Projection of fossil fuel demands in Vietnam to 2050 and climate change implications

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Abstract
Over the past decade, Vietnam has emerged as one of the world's fastest growing economies. Fossil fuel use, which is a dominant energy source and vital for economic growth, have been increasing considerably. Undoubtedly, the projection of fossil fuel demand is essential for a better understanding of energy needs, fuel mix, and Vietnam's strategic development. This paper provides an outlook for coal, oil, and gas demand in Vietnam to 2050. The projection is based on the calibrated results from a hybrid model (that combines a GTAP- R version for resources, and a micro simulation approach) and an energy database. Under the baseline scenario (business as usual), from 2018 to 2050, the demand for coal, oil products, and gas are expected to increase by a factor of 2.47-fold, 2.14-fold, and 1.67-fold, respectively. Emissions are also projected to increase. Because fossil fuels are the dominant source of carbon emissions in Vietnam, it follows, going forward, that an effective fuel-mix strategy that encourages the development of renewables and energy efficiency is essential.

KEYWORDS
climate change, emissions, fossil fuels demand, projection, Vietnam
INTRODUCTION

Over the past decade, Vietnam has emerged as one of the world’s fastest growing economies with a fundamental improvement in the scale of economic activities and enormous potential new opportunities. Located in the Asia-Pacific, the country’s east seashore (as a “S” letter shape), is entirely laid next to the Pacific Ocean. The north and west land borders are with China, Cambodia, and Laos. The country covers 310,070 km$^2$ of land and 21,140 km$^2$ of water (General Statistics Office of Vietnam, 2018). In 2017, the population was 96.16 million, and gross domestic production (GDP) was $US 223.8 billion (World Bank [WB], 2019).

The past decade has witnessed considerable changes in the economy, recorded as one of the world’s leaders in economic growth, fast improvements in the standard of living, and extensive urbanization. During 2010–2017, the average GDP growth was 6.13% per annum, reaching 6.8% in 2017. In 2018, the GDP growth was highest over the past 11 years at 7.08%. Accordingly, GDP per capita in Vietnam has been rising rapidly from $US 376.6 in 1984 to $US 1,835.7 in 2017, and $US 2,490 in 2018 (based on WB, 2019; International Monetary Fund [IMF], 2018; General Statistics Office, 2018; Trading Economics, 2019).

Energy and energy security, of which fossil fuels (coal, oil, and gas) are the dominant source for the country, are essential for long-term economic growth. The contribution of fossil fuel consumption over total energy consumption has been increasing rapidly in Vietnam, from 27.6% in 1990 to 70% in 2016 (computed from British Petroleum [BP], 2018; International Energy Agency [IEA], 2018; CEIC, 2019). However, fossil fuel is a key source of global greenhouse gas (GHG) emissions (58% of total) (United Nations Framework Convention on Climate Change [UNFCCC], 2019).1 Undoubtedly, a relevant fuel-mix strategy is essential for climate change mitigation.

Given a growing concern over GHG, carbon emissions, and climate change effects, the Vietnam government has been focusing on sustainable development with low carbon emissions. Vietnam’s focus on global warming as a future threat has indeed been increasing over the recent years (Danish Energy Agency, DEA, 2017; Tran, 2013b). Rising sea levels (through the global warming process), for example, is a considerable threat to the Cuu Long River Delta (the most important agricultural and economic region).

Aiming for a low-emission economic growth target, the Vietnam government has been committed to implementing the Paris Climate Accord, which requires international collaboration based on a shared understanding of long-term goals and agreement on frameworks for action (Stern, 2016). The Agreement aims to reach global warming by around 1.5°Celsius by the end of the century (2100), with focusing on reducing carbon emission (UNFCCC, 2018). As a result, the Vietnam government has developed energy policies and strategies that aim to coupling strategic exploitation of fossil fuel resources and a relevant development of renewables (DEA, 2017). Undoubtedly, a comprehensive analysis of future energy demands, especially fossil fuels under the “business as usual” case is essential. That analysis will provide a better understanding of

1Greenhouse gases (GHGs) are gases that trap heat in the atmosphere, including carbon dioxide (CO2), methane (CH4), nitrous oxide (NO2), and fluorinated gases (HFCs). When sunlight reaches the Earth’s surface, it can either be reflected back into space or absorbed by Earth. GHGs absorb energy, slowing or preventing the loss of heat to space. GHGs act like a blanket, making Earth warmer as the “greenhouse effect” (UNFCCC, 2019). On the basis of UNFCCC (2019) and CEIT (2017), fossil fuel use shares 86% of CO2 in energy. Agricultural activities produce most of CH4 and N2O emissions. Industrial processes produce HFCs (F-Gas).
future energy demand and for the development of energy policies that achieve low carbon emissions as committed to in the Paris Climate Accord.

A hybrid modelling approach, including a GTAP-R model and a microsimulation process, is applied in this paper. Global Trade Analysis Project (GTAP) is a global recursive computable general equilibrium model that provides an essential tool for policy analysis and forecasts of economic growth. A GTAP-R version is a model developed by Kompas and Che (2018), using GTAP, with the extension for energy and electricity generation. On the basis of the results of GTAP-R, a microsimulation is carried out for the projection of future energy demand of Vietnam.

Section 2 provides a background for fossil fuel production in Vietnam. Section 3 reviews the historical consumption of fossil fuels and associated carbon emissions. Analysis of energy intensity and time-series econometrics is presented in Section 4. The projection of fossil fuel consumption and associated carbon emissions to 2050 is analysed in Section 5. Section 6 is devoted to a sensitivity analysis of future energy demand across scenarios of various energy intensities. Renewables and emissions are discussed in Section 7. Section 8 concludes.

2 | BACKGROUND OF FOSSIL FUEL PRODUCTION IN VIETNAM

2.1 | Coal production

At the end 2016, Vietnam's proven coal reserves were 3,360 million tons, including 3,116 and 244 million tons for hard coal (anthracite and bituminous and sub-bituminous) and lignite, respectively (BP, 2018). To meet the rapid demand for domestic production, coal production has surged by almost 10-fold during 1990–2016, from 5.1 million tons in 1990 to 46.5 million tons in 2011. Coal production has slowed since 2012 and reached to 39.4 million tons in 2016 (BP, 2018).

According to the IEA (2018), historically, the industrial sector has been the largest coal consumer, although the power sector generally requires much more coal supply. The government has recently promoted coal use to fuel the power sector as a low fuel cost for meeting power shortages and volatility in addition to the use of substantial hydroelectric capacity.

After two decades of being net exporters, coal exports began slowing after 2009, and the country became a net coal importer in 2015. At present, the production of coal is very much balanced with consumption. In 2016, coal production and consumption were 22 and 21.3 million tons of oil equivalent (mtoe), respectively (BP, 2018).

2.2 | Oil production

Vietnam's proven oil reserves have been increased significantly from 0.2 billion barrels in 1990 to around 4.4 billion barrels during 2010–2016 (BP, 2018), placing the country at a high rank in terms of proven oil reserves in the Asia-Pacific region.

Vietnam's oil production increased rapidly over the past two decades from 55,000 barrels per day (bbl/d) in 1990 to 424,000 bbl/d at a peak in 2004. Since 2004, oil production has slowed down to 322 bbl/d in 2010, and back to 373 bbl/d in 2014. Since 2014, however, oil production has decreased to 362,000 and 333,000 bbl/d in 2015, 2016, and 2017, respectively. In July 2018, oil production was 239,000 bbl/d (BP, 2018; Trading Economics, 2019). With further efforts to
intensify the exploration and development of offshore fields, oil production could increase in the near future. However, by the end of 2018, the depletion of current mature fields and the lack of new ongoing exploration and investment may likely mean that oil production will decline (perhaps slightly) over the short to medium term.

Vietnam's oil refinery capacity has increased significantly over the past decade, from 11 bbl/d in 2006 to 163 bbl/d in 2016. Given the gap between crude oil production and refinery capacity, the country will remain in the role of oil exporter over the next decade. Crude oil exports of Vietnam were reported at 129,500 bbl/d in Dec 2017 (Organization of the Petroleum Exploration Countries (CEIC), 2019).

That said, Vietnam is a net exporter of crude oil but a net importer of oil products. Dung Quat refinery commenced since 2009 with a capacity of 130,000 bbl/d. Petro Vietnam intends to increase Dung Quat's capacity for sweet and less expensive sour crude oil from Russia, the Middle East, and Venezuela (EIA, 2017). Given the limited refinery capacity, about 64% of oil product consumption was imported in 2016 (estimated from UNEP, 2019). A new refinery project by SCG (Thailand) will commence in 2023. This project is valued at $US5.4 billion, providing 1.6 million tons of oil product per year (Vnexpress, 26 February, 2019).

2.3 | Gas production

Vietnam's proven gas reserves have increased steadily from 100 billion cubic meters (bcm) in 1992 to around 600 bcm in the past decade (BP, 2018). Natural gas production has been increasing rapidly over the past decade from 6.8 to 10.2 bcm in 2016, and 9.5 bcm in 2017 (Statista, 2019).

According to EIA (2017), half of the gas reserves are located in the northern deep-water areas of the Song Hong Basin and have high carbon dioxide contents and are costly to extract. Major potential projects are from ExxonMobil’s Ca Voi Xanh field, PetroVietnam’s Block B project, and the overlapping basin with Malaysia. However, according to the IEA (2018), low natural gas prices and the lack of gas infrastructure outside of the southern part of the country are impediments to upstream investment. At present, gas production and consumption is at a balance. In 2016, gas production and consumption was 9.6 mtoe (BP, 2018).

3 | CONSUMPTION OF FOSSIL FUELS IN VIETNAM AND CARBON EMISSIONS

Total primary energy consumption in Vietnam has been increasing at a growth rate of 6.1% a year during 1990–2016, of which the industrial, residential, and transport sectors accounted for about 93% of total end-use consumption (BP, 2018; IEA, 2018). In 2015, the share of these sectors in total end-use energy is 43% for industry, 27% for residential areas, and 23% for transport, respectively. Service and commerce, agriculture, and the non-energy consumption sectors accounted for 3%, 1%, and 3% of total end-use energy consumption. During 2006–2015, the share of energy consumption in total has increased for industry (32% in 2006) and transportation (20% in 2006) but decreased significantly for residential use (41% in 2006; Institute of Energy, 2016, cited by DEA (2017). In 2016, total primary consumption was 80,995 thousand ton of oil equivalent (ktoe). The structure of end-use energy was 43% for industry, 23% for transportation, 27% for residents, 3% for services, 1% for agriculture, and 3% for other sectors. The share of energy use from the
industrial and transport sectors has increased from 32% and 20% in 2006 to 43% and 23% in 2015 (Institute of Energy, 2016).

Throughout 1990–2016, consumption of all fossil fuels has been increasing rapidly at a growth rate of 10.6%, 7.9%, and 31.8% a year, respectively (computed from BP, 2018; IEA, 2018; CEIC, 2019; UN Environment International Resource Panel [UNEP], 2019). Figure 1a presents the upward trend of all fossil fuel use, with a steadily increase for oil products and a faster growth rate for coal and gas since 1999 and 2003, respectively. In particular, coal consumption has elevated by 12-fold, from 2,223 ktoe in 1990 to 27,672 ktoe in 2016. Consumption of oil products has increased by 7-fold, from 2,711 ktoe in 1990 to 19,882 ktoe in 2016. Since 1995, gas consumption started to raise from 186 ktoe to 9,486 ktoe in 2016.

The share of fossil fuel consumption over total energy use has been increasing rapidly in Vietnam, from 27.6% in 1990 to 70% in 2016 (see Figure 1b and Figure 2a). The share of coal use has been increasing steadily from 12.44% in 1990 to 34.3% in 2016. The share of oil product consumption had increased from 15% in 1990 to 28.75% in 2004, but decreasing slightly since then, to 24.55% in 2016. The share of gas use has increased from 1990, with a peak in 2013 (13.81%). The decreasing share of oil products and gas of recent has been replaced by the new expansion of biofuels and waste and hydroelectricity generation.

The carbon emissions resulting from fossil fuels is estimated from consumption and the rate of emission intensity, which is derived from IEA (2018) and EIA (2018). The emission rate applied is 2.86, 1.97, and 1.46 ton of CO2 for a ton consumption of coal, oil, and gas, respectively. The rapid growth of fossil fuels has been associated with a significant increase in emissions (see Figure 2b).

Figure 3 presents the trend and fuel mix of electricity generation. During 1990 to 2016, electricity generation has increased at a growth rate of 12.8% per year, or almost 20-fold. The fuel mix of electricity generation is 38.9% from hydro generation, 32.6% from coal, and 27.7% from gas. Renewables and oil only accounted for 0.2% and 0.7%, respectively.

Since 2015, Vietnam has switched from a position of coal exporter to a net coal importer. The country is a net oil products importer. In 2017, imported coal was 8,800 ktoe, which accounted for 29.2% of total coal consumption. Although the country exports a small quantity of oil products, the entire consumption of oil products relies on imported sources. In 2017, Vietnam's consumption of oil products was 12,700 ktoe, with imports at 17,200 ktoe (with the balance between consumption and imports is the exported quantity [3,100 ktoe] and others). Gas production was in balance with consumption without imports and exports in 2017 (IEA, 2018; Trading Economics, 2019).
Over a long-term outlook, the nation’s energy supply is not secure. It is expected that the import share of total primary energy supply will increase to 37.5% in 2025 and 58.5% in 2035, which is dominated by coal (DEA, 2017). The consequent impacts on the security of supply could be significant. However, the country aims to replace coal and oil product imports by renewables and increase energy efficiency (Thu Tuong Chinh Phu (Primer Minister, 2015; and IEA, 2019).

### 4 TREND OF ENERGY INTENSITY AND REGRESSION RESULTS

In this paper, energy intensity is measured as the quantity of energy (toe) required for a $US million value of GDP. The data sources for energy consumption are based on BP (2018) and IEA (2018). The time series data for the GDP of Vietnam is from IMF (2018).

Figure 4 presents the trend of intensity for coal, oil products, gas, and total energy use throughout 1990–2016. Over the study period, the pattern of intensity for coal and oil products (toe/$US million) has decreased significantly from 343.5 and 418.9 in 1990 to 105.94 and 63.1 in

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*Acknowledgement to Dr T.N. Che (Commonwealth Scientific and Industrial Research Organization of Australia) for valuable comments and assists on energy data of Vietnam.*
2018, respectively. The trend of total energy intensity (including fossil fuels and non-fossil fuel use such as renewables and bioenergy) also shows a continuous declining trend. The key drivers of the decreased trend of energy intensity is likely driven by economic structural change from high to lower energy intensity sectors, including services, light industries (textile and garment exports), and tourism.

### TABLE 1 Regression results for energy intensity, 1990–2016

| Variable   | Estimate | SE   | tStat | pValue |
|------------|----------|------|-------|--------|
| **Coal**   |          |      |       |        |
| Intercept  | 224.43***| 15.11| 14.85 | 0.00   |
| Time trend | −5.056*** | 0.94 | −5.36 | 0.00   |
| Adjusted $R^2$ | 0.52; $F$-statistic: 28.75 |
| **Oil products** | | | | |
| Intercept  | 359.84***| 13.96| 25.75 | 0.00   |
| Time trend | −11.68*** | 0.87 | −13.40 | 0.00 |
| Adjusted $R^2$ | 0.87; $F$-statistic: 179.64 |
| **Gas**    |          |      |       |        |
| Intercept  | 169.50***| 11.86| 14.29 | 0.00   |
| Time trend | −4.78***  | 0.54 | −8.77 | 0.00   |
| Adjusted $R^2$ | 0.77; $F$-statistic: 76.83 |
| **All energy** | | | | |
| Intercept  | 1,838.9***| 125.07| 14.70 | 0.000  |
| Time trend | −65.134*** | 7.8064 | −8.346 | 0.000  |
| Adjusted $R^2$ | 0.73; $F$-statistic: 69.6 |

***presents 99% significance.
The use of gas per GDP output is relatively lower than coal and oil products. The trend of gas intensity, however, was increasing from 1990 to 2004, but decreased from 2005 to 2016. The increasing trend of the early period reflects the fact of the rapid growth of gas use. The decreasing trend in the post-2005 period reflects the current trend of energy intensity driven by economic structural changes.

The regression results on the time trend for energy intensity are presented in Table 1. Given the turning points of gas intensity (see Figure 4d), the regression for gas is carried out for the period 2005–2016 only.

The results show energy intensity for coal, oil products, gas, and total energy has been declining by 2.25%, 3.25%, 2.82%, and 3.54% per year, respectively. The falling trend of energy intensity is likely driven by economic structural changes (with a faster growth rate of lower energy intensity sectors, such as services, light industries, etc. (WB, 2019)).

5 PROJECTION OF FOSSIL FUELS CONSUMPTION AND ASSOCIATED CARBON EMISSION TO 2050

The GTAP is a global recursive computable general equilibrium model that provides an important tool for researchers and policy makers conducting quantitative analysis of international policy issues (GTAP, 2019; Hertel, 1997). The projection of energy demand is based on the calibrated results of a hybrid model (combining a GTAP-R model (Kompas & Che, 2018) and the top-down analysis for energy flows of Vietnam to 2050). The GTAP-R by Kompas and Che (2018) is a recursive computable general equilibrium GTAP model that includes energy flows with an extended component for electricity generation and resources. The content for the fossil fuel analysis is based on Truong (2007) and Burniaux and Truong (2002). GTAP-R includes 27 economic sectors and 30 regions. The current trend or the base case is carried out by using known assumptions on population trends. The percentage projection for energy demands of Vietnam (by percentage change to 2050) is from the base case (BAU or business as usual) in Kompas & Che, 2018. The database in GTAP-R is based on GTAP database V9 (Aguiar, Narayanan, & McDougall, 2016; GTAP, 2019). The database of electricity generation is based on GTAP-Power database by Peters (2016).

The base year for projections is 2018, of which the quantity of fossil consumption is estimated from 2016 and the last 5 years of growth. Under the scenario of BAU, Vietnam’s energy demand in 2035 and 2050 is projected to increase to 161,251 and 219,497 ktoe, respectively.
The role of fossil fuels will increase, reaching to 68.2% of total energy consumption in 2050. In addition, coal consumption will increase from about 39,452 ktoe in 2018 to 99,274 ktoe in 2050. Consumption for oil products and gas will increase from 15,733 ktoe and 10,319 ktoe in 2018 to 33,733 ktoe and 17,192 ktoe in 2050, respectively. Coal, in short, remains a dominant fossil fuel that accounts for 56.7% of fossil fuels use in 2050 (not including crude oil for refinery).

The carbon emissions associated coal, gas, oil (crude oil and refined products) is presented in Figure 5b. Carbon emission resulting from fossil fuels will increase from 151.8 in 2018 to 344.7 million tons in 2050.

6 | SENSITIVITIES BY ENERGY EFFICIENCY SCENARIOS

Given the significance of the econometric results (see Table 1), it is essential to take into account the improvement of energy intensity over the future. Since Economic Reform (Doi moi), primarily since the 2000s, the country’s economic structural changes have been significant. As a result, going forward, energy intensity is unlikely to decline at such a high rate as in Table 2. Besides, to meet rapid energy demand for economic growth, the effects of urbanization and the need for improvements in living standards, it is probable that the energy intensity of fossil fuels would also increase. For sensitivity analysis, four scenarios of energy intensity of fossil fuels are considered in this paper (see Table 2).

Projections of fossil fuel consumption by the scenarios of energy intensity are presented in Figure 6. With the assumption for energy efficiency given by scenarios 2–4, energy demand for economic growth would be lower. The higher the energy efficiency, the lower the energy demand required. However, if energy intensity increases by 1% per year in the future, energy demand for fossil fuels would increase.

Table 3 summarises the potential energy saving by scenarios using scenario 1 (without energy efficiency taken into account) as the base. With better energy efficiency, the potential energy savings increase. For example, for scenario 3 (the trend of future energy intensity equals two thirds the current pattern), the average coal per year use would be 44,029.1, 54,061.4, and 59,733.1 ktoe for 2018–2030, 2031–2040, and 2041–2050, respectively. For this scenario, the potential energy saving of oil products would be 4,457.5, 16,566.9, and 30,933.7 ktoe for 2018–2030, 2031–2040, and 2041–2050, respectively.

In the pessimistic case, energy intensity could increase (scenario 5), likely the case if economic structural change implies moving toward high energy intensity sectors. In such a case, the energy saving would be negative (or more energy would be required; see Table 3).

| Scenario | Coal  | Oil   | Gas   | Note                                      |
|----------|-------|-------|-------|-------------------------------------------|
| Scenario 1 | 0.0   | 0.0   | 0.0   | No change                                 |
| Scenario 2 | −1.13%| −1.62%| −1.41%| Equal to one half of the current pattern  |
| Scenario 3 | −1.50%| −2.16%| −1.88%| Equal to two thirds of the current pattern|
| Scenario 4 | −2.25%| −3.25%| −2.82%| The current pattern                       |
| Scenario 5 | 1.00  | 1.00  | 1.00  | Increase by 1% per year                   |
Different energy efficiencies are associated with a change in carbon emissions resulted from fossil fuels (see Table 4). The better the energy efficiency, the lower are carbon emissions. However, if the energy intensity increases over the future (scenario 5), more carbon emissions result.

**TABLE 3** Potential energy saving by scenarios *(Scenario 1 = base) (ktoe)*

| Fuels     | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|-----------|------------|------------|------------|------------|
| Coal      |            |            |            |            |
| 2018–2030 | 3,404.8    | 4,457.5    | 6,502.3    | −3,267.9   |
| 2031–2040 | 12,870.5   | 16,566.9   | 23,369.0   | −13,676.8  |
| 2041–2050 | 24,430.2   | 30,933.7   | 42,263.9   | −28,790.3  |
| Oil products |        |            |            |            |
| 2018–2030 | 1,559.4    | 2,041.7    | 2,962.2    | −1,053.1   |
| 2031–2040 | 6,096.9    | 7,796.7    | 10,801.9   | −4,645.7   |
| 2041–2050 | 10,995.0   | 13,739.9   | 18,221.0   | −9,493.3   |
| Gas       |            |            |            |            |
| 2018–2030 | 814.0      | 1,068.3    | 1,553.3    | −626.6     |
| 2031–2040 | 2,996.5    | 3,852.3    | 5,379.1    | −2,579.1   |
| 2041–2050 | 5,141.7    | 6,476.3    | 8,698.7    | −4,969.0   |

Different energy efficiencies are associated with a change in carbon emissions resulted from fossil fuels (see Table 4). The better the energy efficiency, the lower are carbon emissions. However, if the energy intensity increases over the future (scenario 5), more carbon emissions result.

**TABLE 4** Change of carbon emission by energy efficiency scenarios *(’000 tons of CO2)*

| Period   | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|----------|------------|------------|------------|------------|
| 2018–2030 | −10.24     | −13.42     | −19.56     | 8.61       |
| 2031–2040 | −41.25     | −53.04     | −74.46     | 38.78      |
| 2041–2050 | −77.46     | −97.75     | −132.42    | 81.75      |
Globally, GHG emissions increased from carbon emission by 76% (65% from energy-related industries; 11% from forestry and others), methane (16%), nitrous oxide (6%), and fluorinated gases (2%). Energy causes the largest share (68%) of global GHG emissions, with 65% is CO2 (UNFCCC, 2019).

According to CAIT (2017), in 2014, carbon emissions accounted for 65% of Vietnam’s GHG, of which energy sector generated about 96% of carbon emissions. Between 1990 and 2014, the growth rate of GHG was 6.1% per year, driven by a significant growth rate of CO2 (10.6% per year). Other GHG emission types (CH4 and NO2) were growing at about 2.5% per year.

Carbon emissions (dominated by fossil fuel use) in Vietnam has been increasing rapidly by 10.1% a year during 1990–2014 (CAIT, 2017). Energy and industries are indeed the key drivers of emissions in Vietnam. The CO2 equivalent growth rate for energy and industries was 8.7% and 15.3% a year, respectively. Emissions from the agriculture sector has been increasing at a much lower rate of 1.6% a year.

Given a significant growth of carbon emission from fossil fuels and the growing concern of climate change effects, Vietnam has been focusing on the development of renewables for ensuring future energy security (Tran, 2013a). To achieve the target of low carbon economic growth, the role of renewables is vital. For the baseline (BAU) in this study, the demand for renewables is projected in Tran (2019). The energy demand for renewables is expected to increase from about 25,000 ktoe in 2016 to 45,274 ktoe in 2030, and 72,365 ktoe in 2050.

Toward low-carbon economic growth, the Vietnam government has clearly been focusing on exploiting and investing on renewables (DEA, 2017; Tran, 2015; Tran & Tran, 2014). Although hydro generation and biofuels and waste are dominant, Vietnam has also been focusing on wind and solar. Following DEA (2017), the Renewable Energy Development Strategy (REDS) aims to increase renewable energy use and generation and use from about 25,000 ktoe in 2015 to 37,000 ktoe in 2020; about 62,000 in 2030 and 138 million ktoe in 2050 PEJSC (Petrolimex Engineering Joint Stock Company (PEJSC), 2016).

In 2016, Vietnam’s electricity generation was 176 million mWh (BP, 2018). The role of “clean” energy for electricity generation has been increasing. For example, the Ninh Thuan solar project ($USD 300 million value) will commence in March 2019, with a capacity of 450 mWh. The Dung Quat gas electricity project that uses gas from the ExxonMobil’s Ca Voi Xanh field is expected to commence over the next 5–7 years. At a value of $USD 3 billion, this project will provide 13 million mWh, which is equivalent to Vietnam’s 7.4% of total electricity generation in 2016 (Vnexpress, 28 February, 2019).

The carbon capture treatment is also seen as required for new coal generation projects. The Thai Binh coal generation project with carbon capture treatment commenced in February 2019. This project is valued at $USD 1.3 billion, providing a capacity of 3 million mWh (1.7% of total electricity generation in 2016) (Vnexpress, 14 February, 2019).

Given the REDS target, the future fuel mix of Vietnam would mandate a change toward a much lower role of fossil fuels. The mix of fossil fuel consumption in Vietnam’s energy-intensive sectors, especially electricity generation and manufacturing would also change.

However, the target of REDS is higher than the projection of renewables from GTAP-R for Vietnam. As a result, to achieve the renewable energy targets, Vietnam cannot be in a BAU state. It needs substantial, further investment in low emissions energy production. Renewables
are low carbon, but expensive. The Levelised Cost of Energy of generation (LCOE)\(^3\) using solar and wind are much more expensive than coal. As a result, relevant policies for energy transition to renewables are essential for long-term renewable development in Vietnam. Further analysis of renewable development in Vietnam is analysed in Tran (2019).

8 | CONCLUDING REMARKS

Fossil fuels are a dominant energy source in Vietnam, which accounts for about 70% of total consumption in 2016. Along with rapid economic growth, the use of fossil fuels has been increasing significantly. In particular, to date, the consumption of coal and oil products and gas has increased by more than 12-fold and 7-fold, respectively. The share of coal use has been increased by almost triple in the fuel mix to 2016.

Under the BAU case, from 2018 to 2050, the demand for coal, oil products, and gas is expected to increase from 39,452 to 99,274 ktoe, 15,733 to 33,713 ktoe, and 10,319 to 17,192 ktoe, respectively.

Although fossil fuels are vital for Vietnam's economic growth, they are the predominant source of carbon emissions. Carbon emissions resulting from fossil fuels is projected to increase from 143.9 million tons in 2018 to 344.7 million tons in 2050. Undoubtedly, the role and response of Vietnam's authorities on emissions reduction and the environment is essential for long-term sustainable development (Tran 2015). The country has begun focusing on low carbon economic development over the long term. According to DEA (2017), Vietnam's targets, following the Paris Climate Accord, for a 25% reduction in GHG could be achieved through strengthening energy efficiency and exploiting resource sources with significant international support.

To achieve a low carbon economic growth, relevant fuel mix policies with a significant development of renewables is essential (Tran, 2013a). Implementation of the REDS is crucial to energy security in Vietnam. This strategy, however, requires an intensive investment and policy support. The way forward needs considerable thought and effective response.

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How to cite this article: Tran QM. Projection of fossil fuel demands in Vietnam to 2050 and climate change implications. Asia Pac Policy Stud. 2019;6:208–221. https://doi.org/10.1002/app5.274