way, a conversation can be established that pulls in consumer interest and input, because public ownership of strategies, plans, and anticipated challenges after all, is essential to instilling business confidence, responsive governance, and public support.

The Manila Electric Company (MERALCO), while a distribution utility, deserves mention as well. Its network covers the National Capital Region and surrounding provinces providing a significant part of the total load of the country. Moreover, it is likely the only local electric utility that can be ranked as world class and as such may be considered a model for other electric utilities in the Philippines.

The key document for regulating the electricity distribution companies is the Distribution Development Plan. Because the Meralco service area includes many of the major economic hubs of the country, its plan is keyed to providing reliable service to a rapidly increasing load from a likewise increasing customer base which varies from the largest manufacturing plants to informal settlements. While continuously undertaking network asset renewal and refurbishment, Meralco has focused on improving its internal processes related to planning, operations, and maintenance of its growing network. Specifically, this amounted to increased investment in information and communications technology including wireless and fiber optic systems that enable better links to its customers and protection equipment that secure their systems. Perhaps of even greater importance to the transition, Meralco is also investing in smart technologies that enable automated management of bi-directional flows of both energy and data to and from its customers and its network that enable integration of distributed energy resources such as residential rooftop solar. A clear example of this would be Meralco's acquisition of an Advanced Metering Infrastructure (AMI) built on an enhanced telecommunications network, including smart meters in customer premises.

The key objective of Meralco's resilience plan is a quick and efficient response to outages. To achieve this, it first invested heavily in technology to make its network infrastructure more robust to reduce the incidence of unplanned power interruptions. Meralco invested heavily in a Fault Location, Isolation and Service Restoration (FLISR) response mechanism that pinpoints outage locations and reroutes power to affected customers, shortening power restoration times. The mechanism is integrated into a mobile computing system that coordinates dispatch of repair crews. To preempt the effects of extreme weather events, Meralco in coordination with Local Government Units (LGUs) have instituted regular inspections and tree-trimming. It has also hardened its physical infrastructure including replacing older wooden poles with concrete ones, upgrading conductors and lead wires, installing line and equipment covers, and using fiberglass cross-arms. Moreover, it has improved its lightning and consequential surge protection with the addition of surge arresters, overhead static wires and system-neutral grounding and the acquisition of lightning detection systems that provide information on the magnitude and location of strikes within its area.

Box 3. Meralco's Cybersecurity Actions

Meralco upgraded its cyber-security to comply with the latest industry standards:

a. The Cybersecurity Roadmap of 2020 covers important issues such as governance, security engineering, and incident response for its IT and operational technology (OT) environments.
b. The Cybersecurity risk assessment includes regular risk assessments and penetration tests by external parties on both its IT and OT systems to uncover vulnerabilities in the company's systems.

MERALCO: PROMOTING THE USE OF RENEWABLE ENERGY

The bulk of Meralco's electricity is from sourced from fossil gas and coal-based power generators, with a portion comprising its peaking energy purchases from oil-based units. As it has less significant RE share in its power mix compared with utilities VECO and Davao Light, Meralco is likely to face more volatility in its blended generation rates. In 2019, fossil fuel-based power accounted for about 97% of the power Meralco distributes, but it has begun securing renewable energy, particularly rooftop solar from its customers under the net metering program of the government in implementation of the renewable energy law. Recently, Meralco began purchasing power from grid-scale solar and large hydroelectric plants. More importantly, Meralco has committed to contract 1,500 MW of renewable energy over the next 5-7 years from its own renewables power development subsidiaries, MGen Renewable Energy (MGreen) and Spectrum. Spectrum began as an installer of solar rooftop systems and microgrids, and is planning to construct wind and battery systems. While not yet feasible in its current operations, Meralco may need to build internal operational capacity to be able to consider smaller contracts that may be more cost-effective.

Similarly, Meralco is piloting a 2-MW Battery Energy Storage System (BESS) in its franchise area. This, however, is much smaller compared to plans of other players such as San Miguel which aims to switch on 690-MW of BESS in 2022.[11]

In anticipation of customer choice of electric service provision under the Retail Competition and Open Access program of government, Meralco established two Retail Electric Suppliers (renewables), MPower and Vantage, to compete within and outside its area. This development is critical to the energy transition as it creates a clear path for customers to secure clean energy.

The plans and programs for the grid provide insight into the future of the electricity network in the Philippines. Whether they will accelerate or impede the energy transition is largely dependent on top-down cost-effective resilience as the policy drivers.

Box 4. Meralco's Subsidiaries

- MPower serves as Meralco's Local Retail Electricity Supply unit. It operates exclusively within the Meralco franchise area. It provides energy and value-added services to eligible contestable customers with a demand of at least 500 kW. MPower has a nearly 28% share of the country's total Competitive Retail Electricity Market with a contract renewal rate of almost 90%. To maintain that premier position, it manages a diversified supply portfolio to cater to its clients' growing renewable energy requirements by contracting solar and hydro energy sources to complement its traditional sources of power supply.

- Vantage Energy Solutions and Management, Inc. (Vantage Energy) is Meralco's first affiliate Retail Electricity Supplier. It operates in Luzon and Visayas. Vantage Energy began commercial operations in February 2017, supplying the energy requirements of contestable markets across the country where RCOA is in effect. In its first three years of operations, its retail portfolio grew significantly, now serving the energy needs of over 50 customers.

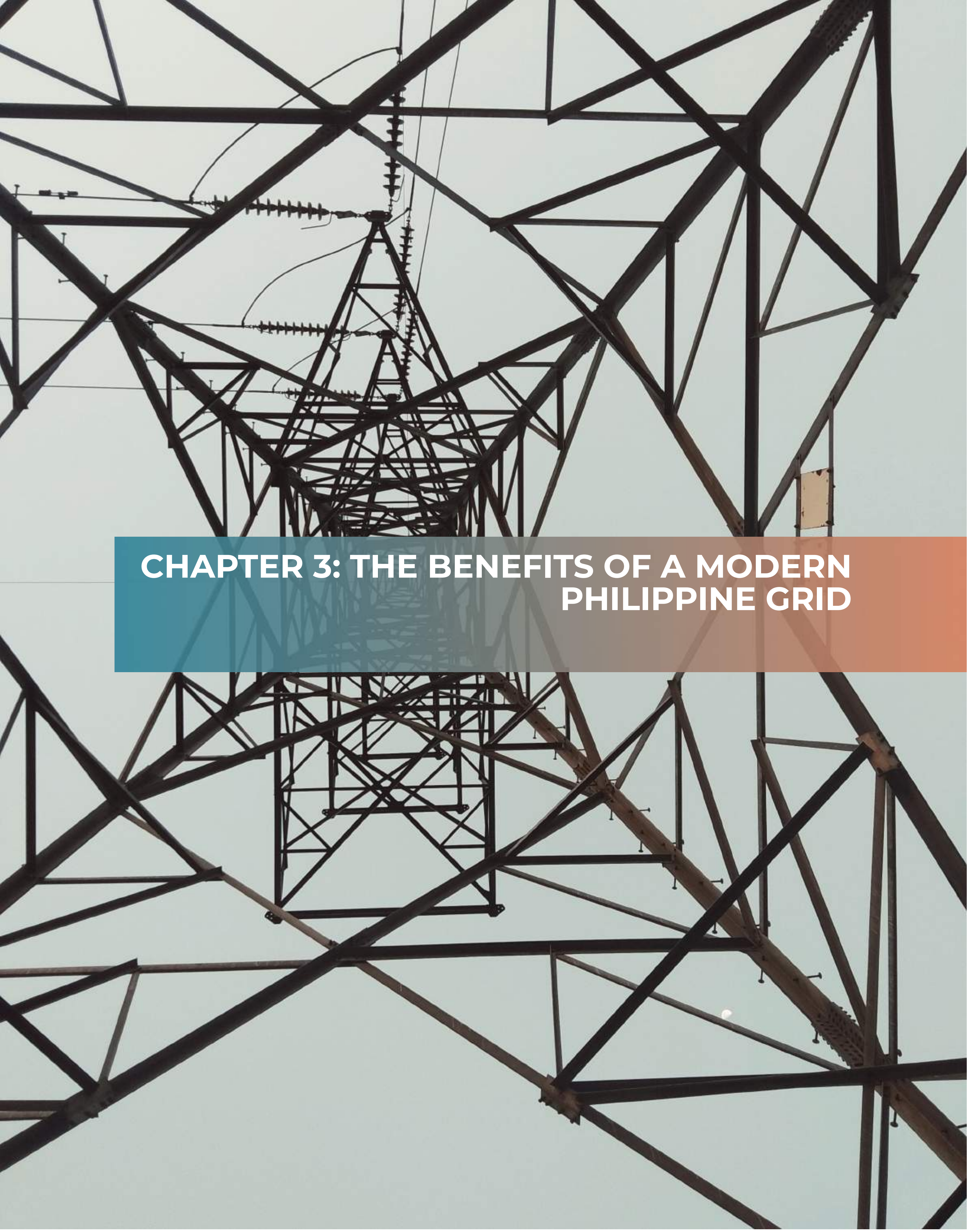
THE FUTURE OF THE ELECTRICITY NETWORK

The fragmented character of the Philippines' power market reflects a combination of factors including geography and overlapping regulatory mandates. To get the most out of new grid technologies, policymakers will want to examine new planning strategies. The planning of the transmission and distribution network involves simulations of long-term future networks in determining its performance against technical standards.

Traditional grid planning prioritizes reliability and adequacy of supply. The process is as follows:

1. Simulations analyze the transmission lines and substation capacity required by operating and planned generating plants to compare the network's performance with technical standards. The network's capacity is then studied, and network additions are planned to guarantee load growth requirements are met.
2. Several development options are tested under different system scenarios and the least-cost planning candidates that meet reliability and efficiency standards are selected. Transmission, distribution, and generation infrastructure is planned to meet peak system needs, and simulations incorporate reserve capacity into capacity estimates. Reserve capacity addresses demand fluctuations, demand forecast errors, and outages of a large generator or a key transmission component in the grid. The goal of the plan is a reliable grid that provides power dependably when and where its users need it, and that can withstand most disturbances without failing.

Based on the foregoing, the process for grid planning can be inferred. But a key point needs highlighting nonetheless: Traditional grid planning is based on ensuring reliability and adequacy of supply. As such, it needs to be coordinated with the type of generation planned along with patterns of electrical consumption. While it should be indifferent to either as inputs, it is very easy to assume business as usual conditions in planning. It is the task of policy makers to set directions for grid planning. However, absent a firm grasp of the technicalities involved in planning grids, it may be difficult for policy makers to break from the inertia of continuing on business as usual. It is only when customers participate in issues such as undependable service or tariff hikes that discussions are forced to go beyond the usual. Climate change, the pandemic, and the Russia-Ukraine war have forced movement toward a new normal. It is only wise to respond to this situation using a wider horizon for planning grids.



CHAPTER 3: THE BENEFITS OF A MODERN PHILIPPINE GRID

Despite the strong case for modernizing the Philippine grid to enhance the cost-effectiveness and resilience of the system, the only targeted policy driver currently in place focuses on designated Competitive Renewable Energy Zones (CREZ). While there are no policies or plans to address the role that a smart grid can play in accommodating the variability of the new wind and solar farms or in aligning the Philippine power market with new technology trends, it is important to note that the more variable RE capacity, the less the variability. Reason being, more variable RE deployment smoothens the generation profile of all variable RE in the system. There may also be some progress made if an updated ancillary services program wins support. Unfortunately, details on this initiative are not yet available.

On the matter of grid resiliency, transmission plans are more detailed, but they seem to take a one-dimensional approach. So far, the focus is on placement or replacement of grid elements such as substations and transmission towers away from hazardous areas, strengthening of these grid elements, creating redundancy through transmission loops, and adding more intelligence to the grid by way of smart technologies and analytics to improve operations that, in turn, preserve and extend the lives of the grid elements. While these plans may be effective, they fail to capitalize on recent innovation in grid design or operation. For example, although there is growing evidence on the ability of new grid configurations such as distributed energy resources (DER) and mini-grids to enhance resilience, there are no plans yet to integrate them into the existing Philippine grids for such a purpose.

In the nomenclature adopted by the Philippine energy authorities, mini-grids refer to isolated grids that are not connected to the main transmission grid where power is supplied mostly by diesel generators. They are located on small islands and in remote areas within the larger islands served by the main grid. Within this context, distributed energy resources (DER) refer to the power supply of these mini-grids. These mini-grids are the focus of the government's efforts to provide access to electricity to all Filipinos and, as a result, electricity to consumers in such areas have been heavily subsidized. While there are plans to replace diesel generation with renewables to decrease the ballooning cost of subsidies, such plans quickly give way in implementation to more easily deployed diesel gensets without much thought to the difficulty of keeping them continuously supplied with diesel fuel. This particular understanding of mini-grids and distributed energy resources makes it far more difficult to see how they can be valuable in increasing the resilience of the main grid.

On the other hand, there are the industrial zones which qualify for legal designation as Ecozones that are already connected to the main grid. Within these zones, power facilities including distribution networks can be built and operated as “economic zone utilities enterprises”. The Ecozones are ideal sites for testing the value of mini-grids and distributed energy sources in enhancing the resilience of the main grid. These models could be emulated by school campuses, commercial districts, and even residential subdivisions. In this developmental area as with many others pertaining to grid operations, however, policy guidance is missing.

If the Philippines aspires to increase the production of sustainable energy to meet its growing need for economic development, then the country has to build more variable renewable power plants. While they already produce power at costs lower than fossil fuel plants, their costs continue to decline.

Additional policy gaps are in evidence related to system planning for battery electric storage systems. Storage will be critical to effective deployment of variable renewables because variable renewable power will, at times, be generated when there is no coincident load to absorb it. To avoid wasting power, it must be stored cost-efficiently. BESS has proven commercially that it can perform this function well. While San Miguel is already building them, it is doing so in a policy vacuum. Accelerating the build out of BESS to support the increase in variable renewables will require clear policy and regulatory guidance that will assure investors in BESS of capital recovery with reasonable returns.

Because climate change brings a novel level of uncertainty, it may also be the catalyst for utilities to consider novel approaches to reducing vulnerabilities and increasing their resilience to hazards amplified by the climate crisis. While highly centralized grids connecting large generating plants to equally large loads used to provide the lowest cost power to consumers, they also tend to concentrate risk in fewer areas in the entire power system. In a climate-changed world, that increased risk has translated into higher costs that, in turn, make the centralized design of the grid far less cost-effective than it used to be. This has happened, at least once. In May 8, 2013, five days before the May 13 elections, an over-loaded Biñan-Calaca 230kV line caused an outage in the entire island of Luzon.[12]

Ultimately, the value of investments in the ability of the grid to absorb and deploy more variable renewables, and to become more resilient to climate-induced weather events, will be measured in terms of delivered benefits against incurred costs. It may not be as costly as feared as many elements of the current system will be key components of a modern system. It will be a case of addition and enhancement rather than decommissioning. What is clear is that the modern grid will be designed and constructed for the purpose of achieving a larger set of societal objectives.

What then would be the benefits of a modern grid? Briefly, these are reliability, resilience, efficiency, environmental improvement, security, and safety. These can be linked to modern grid technologies as illustrated in Figure 4.[13]

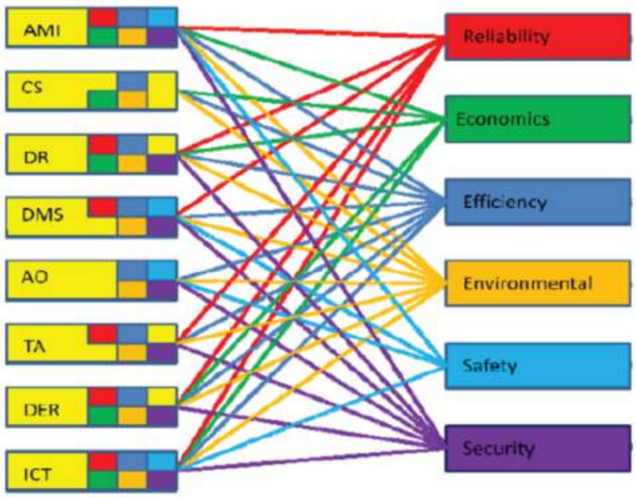


Figure 4. Relationship Between Modern Grid Technologies and Key Benefit Areas
Notes:
AMI = Advanced Metering Infrastructure; CS = Customer Side Systems;
DR = Demand Response; DMS = Distribution Management System/Distribution Automation;
AO = Asset/System Optimization; TA = Transmission Enhancement Applications;
DER = Distributed Energy Resources; ICT = Information and Communications Integration.
Source: Figure 1, p.4, National Energy Technology Laboratory (NETL) 2010

RELIABILITY

Reliability means electricity delivered to customers is in sufficient quantity and quality, and electricity services are maintained amidst uncertainties in operating conditions. Most grid technologies are associated with reliability. An example of that is the AMI with communicating smart meters that provide instant detection of power quality issues and power interruptions enabling speedy diagnosis of system problems and quick restoration of services. Modern grid technologies also enable early detection of damaged equipment and quick isolation of system problems. All these redound to the benefit of customers.

Benefits from modern grid systems include reduced power interruptions and better power quality, which will reduce costs from outages and similar disruptive events. In an earlier reference, the cost of one-hour of power outage in the Philippines is roughly estimated to be equivalent to PHP 8.1 billion (2019). In the province of Albay, where there were around 11-17 interruptions per month in 2015-2018 of an average duration of 5 minutes to one hour, the cost of interruption was estimated to amount to PHP 4.8 billion or about 4.8% of GDP in 2018.[14] Much can be saved from reduction in power interruptions alone. In the US, a modern grid project in the beginning phase was projected to already reduce customer interruptions by about 12% to 20%.[15]

ECONOMICS AND EFFICIENCY

A modern grid also creates efficiencies in operational and market systems that contribute to reduced peak load, increased energy efficiency, as well as reduced transmission and distribution (T&D) losses all of which can exert downward pressure on prices. Moreover, with modern grid technologies, customers can participate in the system. One example is through the two-way communication facility using the AMI. Customers will also be able to alter usage in response to price signals, actions which can reduce peak demand and exert further downward pressure on electricity prices. Distributed Energy Resources, which include local generation and local storage, avoid T&D losses experienced in remote generation and enables customer demand response such as energy conservation that ultimately reduces stress on the grid leading to more efficient and economical operation.

In Italy, the power company Enel implemented a smart meter roll-out program called Telegestore Project[16] that cost EUR2.1 billion (Faruqui et al 2009).[17] The company estimated savings of EUR500 million annually, implying recovery of the total project cost in about five years. Specific estimates of savings include 70% reduction in purchasing and logistic costs, 90% reduction in field operation costs, 20% reduction in customer service costs, and 80% reduction in revenue losses, e.g., thefts and failures.

In terms of energy consumption reduction, grid modernization efforts in the US have likewise demonstrated benefits even at the early stages of implementation. Observed reduction in energy consumption was from 1-2% due to distributed automation volt/VAR control, 9% through demand response programs, and as high as 20% through energy efficiency programs. Peak load reduction was also demonstrated, where the lowest observed rate was 1.2% while the highest registered 20%.

Employment is another benefit of grid modernization. Some types of jobs that will be created include technicians for smart grid installation, communication technicians, network technicians, cybersecurity personnel, and likely a breed of hybrid electrical-communications engineers will emerge.[18] There may be concerns that some 'old jobs', for instance meter readers, may be displaced, but it is expected that there will be 'new tasks in old jobs'. Reskilling and retooling will be just as important. Meter readers may be trained in AMI or may develop themselves to take on jobs as line engineers or substation engineers.

As modern grids promote more renewable energy use, more jobs can be generated from expansion in renewable energy deployment. In the Philippines, the number of jobs in the renewable energy sector show an increasing trend from 2018 to 2019, particularly in biofuels, solar PV, wind, as well as biomass. According to IRENA, in 2020, if not for the pandemic, the sector could employ up to 178,000 people.[19] Unfortunately, the pandemic caused delays in project development activities and construction. Geothermal energy was particularly affected with an estimated 30% reduction in jobs. As the economy gradually recovers, it is expected that employment in renewable energy will increase as the country moves to realize its clean energy goals. On the other hand, employment in fossil fuel-based generation[20] has steadily declined from an already low base compared to other capital-intensive industries.

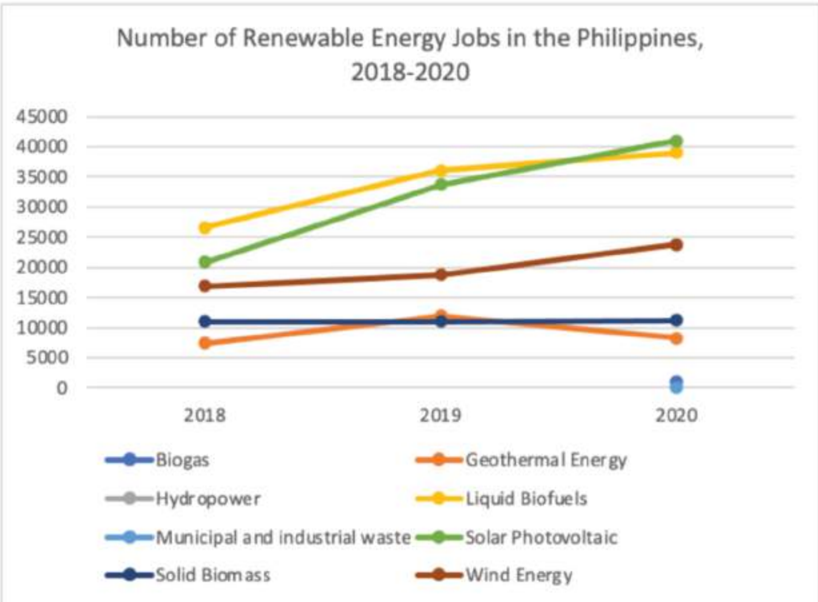


Figure 5: Number of Renewable Energy Jobs in the Philippines, 2018-2020
Note: Data not available for 2018 and 2019 for biogas, hydropower, and municipal and industrial waste.
Source: IRENA's Renewable Energy and Jobs Annual Review 2019, 2020 and 2021.

In the Philippine Energy Plan 2018-2040, there is a clean energy scenario (CES) which involves a higher share of renewable energy. It is projected to require additional employment compared to the reference or BAU scenario (described in Box 6 in Chapter 5 of this paper). The projections indicate that by 2040, there will be more employment generated in CES (626,073) than in a BAU scenario (515,881). There are more capacity additions under the CES than BAU, hence, more workforce is needed. Under the CES, estimated capacity additions decline for coal and oil, and increase for renewables, which tend to be more labor intensive.

Type of Plant	Reference/BAU Scenario		Clean Energy Scenario (CES)	
	Capacity Additions by 2040, MW	Additional Jobs	Capacity Additions by 2040, MW	Additional Jobs
Coal	22,626	71,272	10,506	33,094
Oil	115	329	75	215
Natural gas	14,787	42,291	18,207	52,072
Geothermal	697	18,392	1,597	42,152
Hydropower	7,659	68,009	9,882	87,749
Biomass	402	7,055	1,292	22,675
Solar	21,154	265,060	24,064	301,522
Wind	4,378	43,474	8,503	84,435
Other	-	-	1,200	2,160
Total	71,817	515,881	75,325	626,073

Table 1: Estimated Job Generation in Power Generation Projects (PEP 2018–2040)
Note: Reflects projected number of jobs for construction and operation and maintenance activities
Source: Table 74, Philippine Energy Plan 2018-2040

Box 5: Energy Outlook Assumptions for Clean Energy Scenario (CES) (from PEP 2018-2040).

Energy Demand:
- Assumptions under the Reference/BAU Scenario, including the following:
  - 10.0 percent penetration rate for electric vehicles for road transport (motorcycles, cars, jeepneys) by 2040;
  - 3.0 percent increase in aggregate natural gas demand between 2018 and 2040; and,
  - 5.0 percent aggregate energy savings from oil and electricity by 2040

Energy supply:
- Assumptions under the Reference Scenario, including the following:
  - Highly-efficient power technologies,
  - 10,000 MW additional RE capacity by 2040; and,
  - 1,200 MW from other emerging technologies by 2035.

Source: Philippine Energy Plan 2018-2040

ENVIRONMENTAL IMPROVEMENT

Integrating modern grid technologies into the grid network would also contribute to environmental improvements. Emissions are reduced through enabling greater penetration of renewables and their increased use such as in electric vehicles, and incentivizing energy conservation. In the Philippine Energy Plan's clean energy scenario (CES), GHG emissions grow at a slower rate (4.6%) than in the reference/ BAU scenario (6%) from 2018-2040. From 123.3 MtCO2e in 2018 (beginning of the planning period), the reference/BAU scenario is projected to have an increase of GHG emission to 444.5 MtCO2e in 2040; while in the CES, it is estimated to reach only 329.1 MtCO2e. The projected slower growth in GHG emission under the CES is linked to the decreased use of oil for transport and coal for power generation in such scenarios.

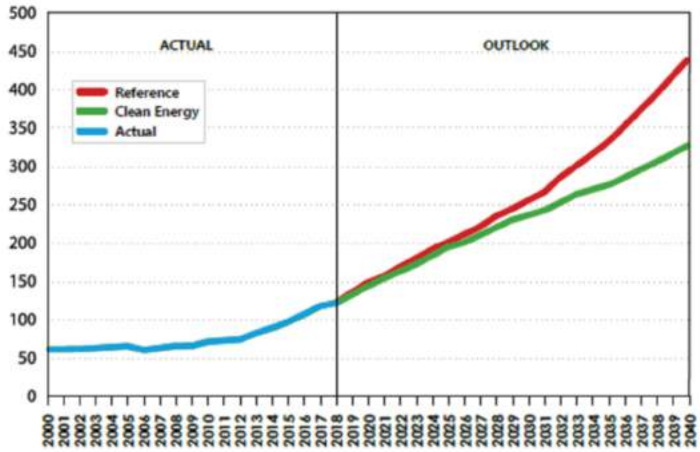


Figure 6. Total GHG Emission: Actual, Clean Energy and Reference/Business-As-Usual Scenarios, 2000-2040 (in MTCO2e)
Source: Figure 44, Philippine Energy Plan 2018-2040

GRID MODERNIZATION VIA A CLEAN ENERGY SCENARIO: COSTS AND BENEFITS FOR THE PHILIPPINES

The clean energy scenario of the Philippine Energy Plan 2018-2040 can be used to assess the costs and benefits of modernizing the Philippine grid. Costs include capital investment for installation of new renewable energy capacity, which amounts to a total of USD 121.13 billion by 2040. Benefits from developments include an increase in gross power generation by 2040 (76% from 2030) including an increase in the share of renewable energy from 32% to 37% from 2030 to 2040. Moreover, it's estimated that an additional 600,000 jobs can be created. Assuming a 6.5% annual growth in the GDP, output per kwh in a CES is about USD 3.59 in 2030 and higher in 2040 at USD 3.84.

Comparing the two scenarios, the capital investment cost for power generation capacity is higher in CES[21] (USD 121.13 billion) than in BAU (USD 102.25 billion). The bulk of the difference is attributable to a higher level of investment in renewable energy capacity that is reflected in the higher renewable energy percentage in CES than BAU. This CES also projects a lower GHG emissions growth rate of 1.4% compared to BAU as the share of coal projects are expected to decline in 2040 (33% for CES vs 55% for BAU). The relatively higher investment will also generate 110,000 more jobs. In terms of gross power generation, CES is lower than BAU by 4% in 2040, which could be attributed to the efficiency of electricity generation. However, electricity in CES appears to be more productive than in BAU, i.e., higher economic output per kWh of consumed electricity. In respect of health and environment benefits, the lower amount of coal-powered generation alone in a CES is expected to lead to a reduction in air pollution which resulted in health costs estimated at USD 13.1-B in 2019. That constituted 23% of GDP in the same year. While the electrical system functions as a single unit, it cannot be emphasized enough that the CES is highly dependent on a modern grid to meet its targets.

	2030	2040
CES		
Gross generation (TWh)	215.68	378.80
Build cost (capital investment), billion USD	58.73	62.38
Build cost (USD) per kwh	0.27	0.16
GDP output (USD) per kwh	3.59	3.84
Build cost to GDP output ratio	8%	4%
% RE	32%	37%
Additional jobs	-	626,073
GHG emissions growth % (2018-2040)	-	4.6%
CES vs BAU		
Generation conserved	0.3%	4%
Build cost (USD) per kwh	0.02	0.04
GDP output (USD) per kwh	0.01	0.15
% RE	-2%	11%
Additional jobs	-	110,192
GHG emissions growth % (2018-2040)	-	-1.4%

Table 2: Using Clean Energy Scenario (CES) for Grid Modernization: Costs and Benefits, with BAU Comparison
Source of data: PEP 2018-2040; PSA
Notes: Assumption for GDP - 6.5% annual growth rate using 2019 GDP; PHP 50/USD exchange rate. Build cost refers to capital investments for power generating capacity.

CHAPTER 4: THREATS AND VULNERABILITIES FOR THE GRID UNDER BUSINESS-AS-USUAL

If the Philippines is to achieve its energy system goals, it is crystal clear business-as-usual approaches will stand in the way. In fact, BAU seems to lead in the opposite direction. Detailed plans and programs for the grids add little in the way of absorbing and deploying large amounts of variable renewables. That is likely due to the absence of clear policy direction on BESS, and, perhaps more importantly, because a vision for the future grid remains missing.

TRANSMISSION NETWORK

While the modern grid will be flexible in terms of accommodating and managing the variability of renewable sources, the transition to it from the current grid will not be easy. Significant penetration of renewable sources, with their variable output into the grid, new types of loads such as electric vehicle charging, and extreme contingencies such as severe weather events may easily cause line overloading or over-voltage in the network. To address this, integration of renewable resources requires the following:

- More comprehensive and detailed monitoring of the grid to improve preparedness for disruptions and reduce the risk of curtailment
- Closer monitoring of and increased capability for congestion management (N-1 planning) and reserve scheduling
- Adoption of a logic for automated fault detection followed by automated repair (automation and advanced relay protection)
- Installation of advanced prediction tools in renewable energy dispatch schedule management

The current transmission system faces the following threats:

- **Bi-directional load flows between the distribution and transmission networks.** Transmission-distribution interface infrastructure typically operates with one-way power flow or radially from the grid to the end users. Distribution-connected resources such as rooftop PV solar and electric vehicle battery charging present a challenge to network operations. Reliable system operation will require adaptive protection systems and real-time control over the distribution-connected energy sources. It may also require smart grid functionalities with built-in logic for dispatch, islanding, and load forecasting. These are used in microgrids, allowing them to operate independently with their own generation and storage resources.

- **Significant deviations from the predicted schedules of renewable energy resources that adversely affect reserve scheduling.** Grid operation is the scheduling and dispatch of power plants to produce the right amount of electricity to match the total power withdrawn. This balance between electricity supply and demand is critical to the power system and should be maintained at all times. The variability of renewable energy sources creates imbalances in the system that require the grid to schedule more power plants for reserve service.

- **Generation volatility that results in the variable loading of the network assets.** This difficulty stems from the presence of a centralized controlled network, specifically from the fact that the power grid was designed around the concept of large, controllable electric generators. Large transmission lines support this generation, allowing for contingency events or anticipated and unanticipated losses, while still meeting electricity demand. Integrating more distributed generation will challenge the economics of large transmission networks and may result in fewer upgrades and new lines being built.

- **Inverter-based power plants that do not provide the significant amounts of short circuit power that synchronous generators do.** Inverter-based resources such as wind and solar power generation lower the overall system strength as they do not provide sufficient short circuit power to maintain stable frequency and voltage for secure system operation.

- **Inadequate short circuit power.** Short-circuit currents in transmission lines must be quickly cleared to avoid loss of synchronism of the generation plant, requiring fast identification of line faults by the protection equipment and selective fault clearing.

DISTRIBUTION NETWORK

The growing use of distribution-connected renewable energy sources will require the transmission grid to accommodate bidirectional flows at transmissiondistribution interface points. Monitoring and controlling distribution-connected renewable resources require advanced data and communication systems. Smart solutions will reduce disruptions and improve recovery after disruptions, leading to greater efficiency and resilience of distribution networks. They will also enable more sophisticated demand management, improve billing accuracy, and enhance customer engagement. Integrating more renewable resources requires the following:

- Substation automation, enhancing remote management and improving network data communication.
- Improved sensors and an adaptable protection system that will allow for better outage detection and power quality management.
- Microgrids to allow for self-reliance and the potential for islanding under certain circumstances.

The distribution system faces new opportunities in the following areas:

- Maintaining the balance between demand and generation from distributed energy resources opens opportunities to provide grid balancing as a service.

- Voltage control: The system may need to be adapted for bidirectional power flows.

- Enhancement of network assets: The capacity of the system will need to be both increased and managed to meet the peaks in demand caused by simultaneous charging of electric vehicles

- Reverse short circuit direction also has an impact on the feeding network: It is necessary to disconnect the distributed generators during fault. This could be done with adaptive protection via high-speed communication-based solutions.

- Island operation: After a disturbance, stable islanded networks may continue the power supply. In such situations, the control system will be transferred to a mode wherein the protection recognizes islanding to ensure stable island operations.

- Electric vehicle charging/discharging: Simultaneous rapid charging of a number of electric vehicles performed at home or at an EV charging station has a greater impact on the distribution network.

Utilities have a clear roadmap for increased reliability, resilience, and security of the grid based on future needs. These are contained in the long-term infrastructure projects that are complete or implemented. For example, electric vehicle charging, initially considered a local issue, is now being analyzed based on its impact on the entire grid.

The planned integration of distributed energy resources, especially variable renewables, has large market opportunities. Variable generation encourages a modernized grid. The current grid needs to be updated to provide a variety of power system support for integrating larger amounts of power from a greater number of distributed energy resources.

Increased reliability, resilience, and security can be achieved by sophisticated information communication technology working with a network of smart sensors and big data. However, technology alone will not be sufficient. Supportive policy and regulation must be considered essential to durable success.

Continuing BAU in a vastly changed and quickly evolving situation will clearly not enable the Philippines to achieve its energy goals. Power outages as a result of climate-change-induced extreme weather events and other non-financial external shocks such as a pandemic, along with increased prices due to increased fossil fuel volatility, are fast becoming the norm. They impart key lessons for the designbuild and operations and maintenance of the future grid.

CHAPTER 5: COST-BENEFIT ANALYSIS OF BUSINESS-AS-USUAL

Understanding the costs and benefits of a modern grid requires measuring its physical impacts and estimating its economic benefits. The substantial investment necessary to establish a modern grid is intended to ensure high levels of reliability but still minimize environmental impacts. In this chapter, the term business as usual or BAU refers to the scenario that would have occurred without transitioning to a modern grid. When estimating the impact of a modernized grid, specific quantities are estimated in which cost categories extend beyond utility cost accounts and include costs or benefits felt by customers. The methodology is available in Annex 1.

Historically, the value of lost load (VOLL) was used to quantify the cost-of-service interruptions during periods of peak demand, when resources are most scarce. In this chapter, the investment cost of modernizing the grid is compared to the cost to customers of service interruptions.

The following are general information about the power sector in the Philippines:

- Peak electricity demand was 15,282 MW in 2020, which is 299 MW lower than peak demand in 2019 (-1.9%) (DOE 2020).[22]
- This is because of reduced business activity during community quarantine. Nonetheless, electricity demand is projected to grow by about 5% annually, reaching 49,287 MW by 2040 (DOE 2017).[23]
- Twenty-one percent of the power generation mix was from renewable energy in 2020, which is 0.4 percentage points higher than in 2019. As for installed capacity, RE generated 7,653 GWh in 2020 (254 GWh higher than in 2019). By 2030, the target for RE-based capacity is 15,304 MW.
- Electric power generation, transmission, and distribution establishments employed approximately 68,000 workers, including sub-contract workers, in 2018 (PSA).[24] Renewable energy deployment is estimated to have generated nearly 120,000 jobs in 2019 (IRENA).[25]

The power generation mix from 2011 to 2020 indicates a decreasing share in renewables (21% in 2020), and coal increasing in share (57% in 2020).

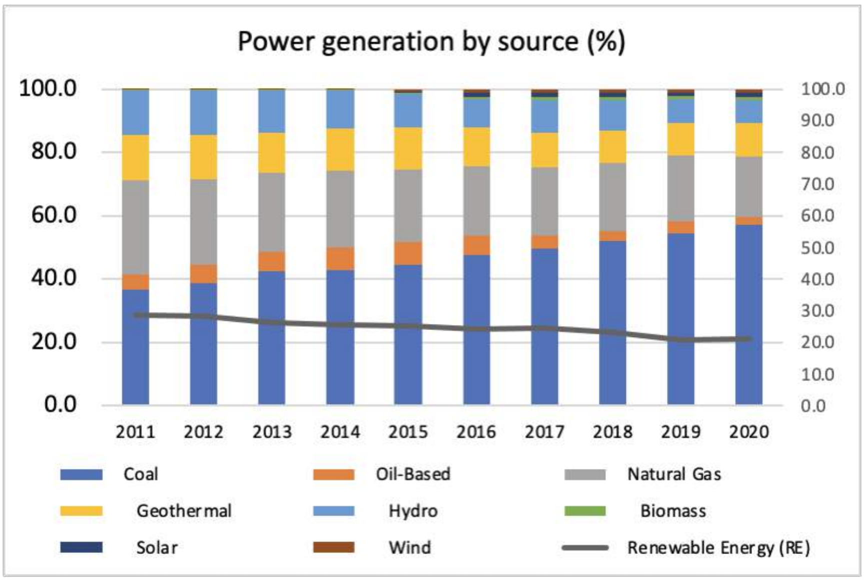


Figure 7: Power Generation by Technology Source
Source: DOE Power Statistics

Meanwhile, based on the Philippine Energy Plan 2018–2040 gross generation by source, a BAU[26] reference scenario sees an annual 6.5% increase in gross generation, from 99.8 TWh in 2018 to 394.5 TWh in 2040. In this projection period, an annual growth rate of 7% is estimated for renewables, and an average share of 30% in gross generation (2030 and 2040). For coal, a lower but quite close growth rate of 6.8% is projected, including a major share of power generation at an average of 57% for 2030 and 2040, in a BAU scenario.[27]

Fuel Type	2018 (Actual)	2030	% share	2040	% share	AAGR (%) 2018-2040
Coal	51.93	126.31	58.4	218.34	55.3	6.8
Natural Gas	21.33	14.91	6.9	71.14	18.0	5.6
Oil-based	3.17	1.35	0.6	1.23	0.3	-4.2
Renewable	23.33	73.86	34.1	103.81	26.3	7.0
Geothermal	10.44	12.35	5.7	11.84	3.0	0.6
Hydro	9.38	31.92	14.7	34.82	8.8	6.1
Wind	1.15	6.39	3.0	14.99	3.8	12.4
Solar	1.25	21.39	9.9	40.35	10.2	17.1
Biomass	1.1	1.81	0.8	1.81	0.5	2.3
Other Technology	0	0	0.0	0	0.0	-
Total	99.76	216.43	100.0	394.52	100.0	6.5

Table 3: Gross Generation by Fuel Type (TWh), Business as Usual (BAU)

Box 6: Energy Outlook Assumptions for Business As Usual (BAU) (from PEP 2018–2040)

Source: DOE Philippine Energy Plan (PEP) 2018–2040

Energy demand:

- Response to the requirements of the Build, Build, Build infrastructure program and AmBisyon Natin 2040.
- Maintain 2.0% biodiesel and 10.0% bioethanol until 2040.

Energy supply:

- Present development trends and strategies continue.
- Consider 6,300 MW committed and 33,200 MW indicative power projects as of December 2018.
- Increase renewable energy (RE) installed capacity to at least 20,000 MW by 2040.
- Consider the aspirational target of 35.0 percent share of renewables to the generation mix by 2030.

- Adopt 25.0% reserve margin.
- Assume 70.0% load factor for the total Philippines

The DOE estimates greenhouse gas (GHG) emissions from energyrelated activities will grow at an annual rate of 6%, from 123.3 million tons of CO_2 equivalent ($MtCO_2e$) in 2018 to 444.5 $MtCO_2e$ in 2040 in a BAU scenario. On average, 54.8% of emissions come from the power generation sector, where coal contributes significantly. Average emission share from the energy end-user sectors such as transport, industry, and others (commercial, residential, agriculture) are at 26.6%, 10.9% and 7.7% respectively.

Air pollution costs the Philippines (Suarez and Garcia 2021)[28] USD 87.6 billion (PHP 4.5 trillion) annually, or about 23% of the country's GDP in 2019. The national emission inventory[29] indicates that around 15% of air pollutants in 2018 are from stationary sources, i.e., power plants and factories, which is approximately USD 13.1 billion in air pollution cost, or about 3.5% of GDP in 2019.

Systems loss is a common indicator in the power sector and can be considered a measure of the impact of efficiency of electricity delivery. Lower system losses mean more electricity available for consumer use. It also affects the retail price of electricity because a reduction in system losses translates to lower electricity prices.[30] System losses in the Philippines have declined in the last two decades, with the lowest value of 8.8% recorded in 2017 coming from a decade of 10%12%. However, a r

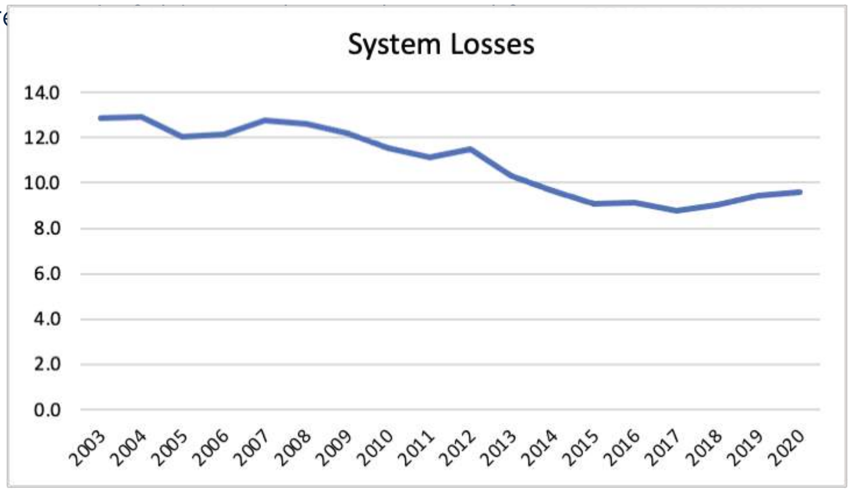


Figure 8: Systems Losses
Source: DOE Power Statistics

Reliability of electricity supply is important for customers; interruptions in power supply can be costly. The value of lost load (VOLL) is an indicator/parameter that is being used to estimate the value or cost associated with an electricity supply interruption. Using VOLL in the methodology, a study by Payonga (2020) looked at the impact of power interruption on quality of life for households in Albay, Philippines, over the years 2015–2018 when there were roughly 11–17 interruptions per month, with an average duration of five minutes or less (60% of interruptions) to one hour.[31] Findings of the study indicate a VOLL of PHP 19.69/kWh in 2018.[32] Undelivered energy also meant an estimated revenue loss to electric companies (including generation, transmission, and distribution) of PHP 10.44/kWh from the residential sector and PHP 10.00/kWh from other sectors. For the whole province's residential sector, a direct loss[33] of about PHP 1.3 billion is estimated (133.54 hours

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of interruption) in 2018. The average cost per household is about PHP seven thousand. Adding the cost of damage to quality of life[34] increases the provincial-level residential sector damage cost to P1.4 billion. Considering all sectors, i.e., residential, industry, and services, the cost of interruption could amount to PHP 4.8 billion, which is about 4.8% of Albay's GDP in 2018.

In a policy brief on energy,[35] the Office of Senator Sherwin Gatchalian estimated the prospective cost of power outages in the Philippines using a highly simplified imputation of the hourly GDP in 2016. It aimed to illustrate the value of production lost during a one-hour power outage. The policy brief, however, notes that because of the highly simplified estimation, factors such as ancillary welfare effects and spillover effects, time of day, season, supply chain effects, and others were not taken into consideration. The imputed values are thus presumed to have been seriously underestimated. Using the same method, with all its limitations, hourly GDP was computed for 2018 and 2019 and used to estimate the loss for a one-hour power outage in the island groups and the national capital region (see Tables 4 and 5 below).

The estimates suggest losses increased from 2018 to 2019 as GDP increased. In 2019, the combined one-hour power outage cost for all sectors amounted to about PHP 8.1 billion. Industry and services (excluding mining/quarrying and construction) would have had a loss of over PHP 6.6 billion for each hour of electricity outage in the whole country. For a one-hour power outage in Luzon in 2019, the loss would be about PHP 5.6 billion; if the outage was in the National Capital Region only, the cost would be PHP 2.6 billion. In the case of Visayas and Mindanao, costs were relatively lower at PHP 1.1 billion and PHP 1.3 billion, respectively. However, considering that the Visayas and Mindanao are future growth engines of the Philippines economy, losses wil

	PHP*		USD**	
	2018	2019	2018	2019
GDP loss	7,610.50	8,076.15	144.52	155.92
By industry				
Agriculture, Forestry, and Fishing	734.42	743.27	13.95	14.35
Industry	2,326.05	2,453.28	44.17	47.36
Industry, without Mining/ Quarrying and Construction	1,685.57	1,754.90	32.01	33.88
Services	4,550.02	4,879.59	86.40	94.21
By island group				
Luzon	5,315.63	5,647.85	100.94	109.04
NCR	2,422.68	2,593.39	46.00	50.07
Visayas	1,035.60	1,098.88	19.67	21.22
Mindanao	1,259.27	1,329.42	23.91	25.67

Table 4. Estimated Hourly Losses in GDP Per Hour of Power Outage
** in million PHP, constant 2018 prices*
*** PHP 52.6614 and PHP 51.7958 per 1 USD exchange rate used for 2018 and 2019, respectively (source: Bangko Sentral ng Pilipinas)*
Note: Hourly GDP was computed assuming 12 months, 20 days per month, 10 hours per day; Island group estimates were based on GRDP share.[36]

With a GDP of PHP 19 trillion (around USD 374 billion) in 2019, economic output per kwh of electricity sold/consumed is about PHP 183 (USD 3.53). Based on the previous discussion, an hour of outage could potentially cost about PHP 8.1 billion (USD 155 million) or eight Philippine centavos per kwh, which is roughly equivalent


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BENEFIT OF GRID MODERNIZATION:
EMPLOYMENT
Old Jobs
Grid installers/technicians
Line engineers
Substation engineers
Meter reader
New Jobs
Communication technicians
Cybersecurity personnel
Network technicians
Technicians for smart grid installation
Reskilling
Meter readers to turn to **Advanced Metering Infrastructure** readers, or upskill to take jobs such as line engineers or substation engineers
Losses Averted
PHP 8 BILLION
Per one-hour outage*
*Source: Economic Output and Loss from One-Hour Power Outage, 2019

to a los :a.

	2019 PHP	2019 USD
*Economic output**		
Total output based on total electricity consumption (million PHP or USD)	19,382,751	374,214.72
Output per kwh of electricity consumed**	183	3.53
Potential cost of one-hour power outage		
Loss from total output (million PHP or USD)	8,076	155.92
Loss per kwh	0.08	0.0015
% of output loss from one hour of power outage***	0.04	

Table 5. Economic Output and Loss from One-Hour Power Outage, 2019
**Output based on GDP in million PHP, constant 2018 prices, and USD equivalent.*
*** 106,041 GWh of electricity sales and consumption in 2019*
**** The same percentage is observed in 2018 data*
Notes: These are rough estimates computed using data from the Department of Energy and Philippine Statistics Authority (OpenStat)
PHP 51.7958/1 USD exchange rate used (source: Bangko Sentral ng Pilipinas)

Meanwhile, looking ahead toward 2030 to 2040, the BAU scenario (as described in Box 6) shows an increase in power generation of 82%, and over 500,000 additional jobs, which entail projected costs related to capital investment for power generation capacity amounting to USD 102.25 billion by 2040. Assuming a 6.5% annual growth in GDP toward 2040, output per kwh is about USD 3.58 in 2030 and USD 3.69 in 2040, which are both higher than the estimated GDP/kwh output in 2019 (USD 3.53). There is a projected decline in renewable energy share in power generation, as fossil gas generation is set to increase and coal projects to remain the major contributor (around 50%). The BAU scenario is associated with a 6% annual increase in GHG emissions from 2018 to 2040. However, this likely underestimates the cor

	2030	2040
BAU		
Gross generation (kwh)	216.43	394.52
Build cost (capital investment), billion USD	54.72	47.53
Build cost (USD) per kwh	0.25	0.12
GDP output (USD) per kwh	3.58	3.69
Build cost to GDP output ratio	7%	3%
% RE	34%	26%
Additional jobs	-	515,881
GHG emissions growth % (2018-2040)	-	6.0%

Table 6: BAU: Costs and Benefits, 2030 and 2040 Policy Horizon
Source of data: Philippine Energy Plan 2018-2040; PSA
Notes: Assumption for GDP - 6.5% annual growth rate using 2019 GDP; PHP 50/USD exchange rate.
Build cost refers to capital investments for power generating capacity.

The transmission grid is a public good built and operated commercially. While key, it is still only a component of an entire system that delivers electricity and its beneficial services. As a result, it is often easy to miss its true value. Within the context of a transition to a cleaner power system, the transmission grid plays a critical role. If the grid were built in a business-as-usual manner, the deployment of renewable power may be limited and the losses reinforced. Increasing renewable generation not only maximizes domestic resources towards energy security, but may improve system stability. In addition, a business-as-usual grid may become increasingly costly to maintain during a time of climate-driven extreme weather events. There is mounting evidence showing the very design of the current grid increases its vulnerability. In seeking to understand the value of the grid, it is necessary to go beyond a simple cost-benefit analysis and undertake more detailed riskreward analysis. Taking into account the previously cited numbers, modernization of the grid may include the following reward of averting PHP 10 billion or USD 200 million[37] of losses to the economy for every one-hour power outage.

CHAPTER 6: MARKET DESIGN RECOMMENDATIONS FOR A MODERN GRID

The current market rules were established to manage the legacy system built around large conventional power plants. The market model results in spot prices that are linked to generators' production costs, which are heavily influenced by coal prices, with coal thermal power generation being the dominant generation technology in recent years.

Given the government's recent plans to phase out coal-fired power plants in favor of RE resources, the grid generation mix will rapidly change toward a higher RE share. Because RE resources have near-zero operating costs, significantly smaller unit sizes, and variable output, this will have a substantial impact on market behavior. There will likewise be significant ramifications for grid operations as well because the shift from large generating units to a mix of lightweight generators with low rotational inertia affects the stability of the power grid. Furthermore, inverter-based RE power plants that do not generate significant short circuit power would reduce the strength of the grid and present current voltage stability problems that would put the system's integrity at risk.

The earlier chapters have defined the future modern grid as one where consumers can actively participate in the market by adjusting their consumption to real-time prices and where efficient integration of renewables into the grid will require building new transmission and ICT infrastructure. Distribution utilities will need to take a more active role in the modern grid, making greater use of new technologies. To realize this, distribution utilities must be (a) enabled to build ICT networks that extend to end customers at the low voltage network level, (b) allowed to recover costs of investments in a smart metering infrastructure, (c) permitted to administer data and metering, due to their reliance on data for secure and reliable grid operation, and (d) allowed to dispatch/coordinate embedded DERs, storage units, and controllable loads (demand response) for network balancing.

The future market will have to exploit the advantages of smart grid technology in the drive towards greater RE integration in the grid. From the market perspective, advanced technologies in both telecommunications and network analysis software will play a significant role in the change of information course from a unilateral to bilateral flow. The same advanced technologies should enable consumers to act as buyers and sellers, based on clear and comparable billing and access to price comparison tools and guided by rules that facilitate switching suppliers.

The market for integrating RE resources will require RE resources to compete on an equal footing with conventional energy generators. However, during the transition where the share of RE in the generation mix is still growing, flexibility remains a necessity to keep the system stable. At the moment, for all types of power, including fossil fuel and renewable energy, the grid needs systems that generate electricity without the variability or volatility and uncertainty in the generation capability and resource availability in the generation mix.

The current structure of the market on energy complemented by another on ancillary services products which is expected soon will ensure the stability and integrity of the grid operation. As RE penetration increases, the earlier cited innovations and reforms become more urgent. Of note, are (1) the development of sophisticated methods to increase observability of the system to determine system needs on changing grid conditions; and (2) the full participation of all resources

including renewable energy and demand response in markets through the use of energy storage systems and smart metering infrastructures.
Current government initiatives to compensate RE outside the energy market will accelerate the growth of RE share in the generation mix. These include the mandatory participation in Renewable Portfolio Standards (RPS) program and voluntary procurement under Green Energy Options program (GEOP). To ensure the markets function well to enable the transition, the following are necessary:

1. A single centralized tracking system similar to the Centralized Registration Body (CRB) of the Market Operator in the creation of Renewable Energy Certificates (RECs). Under the current rules, RECs are created from the generation of Feed-in-Tariff eligible plants. The DUs, as buyers of the energy from FIT eligible plants, would be credited the RECs and may use them to comply with the RPS. Unfortunately, FIT rules were designed solely to attract new investments in RE generation excluding "legacy" plants or plants already in operation prior to the start of the FIT program. A new RE credit tracking system would serve as a common certificate to track RE generation for use by RES and GEOP participants to capture FIT generation and generation from "legacy" plants as well. Taking the case that most multinational corporations are requiring their local offices/factories to procure their energy requirements from RE resources, RES/GEOP suppliers need the certificates to demonstrate the RE energy it delivered to these customers. Leveling the playing field in this manner will increase the uptake of renewable energy even outside GEOP.

2. Providing partial credit for supply contracts featuring a percentage of committed RE content in the delivery to the customer. The current GEOP rules require GEOP suppliers to source their replacement power from RE resources. This makes sense if "replacement power" is understood as substituted energy delivered on behalf of the supplier when it is on either scheduled or forced outage. However, the current definition of replacement power also includes market imbalances resulting from the variable nature of the generated output. Under the market rules, imbalances become market settlement volumes deemed bought from or sold to market. The resulting market purchases would have only a percentage share in RE energy and therefore not qualified under GEOP. A specific delivery protocol should be designed for the GEOP to reconcile the replacement power provision with the market rule on imbalances. The partial credit option may be the "simple" solution. RES may not even need to use GEOP to sell RE but instead sell a portfolio of products with different RE percentages that would provide customers greater choice.

The Philippine Electric Market Corporation (PEMC) proposed a framework for energy storage systems. Its technical committee is undertaking an assessment of the current operations of the Battery and Energy Storage Systems (BESS) in the Philippines with a view to developing BESS policies and implementation paths including DOE applications and WESM registration. To that end, the Committee met with San Miguel Corporation Global Power (SMCGP), the developer of 1000 MW of BESS to discuss opportunities and challenges in the market participation of BESS NGCP has also identified the role of BESS's as a provider of ancillary services, particularly for reserve adequacy.

As coal generation is retired, supply contracts featuring the above RE crediting mechanics will accelerate the growth of RE share in the generation mix. Like the RECs, the RE credits created under that mechanism may have sufficient value to warrant its own market as not all RE buyers are after RPS credits.

Another market that opens as a result of a modernized grid and energy economy is merchant solar or merchant renewable energy opportunities. Because of solar energy's lower LCOE and advantage during peak hours, in addition to new battery

International Experience 5. Spot Market for Renewable Energy – Example from Canada and Spain

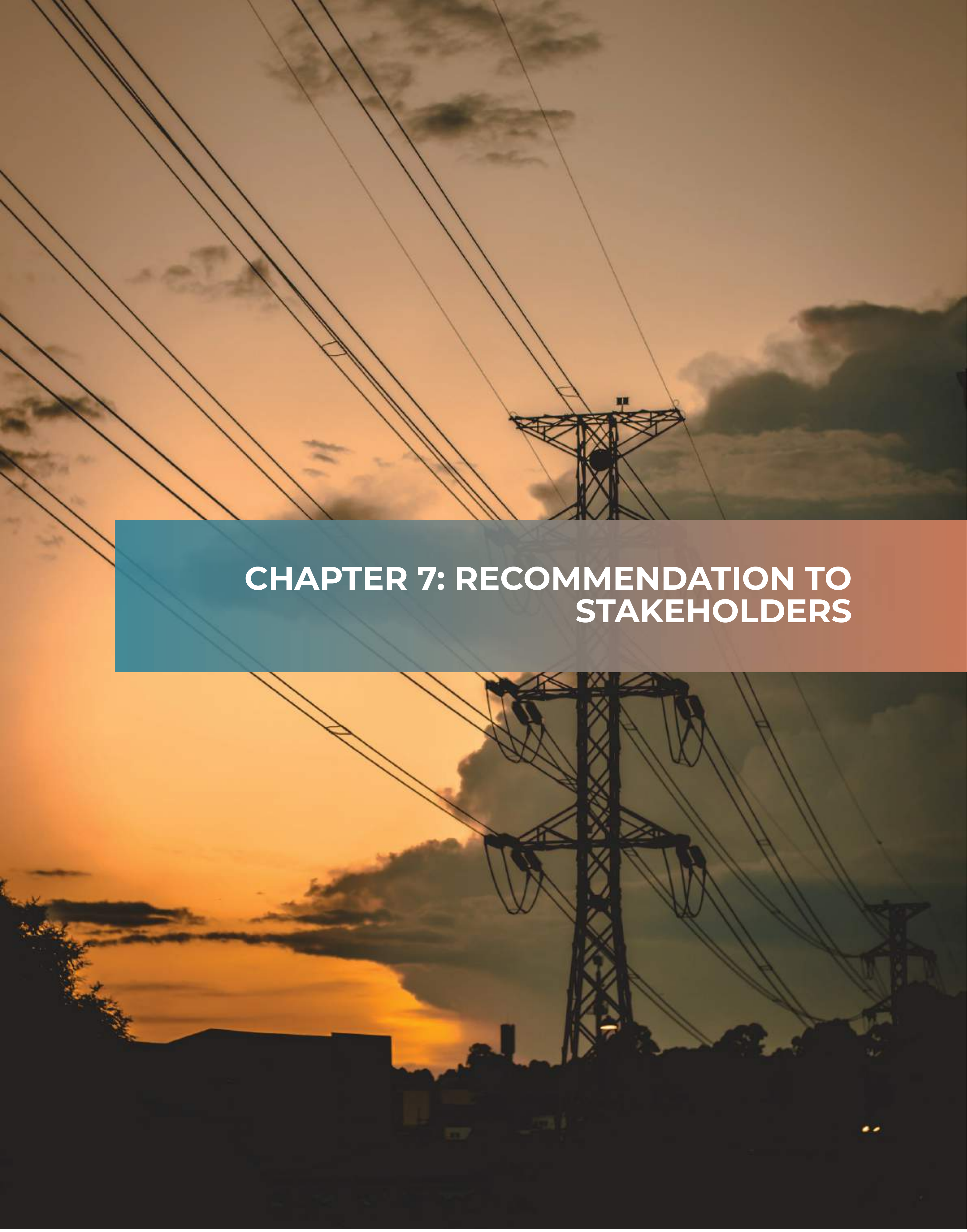
storage technologies and their lowering costs, there is an opportunity to quickly integrate renewable energy through merchant solar initiatives.

In Canada, Alberta is the only province that accepts merchant solar in its electricity market, and it is on its way in building a 600-MW merchant solar farm that is expected to power 100,000 households and offset 472,000 metric tons of greenhouse gas emissions per year.[38] Other than the grid's ability to integrate large amounts of renewable energy to increase flexibility, an active spot market will also help merchant plants become price competitive even without guaranteed power supply deals.

Spanish conglomerate Grupo Forlasa's energy company, Renovalia Energy, was able to secure financing for a 79.2MW merchant solar project with Banco

Sabadell providing 75% of the capital needed. The rest of Europe, Australia, Chile, and Mexico also have an increasing number of merchant solar plants.

While consumers may not be directly engaged in the development of energy markets alongside that of a modern grid, they are the ultimate beneficiaries in terms of resulting better service at more affordable prices.



CHAPTER 7: RECOMMENDATION TO STAKEHOLDERS

There are three distinct elements to the clean energy transition: renewable generation, transmission and distribution, and use. Of the three, power generation through renewables has attracted the most attention and the greatest number of resources. The work on electricity use has been driven mostly by efficiency improvements and by electrification of heating and mobility, energy services previously provided almost solely by fossil fuel combustion. Far less work has been done on transmission and distribution and especially so in countries with less developed electrical networks like the Philippines.

The Electric Power Industry Reform Act of 2001 was the last government issuance that may be said to contain a comprehensive framework for the power sector. Its goal was to ensure adequate supply of affordably priced power to all Filipinos through commercial competition. At the time of its enactment, the notion of an energy transition did not exist and the prevailing model was that of a centralized grid with supply dominated by large generators. Ancillary services were mostly provided by smaller diesel gensets and by pumped hydroelectric plants. There were other renewable energy plants but they were mostly large geothermal and impoundment hydroelectric plants. Distributed generation was for small islands not connected to the transmission grid and for off-grid areas. Since EPIRA, two laws more related to power were enacted. These were the Renewable Energy Act of 2008 and the Energy Efficiency and Conservation Act of 2019. While these may be said to advance an energy transition, they did so without providing a clear fit with the EPIRA framework for the power system. Attempts to remedy this situation came in the form of many subsequent DOE circulars and ERC rulings. Nevertheless, persistent gaps continue to hinder the energy transition.

This Report is focused on the transmission and distribution element of the energy transition and, in particular, on the changes needed to accelerate the transition by keeping in lockstep with the increase in both renewable energy generation and efficient use of electricity with special attention to direct participation by consumers.

The highlights of the Report are as follows:

1. Building a modern grid for the Philippines requires a change in the legacy mindset and the acquisition of new technologies. The former is an effort required of policy makers, regulators and utility operators while the latter is needed of utility operators and, not surprisingly, by consumers themselves. The change will be driven by external forces such as extreme weather events, violent conflicts and pandemics and by an internal one, that is, consumer demand for better service. The change will be enabled by improved ICT and well-designed and smoothly functioning markets.

2. The Philippines has well-developed transmission and distribution plans and programs with significant parts dedicated to increasing resilience and cybersecurity. While these may not be explicitly based on the energy transition, many of their elements would be necessary for achieving it. Enhancing these plans and programs with a clear view to furthering the transition will be key to highlighting its benefits to the economy and the environment.

3. The threats to and vulnerabilities of continuing to build the grid in a business-as-usual way can be identified and measured and the cost and benefits of doing so calculated. The Value of Lost Load (VOLL) is the key metric employed to gauge its impact on the economy.

4. While much of what constitutes a modern grid is technology, its value for all but especially for electricity consumers is optimized with well-designed and well-functioning markets for power.

5. Developing the modern grid in the Philippines requires the cooperative efforts of policymakers, regulators, utility operators, lenders, and investors, as well as consumers themselves working with a comprehensive framework for the energy transition.

Building and operating the grids in a business-as-usual manner is increasingly more costly with diminishing benefits. They will become even more costly as climate driven events occur more frequently and impact more severely and the burden of these costs will ultimately fall on consumers. The energy transition is an urgent need and its grid component likely requires more attention and resources than its counterparts. What will enable the Philippines to break out of business as usual and set it on the path of the transition and the modern grid is the moral imagination.

Considering that the power sector is made up of generation, transmission, distribution, consumption, and regulation, modernization of the grid requires buy-in from stakeholders to truly achieve the desired change. Grid modernization has only become an even more critical investment that can help the Philippines realize economic transformation that achieves climate and economic resilience. This chapter highlights recommendations to each of the stakeholder groups.

DEPARTMENT OF ENERGY

Clear policy direction is key to driving the energy transition in the Philippines. The DOE has sufficient tools at its disposal to drive the transition. What it has yet to do is articulate a clear endpoint for the transition and an actionable process towards realizing this goal. While the DOE has been doing credible work in this area, it may not be possible to reach the objective without close coordination with agencies such as NAPOCOR in order to utilize large storage hydro capacity that helps absorb new capacity. DOE may consider coordinating with NAPOCOR to update existing studies on hydropower projects in Luzon to see if they can be part of a new initiative to integrate more firm and variable RE capacity.

The DOE can strengthen its oversight of NGCP's performance to address the delays in grid expansion and the inability to quickly process applications for interconnection by RE projects thru the SIS.

Traditional grid operators have advanced the argument variable renewables create instability in the grid raising the fear of power disruptions among legislators. Beyond batteries, there are many commercial technologies that can address specific technical issues raised against renewables. A clear vision of and a roadmap for the transition and a firm commitment to them by the DOE can support market participants in playing a meaningful role in the transition.

Energy Regulatory Commission

EPIRA framed the development of the electric industry in terms of increased competition leading to better electric service and reasonable rates. The ERC should consider utilizing benchmarks in pricing matters, and to ensure full disclosure of

PSA provisions that affect customer costs.

The law also assigned the ERC the task of developing and enforcing the rules that would ensure it. Regulating competition, effective as it may be, tends to have a static view of the industry which it regulates. Innovations, insofar as they do not fit well with the prevailing model, often lack the guidance needed to further advance. Building the modern grid will not only require innovative technologies but also novel business models. But these might not prosper without the clear guidance regulation offers.

Regulating fast evolving industries is difficult and, while the electric industry may not be considered as one, it has reached a point where changes may come rapidly. Such was the case with telephony when the public switched telephone network was displaced by mobile phones. Regulating to expedite the buildout of a modern grid will be challenging at best especially as it will consist of many technological and business innovations. Close coordination with the DOE on a vision and a roadmap for the transition will make the task much easier.

INTERNATIONAL AND DOMESTIC INVESTOR GROUPS

In order to complete the energy transition, the Philippine government must consider maximizing a suite of options to leverage private sector capital into its grid modernization outcomes to deliver secure energy security, affordability and resilience. Optimized financing structures to attract foreign direct investment and mobilize domestic private sector capital include but are not limited to the following:

1. Prioritizing the use of public-private partnerships (PPP) as a key solution to climate investment in coordination with the PPP Center as it may enable access to bonds or syndicated loans.

2. Creating special-purpose vehicles (SPV) or partnerships for climate resilience. For example, joint ventures or partnerships with electric cooperatives and/or with the Small Power Utility Group (SPUG) of the National Power Corporation of the Philippines (NPC).

3. Adopting alternative financing tools in banks (both public and private) such as a special leasing facility window. Modernized technology requires sizable capital expenditure and by changing the financing from a capital-expense model into an operating-expense model, and by matching expected revenue or savings with lease payments, it would greatly improve the affordability of modernization.

4. Enabling the Bangko Sentral ng Pilipinas (BSP; central bank) to use a variety of tools to incentivize investment in adaptation and resilient low-carbon infrastructure, including preferential refinancing rates, differentiated capital requirements such as a “fossil fuel penalizing factor”, and setting higher capital requirements for non-low-carbon and non-climate-resilient projects.

5. Enabling transition bonds as a new class of debt security that can finance brown energy’s transformation to green and to catalyze resilience building. A well-established framework and platform would support in reducing information asymmetry by improving and standardizing metrics for the classification of assets.

6. Blended finance can be used as catalytic capital from philanthropic or public sources to increase private sector funding for high impact projects. Blended finance aims to de-risk investment for greenfield projects that will not proceed in the absence of concessional financing. It enhances asset credit value as it reduces uncertainty and costs in terms or risk-return expectations. For example, utilizing the V20's Accelerated Financing Mechanism[39] for the targeted use of credit strengthening for the Philippines' Wholesale Electricity Spot Market (WESM) by providing a minimum revenue coverage could support a rapid deployment of new renewable energy capacity.

7. Donor-supported battery storage smart subsidization program to generate market scale and internal momentum to reduce risk of new and extended fossil fuel lock-in during the transition decade until 2030, or earlier subject to technology transfer success.

8. Export Credit Agencies in developed countries can reinforce the cooperative relationship among financial institutions and government agencies through financial support for resilient infrastructure projects. In support of this, the BSP for example, can craft enabling regulations in terms of hard currency being advanced by ECAs to local commercial banks to ensure borrowing is affordable and accessible for projects.

9. Climate and disaster risk financing and insurance solutions to protect liquidity needs of power service delivery and to improve recovery times may be considered in light of accelerating extreme weather events. A sustainable insurance facility for the grid operator, electric cooperatives and/or SPUG can improve access to financial reserves and working capital.[40]

FOUR KEY ASPIRATIONS TOWARDS A MODERN GRID

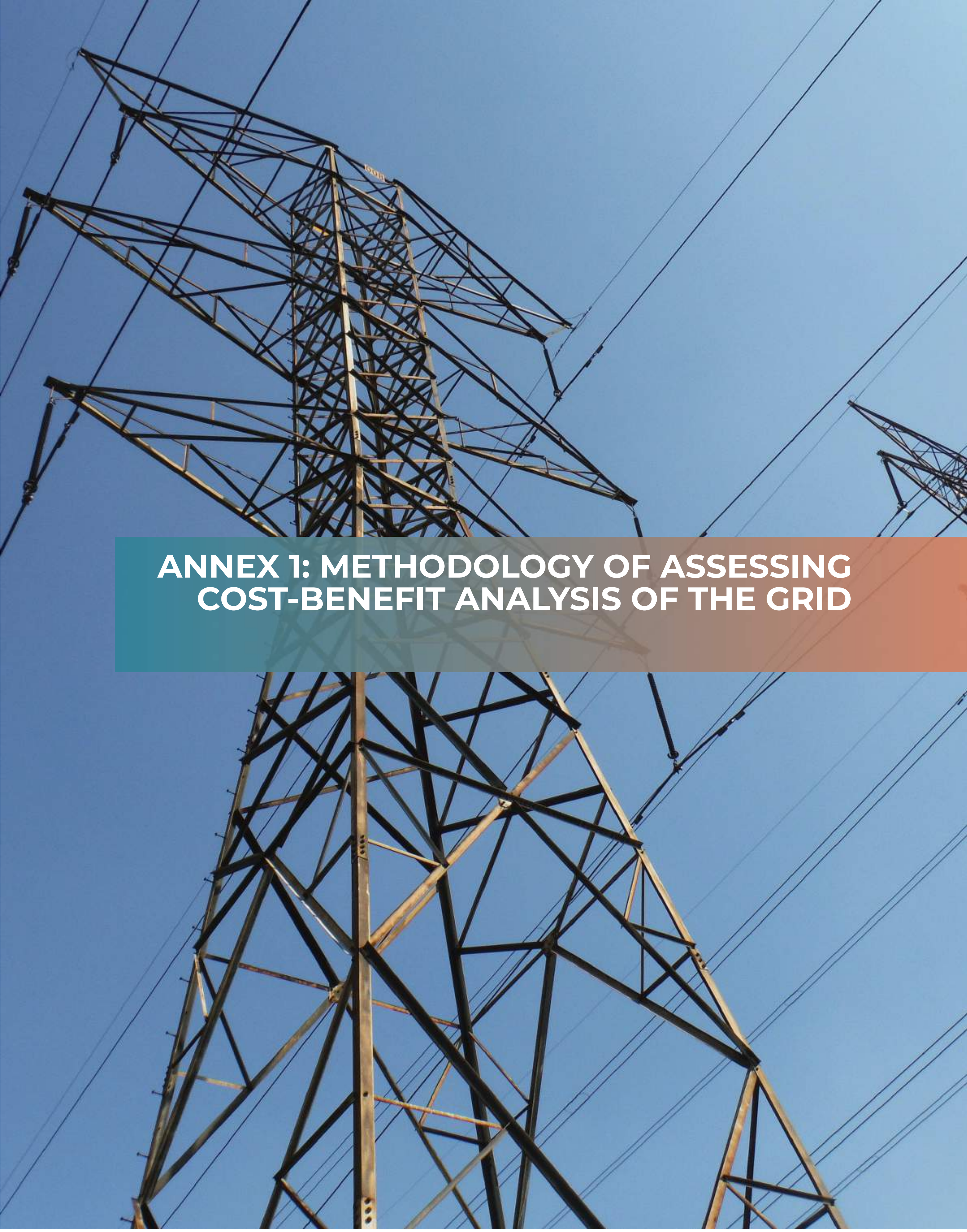
While this paper points to numerous options, the delivery of four key items below can pave the way faster for the Philippines' modern grid:

First: a two-way flow of electrons (electricity) at the transmission and distribution levels with the ability to form microgrids for security and cost-effectiveness.

Second: Real-time data/info on operations and prices to guide customers in their buy/sell excess power.

Third: A harmonious ecosystem of assets, market participants and operating protocols with minimal regulatory oversight but with full transparency sol that any regulatory intervention can be clear.

Fourth: The use of "smart" tech cited in this paper to assist in diagnosing, recording and fixing the system.



ANNEX 1: METHODOLOGY OF ASSESSING COST-BENEFIT ANALYSIS OF THE GRID

An important aspect of a grid modernization project is the assessment of economic and social benefits compared to the business-as-usual (BAU) grid. Cost-benefit analysis (CBA) is the methodology applied. Business-as-usual and grid modernization scenarios are assessed with an emphasis on reliability, resilience, and economic and environmental attributes.

CBA is an analytical tool to determine if a project or decision is worth pursuing, that is, if the benefits outweigh the costs (EPRI 2012).[41] There are different methods for applying this to powerrelated projects. One approach is to quantify monetary values of costs and returns to an investment, analyze them over the lifetime of the investment, and include discounting to determine the present values of costs and benefits (Woolf et al 2021; ADB 2013).[42] Another approach is to use surveys to estimate consumers' WTP or willingness to pay (ADB 2013). In energy, the WTP approach is used in computing the value of lost load, an estimate of what customers are willing to pay to avoid electricity supply interruptions. This type of approach looks at the consumer perspective.

The flow of analysis for this CBA is presented in Figure 9. It is adapted from the methodology used by IRENA (2015),[43] which adopts a societal perspective and can cover assessment for business or consumers/society, or both. The analysis takes into account available technologies. The business-as-usual (BAU) scenario is assessed first. Technologies that will be applied in modernizing the grid are mapped to their specific function. This function can then be mapped to certain benefits that can be quantified or monetized (to the extent possible) and compared with the cost of the technologies. Some of the benefits identified in assessment of grids are reliability and security, resilience, sustainability, and affordability. Such benefits can be difficult to directly monetize, so identification of indicators or other possible valuation measures would be applied.

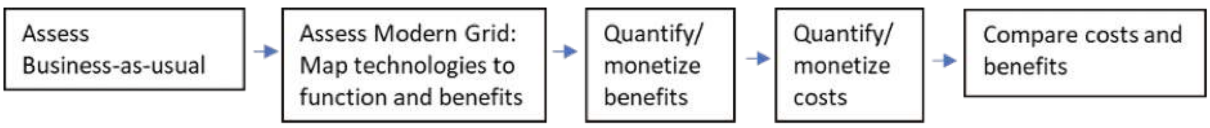


Figure 9: Framework for Cost-Benefit Assessment of the Modern Grid

Source: Adapted from IRENA (2015), modification by the authors

In this study, the technologies being examined are advanced metering infrastructure (AMI) and battery energy storage system (BESS). Functions that can be mapped into the AMI include automated volt/VAR control, customer electricity use optimization, and real-time load measurement and management (IRENA 2015). On the distribution side, these enhance stability and reliability. For customers, they support informed decisions about electricity use that could be aimed at cost-effectiveness, reliability, convenience, and environmental impact (EPRI 2012). Economic benefits would include reduced distribution operating cost and reduced electricity losses. With BESS, excess energy can be stored for future use, making the system adaptable to generation variability and uncertainty. In such cases, more renewables can be integrated into power generation yielding environmental benefits such as improved air quality and reduced carbon emissions.

Implementing a CBA is data intensive; analysis in this study would depend on availability of data. Analyses using CBA have proposed methods of monetizing cost and benefits to the extent possible (IRENA 2015; Woolf et al 2021). This approach will be taken in the study, contingent on the availability of data. Qualitative assessment will also be done to discuss costs and benefits that would be difficult to monetize or quantify.

Another challenge to conducting a CBA is assessing functions and benefits from technologies that are highly interdependent and contribute both individually and as a part of the whole grid system. This also makes separating the baseline scenario from the modern grid project challenging. As available data and information permits, the study will endeavor to distinguish between the BAU scenario and technological modernization. Findings from the CBA can be used to develop conclusions and recommendations about modernizing the grid vis-à-vis continuing business as usual.

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FINANCIAL FUTURES CENTER

ABOUT THE FINANCIAL FUTURES CENTER

The Financial Futures Center main objective is to support developing countries catalyze an economic transformation to launch a decade of progress with 5-years of fast-tracked action aimed at ultimately achieving, by 2030, "climate prosperity", and the reversal of systemic climate vulnerability towards becoming systemically climate resilient economies. This goal can be achieved by seeking the improvement of key socio-economic growth outcomes: national and disposable income, poverty reduction, investment, jobs, economic stability, trade balance, and other critical socio-economic results – by optimizing core economic and climate responses together within the real economy.

Supporting developing countries pursue climate prosperity can exceed or ensure early achievement of the 2030 Sustainable Development Goals and be well on track to emerge, at the latest by 2030-2050, as wealthy nations achieved through strongest possible climate-smart economic growth. To do so, there is also a need for systems change to the global economy and parallel and supportive contributions of major economic actors, including private sector, international financial institutions (IFIs), multilateral development banks (MDBs), and the development assistance and economic cooperation between the Vulnerable Group of Twenty (V20) Ministers of Finance, the Group of Twenty (G20) and the Organisation for Economic Co-operation and Development (OECD).

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	2018	2019
Luzon	69.8	69.9
NCR	31.8	32.1
Visayas	13.6	13.6
Mindanao	16.5	16.5
All	100.0	100.0

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GLOSSARY

TERMINOLOGY	DEFINITION
Adaptation	Adjustments to ecological, social and economic systems in such a manner as to build resilience of human communities and natural ecosystems so as to moderate or minimize potential damage or to benefit from opportunities associated with climate change.
Advanced metering infrastructure (AMI)	Smart meters, data management systems, and communication networks are all part of the AMI, which enables two-way communication between utility companies and their consumers.
Ancillary services	Functions that help grid operators maintain a secure grid operation.
Baseload	It is the minimum level of demand on an electrical grid over a span of time. Baseload supply is not a technical concept, it is an economic and business concept.
Climate Finance	The flow of funds from developed countries to developing countries to address the issues related to climate change. It refers to local, national or transnational financing, primarily provided by developed countries, which may be drawn from public, private and alternative sources and mobilized to help developing countries mitigate and adapt to the impacts of climate change.
Climate Prosperity	To counteract the threat multiplier of climate change towards maximized socio-economic outcomes through transforming the real economy with technology transfer, new resources and economic partnerships.
Climate Resilience	The ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate
Concessional Loans	These are loans that are extended on terms substantially more generous than market loans. The concessionality is achieved either through interest rates below those available on the market or by grace periods, or a combination of these. Concessional loans typically have long grace periods.
Cost of Capital	Cost of capital refers to the entire cost or expenses required to finance a major capital project, this include cost of debt and cost of equity.

Credit Strengthening	Strategy for improving the credit risk profile of a business or government, usually to obtain better terms for repaying debt.
Department of Energy (DOE)	An executive branch of the Philippine government in charge of organizing, coordinating, monitoring, and controlling all policies, plans, projects, and initiatives the government undertakes in relation to the exploration, production, use, and conservation of energy.
Disaster Risk	The potential disaster losses of sudden or slow-onset events in lives, health, livelihoods, assets, and services, which could be incurred by a particular community or society over some specified future time period. Disaster risk is a function of hazard, exposure, vulnerability, and capacity.
Disaster Risk Financing (DRF)	This refers to a set of tools available to financially manage the impacts of natural disasters.
Distributed Energy Resources (DER)	Distributed energy resources are small, modular, energy generation and storage technologies that provide electric capacity or energy where you need it.
Energy Management Systems (EMS)	A robust monitoring and control system that can be augmented with energy storage.
Energy Regulatory Commission (ERC)	A regulatory body to ensure consumer education and protection, and to promote the competitive operations in the electricity market.
Energy Security	Uninterrupted availability of energy sources at an affordable price
Export Credit Agencies (ECA)	Export credit agencies offer loans, loan guarantees and insurance to help domestic companies limit the risk of selling goods and services in overseas markets.
Foreign Direct Investment (FDI)	An investment in the form of a controlling ownership in a business in one country by an entity based in another country.
Geothermal	Geothermal energy is a type of renewable energy taken from the Earth's core. It comes from heat generated during the original formation of the planet and the radioactive decay of materials. This thermal energy is stored in rocks and fluids in the centre of the earth.
Green Energy	Green energy is any energy type that is generated from natural sources, such as sunlight, wind or water.

Greenhouse gas (GHG)	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO2, N2O and CH4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).
Grid Modernization	Improvements needed in the power grid to accommodate new technology
Gross Domestic Product (GDP)	GDP calculates the monetary value of the final goods and services—those purchased by the consumer—produced in a nation during a specific time period (say a quarter or a year). It accounts for all the output produced inside a nation's boundaries.
Hydroelectric	Hydroelectric energy, also called hydroelectric power or hydroelectricity, is a form of energy that harnesses the power of water in motion—such as water flowing over a waterfall—to generate electricity
Inertia	Inertia in power systems refers to the energy stored in large rotating generators and some industrial motors, which gives them the tendency to remain rotating. This stored energy can be particularly valuable when a large power plant fails, as it can temporarily make up for the power lost from the failed generator.
Intelligent electronic devices (IED)	An integrated microprocessor-based controller of power system equipment, such as circuit breakers, transformers and capacitor banks.
Kilowatt hour (kWh)	A measure of the amount of electricity used in an hour.
Levelized cost of electricity (LCOE)	Calculates present value of the total cost of building and operating a power plant over an assumed lifetime.
Leverage	Leverage is used in the context of climate finance in which it refers to public finance (e.g. from international finance institutions)

	that is used to encourage private investors to back the same project. This can be in the form of equity, loans, risk guarantees or insurance. This is also intended to reduce the perceived risk for the private sector. Financial institutions apply the terminology ‘leveraging’ to understand how their core contributions (for example, money provided by donor governments to a multilateral development bank) can be invested in capital markets to create an internal multiplier effect.
Local Government Unit (LGU)	A provincial, city, municipal, or barangay-level political entity.
Mini-grid	An off-grid electricity distribution network involving small-scale electricity generation
Mitigation	Efforts to reduce or prevent emission of greenhouse gases. Mitigation can mean using new technologies and renewable energies, making older equipment more energy efficient, or changing management practices, consumer behavior,, improving the insulation of buildings, and expanding forests and other 'sinks' to remove greater amounts of carbon dioxide from the atmosphere.
Off-grid	Traditionally refers to not being connected to the main electrical grid.
Outage management systems (OMS)	An outage management system (OMS) is a utility network management software application that models network topology for safe, efficient field operations related to outage restoration. OMSs tightly integrate with call centers to provide timely, accurate, customer-specific outage information, as well as supervisory control and data acquisition (SCADA) systems for real-time-confirmed switching and breaker operations. These systems track, group and display outages to safely and efficiently manage service restoration activities.
Peer-to-peer (P2P) energy trading	A virtual marketplace that allows parties to buy or sell energy, managing price and volume risk themselves, optimizing the traditional role of the energy retailer, and gaining access to additional financial and non-financial benefits. Participants in a P2P energy trading platform can transact with one another, and the aggregated transactions are then managed by a balance responsible party.
Price volatility	Price fluctuations of a commodity. Volatility is measured by the day-to-day percentage difference in the price of the commodity.
Public-private partnerships	Public-private partnerships involve collaboration between a government agency

	and a private-sector company that can be used to finance, build, and operate projects, such as public transportation networks, parks, and convention centers.
Renewable energy	Energy that is produced through natural processes and is constantly replenished is known as renewable energy. Sunlight, geothermal heat, wind, tides, water, and other biomasses are examples of this.
Resilience	The ability of a system, community, or society exposed to hazards to resist, absorb, accommodate to, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both before and during times of need.
Reskilling	Process of learning new skills to do a different job, or Training people to do a different job.
Solar photovoltaic cell	A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon.
Supply chain	A system that connects a business with its suppliers to manufacture and deliver a certain product to the customer. Different activities, people, entities, information, and resources are included in this network. The process of getting a good or service from its starting point to the customer is also represented by the supply chain.
Synchrophasors	Time-synchronized numbers that accurately describe the size and phase angle of the sine waves present in electricity. Phasor Measurement Units (PMUs), which are 100 times quicker than SCADA, are used to measure them.
Technology transfer	The process of transferring (disseminating) technology from the party that owns or holds it to another, in an attempt to transform inventions and scientific outcomes into new products and services that benefit society.
Trade balance	Difference between the value of the goods that a country (or another geographic or economic area such as the ASEAN area) exports and the value of the goods that it imports.
Transformation	A change in the fundamental attributes of a

	system that are revolutionary and large scale. This type of changes cross the threshold and creates discontinuity in the system through adoption of new policies, measures, institutional constructs and activities. This change is a part of the ongoing decision-making process, which helps to improve the adaptation and mitigation actions.
Transition bonds	A relatively new class of debt instrument used to fund transition towards reduced environmental impact or lower carbon emissions.
Ultra-High Voltage (UHV)	Power transmission lines that operate at voltages greater than 800,000 volts are known as ultra-high voltage (UHV) transmission lines (800 kV).
Voltage	When charged electrons (current) are forced through a conducting loop by the pressure of an electrical circuit's power source, they can perform tasks like lighting a lamp.

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