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Counting all of the Costs: Choosing the Right Mix of Electricity Sources in Vietnam to 2025

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Introduction

Vietnam has a proud history of extending grid electricity to almost every village and of increasing the total amount of power by more than 12% a year – from 14.7 billion kWh in 1995 to 175 billion kWh in 2016. In the past, most generation came from hydroelectricity, but as the best sites have been developed, the share of hydroelectricity has fallen and is projected to fall, even as some new projects are brought on line. Current plans call for most incremental supply to come from a string of coal plants throughout the country, especially since nuclear power plans have been shelved. If natural gas supplies increased, a portion could come from that fuel or from LNG imports – at more expense. Renewable energy is quite small and does not figure into current supply projections except as a single digit share to 2025, as its rapid growth rate is from a low base. However, recent developments cast doubt on the current plan. Most international banks no longer lend for coal plants (Chinese banks are an exception) and recent declines in renewable energy costs have made it competitive with fossil fuels.

It is a given that Vietnam needs to produce enough electricity to satisfy demand at a reasonable cost. A "reasonable" cost is one that covers the costs of producing and distributing reliable power – something that is yet to be accomplished. It should also be a given that existing laws regarding pollution should be enforced. Many groups are objecting to new coal plants on the grounds that they will foul the air and water with ash, mercury, and acid emissions. Coal is also the heaviest source of carbon dioxide, contributing to global warming which threatens the Mekong Delta and many coastal areas, including HCMC. Some are concerned that rising imports of coal will weigh on the balance of payments and be less reliable than domestic power sources. But are there realistic alternatives to using a lot of coal in the next 5-10 years?[1]

The state utility, EVN, has had allegations of corruption and investing billions of dollars in questionable assets not related to its core functions. However, it is also faced with selling at a regulated price well below the cost of producing and delivering its product. This burden has not allowed much creative investment about alternative ways to deal with energy policy on the part of the utility. Paying customers to save money by buying more efficient equipment (and thus delay capacity additions), finding ways to use renewable energy with its existing fleet, and developing a "smart grid" are all at early stages of introduction. Yet the rapid decline in renewable prices, the possible access to low cost finance for "green" investments, and the introduction of consumer-producer agreements for voluntary demand curtailment provide many more alternatives than "build out coal" – at a potentially lower long run cost, pollution and public resistance.

To answer the question about the best path forward, a number of other questions must be answered: How rapidly will *or could* demand for power grow? What will interest rates be? Will the cost of generating plants go up or down, and by how much? What will the cost of each fuel be? Will the cost of carbon or other pollution begin to enter into investment decisions?

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[1] The time needed to bring a plant online varies from 4-6 years for coal plants to 2-3 years for combined cycle natural gas and less than 2 years for wind and solar photovoltaic. Nuclear power plants normally take 6-10 years but some Chinese nuclear plants are apparently built more quickly and for much less cost than other models.

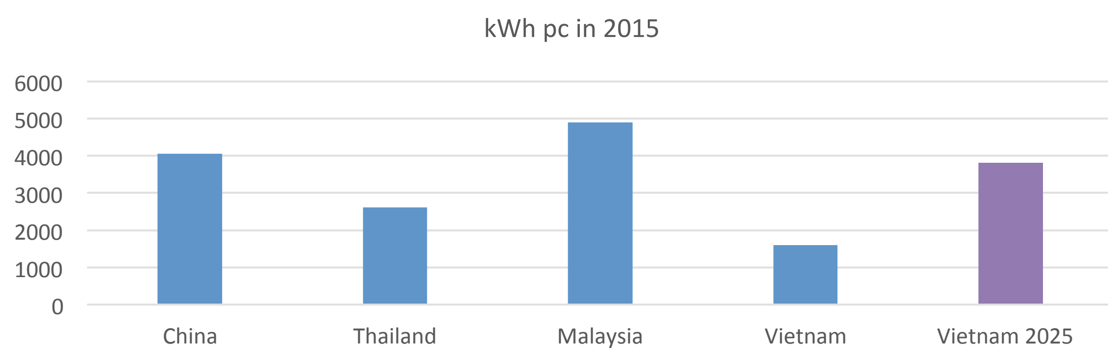
This paper will examine these questions. It will begin by looking at demand projections and investments in efficiency – getting more output per kilowatt hour used. It will then try to estimate the costs of building and running various types of generating plants in Vietnam over time. It will also use various costs of carbon to see if including these both as a source of global warming *and* as an indicator of local pollution changes the calculation. Changes in the domestic supply of gas will also influence the set of potential solutions, as will the declining costs of solar electricity and battery storage. In all of this it is the system or mix of investments that need to work, not any single investment.

The conclusions of the paper are that there are various ways to economically and environmentally satisfy the rising future demand for electricity, and they do not need to rely on coal so much as currently planned. Exactly what mix is chosen is partly a decision for engineers and utility managers, but part is also a political decision about how much to listen to citizens concerned with pollution; and how much to rely on imports as opposed to local sources of energy. If global concern over carbon emissions grows, it is possible that Vietnam, and other developing nations, would need to tax its carbon emissions in the next decade. That would decisively make coal uncompetitive with alternatives.

Demand Growth

Demand and supply of electricity has grown just over 12% a year in the last two decades, but more recent growth (2010-16) has been in the 11% range.[2] There has been a tendency to project future growth in the same range, though some sources project even higher demand growth. Yet Vietnam reached electricity consumption of 1700 kWh per capita in 2016, taking it into a range when electricity demand often slows. The graph below shows consumption per capita in 2015 for various nations and a projection for 2025 taking demand growth for Vietnam at 10% a year and population at 0.9%/yr.

Consumption in kWh per capita in 2015, and Vietnam Projections for 2025 (World Bank/ADB data)

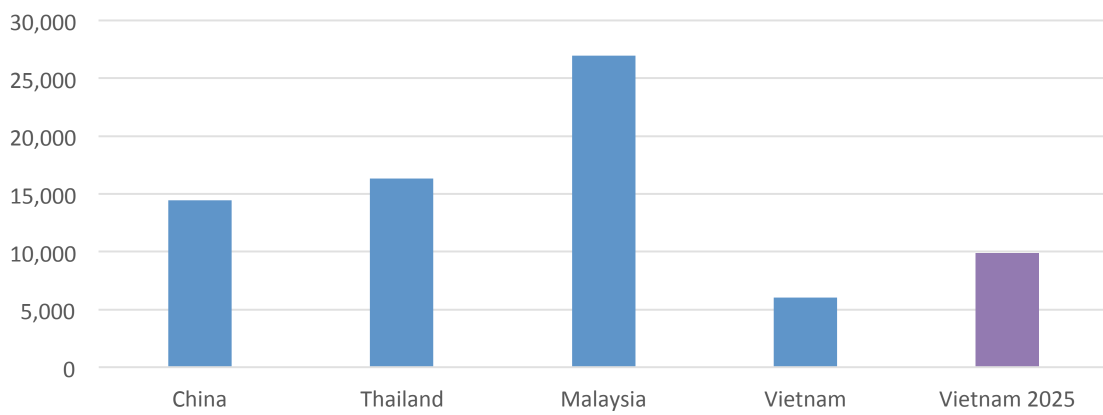


If Vietnam's population plausibly grows 0.9% a year from 2015-2025 and its electricity supply and demand grow by 10% a year, its per capita consumption of electricity would be 3780 kWh per capita by 2025. This is well above where Thailand's consumption is now and approaches China's current per capita

[2] The ADB, World Bank and Vietcombank mostly project about 10-12% annual growth from 2015 to 2025 – faster up to 2020 and slower to 2025. The ADB 2015-2025 projection is for 9.7%/ year. The government's revised Power Development Plan has 11% growth from 2015 to 2020 and 8% a year from 2020 to 2030, consistent with 9% a year from 2020 to 2025 and 7% from 2025 to 2030. In all cases, electricity growth is well above real GDP growth.

power consumption. China's current GDP per capita is more than twice that of Vietnam. Is it likely that Vietnam would consume as much power as China now does? The next graph shows the 2015 estimates of GDP per capita at comparable (PPP) international prices, plus the 2025 projection for Vietnam with real GDP growth of 6% a year and population growth of 0.9% a year from 2015 to 2025. This 6% GDP growth rate is somewhat slower than targets but equal to 2010-2016 growth.

GDP Per Capita in 2015, Selected Nations, and Vietnam in 2025



World Bank data, except projection for Vietnam at 6% GDP growth and 0.9% population growth

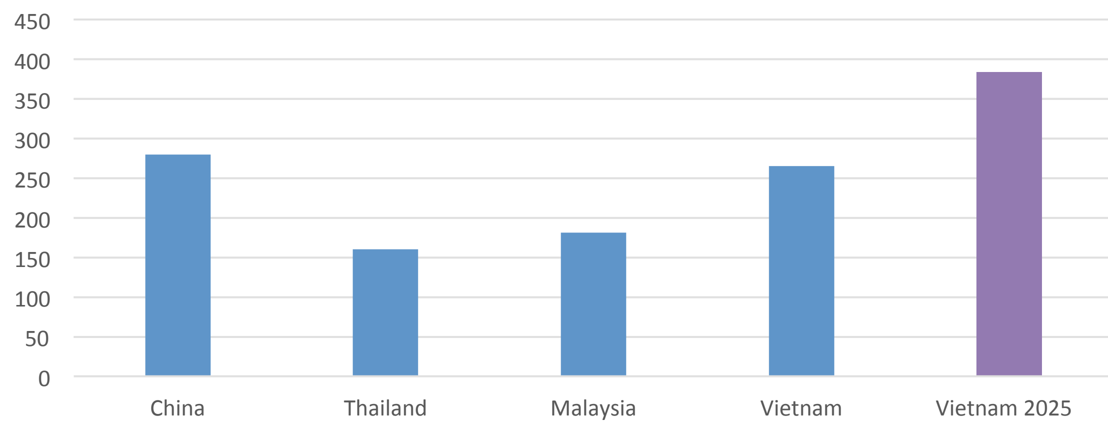
This graph shows that Vietnam's GDP per capita growing fairly quickly but still, in 2025, it would be well short of 2015 real GDP per capita in China and Thailand.[3] Is it reasonable to think that Vietnam will be more energy-intensive per unit of GDP than China? Vietnam has a more moderate climate, less heavy industry, is less urban and is already well connected. There will not be a spurt of demand due to new households being connected. In addition, there have historically been relatively low prices for electricity in Vietnam, so energy efficiency had not been an urgent matter. There is much low hanging fruit – good opportunities to reduce electricity use through efficiency – especially if efforts are made to promote (and provide loans for) efficient capital equipment that would pay for itself. See the "Box" discussing energy efficiency efforts in China. In contrast, Vietnam has made only modest efforts.

In short, it ***may*** be that the projections of electricity demand growing at 9- 10% a year to 2025 are too high and that demand growth will moderate if prices reflect the costs of production and delivery, while efforts are made to promote efficient electricity use. China has found its electric demand slowing drastically (to less than 5% a year) in recent years and greatly overbuilt its generation capacity because it too projected the past into the future. The third graph shows the energy intensity of GDP - the ratio of electricity consumption per capita per $1000 of PPP GDP per capita, underlining the questionable

[3] GDP per capita is not the only determinant of electricity demand. The price of electricity, urbanization, climate and industrial structure are also important. Thailand has a similar climate, much higher urbanization (50% vs. 34% for Vietnam) and higher prices for electricity. They have similar shares of industry/GDP. Yet 2025 projections are for Vietnam's per capita electricity to be more than double Thailand's in 2015, even though GDP pc will be much lower, even with fairly rapid growth.

implications of such rapid demand growth for Vietnam. This third graph projects an unlikely energy intensity for Vietnam if electricity demand grows at 10% to 2025, as many project.[4]

kWh pc per $1000 of Per Capita GDP in 2015 in Selected Nations and Projected for Vietnam to 2025



ADB and World Bank GDP and electricity consumption data, both per capita in 2015. Vietnam is projected from 2014 at 10%electricity demand and 6% GDP growth, with 0.9% annual population growth. GDP is PPP - GDP using international prices.

It takes 4-6 years to build a coal plant, and only 2-3 years to build a natural gas plant and even less time to put in place wind or solar power.[5] If there is uncertainty about future demand growth for electricity, it makes sense to tailor supply more closely to actual growth rather than try to peer too far ahead. This argument only works if the costs of the various options are fairly close. The next section investigates the likely costs of each type in purely financial terms. Later refinements will ask about the impact of including environmental costs and storage costs, which are falling as rapidly as renewable energy costs. The combination of increasingly competitive intermittent renewable power and affordable storage makes it possible to replace a coal intensive path economically.

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[4] The Made in Vietnam Energy Plan by Economic Consulting Associates (November 2016) also argues that electricity intensity in Vietnam is high and there is potential for sensibly reducing demand. The argument here is similar, but relies on the need for prices to reflect costs and the high economic returns to using efficient machinery, appliances and structures. This paper takes an agnostic stance towards energy imports but is sympathetic to the risk reduction implicit in renewable energy – avoiding potential carbon taxes and pollution costs, as well as fluctuating exchange rates and coal prices. In short, similar conclusions but different reasoning.

[5] Again, the question of nuclear power is a complicated one. It is unclear if a nuclear plant could be operating by 2025, even if it were started in 2018. Close monitoring of China's experience and of developing nuclear technology in other countries is needed to decide if the balance of risks and benefits favors large and long-to-market-investments and dealing with later problems of nuclear waste disposal. Nuclear energy is not covered in this paper.

Box: Electricity and GDP Growth in China and Vietnam

Both China and Vietnam have greatly increased their electricity and real GDP since 2000. Vietnam's electricity from 2000 to 2016 grew 6.6 times while its GDP grew 2.7 times. China's electricity grew 4.5 times and its GDP 4.2 times in the same period. To put it another way, a 10% increase in real GDP is associated with Vietnam's electricity growing 24% while China's electricity grows (for 10% GDP growth) less than 11% since 2000. [1] In the last five years, Vietnam's electricity growth is still more than double its GDP growth while China's electricity growth is only ¾ of its GDP growth. China is growing more rapidly than Vietnam with less electricity.

One might argue that at very low levels of income, it is natural to have a high growth of electricity demand, while such growth slows as incomes increase and almost everyone gains access to a connection. In both countries, virtually everyone now can and does have power. However, while projections for China's growth are low to mid-single digit and have grown only about 4% a year recently, Vietnam's projected electricity demand (with similar or even lower GDP growth) is at least double China's growth rate. If projections of 9% to 10% average growth for Vietnam to 2025 are correct, and if China continues its recent 4% electricity growth, the gain in kWh per capita for Vietnam will exceed China's in the next decade.

One major reason for this difference is that China has an aggressive policy of energy conservation while Vietnam does not. The International Energy Agency lists 24 significant Chinese conservation programs and policies since 2005 and none for Vietnam. If Vietnam were to take advantage of the lessons learned from China's experiences, it is likely that the demand for electricity could also grow more slowly. The revised Power Development Plan 7 for Vietnam does have a general commitment to save 10% of consumption by 2020 from 2016 and to:

Enhance communication, dissemination and implementation of the Law on energy saving and efficiency to improve energy use efficiency in general and electricity consumption in production, business and households in particular.

But this is a rather general statement. In contrast, China had detailed plans in 2011-2015 for the top ten thousand large industrial factories, transportation, schools and hospitals as well as subsidies for buying energy-efficient appliances. These appliances cost more upfront, but save money over the life of the appliance. Each province was assigned an energy saving target. It is likely that more detailed and sustained effort in Vietnam would also be productive. If growth in electricity could be cut to 6% a year – similar to GDP growth - output in 2030 would be less than 400 billion kWh – rather than reaching it in 2025 or earlier. This would allow more modest capacity additions for coal and the savings of tens of billions of dollars, even after deducting the cost of promoting conservation. Of course, the surest way to get people to conserve is to raise the price – at least to the cost of delivered electricity from new generators. In most of Asia, this is in the vicinity of 10 to 12 cents per kWh, well above where Vietnam is now – China's average price is 11 cents and Vietnam is 8 cents. Electricity prices could be raised slowly with lower prices for the poor. But the cheapest way to provide electricity is often to find ways to use less of it.

[1] China is used for comparison but its experience is close to several other countries. Thailand and India have ratios of electricity to GDP growth of 1 or less, though Indonesia is 1.2 since 2010.

Costs of Various Alternative Generating Options

The cost of a kilowatt hour of electricity depends on fixed costs and variable costs. Fixed costs depend on the capital intensity (usually measured per kilowatt or per megawatt) of the generating plant and the financing costs, along with some fixed maintenance costs. Variable costs are mainly fuel costs plus some minor variable maintenance costs. It is usual for more capital intensive generating options to have higher fixed costs and lower variable costs. Nuclear and hydroelectric plants and wind or solar are relatively expensive to build[6] but have low costs to run once built. Coal is fairly expensive to build but relatively cheap to operate, though maintenance costs are high. Natural gas combined cycle is cheap to build but gas as a fuel is often more expensive. Single cycle gas turbines are very cheap to install but have the highest operating costs, so they are often used as "peaker" plants and operate only a few hours a month during periods of very high demand. Appendix I shows current and projected sources of electricity generation capacity by type of fuel or renewable.

COAL

A huge proposed coal plant in Long An has a published cost of $1800 per kilowatt (kW). The plant is expected to operate 6300 hours per year and use 1 ton of coal for 2700 kilowatt-hours.[7] If we assume 6% loan costs and a sixteen year period to repay the loans, the annual repayment cost would be $180 per kilowatt of capacity. Fixed maintenance would be $42 per kW of capacity.[8] Coal costs are (late 2016) about $90 cif, or $210 for fuel for the year for 6300 kWh – which is 3.33 cents per kWh. In total, and counting minor variable maintenance costs**, the total cost is 7 cents per kWh, excluding any externalities**.

In comparing coal with gas or renewable projects, it is important to consider the different time needed to bring each type of generation on-line. A coal plant planned in 2017 and begun in 2018 may not be on-line until 2023. But a solar plant planned in 2022 could easily be up and running in 2023, assuming connections were available. Thus the comparison should be the *projected* cost of solar in 2022 with the current cost of coal plants, rather than the current solar compared to the current coal. Given that utility scale solar costs in the US fell 20% from 2015 to 2016 and solar capital cost declines of 6-10% a year are likely, the analysis should be using much lower solar capital costs than today's if the power is available at the same time as the coal.

The seven cent cost *assumes* that the plant will meet existing environmental laws, though reports suggest that this cannot be certified. Extra costs of pollution equipment and operating costs may have to be added to those estimated here if the proposed plant is going to meet current legal requirements. Even then, burning millions of tons of coal a year has health and economic implications due to heavy metals, ash and acid pollutants released. In addition, incremental coal demand will come from imports as coal reserves in Vietnam are either not available or not competitive with imported coal, beyond

[6] Wind and solar are not very expensive per kilowatt of capacity but are more costly if calculated as investment per expected kilowatt-hours of production. This is because, unlike fossil fuel plants, they only produce when the wind is blowing and the sun is shining, which is 1400-1800 hours/year for solar in southern Vietnam and 2000-3600 hours per year for wind, depending on the site of the wind project and the size and efficiency of the wind turbine.

[7] Australian thermal coal has 23.8 million BTU per metric ton. An efficient coal plant will need 8800 BTU per kilowatt-hour. The 2,800,000 kW Long An plant would burn 6.5 million tons of coal per year. If only 1% of the coal is heavy metals or other toxins, that would add 65,000 tons a year to the area.

[8] Maintenance costs are taken from estimates of new US plants. https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf

current production levels. In addition, the 6% capital cost may prove optimistic if few loans are available for coal power plants. Finally, coal plants last for many decades and if global agreements place a tax on carbon, it would be difficult if most of Vietnam's new capacity was a heavy carbon polluter.

NATURAL GAS

A generic combined cycle natural gas plant costs $1000 per kW and has fixed maintenance costs of $10 per kW. The plant can extract 150 kWh from one million BTU of gas. Piped gas from an offshore field should cost about $7 per million BTU at wholesale while imported LNG would cost $10 per million BTU at current prices. Retail prices of gas can be taken at $10 per million BTU. Using the same 6% and fifteen year financing, the fixed costs are $113a year per kW of capacity and variable costs would be 4.7 cents per kWh for piped gas and 6.7 cents per kWh for LNG. Adding fixed and variable costs and assuming 6300 hours per year, **the gas cost 8.5 cents per kWh.** Gas generators can cycle up or down much more quickly than coal and thus can work better combined with renewable energy. Gas generators also take less time to install. The main problem is if there is enough gas available from domestic sources. If not, it is possible to import LNG, but this is more costly. As the "Blue Whale" field near Quang Nam comes online in the 2022-24 period, it should be able to supply up to 7300 megawatts of electricity capacity. If new fields are found, more gas-fired units could be built at lower cost with less pollution, though fields can take 5-7 years to bring into production from initial exploration.

Gas fired electricity is sometimes also produced by single stage turbines. These cost less to install per kW of capacity (about $680 compared to $1000-$1100 per kW for combined cycle gas), but are less efficient and use more gas per kWh produced. Since gas is a relatively expensive fuel, it only makes sense to use single stage gas generators as a backup. If a backup plant were used 700 hours a year, its cost of electricity would exceed 20 cents per kWh, counting both fixed and variable costs.

SOLAR

Renewable energy sources are not very important in Vietnam's current energy mix. This is understandable because they have not historically been competitive with gas and coal, or with hydro. They have tended to be capital intensive and only produce power when the sun is shining and the wind is blowing. EVN has not invested in sophisticated grid management systems that would integrate these variable sources easily, though this becomes an issue mainly when solar/wind is 20% or more of total consumption. However, extremely rapid declines in solar costs have driven the cost of utility scale solar energy to below $1500 per kW of capacity in the US in 2016 and costs of $1000 per KW in 2020 are anticipated.[9] Costs in Vietnam have been reported even lower than $1000 per kW in 2016, though these are not confirmed.[10]

Since Vietnam tends to be further south than the continental US, it receives more sunlight, so solar energy should be cheaper than in the US. In addition, very low cost loans are available from the US Export-Import Bank – about 3.5% a year for fifteen years. Further substantial declines in equipment costs are anticipated into the 2020's as scale and technology cut costs. What would a kWh of solar energy cost? To answer that, a site has to be selected with the number of hours of sunlight. In south-

[9] http://www.nrel.gov/news/press/2016/37745 Their data show cost of a 100 MW facility including hardware, land, and installation and grid connections has fallen from $3.82 a watt in 2010 to $1.42 a watt in 2016.
[10] Personal communication from Hai Nguyen. This excludes land and may refer only to solar hardware.

central Vietnam, the hours of sunlight tend to average 5 per day, after deducting for clouds.[11] This combination of low investment costs, low interest rates and high solar levels combine to produce competitive electricity costs. A solar plant at $1000 per kW and 3.5% interest rates financed over 15 years or an $800 per kW solar plant financed at 6% over fifteen years would both produce power costing less than five cents per kWh. [12] This suggests the feed-in tariff (officially offered price) of 9.35 cent per kWh for solar is fully adequate if moderate cost loans can be accessed[13]. Indeed, switching, as India has done, to an auction system for solar electricity supply might elicit bids much lower than the current feed-in tariff. India received one solar supply bid of four cents per kWh.[14]

While all generating options are paid off in fifteen years given the financing assumption, solar (like hydro and wind) is essentially free after fifteen years of payments while coal and gas continue to incur fuel costs and higher maintenance costs. A calculation looking at the costs over the lifetimes of the projects would show even more of an advantage for renewable energy. .

As pointed out previously, the falling cost of solar combined with its short time from planning to delivery (one year) allows a different calculation in competition with current coal plants. It is likely that 2020 total costs of solar will be below $1000 per kW of capacity, implying a cost per kWh of less than five cents for power being delivered in the same year as a coal plant starting now, even with a 6% cost of capital. When total solar costs fall below $1000 (and they may already be this low), arranging bids for electricity supply rather than feed-in-tariffs may be one way to lower the costs of electricity for EVN.

The other aspect of solar is that it is likely to combine well with hydroelectricity, which is plentiful in Vietnam. When the sun is shining, there is often little rain and reduced hydro capability. When it is raining, (as during the monsoon), solar is not needed as much. High solar output during the dry season would allow reservoirs to save water during the day and supply more power at night. While detailed studies are needed to ensure this combination would work well during cloudy dry season days, it is promising enough to warrant careful follow-up[15]. Solar installations are guaranteed to last 25-30 years and will still work at 90% of their installed efficiency after 25 years. Finally, installation of a utility-scale solar project can be done in one year, responding as needed to demand growth.

WIND

Wind powered electricity in Vietnam is very site-specific. It would work best as part of a grid that can adapt to changing wind supply quickly, as hydro and natural gas can but not coal. As sizes of wind

[11] http://dattech.com.vn/Content/uploads/files/Maps%20of%20Solar%20Resource%20and%20Potential%20in%20Vietnam%20REPORT%20FOR%20PUBLISHING.pdf

[12] Middle Eastern solar bids came in at 2- 3 cents per kWh. https://www.bloomberg.com/news/articles/2016-09-19/cheapest-solar-on-record-said-to-be-offered-for-abu-dhabi. There was also a bid in Chile for less than 3 cents and these are all unsubsidized. Solar panels that track the sun are only slightly more costly but get higher output than fixed panels. Wind costs in the US without subsidies are now estimated at 4-5 cents per kWh: http://oilprice.com/Energy/Energy-General/Wind-Energy-Now-Directly-Competing-With-Coal-On-Cost.html

[13] https://www.pv-tech.org/news/vietnam-introduces-utility-scale-solar-fit-and-rooftop-net-metering. It is the weighted cost of capital, which includes interest rates on loans plus the return to equity, which is higher, which determines the total cost of solar repayments and thus the cost of solar electricity.

[14] https://www.nytimes.com/2017/06/02/world/asia/india-coal-green-energy-climate.html

[15] It is likely that backup generation will be needed unless more contracts to allow reduced power to consumers for brief periods are negotiated. Another possibility is to increase wind power, which is less correlated with sunlight.

turbines have grown and costs come down to below $2000 per kW, the unsubsidized cost of wind electricity in good sites has fallen to 4-5 cents per kWh in the US. If similar sites are available in Vietnam, it should be possible to use wind capacity competitively as part of the mix of generating capacity. The World Bank has drawn a wind map of Vietnam and identified southern coastal areas as being favorable for hundreds of thousands of megawatts of potential power.[16] If wind is given the same 9.35 cent price as solar, it should be able to expand considerably and quickly. (Prices paid to wind were 7.8 cents per kWh in 2016 and are likely to increase further in 2017.) Wind energy can be installed in a year, responding to demand as it develops. Once a higher feed-in tariff is approved, many wind projects should move forward, though the same rules should apply to wind as to solar if bidding replaces feed-in tariffs.

Hydroelectricity

Hydropower has played a major role in the supply of Vietnam's electricity in the past and even now is still the largest source of capacity (roughly 45%) but it supplied only 36% of actual generation in 2016, slightly less than coal (37%). Projections are for hydroelectric capacity to grow from about 17,000 MW now to 24-25 thousand MW by 2025, though by then it should account for only 25-30% of total generating capacity. Hydroelectricity produces at maximum capacity when there is sufficient water flow (and demand), but scales back output during the dry season. Generally speaking, they produce 3700-4000 hours per year at their full rated capacity while coal plants often produce more than 6000 hours.

Hydroelectricity has very low maintenance costs and no fuel costs, so virtually the only cost of production is the capital cost of the project and some few people to operate the unit. After the unit is paid off, the cost of production is very low. The reason why more hydroelectric plants are not built is that only certain sites are suitable and environmental costs can offset some of the advantages – displacing people, destroying farm land due to the reservoir and downstream flooding, fish kills and other costs. On the other hand, it emits no pollution, can help to control floods, and provide fish supplies from its reservoirs.

Hydroelectricity is spread throughout Vietnam. It accounts for over 50% of northern capacity, 44% of capacity in the central regions and nearly a third in the southern part of the country. (Gas accounts for half of capacity in the south, while coal accounts for about half of capacity in the center and north.) This means that each region has backup capacity which is not coal, and that can be mixed with wind or solar.

In addition, hydropower can add solar panels floating on the reservoir or located nearby. This makes connections and a stable mix of power from both solar and hydro easier. Pumped storage units are also being introduced. A reservoir below the dam catches "used" water and it is pumped back to the higher reservoir during periods of surplus power. This allows more hydroelectricity to be produced during peak periods of demand. The cost of peak electricity from pumped storage is less than from rarely used peaker plants. However, pumped storage is limited to only a few favorable locations.

[16] http://english.vietnamnet.vn/fms/business/160811/wind-power-still-unattractive-to-investors-in-vietnam.html

Transmission

Transmission of power from one part of Vietnam to another occurs on high voltage transmission lines. If there is a drought in one area, power from other surplus areas can help maintain supplies. This transmission capacity could be utilized and improved if renewable sources in the southern half of the country became significant. Alternatively, gas pipelines could fuel gas-fired plants in the northern half of the country as an alternative, if supplies were adequate. This depends on the sources of offshore gas and demand onshore for them where the gas comes ashore. Again as the share of renewable energy grows, increasing investments in transmission lines will be needed to utilize all sources effectively.

In addition to the transmission of power, a "smart grid" can sense when supplies are not sufficient and make adjustments so that brownouts and blackouts are avoided. This can include reducing supplies to consumers that agree to short interruptions to supply (reduced air conditioning for an hour) or who are able to bring other sources online. If battery storage becomes cheaper and widespread, the smart grid could also use that source. In addition, if renewable sources provide fluctuating power, the smart grid can adjust to use this power without disrupting overall supply by electronically regulating both other supplies and demand.

Costs of Carbon and Other Pollutants

Coal is a relatively dirty fuel. It can be burned more or less cleanly with additional investments in pollution control equipment, but this raises the overall cost of electricity from coal. The local pollutants are ash, heavy metals and nitrogen and sulfur oxides which create acid rain. The global pollutant is mainly carbon dioxide. The proposed Long An coal plant would **alone** burn 6.5 million tons of coal a year if fully built out. It is difficult to project the local pollution without knowing the type of coal to be used and the pollution control equipment and its operation. China has relied on coal and faces deadly pollution problems, rising citizen opposition, and expensive attempts to find alternatives or clean up existing plants.

The question for Vietnam is if there should be a charge on top of financial costs to reflect the costs of local and global pollution. Some might take the position that existing pollution laws will be enforced and that any excessive societal cost of coal (or any other fuel) is already factored in the permissible pollution, so no added cost should be imposed. However, a public health approach would check to see if there is excessive mortality or sickness even if the pollution laws are followed. The cost per life could be calculated and multiplied by the number of lives lost, suitably discounted. The mortality costs would be added to the cost of coal. (Natural gas should have a similar procedure, but its pollution levels are much lower.) In China, recent estimates of coal linked premature mortality were put at roughly 1 death for every 10,000 tons of coal burned – 366 thousand deaths per year and 3.7 billion tons of coal burned. If a similar ratio applied to Vietnam (this is a supposition, not a fact), deaths from coal would rise from 4800 in 2016 to 12,100 in 2025 as coal consumption rose from 48 million tons to 121 million tons. Assigning a value to a life is as much a political as a technical exercise, but one academic paper estimated a "statistical life" in China was worth $58,000 to $98,000 in 2000 constant prices based on willingness to pay for cancer prevention or cure. (https://ideas.repec.org/a/fec/journl/v9y2014i2p183-215.html) It would be perhaps 70% higher now if inflation were considered. If levels in Vietnam were now between $50 and $85 thousand, then the annual mortality cost would be $0.6 billion to $1 billion a year by 2025 –

adding about half of one cent per kWh to the cost of coal electricity. Costs of treating illnesses would be extra.

The costs of carbon pollution are harder to estimate since the main impact is on global warming. Rising sea levels and weather/temperature issues are major threats to Vietnam but Vietnam is not, by itself, going to have a major impact on global temperature levels. However, there may be a global compact that essentially negotiates a carbon cost for all fossil fuel users. This tax, if it occurs, would be paid to the national government but would show up as an extra financial charge on each coal plant. A metric ton of thermal coal produces about 2.5 tons of carbon dioxide when burned, so the question becomes, what is a reasonable estimate of the cost of carbon dioxide? No one knows but there are many estimates. One recent and plausible estimate by a well-known academic expert put it at $31 per ton of CO2 (2010 prices) or $35 now. (http://www.pnas.org/content/114/7/1518.full) If this were the amount negotiated, it would cost coal producers in Vietnam about $4.2 billion in 2016 rising to $10.5 billion by 2025. This would add 4.6 cents per kWh to the cost of coal-fired electricity. Of course, there may be no such carbon agreement or if there is one, it might be for a lower initial amount. But applying even half of this estimate to the cost of coal plants would make them uncompetitive.

If these highly speculative efforts are taken seriously, then adding four or five cents (roughly 1000-1100 dong per kWh) to the cost of coal fired electricity would be justified. Natural gas would also be hit, but much less. A million BTU of gas generates 53 kg of carbon dioxide and creates 150-160 kWh of power. So it would take 2900 kWh of gas-fired electricity to generate a ton of carbon dioxide, or 1 to 1.2 cents per kWh with a cost of $35 per ton.

Political Costs of Coal

In part because of the experience of China, many local and community groups are aware that coal may create dirty air and water in the areas around large coal-fired electricity plants. They often try to deter such investments by normal political means and also by using social media or demonstrations. It is up to the Party and Government to decide if such objections should carry much weight, but if there are cleaner and more or less equally competitive alternatives, it is not clear why a coal intensive expansion path should be preferred. If indeed pollution is severe, then land values in the area of the coal plant are likely to plummet and this could reduce the ability of local governments to pay for services or investments. That too, may add to the reluctance to support “dirty” investments.

Another issue is if only or mainly Chinese banks will lend for coal plants, that likely means that reliance on China will increase in general – it will be necessary to use Chinese capital equipment, spares, and rely on them to fulfill promises regarding pollution. This may not be a preferred path. China has excess capacity in coal generating plants and is willing to finance them to lessen unemployment. There are also indications that Japan is willing to finance coal plants for similar reasons.

Finally, if demand does slow and Vietnam found it had invested billions of dollars in idle coal plants (as has China), there would also be political costs to having imposed an unnecessary burden on society through either higher electricity bills or lower spending in other vital areas.

Conclusions

This survey argues several things:

1. Demand projections are uncertain and could be too high if Vietnam follows ASEAN or Chinese experience with respect to electricity intensity. *Vietnam can and should gradually raise electricity prices to cover costs of new power plants and promote efficient energy use so demand is reduced to levels more typical of other similar nations.*

2. Coal plants take longer to bring on line, so are riskier compared to alternatives if demand does slow. Since private power plants usually require government or EVN promises to buy coal power for many years in advance, they could become a burden. *Limiting take or pay contracts to a limited number of years would put more risk on the investor, but would reduce investment, especially now that most international banks do not favor financing coal plants.*

3. China has followed a coal-centric strategy and generated considerable costs in pollution, excess capacity of electric generation, and costs of mining. *Serious effort should be made to reflect the costs of coal pollution in coal-fired electricity prices. The same is true for gas, but is much less significant.*

4. Electricity from renewable energy, pipeline gas and even LNG are competitive with coal, in some cases without considering pollution and carbon costs but certainly if these are included. *Considering the falling costs of wind and solar and their shorter completion periods both reduces risks and reflects rapid cost reductions in their capital costs. They are or will be competitive in the cost of generating electricity, even with similar financing costs as fossil fuels. Allowing bids for electricity from independent generators rather than feed-in tariffs might help to lower costs.*

5. Coal will have to be imported on the margin. Domestically supplied power may be preferred. *After fifteen years of repayments, renewable energy is essentially free and coal and gas continue to incur fuel and higher maintenance costs. Life cycle costs show renewable energy to be cheaper. .*

6. There are rising domestic and international political costs to coal that may need to be considered. *A transition to more renewable energy will require more investment in "smart grids" that manage demand and in fossil fuel types (mainly gas) that can easily respond to fluctuations in renewable supplies. This is an additional cost but is modest compared to the costs of coal pollution.*

Appendix I: Current and Projected Types of Generating Capacity ('000 MW)

	Share of Capacity			*Installed Capacity*			*Growth/Year*	*Output (billion kWh)*		
	2016	*2020*	*2025*	*2016*	*2020*	*2025*	*2016-2025*	*2015*	*2020*	*2025*
Coal	33%	43%	49%	12.7	26.0	47.6	15.8%	59	134	228
Gas	20%	15%	16%	7.7	9.0	15.0	7.7%	41	45	79
Hydro	44%	37%	26%	17.0	21.6	24.6	4.2%	56	80	85
Other	3%	5%	9%	0.1	3.4	9.3	65.0%	3	13	23
Total	100%	100%	100%	37.5	60.0	96.5	9.9 %	159	272	415

"Other" includes wind, solar and small hydro and a small and declining share of diesel-fired generators. Capacity is taken as of 1/1/2016 but 12/31 in 2020 and 2025. Capacity and output are taken from midpoints of the VCBS (Vietcombank Securities) survey, Vietnam Power Industry 2016.

Appendix II: Actual and Projected Electricity Supplies (2000-2016 is Actual)

	Generation *in billion kWh*	Annual Growth *from previous period*	Sources
Data from 2000-2016			
2000	26.7		
2005	52.1	14.2%	
2010	91.7	12.0%	
2015	158.0	11.6%	
2016	175.4	11.1%	
Projections			
2020	320	16.2%	World Bank "Smart Grid" document, 2016
	265-278	10.9%-12.2%	VCBS, Vietnam Power Industry 2016
	265	10.9%	ADB, 12/2015, Vietnam Energy Road Map
2025	400-431	8.6%-9.2%	VCBS
	400	8.6%	ADB (9.7% a year from 2015 to 2025)
2030	572-632	7.5%-8.0%	VCBS (8.0% and 8.6% from 2020-2030)
	572	7.5%	ADB (8.0% a year from 2020-2030)
	690	8.0%	World Bank, "Smart Grid" document (2020-2030 growth)

If the **lowest** projections are correct, the 2030 output would be 572 billion kWh in 2030. That would raise the output of electricity in 2030 to nearly 5600 kWh per capita and consumption would be about 5200 kWh pc. **That electricity consumption is double Thailand's current per capita use and more than the UK in 2014**! The higher growth estimate puts output per capita at 6700 kWh and consumption at 6300 kWh pc, getting Vietnam close to France's 2014 per capita use. Yet even with a 6% annual GDP growth rate, the 2030 PPP GDP per capita would be $13,000 – less than China or Thailand in 2015, and less than a third of the UK's current GDP pc! If electricity prices reflect costs of production and distribution, it is hard to imagine how Vietnam would reach such high levels of consumption at such a relatively low level of GDP per capita.

It is noteworthy that after China reached 3300 kWh pc, its electricity growth rate fell to about 5% a year (2011-16). It is unlikely that Vietnam will surpass China in its per capita power consumption unless it keeps electricity prices below costs and also ignores energy efficiency investments. China's GDP per capita is far higher than Vietnam's and it is nearly twice as urban. It has a much higher fraction of heavy industry and more need for electric cooling and heating, with its location and continental climate. It is not certain how fast electricity demand in Vietnam will grow, but it is dangerous to draw straight lines. The 10% annual growth from 2015 to 2025 is consistent with ADB projections, but that projected amount may be higher than what is realized. If, for example, Vietnam reached the 2014 Thai per capita level of 2566 kWh by 2025. In that case, consumption would be about 256 billion kWh and production would be about 7% higher or 274 billion kWh rather than the projected 400 billion kWh. (Vietnam even then would be poorer and less urban than Thailand in 2014 with a similar climate and industrial structure.) That would imply only a 5% annual electricity growth rate from 2016 to 2025! The point is not that growth will be 5% or 10%, but that it is hard to tell for sure. If China's electricity growth fell to less than 5% a year after 2011, the same could happen or be caused by Vietnam by 2020 or after 2020.

The following data show PPP GDP per capita, urbanization, industry as a share of GDP and prices per kWh. In all countries, virtually all households are connected. Data are World Bank for 2015, except prices which are from various sources.[17] Projections are 6% GDP and 10% electricity growth.

Variable	China	Thailand	Malaysia	Vietnam	Vietnam 2025
PPP GDP pc	$14,450	$16,340	$27,000	$6035	$9925
Urban %	56%	50%	75%	34%	40%
Industry%	43%	37%	37%	37%	37%
US cents per kWh	12-16	9-12	9-13	7-8 (average)	?
2014 Electricity pc	3927	2566	4646	1430	3780
Electricity Use/GDP pc	.27	.16	.17	.24	.38

Notes: Vietnam 2025 takes electricity demand from 2016 actual levels, growing at 9% per capita per year, or 10%. Urbanization rate is projected growing at 0.6% a year, its historic growth rate. Industry/GDP has not shown any trend growth recently.

The policy question for Vietnam is if it can grow rapidly with a lower energy intensity than it is projecting – closer to those of the richer ASEAN or other developing economies. If it raises prices to allow private generating investments and helps producers reduce electricity use per unit of output with information on efficiency and loans for improved equipment, it is likely to slow the rate of electricity demand growth below the 11% projected for the rest of this decade and the 8-9% for the 2020-2025 period. By reducing the rate of demand growth, it would not need to invest so much in energy and could redirect its investment into other areas such as infrastructure or education.

If it is uncertain that the rapid growth of electricity demand will continue, it makes sense to build just a little ahead of need rather than bet on continued rapid expansion. If it takes 4-6 years to build a coal plant, it is necessary to commit to a highly uncertain expected demand. The cost of coal without adjusting for carbon and other pollution costs is roughly on par with other sources. If the completed coal plant is not needed, its effective cost rises since it either goes underutilized or EVN is forced to close its own plants if there is a "take or pay" contract with a private producer. If pollution costs are considered, then the argument in favor of other sources of power becomes overwhelming.

[17] While this paper focuses on Asian economies, even richer, highly urban economies in Latin America have much lower than projected (for Vietnam) electricity use. Brazil, at $15,400 GDP pc, uses 2600 kWh pc, and Argentina, with $20,000 GDP, uses 3052 kWh pc. Even with 7% real GDP growth, Vietnam would not reach $11,000 GDP pc by 2025. The 10% electricity demand growth for Vietnam, not the highest, reaches nearly 4000 kWh pc by 2025.There is no question that unsubsidized power and modest efficiency measures would reduce projected demand growth.

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