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The development and cost of renewable energy resources in Vietnam

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ABSTRACT

Vietnam has abundant natural resources, but a high vulnerability to climate change. The Vietnamese government, therefore, has avddeclared its intention to encourage clean energy development. To achieve this, the cost of renewables needs to be competitive with fossil fuels. The purpose of this paper is to review past studies of the levelised international costs for various renewable energy resources and compare them to the costs of renewables in Vietnam. In Vietnam, there is evidence that the cost of non-hydro renewables has fallen in recent years, as they have internationally, making them more viable. In the Vietnamese case, however, the potential for growth in the use of non-hydro renewables is impeded by the low cost of hydropower, which constitutes a significant barrier to the introduction of non-hydro renewables in the short to medium terms.

1. Introduction

Since 2015, Vietnam as an active member of COP21 (known as the 2015 Paris Climate Change Conference aimed at keeping global warming below 2 °C) has made commitments to the international community to take action against climate change, particularly in terms of the promotion of renewable energy. In order to achieve this goal, the Vietnamese government has implemented a number of regulations and taxes with the hope, of promoting renewable energy. These measures are intended to not only increase the proportion of renewable energy in the supply of electricity but also to address the difficulties involved in providing energy to regions of the country where accessing the electricity grid is difficult access (Zimmer et al., 2015; Nguyen, 2015; Nong, 2018a,b).

As is the case with all energy sources, renewable energy must be cost-effective relative to other sources if it is going to be able to create sufficient returns for investors. In many countries of Western Europe as well as China and India, subsidies have been used to promote renewable energy (Simshauser and Tiernan, 2018; Nong and Siriwardana, 2018a,b). In Vietnam, decision No. 2068/QD-TTg of Vietnam Government's Renewable Energy Development Strategy to 2030 (with a vision to 2050), electricity prices are adjusted by the national electricity utility to ensure fair returns for private investors in renewable energy; these adjustments are based on the cost conditions of different regions (Vietnam Prime Minister, 2015). This means that an effective subsidy is paid to renewables. However, Tran Dinh Long, Vice President of the Vietnam Electricity Association, has stated that this subsidy of approximately 1 cent/kWh for wind energy is insufficient to attract investors to this form of renewable energy (EVN, 2016). If subsidies are to be used, whether for wind, biomass, or solar energy, they must be accurately determined (Tran Dinh Long, 2014). In addition, taxes have also been levied on coal and petroleum use and have been raised from the beginning of 2019 onward (Nong, 2018a,b, 471).

In light of these challenges, it is necessary, to review the production costs of renewable energy in Vietnam to determine if prices are competitive enough to assist the Vietnamese government in setting up specific policy and regulatory frameworks for clean energy development that does not overburden consumers. Past research has been conducted on the promotion of renewable energy in Vietnam (see Nguyen et al., 2018; Le et al., 2013; Nguyen, 2007) but it tends to focus on the Vietnam government's overall approach to climate change policy rather than the costs of renewables (see for instance Luong, 2015; Zimmer et al., 2015).

The purpose of this paper is to review past analyses and calculate the present costs of renewable energy relative to other sources of energy, both in Vietnam and internationally. The resSults are suggestive of the potential for making use of renewable energy in Vietnam. The paper is structured as follows. In the first section, we review international investment in renewable energy as well as the literature on relative costs. This is followed by a discussion of trends in the relative costs of renewables. The next section considers the situation in Vietnam and the final section provides conclusions.

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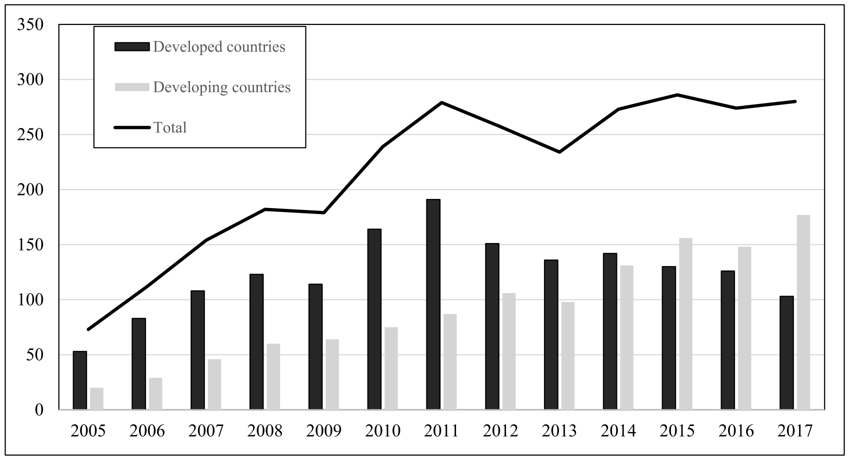

Fig. 1. Global new investment in renewable power, developed and developing countries, 2005 to 2017 ($billion).
Source: REN21 (2018a, 2018b).

2. Global investment and cost trends

Recent years have seen, considerable investment in and growth of the renewable energy sector globally. Aided by a fall in costs and the provision of support policies, the total investment in renewable energy worldwide has increased from $73 billion in 2005 to $280 billion in 2017 (see Fig. 1).[1]The growth in investment has not just been confined to developed countries. As can be seen from Fig. 1, investment in developing countries rose in 2014, up 36 percent from the previous year to $131 billion. In 2014, developing country investment came close to surpassing that of the developed economies ($138.9 billion) and in 2015, for the first time, total investment in renewables in developing nations exceeded that of the developed economies ($156 billion compared to $130 billion). This situation was retained through 2017 (REN21, 2018a,b). This spread of renewable energy investment from developed to developing and emerging economies is a result of the lowering costs of renewable energy, rapidly rising demand for electricity in developing countries, the need for additional power generation capacity and changes in market regulations (Simshauser and Tiernan, 2018; Nong and Siriwardana, 2018a,b).

One reason for the growing investment in renewables, and the expansion of the industry, has been the fall in the production costs of renewables, which has made renewable energy more competitive with traditional energy sources such as fossil fuels. A number of studies have looked at the costs of renewable energy compared to that of conventional fossil fuels, both internationally and in Vietnam. Most prominent among this work has been that by the International Energy Agency (IEA, 2010), the International Renewable Energy Agency (IRENA, 2015, 2016a, 2016b) and the Renewable Energy Policy Network for the 21 Century (REN21, 2018a,b). In these assessments, average levelised costs of energy (LCOE) are calculated for a range of regions for a variety of electricity generation types. For Vietnam, Luu and Nguyen (2013) have calculated comparable figures.

In terms of the changes in costs and prices over time, solar energy is a typical example of the downward trend in costs, the work by IRENA finding that solar PV module prices in 2014 were around 75 percent lower than their levels in 2009 (IRENA, 2015). The most competitive utility-scale solar PV projects are delivering electricity for $0.08 per kWh without financial support, compared to a range of $ 0.045 to $ 0.14 per kWh for fossil fuel power (IRENA, 2016a). Onshore wind is another growth area. In 2016, the lowest-cost wind projects in the world delivered electricity for $ 0.05 per kWh without financial support (IRENA, 2016a).

In light of these changes in costs for renewables, policy-makers in Vietnam are considering setting national targets for their long-term development. To accomplish this, the integration of clean energy use must be constantly reviewed in order to facilitate the active contribution of communities, consumers, and investors in renewables development. Energy production in Vietnam must be compared to the cost of other sources of energy, both domestically and internationally. In this context, clean renewable energy is expected to be increasingly competitive with traditional sources.

3. Levelised costs of electricity from renewable energy

The levelised costs of electricity (LCOE) is generally regarded as the best tool for comparing the unit costs of different technologies over their economic life; this also corresponds to the cost to investors, assuming the certainty of production costs and the stability of electricity prices (IEA, 2010). LCOE calculations reflect the return on capital for an investor in the absence of specific market or technology risks. It is assumed that the electricity sector consists of monopolies with loan assurances and regulated prices.

With annual discounting, the LCOE calculation begins with the equation expressing the equality between the present value of the sum of discounted revenues and the present value of the sum of discounted costs:

$$\Sigma_t \ (\text{Electricity}_t{*}P_{\text{electricity}}{*}(1 + r)^{-t}) = \Sigma_t \ ((\text{Investment}_t + \text{O\&M}_t + \text{Fuel}_t + \text{Carbon}_t + \text{Decommissioning}_t){*}(1 + r)^{-t}) \quad (1)$$

Where:

Electricity_t: is the amount of electricity produced in year "t"
$P_{\text{electricity}}$: is the constant price of electricity
$(1 + r)^{-t}$: is the discount factor for year "t"
Investment_t: is investment costs in year "t"
$\text{O\&M}_t$: are operation and maintenance costs in year "t"
Fuel_t: are the fuel costs in year "t"
Carbon_t: are the carbon costs in year "t"[2]
Decomissioning_t: is the decommissioning cost in year "t"

[1] All monetary values in the tables and figures are in United States dollar and cents unless otherwise indicated.

[2] In many countries, there are no climate change policies, such as emissions trading schemes, carbon taxes etc. This cost would thus be zero (Simshauser and Tiernan, 2018; Nong and Siriwardana, 2018a,b).

Table 1
Average levelised cost of electricity from renewable energy sources, 2017 ($/kWh).
Source: Authors compiled from renewable energy statistics of IRENA (2016a, 2016b) & REN21 (2018a, 2018b). Luu and Nguyen (2013).

	Biomass power	Geothermal power	Hydro power	Solar PV power	Onshore wind power	Offshore wind power
Vietnam	**N/A**	**N/A**	**0.037**	**0.10**	**0.086**	**0.15**
Africa	0.08	0.07	0.04	0.18	0.08	0.15
Asia	0.04	0.06	0.03	0.13	0.06	na
Central America & Caribbean	0.05	0.09	0.10	0.14	0.07	na
Eurasia	0.04	0.06	0.05	0.21	0.07	Na
Europe	0.07	0.12	0.08	0.15	0.065	0.15
Middle East	0.07	na	0.07	0.14	0.09	na
North America	0.06	0.08	0.06	0.15	0.06	0.12
Oceania	na	0.07	0.11	0.20	0.10	na
South America	0.05	0.06	0.04	0.09	0.06	na
China	0.03	na	0.03	0.10	0.05	0.14
India	0.04	na	0.04	0.09	0.07	na
United States	0.07	0.09	0.05	0.13	0.05	0.12

Wh'ich is, LCOE, equivalent to:

$$P_{electricty} = \Sigma_t \ ((Investment_t + O\&M_t + Fuel_t + Carbon_t + Decommissioning_t)*(1 + r)^{-t}) \ / \ \Sigma t(Electricity_t*(1 + r)^{-t})) \quad (2)$$

The LCOE is an economic assessment of average total cost and is used to measure and to compare the different methods of electricity generation. This measure makes it is possible to compare the relative costs of different sources of electricity and to see how these relative costs change over time. Table 1 provides the LCOE of different energy sources for Vietnam as well as for other countries and regions. Before turning specifically to the Vietnamese case, it is necessary to understand long-run global trends in relative costs.

3.1. Wind power

In recent years, one of the fastest growing types of renewable energy has been wind power. Production costs of wind power have become more competitive due to the rapid development of technologies in the industry and the reduction of installation costs. The best wind projects in the world in 2016 delivered electricity for $0.05/kWh, without financial support (Table 1: IRENA, 2016a,b). Onshore wind, which is considered the lowest-cost source available, had a weighted average LCOE by region of between $ 0.05 to $ 0.09/kWh, while offshore wind a weighted LCOE of between $ 0.12 to $ 0.15/kWh (REN21, 2018a, 2018b). The production costs of wind generation depend on the costs of investment, the quality and location of wind sources, the technical features of wind turbines, the operation and maintenance costs, and the lifecycle of the wind power projects. The amount of power generated by a wind turbine is based on the nameplate capacity, the intensity of the wind resource, the height of turbine tower, and the diameter of the rotor. The capital costs of a wind power project can be listed as follows: turbine cost, civil works (including construction costs for site preparation, and the foundations for the towers), grid connection costs (including transformers and the connection to local distribution), project planning costs, and other capital costs such as construction of roads, building, and control systems.

As seen in Table 2, wind turbines account for as much as 84 percent of the total installed costs. Wind turbine technology has, however, improved in recent years due to the use of larger rotor diameters and higher towers, so wind turbine prices have consequently declined. For example, wind turbine prices in China fell from $1036/kW in 2007 to $ 628/kW in 2014 (CWEA, 2014). The relative installed costs of wind generation may vary across countries due to differences in demand, national policy, or local construction costs. The average instalment costs in China, were the lowest in the world, at approximately $1310/kW in 2014. India also has a low cost of $1370/kW in 2014 (IRENA, 2015). China and India benefit from low-cost local manufacturing, policy support and low materials and labour costs.

Table 2
Comparison of capital cost breakdown for typical onshore and offshore wind power systems in developed countries, 2014 (percentage).
Source: IRENA (2015)

Cost share of	Onshore (%)	Offshore (%)
Wind turbine	64–84	30–50
Grid connection	9–14	15–30
Construction	4–10	15–25
Other capital	4–10	8–30

The installed costs of offshore wind projects are higher than that of onshore wind because of the increased investment needed in deploying cables, building foundations, transporting materials to remote areas, and installing equipment at sea. Offshore turbines require additional corrosion protection and other components to resist the harsh marine environment (IRENA, 2012a, 2012b).

Operating and maintenance costs (O&M) comprised from between 11 and 30 percent of the total LCOE of onshore wind power (IRENA, 2012a). Data for actual O&M costs is hard to collect precisely due to the rapid change in turbine technology and operational costs, such as management costs, fees, insurance, local taxes. Although total O&M costs are not systematically reported, an average value of between $0.025 and $0.05/kWh (IRENA, 2012a) has been estimated.

3.2. Solar photovoltaics

Along with wind power, there has been considerable growth in the use of solar photovoltaic devices that convert sunlight directly into electricity. Solar PV is now a mature technology and increasingly commercially attractive to project developers, and small-scale residential or commercial consumers because of its cost-competitive advantage. The costs of solar PV are continuing to decline while solar PV generation capacity has risen significantly, from 5.1 GW in 2005 to 227 GW worldwide at the end of 2015 (see Fig. 2). A solar PV system consists of the module, other electrical and hardware components such as the inverter, electrical cabling, module mounts, and controls, which are mounted on rooftops or in fields. The system's LCOE will be lower when the level of solar resource is higher. The global average LCOE of solar PV has fallen by half the years before 2015 (IRENA, 2015).

The most competitive utility-scale solar PV projects delivered electricity for just $0.09 per kWh without financial support in 2016 (Table 1). The total installed costs have also declined by between 29 and 65 percent between 2009 and 2014, depending on the region, whereas the module prices of solar PV in 2014 were 75 percent lower than their levels in 2009 (IRENA, 2015). The capital costs of PV systems consist of the PV module cost and the costs of structural systems. The

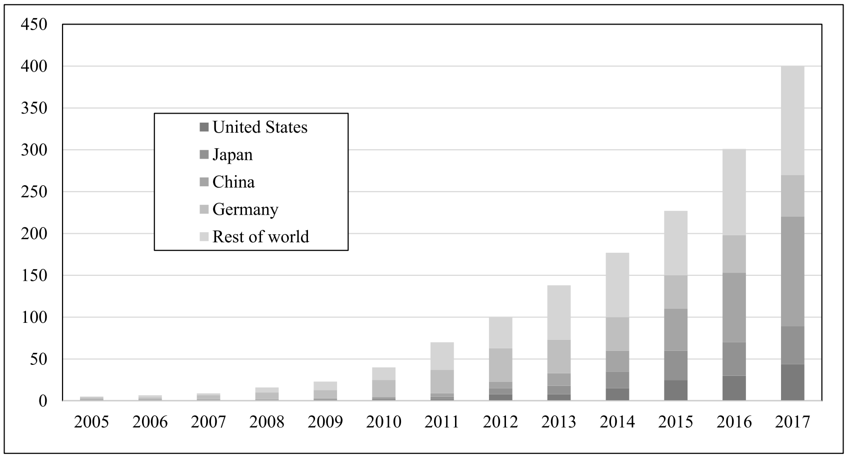

Fig. 2. Global cumulative installed solar photovoltaics capacity, 2005 to 2017 (GWs).

soft costs of system development, including customer acquisition, permitting, and the labour costs of installation, are becoming important drivers of cost reduction. The cost of solar PV modules can also be reduced by efficiency improvements, such as the reduction of materials costs, increased efficiency in converting sunlight into electricity, the achievement of economies of scale, and production optimisation based on more efficient processes and integration. Total installed costs for solar PV systems have fallen, from $3.9 per W to $2 per W in the worldwide (IRENA, 2015).

In 2014, the highest country average for total installed costs was almost 2.4 times higher than the lowest country average. The residential PV systems in Germany and China were the least costly in the world with an average of $2200 per kW. According to the renewables global status report of REN21 (2018a), total R&D spending on solar power rose 2 percent, equalling $6.1 billion. Accordingly, solar power attracted more than all other sectors combined for the fourth year running (REN21, 2018a).

3.3. Hydropower

Traditionally the most important source of renewable energy is hydropower. Hydropower is currently the largest renewable power generation source, with global capacity of 1064 GW. In many parts of the world, hydropower produces the least-cost electricity of any power generation technology; cost-reduction opportunities are low and typically tied to advances in civil engineering practices. Hydropower is also linked to the provision of other services, such as water storage, irrigation, and flood control. The hydro sector in its operation needs to take into account a range of factors, including projected changes in river flows, dam safety, vulnerability, and climate change risks. IRENA (2015) reports that the LCOE of large-scale hydro projects at good sites can be $0.02 per kWh, while average costs are around $0.05 per kWh. Small hydro projects have an average LCOE of 0.05 per kWh.

The costs of hydro projects can be grouped into the civil works and project development costs, and the costs related to electro-mechanical equipment. The largest share of installed costs is civil construction works (namely, dams and tunnels) and development costs (planning and feasibility assessments, licensing, environmental impact analysis, biodiversity mitigation measures and water quality monitoring and mitigation). The total installed costs for large-scale hydro projects normally range from $ 1000 per kW to roughly $ 3500 per kW. However, in some cases, installing hydropower capacity at an existing dam built for other purposes, such as flood control, may cost as low as $ 450 per kW. In contrast, projects at remote locations may cost more due to higher logistical and grid-connection costs.

Hydro plants have low O&M costs over their lifetimes. A large-scale plant has O&M costs similar to those for wind power, but higher than solar PV power (IRENA, 2012b). When hydro plants are installed along a river, O&M costs can be reduced at a very low level because of the chain of stations. The International Energy Agency (IEA, 2010) assumed O&M costs were 2.2 percent of total costs for large and 2.2 to 3 percent for smaller hydro projects, with a global average of around 2.5 percent of operating and maintenance costs (IRENA, 2015). The LCOE from hydropower is thus very cost competitive, although the range of estimated costs is wide, ranging from 0.03 $/kW to 0.11 (IRENA, 2015).

3.4. Biomass

In recent years, an additional area of growth has been in biomass. A range of biomass power generation technologies are mature and biomass is a competitive power generation option wherever low-cost agricultural or forestry waste is available. New technologies, such as direct combustion in stoker boilers and low-percentage co-firing, have relatively modest cost-reduction potential. Cumulative worldwide installed capacity was 86 GW in 2013 (IRENA, 2012c), and is predicted to reach 130 GW by the end of 2025 (Global Data, 2014).

Biomass can be produced from any source of organic material, such as trees, grasses, or agricultural crops. The range of costs for feedstock supplies is extremely variable, from negative prices for waste that would have incurred disposal costs, zero for waste produced as a result of industrial processes, to potentially high prices for dedicated energy crops if transport costs are high. Transportation or transformation costs can add a significant amount to the costs of feedstock in case of large distances of transportation. Feedstock costs, therefore, typically comprised between 20 and 50 percent of the final cost of electricity, depending on biomass technologies (IRENA, 2015). The total capital expenditure of a biomass plant consists of planning, engineering and construction costs, fuel handling and preparation machinery, and conversion equipment. Additionally, grid connection and improvement costs for infrastructure requires can be added to the investment costs. Biomass in developing countries can have remarkably lower investment costs than the cost ranges for projects in developed countries because of the lower equipment costs and less stringent environmental regulations (REN21, 2018a, 2018b). Some small manure and wastewater systems for electricity generation under the Clean Development Mechanism project of the Kyoto protocol have capacities between 1 MW and 3 MW with the investment costs ranging from 500 to 5000 $/kW (IRENA, 2012c). According to IRENA (2012c), variable O&M costs for biomass are around 0.005per kWh (IRENA, 2012c).

The lowest weighted average LCOE of biomass-fired electricity generation is about $0.03/kWh in China and $0.04/kWh in India (see Table 1). The LCOE in North America and Europe is higher, reflecting higher feedstock costs, more complicated technologies, and more stringent emission controls. The weighted average in Europe and North

America was $0.07/kWh and 0.08 respectively (Table 1). Individual projects typically generate electricity ranging from $0.03 to $ 0.14/kW. In some of the waste incineration projects in OECD countries, the levelised cost can be up to $0.25/kWh for the purpose of waste disposal (not for electricity generation) (IRENA, 2015).

3.5. Geothermal

Another major renewable resource is geothermal energy. Geothermal resources consist of the thermal energy available from the Earth's interior, stored as heat in rocks or as hot water or steam. Geothermal resources provide energy in the form of electricity, direct heating and cooling and thermal output for various applications. Global geothermal power generation in 2014 was 74 TWh with a total global capacity of approximately 128 GW (REN21, 2018a, 2018b).

Geothermal power plants require intensive investment costs but have low and predictable running costs. Development costs have increased over time as engineering, procurement, and construction costs have risen. The total installed costs of geothermal power projects are composed of exploration and assessment costs, infrastructure for geothermal fluid collection and disposal system, project development and grid connection costs. The installed costs depend on whether the power plant is flash or binary.[3] In 2009, the total installed costs of flash geothermal power generation projects were between $1900 and $3800/kW, while those of binary power plants were between $2250 and $5500/kW (IPCC, 2011). Projects planned for the period from 2015 to 2020 are expected to reduce installed costs below recent levels (IRENA, 2015). The LCOE of geothermal varied from as low as $0.04/kWh for second-stage development of a field to as high as $0.24/kWh for greenfield development (REN21, 2018a, 2018b).

3.6. LCOE of renewable and fossil-fuel resources

In a number of countries, renewable energy resources have recently achieved fairly comparable costs to that of fossil fuels. Fossil fuels tend to have costs between $0.045/kWh and $0.14/kWh. By comparison, hydropower has an average LCOE of USD 0.05/kW, biomass and onshore wind around $0.06/kWh, and geothermal around $0.08/kWh (see Table 1). In other words, where good resources are available, biomass, hydro, geothermal and onshore wind power can provide electricity competitively. Solar PV, in particular, regularly delivers electricity for just $0.08/kWh, without government financial support. Solar technologies also are increasingly providing low-cost energy due to scale economies, technological advances, and other cost reductions (IRENA & ASEAN, 2016; IRENA, 2016a, 2016b; 2016c; REN21, 2018a, 2018b). Given the decline in the cost of renewables worldwide, it is expected that similar trends would be taking place in Vietnam.

4. The levelised cost of electricity from renewable energy sources in Vietnam

4.1. The potential for renewable energy in Vietnam's electricity industry

Turning to the situation in Vietnam, that country has also seen a fall in the costs of renewable energy in recent years. Compared to the case of developed countries, however, energy demand is growing at a steady rate. This has important implications for the development of the renewables sector in Vietnam. Also important is the structure of the electricity industry in Vietnam. Electricity generation, transmission, and distribution in Vietnam are all mainly provided by Electricity of Vietnam (EVN), which is a state-owned monopoly established in October 1994 under the Ministry of Industry. At the end of 2016, the total electricity-generation capacity of the country was 42,135 MW, of which EVN facilities accounted for appropriately 61 percent. The remainder was owned by local and foreign independent electricity producers, such as PetroVietnam (10.5 percent), Vinacomin (4.2 percent), BOT and the others (24 percent) (EVN, 2018a, p. 12). In addition, around 1.2 percent of demand is served by imports from China and Laos (EVN, 2018a, p. 12).

Table 3
Power generation by fuel type in Vietnam, 2016 and projected 2020 (MW and percentage).
Source: EVN (2018a, 2018b). EVN & Phugiasc (2011)

Power source	Capacity (MW)	Per cent	Per cent Projected 2020
Hydropower	15,857	37.6	22.0
Coal-fired power	14,448	34.3	43.2
Oil fired power	1370	3.3	2.9
Gas fired power	7502	17.8	20.5
Renewable	135	0.2	3.0
Other	2283	5.4	na
Import	540	1.2	na
Total	42,135	100.0	100.0

Table 3 shows the ratios of the different electricity generation sources in Vietnam at the end of 2016. The dominant sources are hydro and coal with capacities of 15,857 MW and 14,448 MW respectively, accounting for two-thirds of total generation capacity. The other third of generation capacity is mainly made up of oil, gas, and diesel, with non-hydro renewables representing 5.8 percent of total capacity (2418 MW) (EVN, 2018a, p.12). Hydro is thus a major energy source and plays an important role in the structure of electricity production in Vietnam. Hydro has a low-cost advantage, with low operational costs, low emissions, and the ability to respond quickly to changes in electricity demand (Nguyen-Tien et al., 2018). According to the Renewable Global Status Report of REN21 (2018b), Vietnam is one of the countries that had substantial additions to hydropower capacity created in recent years; in fact, Vietnam ranks fifth in new hydro installations. When the new Lai Chau plant in Vietnam is completed, it will be Vietnam's third largest hydropower facility (REN21, 2018b).

Despite the dominance of hydro, however, the Vietnamese Government's power development plan and strategy are to reduce the proportion of hydro as a share of the total electricity production. The main reason for this is that there is little potential to establish additional large-scale hydro projects in Vietnam, given that the most favourable locations are already being used. Accordingly, the proportion of hydro is projected to decrease from 38 percent in 2015 to 22 percent in 2020, and to 17 percent in 2025 (EVN & Phugiasc, 2011) (Table 4). Based on the EVN's electricity development planning to 2025, the proportion of coal-fired electricity will be raised gradually, while that of hydro and gas-fired power will be reduced. Nuclear power and non-hydro renewable power sources such as wind and solar power and projected to be the major areas of growth.

Besides the cost advantage of hydropower, this source has relatively high investment costs for infrastructure and equipment and long construction times and depends on variable weather conditions. Long droughts decrease water levels in reservoirs, which greatly affects generation capacity. Additionally, natural disasters such as floods may cause damage to dams and grid connection infrastructure. Despite these difficulties, compared to other renewable energy resources such as solar PV, geothermal, biomass, and wind power, hydropower is still considered important to Vietnam's electricity industry (Nguyen-Tien et al., 2018). Vietnam is located in the tropical monsoon region, with hot and humid conditions and rain at annual average levels of 2000 mm. In addition, the river system in Vietnam is varied, with over 2400 rivers

[3] Flash plants take high-pressure hot water from inside the earth and convert it to steam to drive generator turbines. Binary cycle power plants transfer the heat from geothermal hot water to another liquid. The heat causes the second liquid to turn to steam, which is used to drive a generator turbine.

Table 4
The proportion of hydropower in Vietnam's electricity sector (actual and projected); 2005 to 2025 (MW).
Source: EVN & Phugiasc (2011)

Year	2005	2010	2015	2020	2025
Total capacity (MW)	11.286	25.857–27.000	60.000–70.000	112.000	181.000
Hydro (MW)	4.198	10.211	19.874	24.148	30.548
Proportion (%)	36.5	38	28–33	22	17

with lengths of over 10 km. Vietnam thus has substantial hydro potential. According to the Government's hydro master plan (2011), the total estimated capacity of the rivers in Vietnam is approximately 300 billion kWh and installed capacity 31,000 MW. As of 2011, hydro projects in Vietnam, with a capacity of just 8075 MW, represented only 26 percent of the country's hydro potential (EVN & Phugiasc 2011). Currently, the hydro deployment rate is high, but still accounts for only 60 percent of the total techno-economical production of about 95–100 TWh/year (APEC, 2016).

Other reports have argued that there is potential for renewable energy besides hydropower to be developed in Vietnam (Luu and Nguyen, 2013). Vietnam has abundant solar energy sources, as the country has hours of sunlight varying between 2000 and 2500 h annually. Accordingly, solar energy can potentially provide 3 to 4.5 kWh/m^2/day in the winter and 4.5 to 6.5 kWh/m^2/day in the summer. Some 220,000 km^2 of land area is suitable for solar power generation, with installable capacity of 0.06 kWp/m^2 based on current technologies (Asian Development Bank, 2015; cited in APEC, 2016).

Based on a 2001 World Bank survey (APEC, 2016), the total potential of wind power capacity was 513,360 MW; it was later estimated to be in excess of 2 million MW (AWS Truepower, 2011, p. 15), the South Central, Mekong Delta, and Central Highlands, and regions are the main areas of greatest potential. Accordingly, wind energy potential in Vietnam is apparently surpassing the potential of all neighbouring Southeast Asian economies (World Bank, 2014; Nguyen 2017). Recently, 48 wind power projects are being considered, and more than 20 projects totalling 20 MW have been constructed (Luu and Nguyen, 2013). More data on the technical potential of wind energy in Vietnam at altitudes up to 60m is required if a clearer view is to be achieved.

As a tropical country, Vietnam also has great potential for biomass energy (Le et al., 2013). Tens of thousands of biogas systems have been established in rural provinces in Vietnam using animal waste for producing electricity. Biomass in the form of agricultural products has been estimated at about tens of millions of tons per year. According to APEC (2016), currently available sources, such as agricultural residues (from coffee husks, nut shells, and maize), wood waste from wood processing municipal waste, and animal waste, are estimated to be roughly 58 MTOE per year. Available biomass sources are expected to increase to 70 MTOE in 2030, with agricultural residues representing 30 percent, wood fuel 21 percent, municipal and animal waste 11 percent, organic waste 2 percent and energy crops 36 percent of this energy source (GOV, 2015; cited in APEC, 2016). Lastly, the geothermal potential of Vietnam is not large because there are only four hot water sites in the country with a temperature above 100 °C, which provide approximately 200 MW capacity.

4.2. Renewable resource development planning in Vietnam

One of the biggest barriers in the past to the development of renewable energy resources in Vietnam has been the high cost and price per unit of energy compared to traditional energy sources. As the cost of renewables in Vietnam declines in line with international trends, this situation will change. Unlike in a number of developed countries, the Vietnamese Government has not to date provided substantial financial assistance to bridge the cost gap. For example, in the case of wind power in Vietnam, the cost of the ‘cheapest’ renewable resource, onshore wind power, is 2.5 times higher than that of hydro and 1.5 times higher than coal (see Table 1). The reasons for the lower production costs of hydropower in Vietnam are the natural advantages of the country in hydro, combined with the ‘implicit subsidy’ to hydro in that the cost of environmental impacts, such as land loss for plant reservoirs, changing river environmental conditions, and ecology, have not been taken into account. Currently, as hydro remains the main source of electricity supply in Vietnam investors have tended to be more interested in hydro projects than other resources (Nguyen-Tien et al., 2018).

Low electricity prices that flow from the use of inexpensive hydro and coal would act as a deterrent to investment in electricity generation of renewable energy resources in Vietnam. Furthermore, the monopolistic market structure of the electricity industry in Vietnam also limits the introduction of renewable energy resources. Indeed, many small-scale electricity producers in Vietnam, small and medium-sized hydro and wind power plants (e.g., the Tuy Phong plant), have not been able to sign contracts for the sale of electricity to the EVN, which operates the distribution network (MBS, 2015). In power purchasing agreements (PPA) between the EVN and new entrants, the cost of generating electricity has been used as the basis for determining electricity price. Costs, including fuel costs, investment costs, and financial costs (interests and expected profits) must be calculated carefully by the investors before negotiation can take place. The Vietnamese Government's Circular No.56/2014/TT-BTC, issued on December 19, 2014, provides the method for determining electricity prices and the negotiation procedures in PPAs (Vietnam, Ministry of Industry and Trade, 2014b; Nguyen-Tien et al., 2018). Electricity prices cover the average discounted costs of annual investment costs, technology and equipment costs, and operation and maintenance costs and other fixed and variable costs.

Presently in Vietnam, there are two types of PPAs: contracts for projects with capacity of more than 30 MW and contracts for renewable energy and small hydro projects with a capacity under 30 MW (Vietnam, Ministry of Industry and Trade, Circular No 32/2014). Circular No.32/2014/TT-BCT of the Vietnamese Government regulates procedures on the establishment and application of avoidable cost tariff schedule and promulgation of specimen power purchase agreement to small hydro plants (Vietnam, Ministry of Industry and Trade, 2014a). Accordingly, small hydro projects under 30 MW and renewable power projects do not need to negotiate electricity price with the EVN, and the EVN cannot interfere in the prices. The electricity prices stated in the PPAs have been calculated based on the annual avoidable cost tariff schedule of the Ministry of Industry and Trade. However, although avoidable costs are the highest production cost in the electricity grid, prices sold to the EVN are still lower than average production costs (VPBS, 2013). This has discouraged investment in Vietnam's energy sector in the absence of government subsidies. In the case of wind tariffs, the APEC (2016) reported that in Vietnam they were 7.8 cents per kWh, considerably lower than those of other countries, such as Germany (12.1 cents) and France (11.1 cents). The current average rate to consumers is 6 cents per kWh, which means that in most parts of the country wind is not commercially viable (APEC, 2016, 60).

This method of pricing has tended to favour the retention and expansion of the hydro sector. In 2016, Vietnam had 268 hydropower plants connected to the national grid or operating in isolated areas to supply electricity to local communes (APEC, 2016). Due to low O&M costs, the cost of electricity generation from hydro is low in comparison to other sources such as coal, oil, or gas, as well as non-hydro renewables. The investment cost for a hydro plant ranges from $1 to 1.6 million, which is higher than the cost of a thermal power plant. Reports from the VPBS (2013) indicate that the cost for a typical coal thermal power plant was about $1.2 million, for a gas thermal power plant about $0.6 million, and for an oil thermal power plant even lower at about $0.4 million. As the electricity industry is a priority sector of the Vietnamese Government, electricity projects have access to low-interest loans from domestic banks and foreign sources like the ODA (APEC, 2016).

To date, these factors have meant slow growth in the introduction of non-hydro renewables in Vietnam. According to an analysis of the electricity sector by MBS (2015), biomass power generation accounts for the largest proportion of non-hydro renewable energy in Vietnam (approximately 80 percent of the total). Biomass resources are primarily from agricultural waste, namely about 80 million tons from coffee husk, bagasse, landfills, and animal carcasses, as well as industrial waste. Traditional biomass sources have been used for a long time in many rural and mountainous regions, by both households and small industrial and handicraft establishments to produce heat and power at low cost and mainly for their own uses. Recently in Vietnam, biomass electricity has been generated mainly from sugar mill waste.

Besides biomass, the use of wind power is also growing. Wind energy, programs have been undertaken with cooperation between the Ministry of Industry and Trade of Vietnam and the governments of Germany, Finland, and the United States, including the financing of wind power projects (APEC, 2016). In order to further encourage wind power projects in Vietnam, according to the Decision No.37/QD-TTg issued on June 29, 2011 by the Vietnamese Government, the selling price of wind power plants for the EVN is 7.8 cent/kWh, in which 0.98 cent/kWh can be supported by Government through its Environmental Protection Fund Vietnam Decision No. 37 (Vietnam and Minister, 2011).

The biggest barrier to wind power projects in Vietnam is the high investment costs for imported equipment. A wind mapping project was completed by the Institute of Energy in Vietnam in 2016 (IE, 2016; cited in APEC, 2016). As of 2016, there were 42 wind power projects in Vietnam, each with a capacity of between 6 MW to 150 MW, located in the provinces of Ninh Thuan, Binh Thuan, Soc Trang, Bac Lieu. Most provinces with high wind energy potential are planning wind farms with multi-MW wind turbines. The largest scale plant is Tuy Phong, with a total investment cost for the first phase of $70 million, equivalent to 2.3 million $/MW, and has been operating since 2013 (EVN, 2016a). In 2016, the first Phu Lac wind power project with a capacity of 24 MW, using an ODA loan from the German Government, was put into operation. The next project, located in Loi Hai in the Ninh Thuan province, with a capacity of 30 MW is registered for ODA financing from a German bank of KfW (EVN, 2016). Installed wind capacity in Vietnam has significantly increased, from 8 MW in 2008 to 135 MW in 2016 with another 114 MW under construction (APEC, 2016). Moreover, the wind turbine and tower manufacturing industries have gradually developed in Vietnam with the participation of foreign and domestic producers, such as GE (US), CS Wind Tower (Korea), VINA HALLA (Korea), and UBI Tower (Vietnam).

Solar PV power projects are mainly used for internal domestic consumption, so may not be included as a supplier to the electricity grid. The Vietnamese Government encourages the use of solar PV standalone systems to provide electricity in remote and inaccessible areas. Grid-connected solar PV projects are mainly pilots funded by developed countries for research and development purposes in accordance with the socio-economic policy of the Vietnamese Government (APEC, 2016). Prominent projects include a 212 kW capacity project at Big C Binh Duong, a 200 kW project at Intel's factory in Ho Chi Minh City, and other smaller projects at the Danang, Nha Trang airport. Currently, the EVN is preparing to invest in the Phuoc Thai solar farm project with a total capacity of 200 MW (EVN, 2016). For further development, the first largest scale grid-connected solar PV power plant with a capacity of 19.2 MW was initiated in Quang Ngai province in 2015, which it is hoped to provide electricity to the national grid (APEC, 2016). As the cost of solar panels decreases, solar power projects are expected to attract more investors.

Despite the growing experience, there are still barriers to the adoption of renewable technologies in Vietnam (Minh Ha-Duong et al., 2010). The dominant barrier to the wider adoption of geothermal and small hydro schemes is the extra costs of renewables in Vietnam's power sector that arise from the difficult geography, the weak financial and managerial capabilities, and the inadequate electricity pricing system. Moreover, renewable resource sites are located in remote areas where the people are poor and under-educated; inadequate infrastructure, financial resources, and incentives make development difficult. Most potential investors cannot acquire enough capital to finance projects, and more than 80 percent of the capital raised is from bank loans. Investors have a tendency to expect intervention and sponsorship from the Government, rather than negotiating and seeking adequate financing agreements for the projects through power purchasing agreements. Some investors have even failed to estimate the financial requirements of the projects, resulting in delays or postponements (Minh Ha-Duong et al., 2010). Another economic barrier is the manipulation of fossil fuel and electricity prices by the established industry, which can make renewable resources less attractive to investors and independent power producers (Minh Ha-Duong et al., 2010).

To encourage the wider deployment of renewable energy, according to the Decision No.63/2013/QD-TTg issued on November 8, 2013, the Vietnam power market will be formed and developed through three stages. The first stage of the competitive power generation market was completed by the end of 2014, aiming to eliminate the monopoly situation in Vietnam's power market. The second phase was implemented with a pilot wholesale market in 2015–2016; a fully competitive wholesale market is planned for 2021. In the third phase, a fully competitive retail market will be introduced. Whether these measures will create greater incentives for investors to enter the markets remains to be seen.

5. Conclusion

In order to achieve cleaner energy in Vietnam, while also developing generation capacity, the proportion of renewables in total energy resources will need to rise. This will reduce the country's dependence on fossil fuels and pollution, as well as help mitigate some of the effects of climate change. Declining costs globally and in Vietnam will promote the development of non-hydro renewables. Vietnam advantages are an abundance of windy coastal regions and sunny days.

Despite these advantages, and although the Vietnamese Government is projecting a rise in the use of non-hydro renewable energy, considerable barriers remain. One is the dominance of the electricity sector by hydropower and its low cost of production. To date, investors are mainly drawn to investing in this area, despite physical limits to its further growth in Vietnam and a forecast decline in its future importance.

Compared to most developed countries (such as those in Europe and North America) the gap between prices of hydro and non-hydro (wind and solar) resources remains too great to promote the latter. In addition, the Vietnamese Government lacks the financial resources to subsidise the development of renewables, as have a number of developed countries. Compared to international trends, therefore, it is expected that non-hydro renewable energy resources will experience some growth in Vietnam, but lag behind that of other countries in the short to medium term.

These circumstances are not permanent. Rising demand for electricity cannot be met only by the expansion of hydropower generation capacity and with greater reliance on higher cost imports of coal, electricity prices will tend to rise. Rising taxes on coal and petroleum will also encourage the shift toward renewable energy. The cost of wind power in countries such as India and China is closer to that of Vietnamese hydropower, and the declining costs of wind power is also relevant. If the trend toward lower cost renewables continues, and public policy is supportive, non-hydro resources will eventually become attractive to investors in the power sector.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jup.2019.01.009.

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