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Natural gas and transitioning to renewable fuels: considerations from industrial policy

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The Philippines is committed under the Paris Agreement to reduce greenhouse gas emission (GHG). In formulating its intended national contribution program, the government is starting with the energy sector by reducing reliance on coal as the primary fuel in electricity production as it transitions to the use of renewable fuels, such as wind and solar. Given the relatively high cost of renewables at this point, the Philippines is envisioning natural gas (NG), whether imported or indigenous, as a substitute fuel for coal in the interim. Some aspects of recent industrial-policy approaches are considered to make this fuel substitution feasible.

JEL classification: Q4, O25
Keywords: natural gas, optimal investments, industrial policy, carbon tax

1. Introduction

What does a country like the Philippines need to do to transform its economy into a newly industrializing economy (NIE) like Taiwan and South Korea, which both started as largely agricultural? In the 1970s, both Taiwan and South Korea emerged as exporters of manufactured products on a global scale, and today are considered models of successful industrialization. The Philippines, like many developing economies, faces the development problem of transforming its economy into one whose GDP emanates largely from industry and services, while further reducing the share of agriculture therein. What does the Philippines need to do to achieve the status of Taiwan and South Korea? Is there any government intervention that can accelerate the country's transformation into an industrializing economy? In this context, we look at the applicability of some industrial-policy approaches that have been proposed by a long line of economic thinkers.

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In this paper, these issues are examined in the context of the country's decision to accede to the Paris Agreement (PA).[1] As a starting point to reduce greenhouse gas (GHG) emission in the energy sector, the Philippine Development Plan (PDP), seeks to reduce reliance on coal as the main fuel source in electricity power generation and to shift to renewable fuels, including wind and solar. Given the relatively high cost of renewables at this juncture, the PDP envisions substituting natural gas (NG) for coal as an interim measure. Although NG is also a fossil fuel, it has a lower GHG index than coal.

Moreover, NG is a sufficiently large sector wherein one or a few firms can meet total demand. Rules of competition do not apply. And so, the NG industry is viewed from the lens of imperfect competition that is subject to government regulation. The regulatory framework must be carefully designed to raise the likelihood of realizing non-trivial economies, such as, realization of scale economies in the NG industry and in other sectors that have strong complementarities with it.

In the transition to renewables and in line with the long-run targets of the PA, the Philippines and other developing countries that are currently heavily reliant on coal and imported oil for generating electricity are looking at NG as a substitute energy source in the interim period. NG is also a nonrenewable fossil fuel, but it is less polluting than coal and oil. A large number of existing power plants at this point are coal-fired. The fuel mix can change if NG can be made cost-competitive against coal with appropriate fiscal policies, such as, relying on a carbon tax or a cap-and-trade regulation. In addition, investment incentives typically extended under an industrial-policy program of the government may also help. The use of NG as a substitute over a reasonably long period of time opens a window of opportunity for renewables to achieve technological innovations that result in competitive prices.

We support the smooth transition to renewables using NG as a substitute fossil fuel for electricity in the interim for several reasons. First, it is in the service of promoting an international public good, being climate-change mitigating in generating electricity. Second, it is an opportunity to put in place an industrial policy that promotes broad-based economic growth in the long run, namely, the development of a Philippine Upstream Indigenous Natural Gas Industry (PUINGI). Third, the development of PUINGI will enhance energy security in the face of volatile international markets.

The study is organized as follows. Section 2 revisits aspects of industrial policy that justify possible government interventions geared to accelerating the desired growth and industrial transformation. Selected formal models of growth and industrialization are presented. Section 3 presents a screening curve-load duration curve analysis and presents some scenarios that render NG power plants cost competitive relative to coal-fired plants. It looks at the experience of the

[1] The PA is a binding international treaty on climate-change mitigation. It was signed by 196 countries (COP 21) in 2015 and entered into force in 2016. The Philippines acceded to the agreement in 2017.

Philippines with the Malampaya gas-to-power project (MGPP) and uses it as an industrial-policy platform for an indigenous NG industry as the energy sector transitions to renewable fuels in an emission-constrained environment. Section 4 elaborates on an industrial policy for developing an indigenous natural gas. Section 5 summarizes and concludes.

2. Considerations from industrial policy

Pathways to industrialization have been proposed by a long line of economic thinkers using tractable models of growth. One prominent model is that of a dual economy wherein a modern sector, manufacturing, coexists with a traditional sector, agriculture. The development task is to reduce reliance on agriculture for output and employment, and increase, instead, the GDP shares of manufacturing, accompanied by rising productivity and improvements in living standards of households.

2.1. Development of a dual economy

The development problem that many countries in East and Southeast Asia faced after World War II was to transform their economies from one largely agricultural into one that could be considered industrializing. The task has been referred to as developing a dual economy (see, e.g., Jorgenson [1961]). The task entails raising agricultural productivity and ensuring that the non-agricultural sector, namely industry and services, grows at a sufficiently rapid pace to be able to absorb labor rendered in excess in agriculture. The most dynamic subsector in industry is manufacturing but labor absorption therein of surplus agricultural labor is not automatic. It calls for skill acquisition suitable for manufacturing and job creation in manufacturing. The government has a role in both the labor supply and demand sides, generally regarded as part of industrial policy. Neoclassical models of the labor market identify limitations of the labor market that call for collective actions that the government is in a better position to deliver. If, for instance, information is asymmetric, that is, both limited and unequally distributed, rendering job search and job matching lengthy and costly, the government may intervene by improving information dissemination conducive to expediting job mobility and matching. In this regard, we often see the public sector, whether at the national or local level, intervening by setting up a labor-market information system, Moreover, in most monsoon economies like the Philippines, the skills used in agriculture are rarely usable in manufacturing without some retraining (see, e.g., Oshima [1987]). Such retraining may be sponsored by the government.

2.2. Big-push industrialization

To speed up growth of the non-agricultural sector and to accelerate labor absorption, the government is often called upon to identify and promote sectors with production technologies that feature learning-by-doing and increasing returns. The latter occurs when investment by one firm creates knowledge that other firms then imbibe. As other firms invest, they create output at no extra cost in knowledge acquisition, resulting in increasing returns. Promotion of sectors may be limited to one sector but known to have strong complementarities with other sectors. We use this approach in this paper in focusing on the development of the NG industry. The latter is a vital part of the country's infrastructure system and can be counted on to affect the growth of complementary sectors.

Big-push industrialization is closely related to endogenous-growth theory.[2] The latter set of formal models advance the neoclassical Solow-Swan growth model by focusing on the role of increasing returns, human capital investments, and technological progress that overcome diminishing marginal productivity of capital per labor. All this can be integrated into a comprehensive set of industrial policies that are geared to achieving restructuring, coordination, innovation, and a diverse product space.[3]

3. Indigenous NG in the fuel mix

In terms of carbon dioxide (CO_2) emission, NG is lower compared to other fossil fuels. And yet, many countries are still wedded to the latter, particularly in electricity generation. The main reason is that coal-fired power plants, for instance, are said to be least cost if run as a baseload. In reaching this conclusion, the cost of GHG emission is not taken into consideration.

Employing a down-to-earth cost-benefit analysis on NG power plants, whereby we net away from the direct cost of climate-change mitigation the benefits in the form of avoided-cost damages of climate-change policies, we find that NG power plants are cost competitive versus coal-fired power plants.

Recent estimates show that power plants using sub-bituminous coal emit 0.98 metric tons (MT) of CO_2 per Megawatt-hour (MWH) while combined-cycle NG power plants emit only 0.44 metric tons of CO_2 per MWH (MTCO2/MWH) (see, e.g., EIA [2017a]; Cushman-Roisin and Cremonini [2018]). Moreover, coal-fired power plants emit more than 500 times more sulfur dioxide (SO_2) and more than ten times of nitrogen oxide (NOx) than combined-cycle NG power plants (see, e.g., De Gouw [2014]). These pollutants not only harm the environment, but also cause serious respiratory health problems. Table 1 presents the estimated monetary cost of all damages emanating from local pollutants emitted by different types of power plants. The SO_2 damage from coal-fired power plants is the highest, insofar as this induces respiratory problems, including, coughing, wheezing, shortness of breath, or a tightness around the chest. Damages from Combined Cycle Gas Turbine (CCGT) NG plant emissions are lower than either coal or diesel plants in order of magnitude.

[2] See, for example, Murphy et al. [1989]; Romer [1986]; Lucas [1988].

[3] For an expository approach, see, for example, Rodrik [2004] and Juhász et al. [2023].

TABLE 1. Marginal damage costs of local pollutants per generation technology (in USD per MWH)

Generation technology	SO_2	NOx	PM2.5
Coal	14.76	1.05	1.79
CCGT	0.02	0.082	0.008
Diesel	1.16	4.06	0.12

Source: Jandoc et al. [2018].

Moreover, compared to coal-fired power plants, NG power plants are more flexible. Depending on the technology used, gas turbine plants can reach full load from 30 minutes to four hours after start-up, whereas coal-fired power plants take days to reach full load after a cold start (Table 2). In the current Philippine setting, NG power plants are suitable for baseload as well as mid-merit and peaking operations.

TABLE 2. Time it takes for a power plant by type to reach full load

Type	Start- up time	Start-up cost (USD/MW)	Efficiency (at 100 percent load)	Minimum uptime	Minimum downtime
Open Gas Cycle Turbine (OCGT)	5-11 hours	<1-70	35-39 percent	10-30 min	30-60 mins
Combined Cycle Gas Turbine (CCGT)	1-4 hours	55	52-57 percent	4 hours	2 hours
Coal	2-10 hours	>100	43 percent	48 hours	48 hours

Source: IRENA [2019]

In this section, we outline various scenarios to determine the level of new investment needed in natural gas (NG) power plants to reach an optimal energy mix by 2040. This assessment considers existing capacities and includes committed projects scheduled for completion. To establish the ideal generation mix for 2040, we apply the model by Jandoc et al. [2018], analyzing "screening curves" along with a linear "load duration curve." This example focuses on the Luzon grid.

The "load duration curve" offers a simplified representation of electricity demand over a specific year. For this analysis, we used hourly load data from the National Grid Corporation of the Philippines (NGCP) for Luzon, spanning October 1, 2016 to September 30, 2017. Peak demand occurred on May 19, 2017 at 2:00 PM, reaching 10,033 megawatts (MW), while the lowest demand was recorded on January 2, 2017 at 4:00 AM with 4,077 MW. Using these hourly patterns, we then projected demand to meet the Department of Energy's (DOE) forecast for Luzon in 2040.

Luzon's projected electricity demand in 2040 amounts to 30,000 MW. We then net out the projected generation from renewable sources (geothermal, hydro, biomass, wind, and solar).[4] To account for total supply needed in 2040, we assumed a 15 percent adjustment for reserves,[5] and nine percent adjustment for line losses.[6] The total amount that needs to be supplied in 2040 after making these adjustments is 34,617.41 MW. To take account of current infrastructure in place, we further net out the dependable and committed capacities of existing power plants. According to the DOE, dependable (including committed) capacity of diesel is 608.6 MW; CCGT power plants can satisfy 3,914.64 MW; and coal-fired power plants can satisfy 8,342.47 MW.[7] Since existing capacity coming from these three plant-types can only satisfy 12,865.71 MW, the remaining 21,751.7 MW need to be satisfied by dependable capacities coming from new power plants.[8]

The "screening curves", on the other hand, are simplified representations of the cost to generate electricity from the different sources; in our case, coal-fired power plants and CCGT power plants. The screening curves have a fixed-cost component and a variable-cost component. The fixed-cost component consists of the annualized overnight construction cost plus the annual fixed operating and maintenance (O&M) costs. The overnight construction cost refers to the cost of all material, labor, and fuel, among other inputs, needed to construct the facility if that cost were incurred at a single point in time; it ignores financing costs (i.e., interest rates) as though the generating facility is built overnight. The levelized costs include the capital costs, O&M costs (including replacement of capital items as a result of wear and tear), and fuel costs. While capital and fixed O&M costs are proportional to the installed capacity, variable O&M and fuel costs are functions of electricity output. Table 3 presents the different fixed-cost and variable-cost components of the screening curve.[9] Table 3 shows the tradeoff inherent in the different technologies. For instance, the fixed-cost component in the second column shows that it would be more expensive to build new coal-fired power plants compared to CCGT or diesel power plants. However, the variable cost in the third column indicates that although it is more expensive to build coal-fired power plants, the cost per unit of producing electricity is lowest for them once the plant has been constructed.

[4] Although the recent Philippine Energy Plan 2023-2025 projects 1,200 MW of new nuclear capacity for 2032, we ignore this generation source for several reasons. First, there are still political economy considerations that work against nuclear generation. Second, Van Kooten et al. [2013] find that in the absence of a sufficiently high carbon tax (around USD 150/$MTCO_2$), fossil fuels dominate nuclear generation.
[5] A reserve margin of 15 percent implies that the system has 15 percent excess capacity over expected peak demand.
[6] Electric power transmission and distribution losses (percent output) for the Philippines is nine percent as of 2014 [World Bank 2014].
[7] We assume that diesel plants have a comparative advantage to satisfy peak loads over CCGT fired power plants. (see, e.g., Papaefthymiou et al. [2014]).
[8] Further details regarding the construction of the load duration curve can be found in Jandoc et al. [2018].
[9] For more information on the assumptions on the screening curve, refer to Jandoc et al. [2018].

TABLE 3. Fixed-cost and variable-cost of the screening curve equations

Generation technology	SO_2	Fixed Costs (USD/MW per year) Variable Unit Cost (USD/MWH)
Coal	185,000	34.86
CCGT	5,900	84.42
Diesel	1,028	96.17

Note: Fixed cost for new investments includes both fixed O&M and overnight construction costs. Variable unit cost is fuel cost plus variable O&M costs.
Source: Jandoc et al. [2018].

In this section, we compare three scenarios: First, we look at a business-as-usual scenario where a PUINGI is not developed but the Philippines invests in Liquified Natural Gas (LNG) import hubs and regasification facilities aimed at avoiding the NG power plants from becoming stranded assets. Second, we present a scenario where the NG plant operators enjoy a price discount from the operation of a newly operational PUINGI source, to reflect a scenario similar to the operation of Malampaya. The difference in Malampaya price and the world price for NG is substantial; for instance, the estimated Ilijan gas price is USD 6.616 per gigajoule, compared to the prevailing LNG price of USD 9.47 per gigajoule in the Asian market.[10] The final scenario examines the effect of complementary policies, such as a carbon tax, that will make energy obtained from a less polluting source like NG more attractive.

3.1. Scenario 1: NG with no price advantage

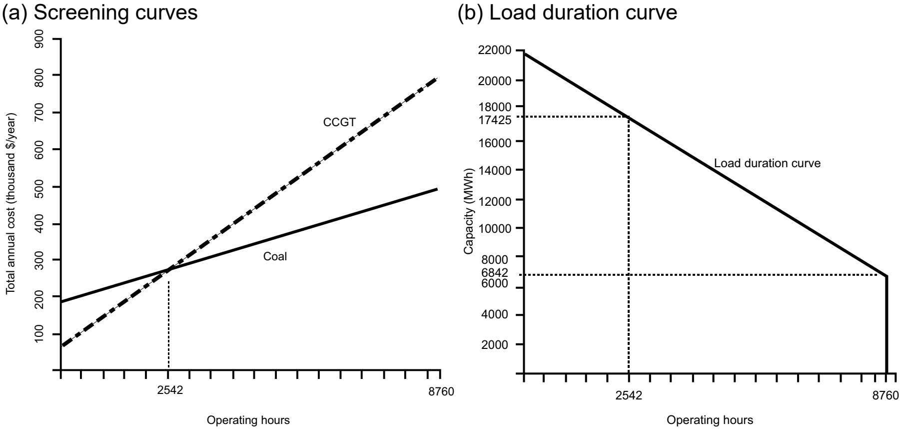
In this scenario we examine the case wherein there are no further developments in PUINGI. However, we consider the more likely alternative of investing in LNG terminals with regasification facilities that will allow imports of LNG. This is to avoid the NG assets from being stranded. However, relying on imports precludes the price advantage offered by using indigenous NG. This will serve as the base scenario against those in the next subsection where PUINGI is developed and where complementary policies are enacted.

Panel (b) in Figure 1 shows the duration curve for the excess load that cannot be satisfied by existing generation capacities of coal, CCGT, and diesel power plants.[11] The load duration curve starts from the hour of the highest demand, with load at 21,751 MW, and slopes downward to the hour of the lowest demand, with load at 6,842 MW.[12] The issue on optimal investment in new power plants is basically what type of plants will satisfy these loads at least cost. The answer may be seen in Panel (a) of Figure 1, which presents the screening curves of the

[10] If we factor in the cost of regasification, the Malampaya gas price becomes even more cost competitive.
[11] According to DOE, there is currently no open-cycle gas turbine (OCGT) dependable capacity, even though OCGT plants exist in the country.
[12] Note that there are 8,760 hours in a non-leap year.

different power plant technologies. The line for coal is flatter than the line for CCGT power plants because the fixed cost is higher (as given by the y-intercept) but the variable cost or cost per unit of electricity produced is lower (as given by the flatter slope). The intersection between these two curves determines where the technologies "switch." In the figure, the first 2,542 hours with the highest demand will be supplied by CCGT power plants. In this segment, the line for CCGT power plants in the screening curve is below coal-fired power plants, which indicates that new CCGT power plants have a comparative advantage in satisfying the higher load hours. The rest of the hours are supplied by electricity generated new coal-fired power plants.

FIGURE 1. Least cost generating mix for residual capacity of Luzon grid for Scenario 1

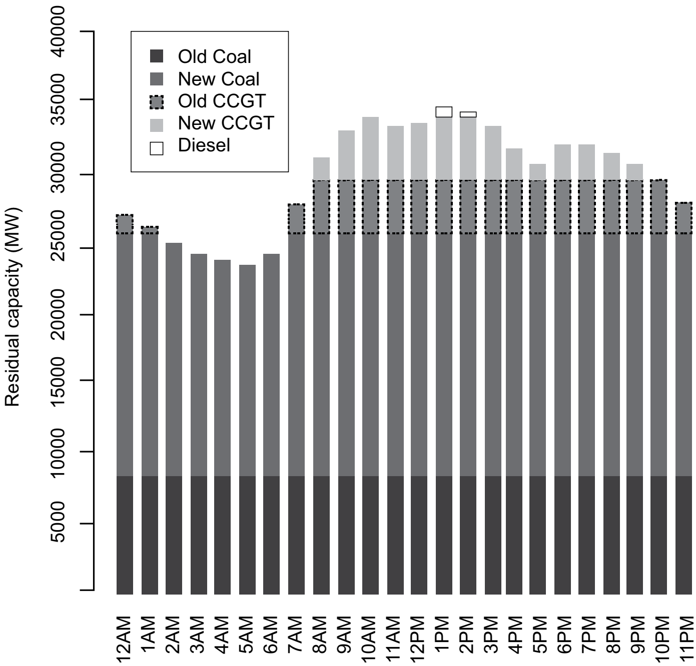


Note: Left panel shows the screening curves while the right panel the load duration curve net of current capacities.
Source: Authors' calculation based on DOE data.

Figure 2 shows the generation profile of the Luzon grid for a typical day, given existing capacities with the additional investments in coal-fired and CCGT power plants. Here, new coal-fired and CCGT power plants satisfy the load indicated by the dark gray and light gray bars. Diesel power plants satisfy the peaking loads given by the white bars. In this figure, new CCGT power plants are only used for the high demand hours from 8:00 AM to 9:00 PM. The other hours can be satisfied either with existing coal and NG power plants or with new coal-fired power plants.

Table 4 summarizes the dependable capacity of the different technologies. In this baseline scenario, the capacity from both new coal and NG power plants is more than double its existing capacity. In the next subsections, we shall compare this scenario to those where NG power plants become more attractive due to the price advantage afforded by the development of the PUINGI, and complementary policies, such as, a carbon tax designed to penalize pollution-intensive sources arising from the dictates of a low-carbon environment.

FIGURE 2. Generation profile for Luzon by 2040 (Scenario 1)



Source: Authors' calculation based on DOE data.

TABLE 4. Dependable capacity for existing and new plants, Scenario 1

Technology	Capacity (MW)
Coal	**25,767.5**
Existing	8,342.5
New	17,425.0
CCGT	**8,241.3**
Existing	3,914.6
New	4,326.7
Diesel	**608.6**
Total	**34,617.4**

Source: Authors' calculation.

Table 5 calculates the costs associated with the least-cost generating mix in Scenario 1. The cost of operating the grid will be USD 14.67 billion, of which 75 percent is accrued by coal-fired power plants.

TABLE 5. Cost of satisfying demand for Luzon grid in 2040 (Scenario 1)
Total Cost (Billion USD)

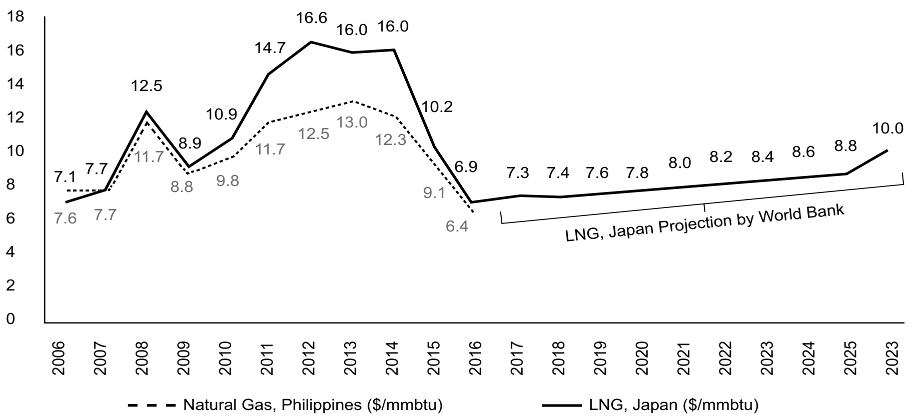
Generation Technology	Fixed	Variable	Total	Percent of Total Cost
Coal	3.24	7.77	11.01	75 percent
CCGT	0.49	3.14	3.63	25 percent
Diesel	0.0006	0.03	0.03	0 percent
TOTAL			14.67	100 percent

Source: Authors' calculation.

3.2. Scenario 2: NG with cost advantage due to PUINGI

We repeat the same exercise of constructing the load duration and screening curves as that in the previous section, but add the scenario where NG enjoys a price discount due to the operationalization of a PUINGI facility. In this subsection, we assume that NG from indigenous sources will cost 20 percent less than the (import) market. Our guide for this price differential is the reported difference between the Malampaya price and the world price of NG. As Figure 3 shows, the difference between NG prices is substantial, especially during episodes of rapidly increasing gas prices.[13]

FIGURE 3. Natural gas prices (USD per million BTU)



Source of basic data: DOE and World Bank.

The main effect of this premium is to flatten the slope of the screening curve. In Panel (a) of Figure 4, the result of this flattening is to increase the number of hours per year in which NG gas plants are used from 2,542 to 3,856 hours. Thus, investments in new NG power plants will displace investments in new coal-fired power plants. This is shown in Figure 5, where the bars associated with new coal-fired power plants shorten, and in their place, the bars from new NG power plants lengthen.

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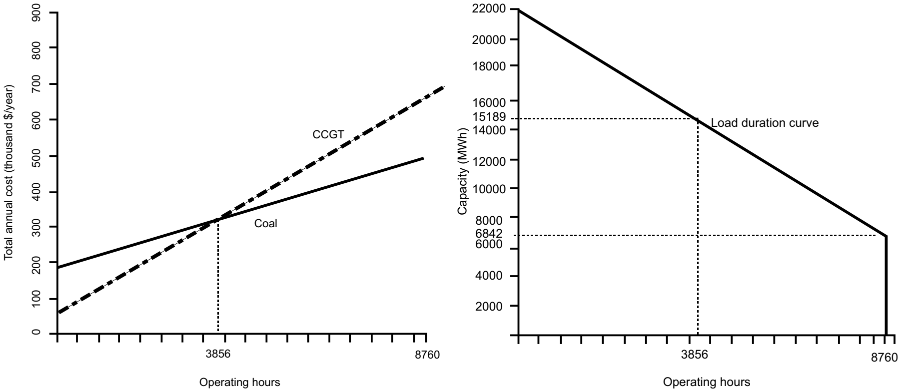
[13] According to EIA [2017b], LNG regasification costs add approximately USD 1.00/MMBTU to landed LNG.

The upshot: power generated from NG power plants will now be used throughout the day, displacing some of the power generated from coal-fired power plants for mid-merit generation.

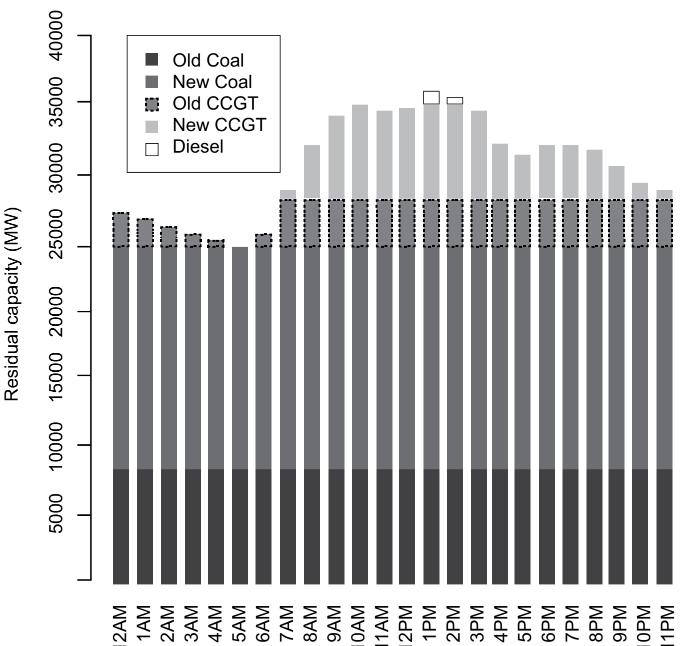
FIGURE 4. Least cost generating mix for residual capacity of Luzon grid for Scenario 2

(a) Screening curves (b) Load duration curve



Note: Left panel shows the screening curves while the right panel is the load duration curve net of current capacities.
Source: Authors' calculation based on DOE data.

FIGURE 5. Generation profile for Luzon by 2040 (Scenario 2)



Source: Authors' calculation based on DOE data.

Table 6 shows the dependable capacity of the different technologies in this scenario. With the price advantage afforded by PUINGI, there will be more than a 50 percent increase in dependable capacity from new NG power plants compared to the baseline scenario. On the other hand, there will be a nearly 13 percent decrease in dependable capacity from new coal-fired power plants.

TABLE 6. Dependable capacity for existing and new plants (Scenario 2)

Technology	Capacity (MW)
Coal	**23,531.5**
Existing	8,342.5
New	15,189.0
CCGT	**10,477.3**
Existing	3,914.6
New	6,562.7
Diesel	**608.6**
Total	**34,617.4**

Source: Authors' calculation.

TABLE 7. Cost of satisfying demand for Luzon grid in 2040 (Scenario 2) Total Cost (Billion USD)

Generation Technology	Fixed	Variable	Total	Percent of Total Cost
Coal	2.82	7.19	10.01	70 percent
CCGT	0.62	3.66	4.28	30 percent
Diesel	0.0006	0.03	0.03	0 percent
TOTAL			14.32	100 percent

Source: Authors' calculation.

Table 7 calculates the costs associated with the least-cost generating mix in Scenario 2. Compared to the baseline scenario, the cost of operating the grid is now cheaper in Scenario 2 with the price advantage afforded by PUINGI. This is due to less reliance on coal, and the associated drop in power generation cost by relying more on natural gas.

The final scenario considers a policy that will give further advantage to NG power plants. We focus on imposing a tax on the carbon content of polluting sources. This further gives advantage to NG power plants since, as mentioned earlier, the carbon emission of NG power plants is lower compared to coal-fired power plants.

There are several initiatives in Congress towards the imposition of a carbon tax. For instance, there is House Bill (HB) No. 4739 or the *Piso Para sa Kalikasan*

Act that would introduce a "climate tax" amounting to ₱1.00 per kilogram of CO_2 (or ₱1,000 per metric ton of CO_2) to discourage carbon emissions from electricity consumption. This proposed amount is roughly equivalent to USD 20 per metric ton (MT) of CO_2, which is substantially below recent calculations of the global social cost of carbon (SCC) estimated to be around USD 40 per $MTCO_2$ (see Feldstein et al. [2017]). In this scenario, we illustrate the effect on the optimal generation mix when damages from carbon emissions are corrected by imposing a carbon tax.

The main effect of a carbon tax works through the slope of the screening curves. The variable-cost component is affected by including the damage caused by carbon. In Table 8, we present what a USD 20 per $MTCO_2$ worth of damage translates to in terms of the tax imposed per technology.[14] The fourth column in this table shows that the damage from CCGT plants is substantially less than coal. When the tax is imposed, the unit cost differential between CCGT and NG power plants narrows from 93 percent to around 40 percent. This means that electricity generated by CCGT plants is cost competitive compared to coal with the imposition of a carbon tax.

TABLE 8. Fixed cost and variable cost of the screening curve equations

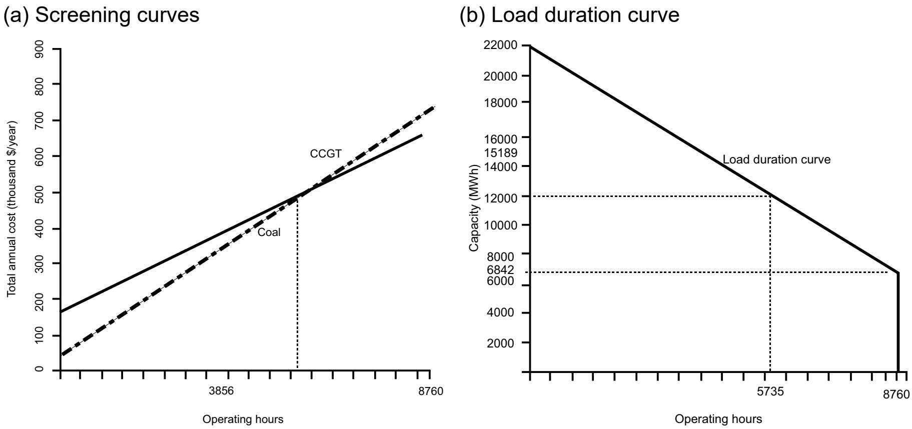
Generation Technology	Fixed Costs ($/MW per year)	Variable Unit Cost ($/MWH)	Carbon Cost ($/MWH)	Marginal Social Cost ($/MWH)
Coal	185,000	34.86	19.41	54.27
CCGT	5,900	67.54	8.71	76.25
Diesel	1,028	96.17	17.92	114.09

Note: Fixed cost for new investments includes both fixed O&M and overnight construction costs. Variable unit cost is fuel cost plus variable O&M costs. Carbon cost considers damages amounting to USD 20 per $MTCO_2$. Marginal social cost is the sum of the variable unit cost and the carbon cost.
Source: Authors' calculation.

In Figure 6, the effect of the carbon tax is to increase further the number of hours per year in which NG power plants are used. Compared to the baseline scenario, the number of hours of operationalizing the NG power plants more than doubles from 2,542 to 5,735 hours. As with Scenario 2, investments in new NG power plants will further displace investments in new coal-fired power plants, which is shown in Figure 7. In Figure 7, the bars associated with the new coal-fired power plants substantially shorten compared to the baseline scenario, with new NG power plants taking up the slack. The power generated from NG power plants will now be used even for off-peak hours, for instance from 12:00 midnight to 2:00 AM.

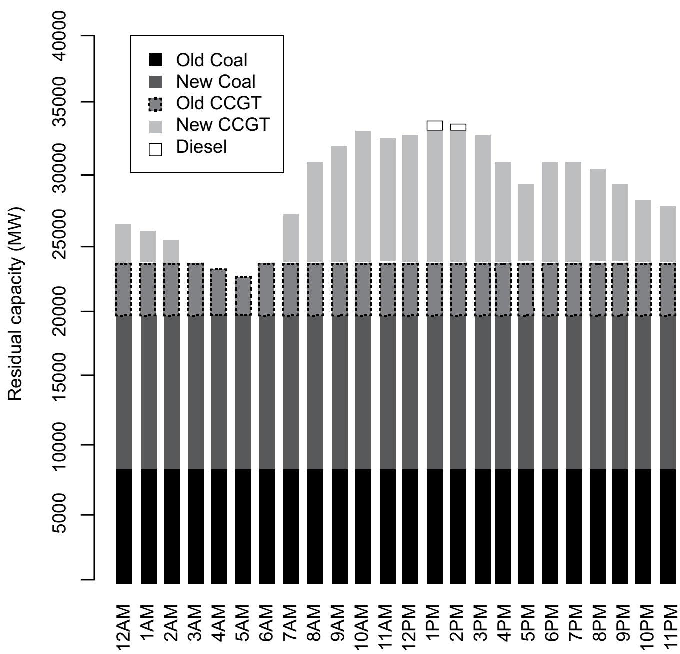
[14] For details, refer to Jandoc et al. [2018].

FIGURE 6. Least cost mix for residual capacity of Luzon grid (Scenario 3)



Note: Left panels are the screening curves while the right panel is the load duration curve net of current capacities.
Source: Authors' calculation based on DOE data.

FIGURE 7. Generation profile for Luzon by 2040 (Scenario 3)



Source: Authors' calculation.

Table 9 summarizes the dependable capacities generated from the three scenarios presented, as well as the total estimated carbon emissions. In Scenario 3, dependable capacity from coal-fired power plants shrinks by more than 20 percent compared to the baseline scenario, while dependable capacity for CCGT plants increases by 66 percent. Since power generated from NG power plants is "cleaner" than that from coal-fired power plants, total CO_2 emissions decrease, and the more price-attractive electricity generated from NG power plants is relative to coal-fired power plants. In Scenario 3, for instance, total CO_2 emissions decrease by almost 29 million MT, approximately a 13 percent drop compared to the baseline scenario.

TABLE 9. Dependable capacity and carbon emissions for existing and new plants

Technology	Capacity (MW)			Emitted CO_2 (in million MT)		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
Coal	**25,767.5**	**23,531.5**	**20,333.5**	**218.5**	**202.0**	**174.6**
Existing	8,342.5	8,342.5	8,342.5	71.6	71.6	71.6
New	17,425.0	15,189.0	11,991.0	146.9	130.4	102.9
CCGT	**8,241.3**	**10,477.3**	**13,675.3**	**16.4**	**21.9**	**31.5**
Existing	3,914.6	3,914.6	3,914.6	10.3	10.3	10.3
New	4,326.7	6,562.7	9,760.7	6.1	11.6	21.2
Diesel	**608.6**	**608.6**	**608.6**	**0.3**	**0.3**	**0.3**
Total	**34,617.4**	**34,617.4**	**34,617.4**	**235.2**	**224.2**	**206.4**

Source: Authors' calculation.

However, the reduction of carbon emissions in Scenario 3 will come at a higher cost of operations. As Table 10 shows, the cost of operating the grid increases to USD 20.06 billion, around 40 percent higher compared to the cost in Table 8. While this increased cost may translate to higher electricity prices for households or firms, this increased cost should be compared with the cost of alternative policies such as a feed-in tariff for renewables, which, as Ravago and Roumasset [2018] discussed, can also be quite substantial.

TABLE 10. Cost of satisfying demand for Luzon grid in 2040 (Scenario 3) Total Cost (Billion USD)

Generation Technology	Fixed	Variable	Carbon Tax	Total	Percent of Total Cost
Coal	3.02	7.48	4.16	14.66	73 percent
CCGT	0.56	4.35	0.45	5.36	27 percent
Diesel	0.0006	0.03	0.006	0.04	0 percent
TOTAL				20.06	100 percent

Source: Authors' calculation.

While ideally carbon taxes should reflect the true global social cost of carbon, there are those who argue that the optimal carbon tax should only address the "domestic social cost of carbon" [Gayer and Viscusi 2016]. This means that for a relatively small economy like the Philippines, the social cost of carbon should be lower. Table 11 presents a scenario where a lower carbon tax of USD 10/MTCO_2 is imposed. With a lower carbon tax, the cost of operating the grid is only USD 3.74 billion or 26 percent above the cost in Table 10. However, the reduction in CO_2 emissions will not be as drastic as that in Scenario 3.

TABLE 11. Cost of satisfying demand for Luzon grid in 2040 with a lower carbon tax (USD 10 per MT of CO_2)
Total Cost (Billion USD)

Generation Technology	Fixed	Variable	Carbon Tax	Total	Percent of Total Cost
Coal	3.15	7.65	2.13	12.93	72 percent
CCGT	0.52	4.06	0.21	4.79	27 percent
Diesel	0.0006	0.34	0.003	0.34	2 percent
TOTAL				18.06	100 percent

Source: Authors' calculation.

The optimal energy mix from these different scenarios shows the advantages of natural gas in terms of flexibility as a baseload or mid-merit source of power. As NG plant technology advances, future NG power plants may also be used during peak load. This will be crucial to address the intermittency problem of renewable power plants. Hence, power from natural gas plants complements the development of renewable energy technology. Clearly, NG plays a role in a diversified fuel mix that is both cleaner and cost-efficient. We showed in Scenario 2 that the price advantage afforded by developing the PUINGI can reduce the cost of meeting future demand in 2040. This is important to achieve DOE's goals of energy security and a low-carbon future.

4. An industrial policy for the PUINGI

In a dual economy that starts with a large agricultural sector, an industrial structure that describes many developing economies like the Philippines, the development problem is industrialization, which is commonly understood as transforming an economy from one that is largely agricultural into one that is considered industrializing in the sense of the four Asian miracles or newly industrializing economies (NIEs), namely: Singapore, Hong Kong, Taiwan, and South Korea (see Table 12).

Among the Southeast Asian countries in Table 12, the Philippines is at the bottom, trailing Indonesia, Thailand, and Malaysia. This underscores the importance of broadening the role of indigenous NG based on the growth experience from the MGPP. If the Philippines is to stand a chance of catching up with other middle-income countries in the list, its fuel mix must diversify with gas and renewables therein.

TABLE 12. Per capita income in East and Southeast Asia (in USD, PPP)

Economy	GDP Per capita
Malaysia	28,900
Thailand	17,800
Indonesia	12,400
Philippines	8,200
Singapore	90,500
Hong Kong	61,000
Taiwan	49,800
South Korea	39,400

Source: US Federal Government, Central Intelligence Agency, as reported in Wikipedia.org/List of Asian Countries by GDP (PPP); PPP stands for Purchasing Power Parity (Downloaded January 20, 2019).

Starting in the 1970s, the four NIEs emerged as exporters of manufactured products on an international scale. Today, these economies are considered models of successful industrialization (see Johnson [1967]; Lucas [1988]). For the Philippines, the experiences of Taiwan and South Korea are highly relevant since both economies started with large agricultural sectors and got transformed into NIEs. The output and employment shares of agriculture in both Taiwan and South Korea pale in comparison to the shares of industry and services.

The accepted strategy is to raise productivity in all sectors of the economy, whether agriculture or non-agriculture (e.g., industry and services). However, as productivity increases in agriculture, some farm workers are released; fewer farmers are needed to produce the food and other agricultural products that the economy requires. Hence, industry and services must grow at a sufficiently rapid rate to be able to create jobs that can gainfully absorb the workers released from agriculture. The problem is not quite solved yet in the Philippines: many unemployed and underemployed workers are in agriculture; meanwhile, most of the employed are trapped in low-wage, subsistence farm activities. As a result, the majority of individuals and families considered poor are in the rural agricultural sector.

The absorption of excess agricultural workers by the non-agricultural sector is not automatic. At the most basic level, such workers must be equipped with skills that enable them to master the advanced production techniques of the non-agricultural sector. They must also develop the industrial discipline that is markedly different from that called for by, say, crop production (see, e.g., Oshima [1987]). Even off-farm activities in the rural areas need to invest in skills for processing manufactured products. In addition, small agro-based food manufacturing needs adequate power to process raw materials from the farm, and farm-to-market roads to transport the surplus to be marketed in urban food markets.

In this context, transforming an agricultural economy has opened a debate about whether or not the Philippines should embrace an industrial policy (IP). By IP, following Rodrik [2004] and Harrison and Rodriguez-Clare [2010], we refer to a package of economic policies consisting of foreign-trade tariffs, subsidies, tax exemptions, and other fiscal and investment incentives that go beyond the theoretical conditions of optimal taxation for raising government revenues. To be sure, however, the Philippine government has since 1986 been embracing structural policy reforms that include import liberalization and tariff reduction.

The government has likewise privatized several formerly monopolistic government corporations, while rationalizing regulation of industries like power, petroleum, telecommunications, transport, and commercial banking. Following the end of martial law in the Philippines in 1986, the government dismantled the monopolistic marketing boards in sugar and coconut. The Philippine National Bank (PNB), a wholly owned government commercial bank that used to be the largest in terms of assets, was privatized. In addition, other major government corporations like the Philippine Long Distance Telecommunications Company (PLDT) and Petron, the largest refinery and distributor of refined petroleum products, were privatized. Then Electric Power Industry Reform Act of 2001 was enacted, ending the monopoly of National Power Corporation in power generation and transmission. In short, the government's policy reform program, though by no means complete at this point, has been moving toward policy neutrality, instead of adopting IP. How then do we justify an IP for PUINGI?

It's widely recognized that the growth of the NIEs, like Japan, relied heavily on government support. Industrial policy underpinned their industrialization (for a collection of varying perspectives on this matter, see Stiglitz and Yusuf [2001]). Export-led manufacturing, for instance, generally received some trade protection through tariffs and some investment incentives given to special economic zones (SEZs). The NIEs started by subcontracting the labor-intensive stages of manufacturing in enterprises located in SEZs and re-exporting their products to firms abroad. Being electricity intensive, the host governments made sure that they could get stable and affordable electricity prices.

In addition, we note that the Philippine government has shown receptivity to foreign direct investments (FDIs) in view of the advanced technologies and managerial techniques they carry. FDI entry into the Philippines has progressively been liberalized since 1991. In sectors where 100 percent foreign equity participation is not allowed, the lists of industries with equity restrictions are spelled out in the so-called Negative Lists A, B, and C. Over time, those lists are being trimmed down. In general, participation of foreigners in natural-resource development is limited by the Constitution. However, there is an exception for "large-scale exploration, development, and utilization of minerals, petroleum, and other mineral oils." Thus, it is possible for a foreign-owned corporation to be awarded a petroleum service contract under Presidential Decree (PD) 87. The special investment incentives that IP allows are quite material in this regard.

At the same time, the enterprises that FDI establishes are vehicles for learning-by-doing with knowledge spillovers to other sectors of the economy (see, e.g., Arrow [1962]), resulting in increasing returns). This may be termed soft industrial policy, to use a term of Harrison and Rodriguez-Clare [2010]. The benefits derived from FDI are the same forces responsible for long-run growth as emphasized in endogenous growth theory (see, e.g., Romer [1986]; Lucas [1988]). Romer [1986] and Lucas [1988], for instance, emphasize introduction of advanced technology, formation of a skilled workforce equipped with modern managerial techniques, learning-by-doing, and knowledge spillover effects to other sectors that yield increasing returns or scale economies. The act of investing yields knowledge that can be used in other sectors without diminution.

This study advocates a soft industrial policy in support of the PUINGI. Based on lessons learned from MGPP, we find profound benefits from developing the upstream natural-gas industry in the Philippines, specifically, technology innovation, formation of a scientific and technical manpower, and sector complementarity that facilitates learning-by-doing with knowledge spillovers, all of which heighten productivity, the building block of industrialization.

The Malampaya Fund, established from the MGPP, should be a feature of the soft industrial policy, to be earmarked for developing PUINGI. Indigenous NG serves the long-term objectives of the Philippine Energy Plan (PEP). A key consideration is to make use of the Fund binding across political administrations. A law to tie the hands of administrations in succession must back the Fund.

Furthermore, laws are also needed to bind future administrations to the commitments under the Paris Agreement on Climate Change (PACC) and ensure that the Philippines transits inexorably to sustainable and clean energy.

4.1. Sector complementarity and interdependence

In this section, we show some evidence bearing on the importance of MGPP as an input in the output of the various sectors of the economy. This is in the nature of further highlighting the microeconomic foundations of the macroeconomic growth that NG use from MGPP supported. The transmission mechanism stems from the use of MGPP gas to generate electricity, which in turn is used by all the other industries in the economy.

The gas-fired power plants using gas from MGPP generate up to 3,211 MW, a sizable share of the total electricity demand in Luzon, the island that accounts for at least 60 percent of the country's GDP. A look at the 2000 and 2006 Input-Output (I-O) Accounts of the Philippines released by the Philippine Statistics Authority [PSA 2006;2014] reveals the significance of electricity to other industry sub-sectors, in agriculture, industry, and services.[15]

[15] Ravago et al. [2021] discuss the potential of natural gas use beyond the power sector, more specifically in manufacturing sectors where natural gas has the potential to replace diesel in production processes that require heating.

I-O analysis uses a general-equilibrium approach to the empirical analysis of production in the economy. It takes account of the interdependence of the various industry sectors. Each sector uses outputs of the other sectors as (a) raw materials or intermediate inputs and as (b) primary inputs representing payments to factors of production like labor and capital. Table 13 shows the intermediate and primary input structures from the 11x11 industry classification of the Philippine economy in 2000 and 2006. We adopt the industry classifications in 2006.

TABLE 13. Sectoral intermediate and primary input structures, 2000 and 2006

Industry	Intermediate	Primary	Intermediate	Primary
1. Agriculture, Hunting, Forestry, and Fishing	0.2489	0.7511	0.3193	0.6807
2. Mining and Quarrying	0.3611	0.6389	0.3122	0.6878
3. Manufacturing	0.6087	0.3913	0.7247	0.2753
4. Construction	0.4632	0.5368	0.4396	0.5604
5. Electricity, Gas, and Water Supply	0.3070	0.6930	0.3202	0.6798
6. Transport, Storage, and Communication	0.4580	0.5420	0.4460	0.5540
7. Trade and Repair of Motor Vehicles, Motorcycles, Personal and Household Goods	0.3382	0.6618	0.3238	0.6762
8. Financial Intermediation	0.3443	0.6557	0.3071	0.6929
9. Real Estate, Renting, and Business Activities	0.1050	0.8950	0.2601	0.7399
10. Public Administration and Defense; Compulsory Social Security	0.2768	0.7232	0.3224	0.6776
11. Other Services	0.4668	0.5332	0.4154	0.5846

Source: PSA [2006;2014].
Note: The industry classification follows the 2006 industry nomenclature.

Focusing on industry structure no. 5 (electricity, gas and water supply), we note that its output as an intermediate input to the other industries increased from 0.3070 to 0. 3202. MGPP started its operations only in 2001. In 2000, the nomenclature for industry structure no. 5 in the I-O accounts was "electricity, steam, and water", as gas was not yet in the fuel mix. This is to be expected in the course of industrialization. To enhance productivity, all sectors of the economy, including agriculture, begin to mechanize and automate, thereby becoming intensive in the use of electricity.

4.2. Sector shocks and business fluctuations

Economic growth is never smooth across time. Business fluctuations, consisting of upturns and downturns, intervene every now and then. We have seen that energy-price shocks have triggered undesirable economy-wide downturns in the Philippines. For example, the deepest recession in the post-World War II history of the Philippines was the 1984-1985 recession. The latter can be traced to the two oil-price shocks in the latter half of the 1970s.

To ward off the expected downturns from the 1974 and 1975 oil-price shocks, the fiscal and monetary authorities of the government engineered expansionary fiscal and monetary policies, which resulted in large and chronic deficits in the national government budget. To finance the budget deficits, the government resorted to heavy foreign borrowing, thereby swelling the public debt.

When interest rates increased worldwide in 1981, the government faced serious difficulties in servicing its debt. In 1983, the debt servicing became unsustainable, forcing the government to default on its foreign debts. The subsequent tightening of fiscal and monetary policies under an International Monetary Fund (IMF) standby credit arrangement eventually led to the recession of 1984-1985.

The oil-price shocks of the 1970s forced cabinet secretaries in charge of energy policy to start a program lessening dependence on imported crude oil. In 2001, NG from the MGPP got into the fuel mix. In addition, Congress legislated the 2008 Renewable Energy Act, bringing in wind and solar energy into the mix.

Another energy-price shock occurred in 2018 from a newly enacted tax-reform program that raised excise taxes on fuel and other energy products. In October 2018, inflation rose to 6.4 percent, overshooting the target inflation rate of two to four percent under the inflation-targeting monetary policy rule of the Bangko Sentral ng Pilipinas. The rise in the inflation rate triggered some social unrest. Workers demanded wage hikes while drivers of public utility vehicles sought fare increases, to the consternation of the riding public. Real GDP did not contract, but its growth rate slowed down. The presence of gas and renewable fuels in the mix helped the economy escape a recession, an outcome that argues for accelerating the energy development program that seeks to broaden the role of gas and renewable fuels in the energy mix.

4.3. Sustainable energy

The current PEP aims for a low-carbon future. Heavy dependence on coal-fired power plants detracts from this goal. Coal plants are heavy polluters and if the costs that they inflict on the environment are not reflected in energy prices, excessive pollution is bound to be result. One fiscal measure to mitigate this is to levy a pollution tax on coal. The government is well advised to levy such a tax. Coal producers do not care about the huge costs to the environment and health hazards that coal emits. Emission capping through tax and nontax measures are indicated.

While the legislation needed to levy a carbon or pollution tax may take time to pass due to political economy issues, there are certain policy actions in the short run that can be implemented to accelerate exploration and to sustain the development of the natural gas industry, namely:

- Award more petroleum service contracts, through the successful implementation of the Philippine Conventional Energy Contracting Program (PCECP) led by the DOE;
- Explore onshore natural gas sources, particularly in Southern Philippines;[16]
- Ensure strong inter-agency cooperation, and comprehensive support to petroleum service contractors, so that exploration activities can be implemented speedily and efficiently;
- Assure potential investors and participants on the clarity and stability of the fiscal terms offered under the PCECP; and
- Ensure energy security, and avoid potential disruptions to power supply and/or potential power rate increases that could be harmful to the economy as a whole.

5. Summary and concluding remarks

Industrialization requires a sustainable, affordable, and low-carbon fuel mix. In this connection, the PUINGI is critical. Natural gas is an important complement in transiting to renewable energy. It is clean and competitive with oil and coal provided the right environmental tax, along with other nontax emission capping measures, is levied on dirty fuels.

Based on the country's experience with MGPP, the country's gas and electricity sector raised the productive capacity of the economy. Real GDP growth peaked at more than seven percent following the MGPP's start of operations. The high-growth path that the Philippines was able to mount was made possible by technological innovation, knowledge creation, and the development of a growing technical and scientific manpower that the MGPP ushered in.

These positive developments from the MGPP must be exploited to the fullest. But this calls for an industrial policy—the package of trade policies, tariffs, and special fiscal and investment incentives that lead to the realization of scale economies in the PUINGI. The vital role of electricity and gas as input in all the other sectors of the economy creates benefits that far exceed the costs, whether direct or indirect.

[16] According to Clarete (2024), Lake Buluan meets the geological characteristics of an area that may have natural gas underneath in commercial quantities. Lake Buluan is in Sultan Kudarat in the Bangsamoro Autonomous Region of Muslim Mindanao (BARMM). He asserts that exploration costs can be significantly less expensive compared to offshore exploration in the West Philippine Sea. The explorer may drill a wildcat/exploratory well of about 5,000 feet deep in Lake Buluan.

The MGPP is a real-world experiment that works, whose economic and social benefits have been touching the lives of all Filipinos, rich and poor alike. It is in the service of the aspiration of the country to industrialize and, hence, deserves to be replicated.

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