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Getting Our Act Together

Optimizing Our Energy Mix

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Getting Our Act Together

Optimizing Our Energy Mix

This policy brief was authored by
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The Philippines is in the midst of rapid change. **It's time to get our act together.**

With economic growth surging over the past six years, the Philippines is set to transition to a high-income economy with an average annual GDP growth rate of 7% and an average annual per capita income growth of 5.96%. Favorable demographics including a younger and more connected workforce alongside the emergence of a vibrant and aggressive private sector are altogether allowing the Philippines to compete with its neighbors in Southeast Asia in ways that are expanding the service and industry sectors. Indeed, it would appear the country is positioned to meet its ambitions of delivering an inclusive and secure Philippines by 2040. **And yet, will this inclusive and secure Philippines by 2040 have the right energy mix to power its growth into the long-term and the proper safeguards to protect its citizens most at risk from the impacts of climate change?**

Indeed, some key questions remain unanswered:

- Why should government treat climate change as a priority policy agenda in the midst of its growth ambitions? How should the country's institutions work towards climate-proofing the economy in line with its global commitments?
- How do we ensure that secure, affordable, and sustainable energy is effectively and efficiently delivered, while providing enough flexibility for the country to take advantage of new disruptive technologies and business models in the global energy arena?
- How should government create the enabling environment to foster investment, innovation, and growth in the climate and energy sectors?

Climate-Proofing our Development Agenda

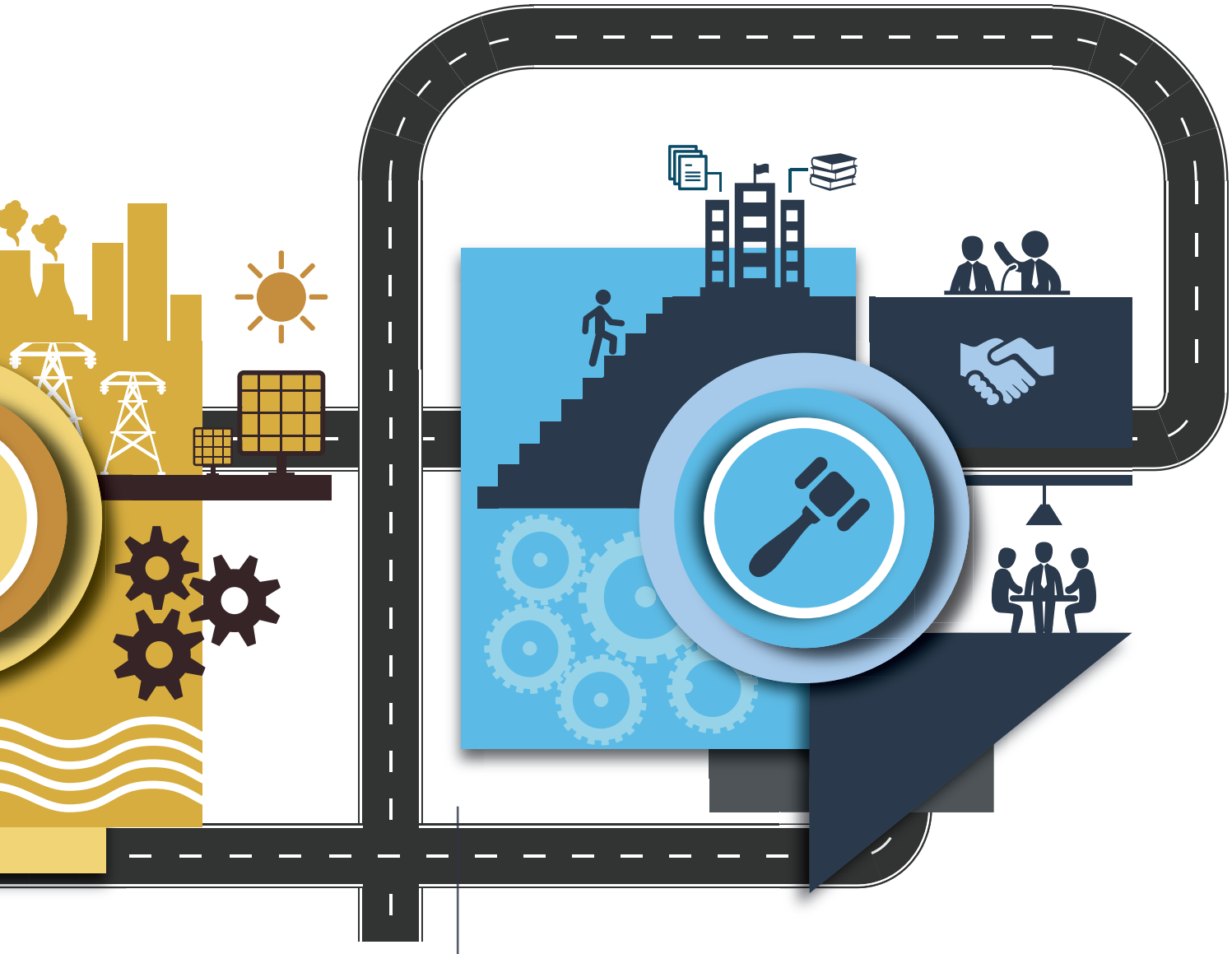
Ownership of climate change as a priority agenda enables the Philippines to climate-proof its growth

Optimizing our Energy Mix

Diversification sets the stage for a secure, equitable, and sustainable energy mix

The Ateneo School of Government and **SSG Advisors** are proud to present the policy brief series entitled: GETTING OUR ACT TOGETHER. This policy brief series brings together insights and recommendations in the realms of climate and energy and crystallizes a clear policy direction for the Philippines to secure its growth ambitions. It draws from current thinking from the public, private and academic sectors and argues for a priority policy agenda that clearly sets the pathway for how climate and energy can and should drive inclusive development for the next decade.

We push for cooperation between the public and the private sector around an agenda to GET OUR ACT TOGETHER:



Creating an Enabling Environment to Support an Optimal Energy Mix for a Climate-Smart Philippines

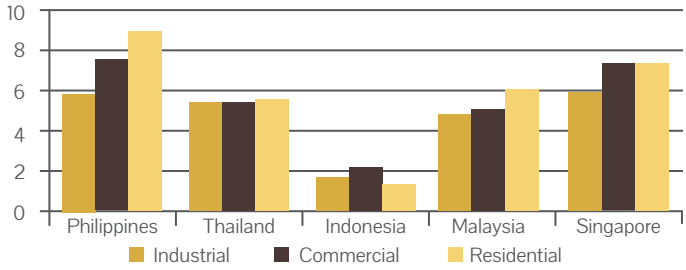
Prioritizing an enabling environment allows the government and the private sector to more efficiently meet the country's growth ambitions and energy requirements

Getting our Act Together
Optimizing Our Energy Mix

The government aspires to achieve a high-income economy by 2040. It would entail an average annual GDP growth of 7%. This in turn would require a total energy capacity addition of 12,307 MW by 2030.

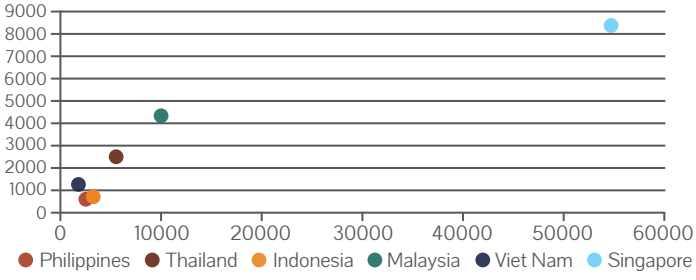
The Philippine economy grew by an average of 6.2% in the past six years.[1] It is currently considered as the top performing economy in Southeast Asia.[2] In the first quarter of 2016 alone, the economy registered the highest growth compared to 11 countries in Asia owing to the expansion in the services (trade, finance, real estate, rental, and business activities) and industry (construction, manufacturing, and utilities) sectors.[3] The country is now in a position to transition to a high-income economy with an average annual GDP growth rate of 7%[4] and an average annual per capita income growth of 5.96%.[5] Achieving a high-income economy is a target of the government by 2040.[6] Doing so would require, among others, addressing issues on energy security, affordability, and sustainability. The country currently has the 4th highest electricity tariffs in the region accompanied by low energy consumption per capita. A higher energy supply is also needed to meet a larger energy demand brought about by an expanding economy and an increasing population. A high GDP growth[7] is forecasted to require a total installed capacity addition of 12,307 MW by 2030 with 7,335 MW in Luzon, 2,872

Figure 1. 2015 Electricity Tariffs in Peso/kWh



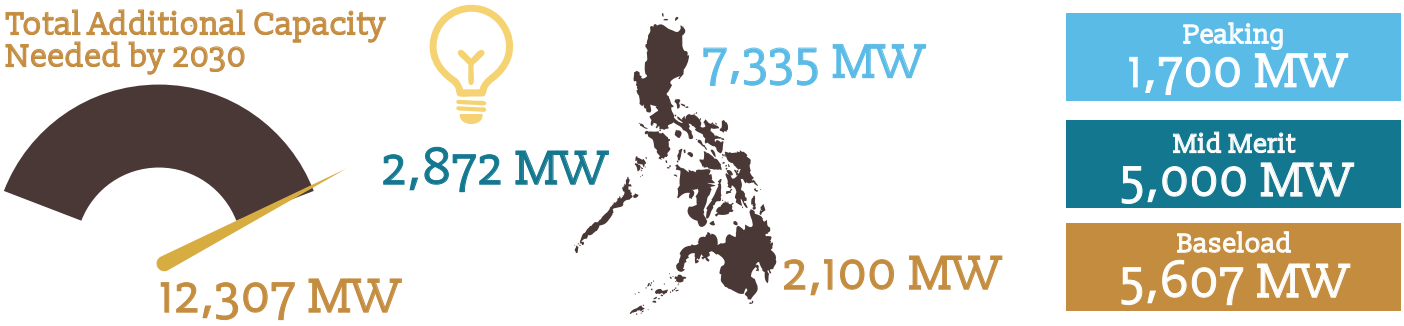
Source: Department of Energy (2016)

Figure 2. GDP vs. Consumption per capita, ASEAN-6



Source: Department of energy (2016)

[1] Accessed from http://cnnphilippines.com/news/2016/05/19/philippines-fastest-growing-economy-asia-gdp-q1.html on 18 September 2016.
[2] Accessed from http://cnnphilippines.com/business/2016/05/13/oxford-business-group-economy-philippines-southeast-asia.html on 18 September 2016.
[3] Statement of Socioeconomic Planning Secretary and NEDA Director-General Emmanuel F. Esguerra at a Press Conference on the 2016 Q1 Performance of the Philippine Economy. 19 May 2016.
[4] See Note 1.
[5] Ravago et al. (2016). Filipino 2040 Energy: Power Security and Competitiveness. Energy Policy and Development Program Working Paper 2016-01R.
[6] *Id.*
[7] GDP growth rate used ranges from 7.0 to 8.0. Presentation by Dir. Irma C. Exonde, DOE Electric Power Industry Management Bureau entitled "Draft Power Development Plan 2015–2030 as of 7 January 2016". Presented on 28 March 2016.



MW in Visayas, and 2,100 MW in Mindanao.[8] The total installed capacity addition is comprised of 1,700 MW peaking, 5,000 MW mid-merit, and 5,607 MW baseload capacities. In Luzon, new capacity additions for peaking and mid-merit are needed beginning 2021 while that for baseload starting 2025. In Visayas, additional mid-merit capacity is needed starting 2018, baseload by 2019, and peaking by 2027. Lastly in Mindanao, additional mid-merit capacity is needed by 2023, baseload by 2025, and peaking by 2030.[9]

To support long-term growth, the country needs an optimal energy mix[10] addressing security, equity, and sustainability. Furthermore, this energy mix should be translated into a tangible program.

The capacity additions and the resource choice for the capacity additions are essential considerations for the energy trilemma of security, equity, and environmental sustainability. The trilemma affects overall energy sustainability, which in turn influences economic growth. Energy security is not limited to meeting changes in energy demand. It also involves managing risks and building resilience when it comes to domestic and external primary energy sources, and providing quality and reliable supply of energy. Not limited to the following, energy security is : **(1) having an energy portfolio that is dominated by indigenous energy sources (or is not heavily reliant on one external energy source); (2) furnishing sufficient ancillary services to maintain power quality as well as reliability and security of the grid; and (3) expanding the transmission lines in time to accommodate incoming capacities while maintaining N-1 or the single outage contingency criterion.** On the other hand, **energy equity encompasses both price and infrastructure for electrification – factors that influence access to and consumption of electricity across sectors of the population.** Energy equity is crucial for economic growth because there is a bidirectional causal relationship between energy consumption and economic growth, and electricity consumption and electricity price.[11] While **environmental sustainability emphasizes sustainability of (1) energy supply through energy efficiency and renewable energy sources especially amidst rapid technological changes, and (2) a healthful environment through low-carbon sources.** Actions towards environmental sustainability have been, as of late, given more global scrutiny because of the Intended Nationally Determined Contributions (INDC) of countries during the 21st Conference of Parties in 2015. Realizing energy security and

Energy security is the "effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure and the ability of participating energy companies to meet current and future demand"

Energy equity is the "the accessibility and affordability of energy supply across the populations"

Environmental sustainability is the "achievement of supply and demand-side energy efficiencies and the development of energy supply from renewable and other low-carbon sources."

Source: World Energy Council (2016)

[8] Presentation by Dir. Irma C. Exonde, DOE Electric Power Industry Management Bureau entitled "Draft Power Development Plan 2015–2030 as of 7 January 2016". Presented on 28 March 2016.

[9] See Table 1 in Annex.

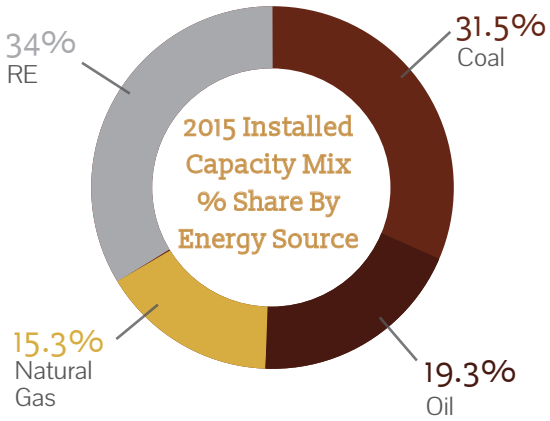
[10] For the purposes of this paper, the energy mix refers to the power generation mix.

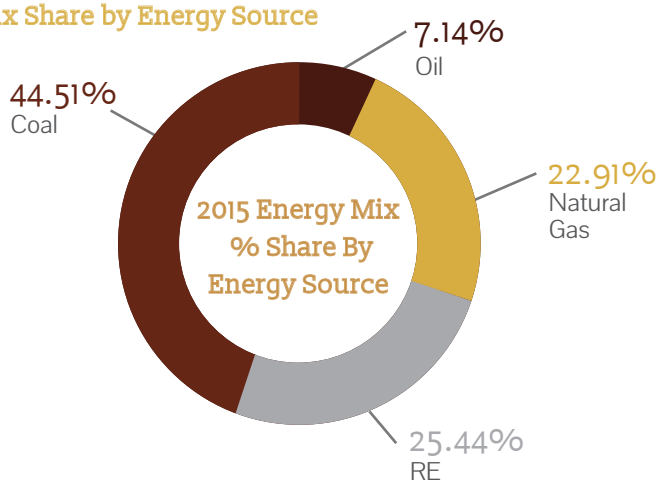
[11] Osigwe, A. C. and D.F. Arawomo (2015). Energy Consumption, Energy Prices and Economic Growth: Causal Relationships Based on Error Correction Model. International Journal of Energy Economics and Policy 5(2), 408-414.

energy equity through a quality, reliable, and affordable supply of energy is the foremost priority of government in line with the objective of attaining a high-income economy. Environmental sustainability, equally sacrosanct in Philippine law, goes hand-in-hand with energy security and equity in achieving overall energy sustainability needed for economic growth. All these can be translated into tangible policy in the form of an energy mix which meets projected demand in a cost-effective way. It is recognized that there are existing studies[12] on the Philippines' optimal energy mix, which made use of varied optimization techniques. This policy brief does not attempt to do the same. Admittedly, the optimization of energy resource combinations to meet forecasted economic growth while safeguarding security and equity would require economic optimization methodologies and or techno-operational approaches; these are outside the scope of this written output. Rather, this policy brief (1) recognizes the expected characteristics of the country's optimal energy mix based on earlier identified needs and targets, such characteristics being quality, reliability (security), affordability (equity), and environmental sustainability; and (2) advocates initial steps for an easier transition towards an optimal energy mix with the such identified attributes.

The installed capacity mix reflects the percentage share of each energy source at the maximum capacity a power plant is designed to run at.[13] The current installed capacity mix is 34% RE, 31.50% coal, 19.30% oil, and 15.30% natural gas. On the other hand, the energy mix displays the percentage share of each energy source by the amount of electricity a power plant produces over a specific period of time.[14] The current energy mix is 44.51% coal, 25.44% RE, 22.91% natural gas, and 7.14% oil-based technologies. The effects of the use of these resources will be assessed using the energy trilemma.

Figures 3a and 3b: Installed Capacity Mix and Energy Mix Share by Energy Source





Source: Department of energy (2016)

[12] Existing studies include: Ravago et al. (2016). Filipino 2040 Energy: Power Security and Competitiveness. Energy Policy and Development Program Working Paper 2016-01R; First Gen presentation entitled "Philippine Power Industry Briefing: Establishing An Energy Road Map" presented on 22 September 2016 before the Management Association of the Philippines; Meralco PowerGen Corporation presentation entitled "The 2015 Paris Agreement and its Impact on the Generation Mix" presented on 22 September 2016 before the Managemetn Association of the Philippines.

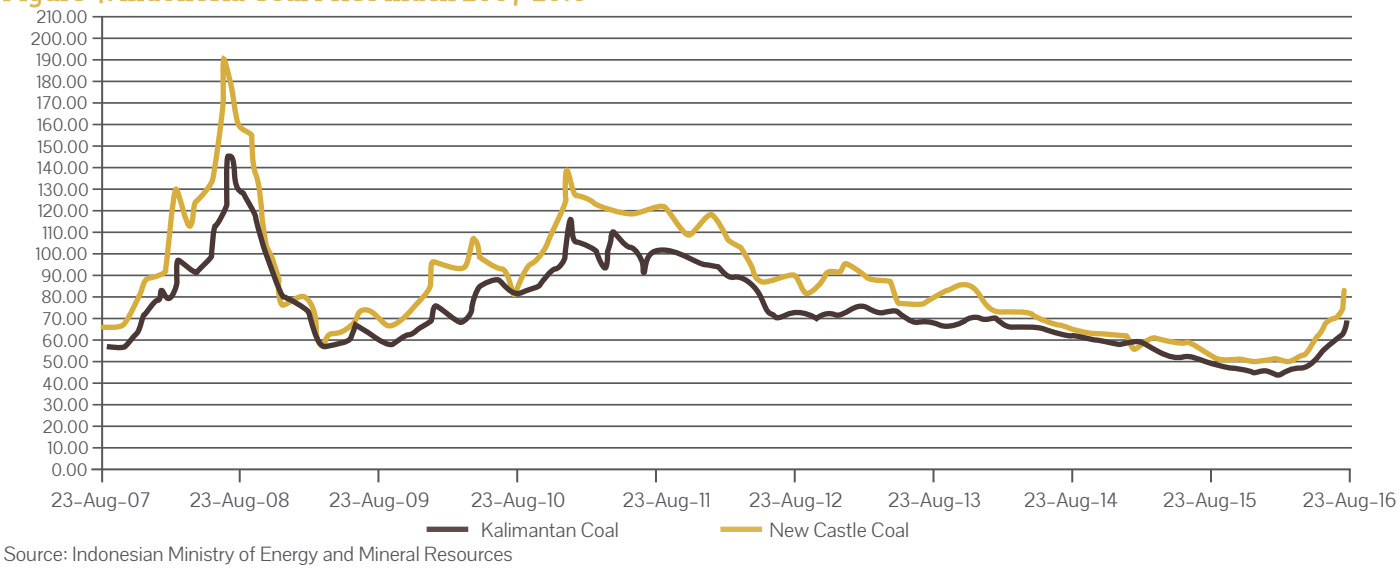
[13] The installed capacity of each power plant is measured in megawatt (MW). The 2015 installed capacity mix is 6330 MW RE, 5963 MW coal, 3610 MW oil, and 2862 MW natural gas.

[14] The energy mix,, also referred to as the power generation mix is measured in gigawatt hour (GWh). The 2015 energy mix is 36686 GWh coal, 20963 GWh RE, 18878 GWh natural gas, and 5886 GWh oil.

In the short-term, coal address security and equity but not sustainability. At certain price levels, it is cost-effective as a baseload plant and may be cheaper that almost all other energy sources. Yet it has a high social cost to the environment. In the long-term, coal fails to satisfy all three components of the energy trilemma. It ceases to be cost-effective once operated at mid-merit. Also, majority of the coal utilized is imported, exposing energy supply and price to volatile international market conditions.

In 2015, 44.51% of the energy mix came from coal.[15] Coal-fired power plants primarily serve the baseload demand of the country but are also utilized for mid-merit purposes. Presently, it is the cheapest fuel, with a contract price ranging from Php 2.9 to 3.5 per kilowatt hour (kWh). However, if a coal plant is not operating at 60% or more capacity factor (which almost always is the case whenever coal plants are not used as baseload), the actual generation cost is higher than the contract cost. Thus, the actual cost charged can range from Php 4 to Php 4.8 per kWh. Majority of the coal used for power generation are imported,[16] with costs determined by the international market for the resource. To illustrate, coal at the present is inexpensive (at 25 USD per metric ton). This was not the case in 2008, at the height of the global financial crisis, where the cost of coal reached an all-time high (at 150 to 170 USD per metric ton). Having a high coal share in the energy mix exposes the country to price volatility arising from international market fluctuations. Apart from this variability, the cost of coal is also influenced by the policies of exporting nations or geopolitics. In 2015 alone, 70% of the coal used in power generation was supplied by Indonesia. Should Indonesia, for any reason, decide to place a cap on its coal exports, the Philippines will be forced to source its coal elsewhere. The country has already increased coal prices by slapping a 10% import tax in 2015. For example, in June 2016, Indonesia declared a moratorium on coal shipments to the Philippines following the kidnapping of two Indonesian sailors by the Abu Sayyaf in Philippine waters.[17] In this event, coal can be imported from Australia, Russia, and Vietnam,[18] but it will be more expensive since these countries are farther. Coal, as an energy source, also has a high social cost. Grausz (2011) calculated the social costs of different kinds of technologies in electricity generation. The total external cost (cost to society) of coal ranges from USD 57 to USD 58 per megawatt hour (MWh) compared to USD 30 per MWH for natural gas, USD 2 per MWh for wind, USD 6 per MWh for solar, and USD 11 per MWh for biomass.[19] Even with the use of coal emissions controls for pulverized coal, the external cost for coal is still higher at USD 34 per MWh.[20] Presently, these external costs are not included in calculating the price of coal. Once taken into account, coal will be more expensive than natural gas, wind, and biomass.

Figure 4: Indonesia Coal Price Index 2007-2016



Source: Indonesian Ministry of Energy and Mineral Resources

[15] Department of Energy (2015).

[16] 74% of coal consumption in the country is for power generation as of 2011. Presentation by Mr. Ismael U. Ocampo, OIC Director of DOE Energy Resource Development Bureau entitled "Coal Supply and Demand Outlook in the Philippines". Presented on February 22-23, 2012.

[17] Philippine power supply jeopardized by Indonesian ban by danessa Rivera. The Philippine Star. 27 june 2016. http://www.philstar.com/headlines/2016/06/27/1597092/philippine-power-supply-jeopardized-indonesian-ban accessed on 25 July 2016.

[18] Orosa-Ople, M. 28 June 2016. "DOE assessing coal needs of energy firms after Indonesia's ban." Accessed from http://interaksyon.com/business/129667/doe-assessing-coal-needs-of-energy-firms-after-indonesias-ban on 25 July 2016.

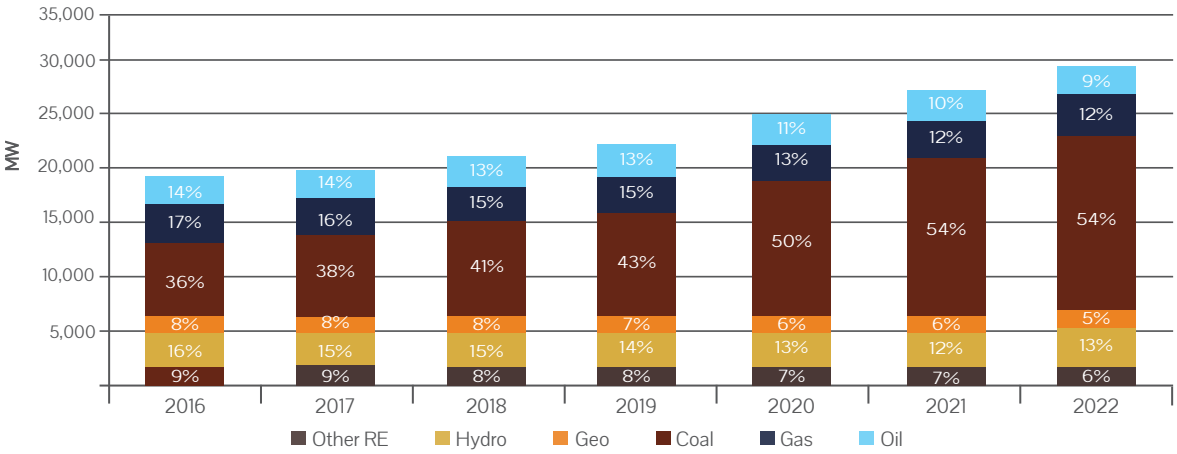
[19] Grausz, S. (2011). The Social Cost of Coal: Implications for the World Bank. See Table 2 in Annex.

[20] *Id.*

If the country continues on its current path, it is headed for a coal-dominated future — which compromises energy security, equity, and sustainability.

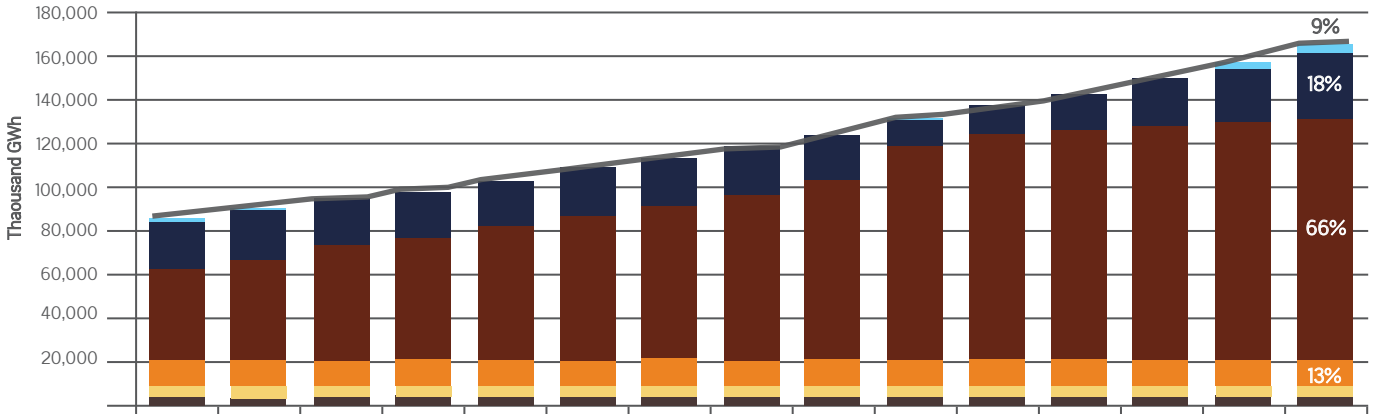
Despite the challenges facing coal, it will continue to dominate the energy mix because of its high capacity factor and the large amount of committed installed capacity (5,924.5 MW) expected to start operations between now until 2019. The committed coal in Luzon and Visayas, together with other committed and targeted baseload resources (geothermal, hydropower, run-of-river hydro, biomass), is not sufficient to fulfill each region's baseload requirements by 2030. The committed coal in Mindanao is another story as it is more than enough to satisfy baseload demand. However, the oversupply of coal plants in Mindanao would mean running some of them at less than 60% dispatch capacity, and paying a higher price for doing so.

Figure 5: Philippine Capacity Mix Forecast (2016-2022) at BAU



Source: Presentation from the Management Association of the Philippines, Energy Committee, September 22, 2016

Figure 6: Philippine Energy Mix Forecast (2016-2022) at BAU



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Oil	1,882	1,721	31	53	–	36	218	231	245	866	275	291	793	3,301	4,536
Gas	21,316	21,316	21,316	21,316	21,316	21,316	21,316	21,316	21,316	11,680	12,424	16,464	20,749	24,023	28,825
Coal	42,042	46,247	51,109	56,103	60,802	65,633	70,113	75,265	80,925	96,946	101,787	104,164	106,116	107,395	108,756
Geo	11,706	11,706	11,706	11,706	11,706	11,706	11,706	11,706	11,706	11,706	11,706	11,706	11,706	11,706	11,706
Hydro	4,886	4,886	4,949	5,369	5,369	5,369	5,901	5,901	5,901	5,901	5,901	5,901	5,901	5,901	5,901
New RE	4,441	4,441	4,441	4,441	4,441	4,441	4,441	4,441	4,441	4,441	4,441	4,441	4,441	4,441	4,441
Consumption	86,274	90,317	94,552	98,988	103,634	108,501	113,599	118,939	124,534	130,395	136,534	142,967	149,706	156,767	164,165

Source: Presentation from the Management Association of the Philippines, Energy Committee, September 22, 2016

In the short term, RE addresses sustainability but not security and equity. Some RE sources (e.g. wind and solar) compromise security because of their intermittency and uncertainty. Moreover, emerging RE is currently expensive compared to other energy sources. In the long term, RE satisfies all three components of the energy trilemma. Advancements in RE have emerged to cope with intermittency and uncertainty, and the rapid developments in technology are bringing the cost of emerging RE down.

Following coal in the energy mix is total renewable energy (RE) with a 25.44% share in power generation. This includes conventional RE (hydropower and geothermal power) at 23.92% and emerging RE (solar, wind, run-of-river hydro, biomass) at 1.520%. The desirability of all RE sources arises because they are (1) indigenous, and (2) environmentally sustainable. Be that as it may, there are differences when it comes to costs and challenges for each RE resource. Conventional RE is cheaper than emerging RE especially since the cost of the latter is pegged to the feed-in-tariff. Also conventional RE like geothermal and hydropower have the ability to serve as baseload plants, and in the case of hydropower as peaking plants. The indicative geothermal projects (with expected commissioning years ranging from 2014 to 2026) have a potential capacity of 1,425MW.[21] They face one substantial barrier: the high financial risk (which includes development uncertainties arising from drilling and well tests) in comparison to other energy sources.[22] Hydropower's share in the energy mix has been decreasing over the years but the National Renewable Energy Program (NREP) is targeting a 3,161 MW of hydropower capacity addition by 2016-2020, and another 1,891.8 MW addition by 2021-2025.[23] Hydropower, just like geothermal power, requires large capital costs and a long development period. Yet, unlike geothermal, hydropower is a season-dependent resource and with climate change, the water supply may decrease to a level where the plant cannot be relied upon from time to time.

When it comes to emerging RE, solar and wind can meet mid-merit load requirements while run-of-river hydro (ROR) and biomass can serve as baseload plants. The committed variable RE in Luzon, Visayas, and Mindanao, together with a committed natural gas plant, is not sufficient to fulfill each region's mid-merit load requirements by 2030. Variable RE also faces the obstacle of intermittency, which compromises the stability of the grid. It also necessitates the provision of additional reserves to cope with the variability of generation. As variable RE penetration increases, grid frequency is affected and more if this is not addressed, then the grid runs the risk of more automatic load dropping instances. To illustrate, when variable RE was first injected into the grid in 2015, there was a 41.48% increase in the frequency load violations of the system operator compared to the 2014 figure. Nevertheless, advances in RE technology can address the difficulties caused by intermittency. There is a new type of flow battery that will allow the capture, collection, and storage of solar and wind energy.[24] Another invention, a hybrid device, combines the functions of a solar cell and a battery in one.[25] Moreover, there are tracking systems now available to monitor sunlight availability in solar farm areas. For ROR, the cost is lower compared to traditional hydropower. Notwithstanding this, there is minimal investment in ROR because of its long gestation period compared to variable RE. As for biomass, the challenge lies in sourcing the feedstock used to produce energy and their collection from separate locations since hauling and storage costs make some biomass proposals not viable. Also, although biomass is carbon neutral, there is still an increase in methane gas production, which is harmful to the environment.[26]

[21] National Renewable Energy Program. Chapter III. Renewable Energy Planas and Programs (2011-2030). p. 33
[22] World Energy Council (2013). World Energy Resources Survey. pp. 9.16-9.17
[23] National Renewable Energy Program. Chapter III. Renewable Energy Planas and Programs (2011-2030). p. 41.
[24] Accessed from http-//www.renewableenergyworld.com/articles/2014/12/researchers-developing-affordable-flow-battery-technology.html on 19 September 2016.
[25] Accessed from http-//www.renewableenergyworld.com/articles/2014/10/all-in-one-solution-solar-that-stores-its-own-power.html on 19 September 2016.
[26] Accessed from http-//www.conserve-energy-future.com/Advantages_Disadvantages_BiomassEnergy.php on 19 September 2016.

The FIT has jump-started emerging RE in the Philippines (from 0.5% to 1.52% of the energy mix). Moving forward, however, there is a question on whether or not the FIT is still needed considering the decreasing costs of technology, most especially for solar.

The main critique against emerging RE is its high cost brought about by the FIT. The FIT lock-in of 20 years (despite the digression rate) is argued as unnecessary considering the steep decline in the cost of RE technology. Deutsche Bank (2015) predicts that solar PV will be at grid parity in about 80% of the global market by 2017.[27] The National Renewable Energy Board (NREB) has already declared that solar is at grid parity since the cost per kWh is now equal to the retail rate per kWh.[28] At the utility level, however, solar cannot compete against other technologies because it is still more expensive (i.e. solar cost/kWh is Php8 to 9 while coal cost/kWh is Php3 to 4).[29] Still, it appears that grid parity is well on its way since the cost of solar PV is expected to further decrease to 9 US cents/kWh in the long run while onshore wind is anticipated to fall to 6.5 US cents/kW by 2020.[30] GIZ (2013) also claims that the levelized costs of wind, biomass, geothermal, and hydropower are now competitive with fossil fuels. The FIT rate for solar has actually already been decreased from Php 9.68 per kWh to Php 8.69 per kWh. Despite this, the FIT allowance was increased from Php 0.04 per kWh to Php 0.12 per kWh to accommodate the increase in the installation target of solar from 50MW to 500 MW and the reduction of the WESM price. The FIT allowance that is collected is a function of the price of RE relative to the WESM. Another possible increase of the FIT allowance (to Php 0.20 per kWh at a maximum) is on the table.[31] The amount of the FIT is, to a certain extent, influenced by international market fluctuations because its adjustment formula allows the pass-through of foreign exchange rate variations.[32] Even with the FIT, the desired installation targets of most emerging RE sources have not been met. Only solar has been fully subscribed exceeding the installation target of 500 MW by 25.95 MW. ROR has an unsubscribed installation target of 223.4 MW, followed by biomass at 148.549 MW, and wind at 56 MW.[33] Critics of the FIT (or of the FIT eligibility structure) further put forth as arguments the distortionary effect of FIT as a carbon abatement tool[34] and the efficiency of auctioning FIT certificates instead of the current quota system of "first come, first served", or the first to get constructed will be the ones to get the FIT[35] Nonetheless, the FIT has indeed paved way for a higher share of emerging RE in power generation from less than 0.5% in 2012 to 2014 to 1.52% in 2015.

In the short-term, natural gas addresses the energy trilemma. It is sourced locally, is ideal as a mid-merit plant because of its flexibility, and can compete with coal at certain price levels. It also produces only one-third of the carbon emissions of coal. In the long-term, natural gas fails to satisfy energy security, environmental sustainability and possibly equity. The Malampaya reserves are facing depletion by 2028. Although natural gas plant owners are preparing for this future by developing LNG terminals, it would mean importing the resource. This, just like imported coal, exposes energy supply and price to volatile international market conditions.

[27] Parkinson, G. 12 January 2015. "Solar at grid parity in most of the world by 2017" Accessed from http://reneweconomy.com.au/2015/solar-grid-parity-world-2017 on 25 July 2015.
[28] Presentation of Mr. Pete H. Maniego, Jr., NREB Chairman entitled "Proposed Update: National Renewable Energy Program" presented on July 19-21, 2016.
[29] Figure based on monthly generation charge of Meralco for July 2016. The figure is the average generation cost per kWh from coal plants.
[30] Duetsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (2013). Renewable Energy in the Philippines.
[31] Meeting with ERC dated 14 July 2016.
[32] Energy Regulatory Commission Resolution No. 16, Series of 2010. "Resolution Adopting the Feed-In Tariff Rules."
[33] Wind still has an unsubscribed target of 56 MW, 223.4 MW for hydro, and 148.549The unsubscribed installation targets. Saulon, V.V. 22 July 2016. "Solar Projects eligible for FIT named" Business World online. Accessed from http://www.bworldonline.com/content.php?section=Economy&title=solar-projects-eligible-for-fit-named&id=129348 on 22 July 2016.
[34] Lin-Ju et al. "Long-Term Impacts of Carbon Tax and Feed-in Tariff Policies on China's Generating Portfolio and Carbon Emissions: A Multi-Agent Based Analysis," Energy and Environment, vol. 24 no. 28, December 2013 (1271-1293).
[35] IRENA and CEM (2015), Renewable Energy Auctions – A Guide to Design.

The third largest share in power generation is natural gas at 22.91%. Natural gas plants are used here both as baseload and mid-merit. However, it is ideally utilized as a mid-merit plant because it provides more flexibility than coal plants in terms of ramp rates, minimum load, and start up time. To illustrate, the total start up time from a cold start of a combined cycle gas turbine takes 205 to 255 minutes while a coal plant takes 440 to 670 minutes.[36] For this reason, natural gas is the best complement to RE generation in order to address the latter's intermittency.[37] Natural gas combined cycle plants (both conventional and advanced) also have the second lowest levelized cost of electricity (LCOE) among dispatchable technologies, next to geothermal. Moreover, it has a lower LCOE than most RE resources (biomass, wind-offshore, solar PV, solar thermal, hydroelectric) except for wind.[38] Natural gas turns out to be cheaper than coal if coal plants serve as mid-merit operating at less than 60% dispatch capacity. Be that as it may, the price of natural gas is still subject to international market commodity prices as well as foreign exchange. In terms of carbon dioxide (CO2) emissions, natural gas is lower by about 2/3 per MWh compared to coal. In the Philippines, natural gas comes from two sources: the Malampaya gas field and the Libertad gas field. It is expected that Malampaya will be depleted by 2020 and this poses a big threat to the energy mix. The estimated cost of replacing energy arising from Malampaya related outages annually is at USD 25 million, which if applied over the next 25 years at a 10% discount rate, is nearly USD 230 million, net present value [39]. Natural gas plants are starting to prepare for this contingency by developing LNG terminals. Still, this would mean importing natural gas and exposing the country to the same risks as importing coal as an energy source.

In both the short and long term, oil-based technologies fail to address the energy trilemma. Oil is imported. It is the most expensive among the fossil fuels, and its price is extremely volatile. Moreover, it is at par with coal when it comes to greenhouse gas emissions. Still, the role of oil plants in the energy mix is recognized because they satisfy the peaking requirements of the country's portfolio, although simple cycle gas plants may equally be capable of doing so.

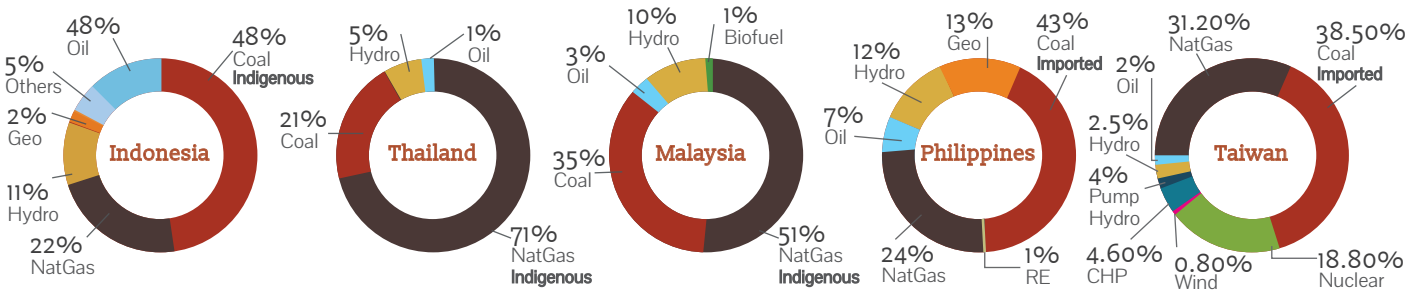
The smallest percentage share of the energy mix is oil-based technology at 7.14%. An oil-fired power plant is best used as a peaking plant because of its rapid response, quicker than natural gas plants. An oil plant is also highly reliable, and can produce power non-stop. However, it is worth mentioning that simple cycle gas plants are equally capable of meeting ramp-up requirements for peaking purposes at a fraction of the emissions. Also, oil is imported, is the most expensive among the fossil fuels (its July 2016 average generation cost is Php 7.87 per kWh),[40] and its price is extremely volatile because of international market fluctuations. To illustrate, in November 2014, the average generation cost of oil is Php 24.72 per kWh.[41] The next month, it almost doubled to Php 43.98 per kWh.[42] When January 2015 came, it plummeted downward to Php 15.42 per kWh.[43] Apart from cost considerations, the emissions of oil-fired plants – CO_2, sulfur dioxide, and carbon monoxide – affect environmental sustainability.[44] It is important to note that the committed oil plants in Luzon, Visayas, and Mindanao, together with committed and targeted hydropower, are not sufficient to fulfill each region's peaking load requirements by 2030.

[36] Parsons Brinckerhoff. (2014). Technical Assessment of Operation of Coal and Gas Fired Plants.
[37] Carrao, C. et. al. January 2014. "The Optimal Energy Mix in Power Generation and the Contribution from natural gas in reducing carbon emissions on 2030 and beyond" The Harvard Kennedy School Discussion Paper 14-63.
[38] U.S. Energy Information Administration. Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook. June 2015. Accessed from http://www.eia.gov/forecasts/aeo/pdf/electricity_generation.pdf ; See Table 10.
[39] Philippines Natural Gas Master Plan Phase One Report. 29 November 2013. The Lantau Group (HK) Limited.
[40] Meralco Computation of the Generation Charge for August 2016 based on July 2016 Generation Costs.
[41] Meralco Computation of the Generation Charge for December 2015 based on November 2015 Generation Costs.
[42] Meralco Computation of the Generation Charge for January 2016 based on December 2015 Generation Costs.
[43] Meralco Computation of the Generation Charge for February 2016 based on January 2016 Generation Costs.
[44] Accessed from http://www.greenworldinvestor.com/2011/07/07/advantages-and-disadvantages-of-oil-cons-disregarded-by-powerful-lobbies/ on 20 September 2016.

Considering the Philippines growth objectives, and the government's mandate to establish an energy mix that addresses the trilemma, it becomes clear that government's priority should be to DIVERSIFY. Three immediate courses of action are required: (1) reduce overdependence on coal to address security and efficiency issues to set the stage for (2) an increased share of natural gas (3) and a flexible environment to capitalize on rapid market and technological changes in RE .

The discussion on the economy's needs, the government's priorities, and the status of the current energy mix show that *first*, additional energy supply must be brought in to meet future projected demand in line with economic growth targets; *second*, the kind of energy resource for greenfield supply and how they will be used – whether as baseload, mid-merit, or peaking – matter; *third* and last, the energy mix cannot be dependent on just one external resource,nor should the energy mix be dominated by imported resources. All these justify the move for diversification. **To work towards diversification, two courses of action must be undertaken together: (1) minimizing dependence on one external resource, and (2) maximizing other energy resources. This is also consistent with the Philippines' neighbors who have either banked on their indigenous energy sources (Indonesia, Thailand, Malaysia) or, for lack thereof, have chosen to diversify (Taiwan).**

Figures 7: Installed Energy Capacity for the Philippines and its Neighboors (various years)

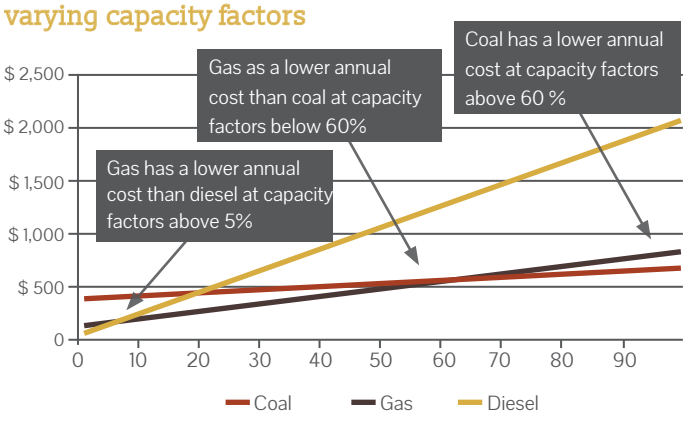


Source: US Energy Information Administration (EIA), Japan Ministry of Economy Trade and Industry, Singapore Energy Market Authority, Phil. NGCP, Thailand Ministry of Energy, PFC Energy, Po-Yao Kuo (2015) The impacts of energy trends and policies on Taiwan's power generations systems.

Optimizing the coal share in the energy mix and reducing the use of imported coal can be done through the following policies: (1) set a cap on coal plant endorsements using a portfolio based approach; (2) create a gold standard for coal plants; and (3) comply with BOI environmental criteria.

The first course of action has two objectives: (1) optimize the percentage share of coal in the energy mix, and (2) reduce the use of coal. Admittedly, the role of coal as a baseload plant is crucial and cost-effective at low coal prices. The problem lies in having a supply of coal plants beyond baseload needs, which will be the case in Mindanao. As result, these "excess" coal plants will most likely be operated at less than 60% capacity factor, which is more often the case when coal is operated as a mid-merit plant. When this is so, coal becomes more expensive than natural gas and efficiency dictates that other energy sources are better suited than coal. Even at the present, the "excess" coal may already be locked in regardless of the actual dispatch capacity of the plants due to power supply agreements with minimum capacity take-or-pay provisions. Moreover, a "surplus"

Figure 8. Comparison of gas, coal and diesel costs at varying capacity factors



Source: Castalia (2015. ERC Consultation Paper.)

of coal plants unnecessarily exposes the country to a higher risk arising from having a greater percentage share of the energy mix from one kind of resource, more so since the resource is imported. **The ideal policy would be to set a cap on approved coal endorsements based on an energy plan detailing the portfolio requirements (baseload, mid-merit, peaking) in Luzon, Visayas, and Mindanao as well as the available transmission lines. This way it can be ensured that there is no oversupply of coal plants beyond baseload needs nor stranded power in each region.** This policy assumes there are sufficient mid-merit and peaking plants in each region, and would require the creation of a comprehensive regional plan as well as additional/supplementary transmission lines between the islands in Luzon and Visayas, and the long-desired connection of Luzon and Visayas to Mindanao. The drafting of the plan is a challenge in itself because of various coordination problems that plague the energy sector. Nevertheless, **the Department of Energy can presently set the cap on approved coal endorsements using a portfolio-based approach.** To address the energy portfolio needs of the country while ensuring a healthful ecology for Filipinos, the adoption of the gold standard is recommended. **The gold standard for new plants should dictate that only ultra-supercritical coal plants , or better, can be built, while the gold standard for both old and new plants should incorporate the emissions standards stated in the Clean Air Act.** This way, non-clean technology coal plants can eventually be phased out as they fail to comply with the gold standard. Efficiency wise, cleaner technology coal plants[45] are better because of reduced fuel costs and emissions, which offset the 20% to 30% increase in building costs.[46] The use of emissions standards in the Clean Air Act necessitates the law's implementation specifically the use of a mass rate rather than the concentration of emissions,[47] and the use of an emissions charging system.[48] Additionally, **the Board of Investments (BOI) should implement Memorandum Circular No. 2015-01 by requiring coal plant developers to submit an environmental compliance certificate and to comply with other measures which support environmental protection and conservation.** The Investment Priorities Plan should also be reviewed to ensure that fiscal incentives given to energy developers are consistent with environmental objectives.

Once coal's share is reduced, natural gas will be allowed to compete and optimize the mid-merit or at the very least, maintain its share in the current energy mix given the expected depletion of the Malampaya reserves. This can be done through (1) the formulation of a comprehensive natural gas policy and legislative framework to attract private sector investment; (2) support for the construction of natural gas infrastructure; and (3) the exploration, development, and production of indigenous natural gas as well as the swift resolution of each Philippine Energy Contracting Round.

Once a regional plan using a portfolio based approach is in place, coal will then be contained to serve as baseload. This gives way for natural gas to supply the mid-merit demand, or in some cases compete with coal (when coal is operating at less than 60% dispatch capacity). Yet, it is not enough that the percentage share of coal in the energy mix is decreased. Rather, incentives must be in place to attract increased energy supply from other fuel types.

When it comes to natural gas, maintaining its share in the current energy mix should be the minimum objective considering the depletion the Malampaya reserves by 2028. This can achieved by the following: **first, the formulation of a comprehensive natural gas policy and legislative framework.**[49] The framework should include the existing natural gas master plans,[50] possible incentives for investors, and needed policy instruments. At the heart of this framework is a decision by government as to the role of natural gas in the energy mix and its appurtenant policy direction; **second, the development and construction of natural gas infrastructure (pipelines, refueling stations, LNG terminals).** The infrastructure is critical if the country is to import natural gas even before the Malampaya depletion. The infrastructure

[45] Specifically ultra-supercritical coal plants.
[46] Santoianni, D. "Setting the Benchmark: The World's Most Efficient Coal-Fired Power Plants." Accessed from http://cornerstonemag.net/setting-the-benchmark-the-worlds-most-efficient-coal-fired-power-plants/ on 11 August 2016.
[47] Sec. 19, Republic Act (R.A.) 8749 (1999)
[48] Sec. 13, R.A. 8749 (1999)
[49] There is a natural gas master plan prepared for DOE in 2013 but it only focused on the role of LNG in the energy market.
[50] Philippines Natural Gas Master Plan Phase One Report: Assessment of the role of LNG within the Philippines energy market. 29 November 2013. Prepared by The Lantau Group (HK) Limited. Philippines Natural Gas Master Plan Phase Two Report: Design of a transactional structure for initial LNG-to-power infrastructure development for Luzon and Mindanao. 3 March 2014. Prepared by The Lantau Group (HK) Limited.

and the importation may increase the price of natural gas. But this is an acceptable trade-off for energy security given the considerable percentage share of natural gas in the energy mix; third, the swift resolution of the PECR process. In 2014, there was a PECR for coal, petroleum, and natural gas. Yet, until now, the contracts have not yet been approved and awarded. The PECR process, if another one will be issued for natural gas, has to be fast tracked.[51]

Additionally, reducing overdependence on one energy source increases the flexibility to take advantage of rapid RE developments. Increasing both conventional and emerging RE can be done through the full implementation of policies in the RE Act, which include net metering, FIT, renewable portfolio standards, and the green energy option. Also, incentives and government assistance for development and construction of conventional RE can be provided.

To increase RE share, the RE Act must be fully implemented.

Net metering and FIT have already been rolled out, and not without arising difficulties and/or opposition. Enrollees in the net metering program are expected to increase[52] because of the lower cost of solar photovoltaic (PV) systems. This will also increase the share of solar power in the energy mix. Yet, an expanding net metering market brings into fore questions on the effect on a DU's long-term demand and supply planning as well as the regulation of leased solar PV systems.

FIT is a good tool to develop RE because of the reduction in the risks faced by investors.[53] It is also found to be more cost efficient because it produces a smaller gap between the cost of generation and the support received for RE.[54] In the country, FIT is an adequate instrument to develop emerging RE (solar, wind, ROR, biomass) but not conventional RE because only the former is entitled to the FIT. Although the share of emerging RE in the energy mix has increased, it is still minimal at 1.52%. This is not expected to increase significantly even with the increase in the

Staying Flexible to Address the Duck-Curve

The cost of renewable energy, particularly solar power is rapidly decreasing. In 1977, solar prices were at $ 76.77/watt and in 2016 it is down to $0.35cents/watt, representing a reduction of 99.5%, likely to be reduced by another 40-50% in the next 2 years.

That being said, solar and wind power have its limitations, requiring the Philippine energy mix to be more flexible.

As solar and wind power continue to penetrate the country's mix (e.g. in 2013, solar generation capacity was estimated at 25MW, in 2016, 1,000MW), there will be a heightened "duck curve" problem. The "duck curve" happens when large shares of solar and wind during the day create ramping problems in the late afternoon (when demand goes up, but the sun goes down). This is a phenomenon currently affecting high-solar power regions such as California, Hawaii, Phoenix, Germany and Spain, and to an extent Negros Occidental in the Philippines.

In California there was a time the grid required 14,000MW in 90 minutes between 4:30-6:00 pm due to poor outputs from solar as a result of cloud cover. Coal was unable to address the demand as starting the plants took time, and heating the boilers too fast risked damaging equipment. Natural gas and hydropower plants, however, were more suited to fulfill this as more flexible mid merit or peaking plants that can quickly respond to dispatch requirements.

Source: http://www.bloomberg.com/news/articles/2015-10-21/california-s-duck-curve-is-about-to-jolt-the-electricity-grid
http://www.bworldonline.com/content.php?section=Economy&title=new-ways-of-allocating-solar-power-quotas-being-studied&id=124076
http://www.greentechmedia.com/articles/read/10-ways-to-solve-the-renewable-duck-curve

[51] Presentation by Ma. Laura L. Saguin, DOE Natural Gas Management Division, Oil Industry Management Bureau entitled "Natural Gas Infrastructure Development" Presented on 23 February 2015.

[52] As of 16 May 2016, Meralco had 392 enrollees in its Net Metering program with rooftop installations at an average capacity of 4 kWs. Rivera, D. 25 June 2016. "More Meralco customers shift to net metering" The Philippines Star. Accessed from http://www.philstar.com/business/2016/06/25/1596294/more-meralco-customers-shift-net-metering on 21 July 2016.

[53] *Id.*

[54] Dong, CC. Feed-in tariff vs. renewable portfolio standard: An empirical test of their relative effectiveness in promoting wind capacity development. Energy Policy 42 (2012) 476-485.

installation targets because of the lower capacity factors of solar and wind, the two most subscribed emerging RE technology. If emerging RE is targeted to have a higher contribution to the energy mix, tailored fit policies for ROR and biomass (which both have higher capacity factors than solar and wind) should be created. One such policy is to provide support to ROR and biomass investors as they locate and build their respective plants. For biomass, in particular, local sources of feedstock must be identified. Another option is to increase the FIT for ROR and biomass (while the FIT for solar is decreasing) in order to offset the long gestation period for ROR and difficulty in sourcing feedstock for biomass.

RPS, unlike net metering and FIT, has only been in the developmental stages. The merits of RPS are: it ensures that existing RE capacities are incentivized to continue producing power, it encourages competition among different RE because any kind of technology can meet the required quota,[55] it produces the least cost (if externalities are accounted for),[56] and if combined with efficiency measures and emissions cap would add significant RE generation and would pave the way for the fulfillment of emission cap levels.[57] A draft circular on the RPS was issued last June 2016. It declared a national energy mix with at least 35% RE by 2030, and a minimum annual increment of 2.15% to be applied to the actual total supply portfolio of mandated participants in the previous year. The numerical figures in the draft circular are updated with 2014 data, and with the price of solar exponentially going down and the price of other RE sources rapidly decreasing, it is important to effect the RPS into policy and implement it as mandated by the RE Law. Following this, guidelines on the RPS mechanism including the institution of the RE registrar, the trading of RE certificates and the establishment of the RE / green energy market should be properly developed.

The green energy option is also still being developed. Consumers will have the choice of sourcing a certain percentage of their consumption portfolio from RE sources. There are no proposed rules on this yet but this can be done by (1) providing incentives for households who exercise the green energy option, and (2) undertaking an information and education campaign on the benefits of availing of the program. This is for DUs to implement since (1) they can survey and then calculate how much of the total MW demand they cater to would want to exercise the green energy option, and (2) they can procure the amount of RE sourced power based on this demand. Just like the RPS, the green energy option encourages competition among different RE technologies because any kind of technology can meet the demand of consumers.

Despite all these, there is no incentive specifically for conventional RE which make up the bulk of the total RE share in the energy mix. **The government can give incentives and assistance for the development and construction of hydropower and geothermal power plants to increase the share of these indigenous RE sources in the energy mix.** Examples of these incentives and assistance include (1) reimbursements for exploration costs which can be absorbed by government, (2) one-stop shop for permits and all necessary paperwork, (3) government support when exploring and/or building in a protected area or an ancestral domain, (4) mechanisms for properly pricing hydropower and geothermal power taking into account the unique cost structure of each industry, and even (5) feed-in-tariffs for new hydropower and geothermal power.

Nuclear power can be explored as a new resource in the energy mix since it is reliable and efficient, and can counter the intermittency of variable RE. However, there is a high set-up cost and long-term skill base required for nuclear plants, while special precautions must also be undertaken to avoid any radioactive leaks and/or accidents.

Nuclear energy is a resource that recently came to the table since the mothballing of the Bataan nuclear plant in 1986. It has the lowest impact on the environment, and is commended for being reliable, efficient, and cheap since the cost of uranium is quite low.[58] Nuclear power can also counter the intermittency of variable RE because of its fast ramping rate.[59] The problem lies with the high set-up cost and extremely specialized training needed to run a nuclear plant as well as manage the risk of radioactive leaks and waste. There is also the question of where to source uranium.[60] The use of nuclear energy as a new resource in the energy mix can be further explored.

[55] Dong, CC. Feed-in tariff vs. renewable portfolio standard: An empirical test of their relative effectiveness in promoting wind capacity development. Energy Policy 42 (2012) 476-485.
[56] *Id.*
[57] Bird, et. al. Evaluating Renewable Portfolio Standards and Carbon Cap Scenarios in the U.S. Electric Sector. Technical Report NREL/TP-6A2-488258 May 2010. National Renewable Energy Laboratory.
[58] Accessed from http-//www.conserve-energy-future.com/Advantages_NuclearEnergy.php on 19 September 2016.
[59] Accessed from http-//energyinformative.org/nuclear-energy-pros-and-cons/ on 19 September 2016.
[60] Accessed from http-//www.conserve-energy-future.com/Advantages_NuclearEnergy.php on 19 September 2016.

All of these set the stage towards achieving a quality, reliable, affordable, and more sustainable energy mix which can be easily adjusted to meet innovations in technology, and even unexpected changes in economic growth and population. It is the responsibility of the government to provide these aforementioned policy directions as it works with the market (contrary to the view of letting the market decide) in order to attain a high-income economy, and energy security, equity, and sustainability.

Diversification by minimizing dependence on one external resource and maximizing other energy resources sets the stage towards achieving a secure (quality and reliable), equitable (affordable) and sustainable energy mix. Diversification brings about flexibility in the energy mix, which is crucial given innovations in technology and even changes in economic growth policies amidst a growing population. **Contrary to the view of letting the market decide, the earlier mentioned action steps clearly demonstrate that it is government's responsibility to set the policy direction towards diversification as it works with the market. This is crucial in order to attain a high-income economy, and energy security, equity, and sustainability in the long term.**

Getting Our Act Together Action Steps

Policy Recommendation	Policy Instrument
Set a cap on coal plant endorsements based on a regional energy plan	Executive Order OR a Joint Department Order possibly between DOE, DTI, NEDA calling for the creation of a comprehensive portfolio based regional energy plan (taking into account present and future energy and transmission needs). Creation of a comprehensive portfolio based regional plan Department Circular mandating a cap on coal plant endorsements using a portfolio based approach (in the short term) and the comprehensive portfolio based regional plan (in the long term) ERC Resolution reiterating/complementing DOE Department Circular mandating a cap on coal plant endorsements
Create a gold standard for coal plants	Executive Order directing a gold standard be applied for both old and new coal plants in the Philippines in the interest of public health and safety Department Circular implementing the gold standard, mandating additional guidelines for the review of ECCs of existing coal plants and the endorsement of new coal plants in that only ultra-supercritical plants or better can be built ERC Resolution reiterating/complementing DOE Department Circular mandating a gold standard Implementation of Sections 13 and 19 of the Clean Air Act through a DENR Circular.

Policy Recommendation	Policy Instrument
Compliance with BOI criteria	Issuance of a Memorandum Circular emphasizing need to enforce XII of Memorandum Circular 2015-01 and specifying guidelines for its implementation. The guidelines should require the submission of an environmental compliance certificate and other measures which support environmental protection and conservation such as but are not limited to equipment and processes that meet environmental standards. Review of the Investment Priorities Plan to ensure fiscal incentives given to investors take into consideration environmental requirements.
Formulation of a comprehensive natural gas policy and legislative framework to attract private sector investment	Executive Order OR a Joint Department Order possibly between DOE and NEDA calling for the creation a comprehensive natural gas policy and legislative framework to attract private sector investment Creation of a comprehensive natural gas policy and legislative framework Passage into law of Natural Gas Bill
Support for the construction of natural gas infrastructure	Amendment of Department Circular No. 2002-08-005 "Interim Rules and Regulations Governing the Transmission, Distribution and Supply of Natural Gas" streamlining the processing of applications for permit for the construction, expansion, operation, maintenance and modification of pipelines, transmission and distribution related facilities for the supply of natural gas Department Order mandating all concerned personnel involved in the processing of applications for permit for the construction, expansion, operation, maintenance and modification and distribution related facilities for the supply of natural gas to prioritize and fast-track the applications.
Exploration, development, and production of indigenous natural gas	Department Circular for the 6th Philippine Energy Contracting Round for Natural Gas and providing a specific timeline for it Department Order directing concerned officials and employees to fast-track all Philippine Energy Contracting Rounds

Policy Recommendation	Policy Instrument
Full implementation of policies in the RE Act	Department Circular implementing the Renewable Portfolio Standards Department Circular instituting the Green Energy Registrar (PEMC) and creating the Green Energy Market PEMC Rules and Guidelines on the Green Energy Market Department Circular implementing the Green Energy Option
Incentives and government assistance in the development and construction of conventional RE	Executive Order calling for all concerned agencies to streamline and fast-track all registration, regulatory, and other requirements for hydro and geothermal power projects. Joint Department Circular between all concerned agencies to streamline and fast-track all registration, regulatory, and other requirements for hydro and geothermal power projects. Amendment of the Renewable Energy Act specifically Sec. 7 so that the feed-in-tariff system will be applicable to new hydropower and geothermal power.

Annex

Table 1. Supply Expansion Outlook 2015 – 2030 (High GDP Scenario)

Year	Luzon			Visayas			Mindanao			Total
	Peaking	MidMerit	Baseload	Peaking	MidMerit	Baseload	Peaking	MidMerit	Baseload	
2015	0	0	0	0	300	0	0	200	0	500
2016	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	100	0	0	0	0	100
2019	0	0	0	0	100	82	0	0	0	182
2020	0	0	0	0	0	164	0	0	0	164
2021	50	200	0	0	0	82	0	0	0	332
2022	50	600	0	0	100	82	0	0	0	832
2023	150	500	0	0	0	164	0	100	0	914
2024	200	500	0	0	100	82	0	200	0	1,082
2025	50	500	135	0	0	164	0	100	105	1,054
2026	150	100	540	0	100	164	0	100	105	1,259
2027	200	200	405	50	0	164	0	100	210	1,329
2028	150	0	675	0	100	164	0	0	210	1,054
2029	250	200	540	50	100	164	0	100	210	1,614
2030	150	300	540	50	0	246	150	0	210	1,646
Total	1,400	3,100	2,835	150	1,000	1,722	150	900	1,050	12,307

Source: Department of Energy (2016)

Table 2. Social Costs of Electricity Generation (2010 USD/MWh)

	Coal		Natural Gas	Wind	Solar	Biomass
	Pulverized Coal	Integrated Gasification Combined Cycle				
Explicit Costs	USD 41	USD 77	USD 53	USD 70	USD 154	USD 78
External Costs	USD 58	USD 57	USD 30	USD 2	USD 6	USD 11
Total	USD 99	USD 134	USD 83	USD 72	USD 160	USD 88

Source: Grausz (2011)

Table 3. Percentage Share Per Fuel of Actual and Committed Installed Capacities (as of September 2015)

Fuel Type	Actual Installed Capacity (MW)	% Share	Committed Installed Capacity (MW)	% Share	Total Installed Capacity	% Share
Coal	5893	31.5	5924.5	31.52	11817.5	31.52
Oil	3610	19.3	3629.3	19.31	7239.3	19.31
Natural Gas	2862	15.3	2877.3	15.31	5739.3	15.31
Geothermal	1917	10.3	1927.3	10.25	3844.3	10.25
Hydro	3600	19.3	3619.3	19.26	7219.3	19.26
Biomass	221	1.2	222.2	1.18	443.2	1.182
Solar	165	0.9	165.9	0.88	330.9	0.88
Wind	427	2.3	429.3	2.28	856.3	2.28
TOTAL	18,695	100%	18,795.1	100%	37,490.1	100%

Source: Department of Energy (2016)

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