Chapter 3

Development of Alternative Policy Scenarios for RE Power Generation in Viet Nam

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Chapter 3

Development of Alternative Policy Scenarios for Renewable Energy Power Generation in Viet Nam

This chapter covers the outlook of business-as-usual (BAU) and alternative policy scenarios (APSs) of renewable energy (RE) technologies for power generation, which are based on the assumption of gross domestic product (GDP) and population growth, changes in technology, oil price trends, and additional policies. The APSs assess the impact of RE policies on energy saving, energy security, and greenhouse gas (GHG) emission reductions, and calculate the costs and benefits of the different RE technology options. They also act as the basis for the evaluation and selection of mitigation technologies, which contribute to set up the strategies and policies for promoting appropriate RE technologies in Viet Nam and the region.

1. Background

In 2013, Viet Nam achieved GDP of US$92.28 billion in 2005 US$ terms. The commercial sector contributes the most to Viet Nam's GDP (43.86%), followed by the industrial sector (38.57%) and agriculture (17.57%). The population of Viet Nam in 2013 was 89.71 million, while GDP per capita was US$1,029 per person (at constant 2005 US$ values).

Although Viet Nam is well endowed with a wide variety of energy resources, the capacity for energy extraction, production, and distribution is limited, especially in the electricity sector, which has a negative effect on production and in improving the standard of living and augmenting income.

Although Viet Nam exports crude oil, production is limited by the capacity of the oil refinery. Viet Nam still imports oil products and will depend on outside supplies of oil until 2020, negatively impacting the economy, society, and the development objectives of Viet Nam.

In 2013, oil products reached 17,457 kilotonnes of oil equivalent (ktoe), of which 10,086 ktoe is exported; coal production reached 22,980 ktoe, of which 7,169 ktoe is exported.

At the end of 2013, the total installed capacity of all power plants was 30,597 MW. Commercial electricity consumption per capita is estimated to be 1,272 kWh/year per capita, considered high in the region.

The rural electrification programme has been implemented over the past few years. According to reports by the Electricity of Viet Nam (EVN), by the end of 2013, 99.6% of communes and 97.9% of households have access to electricity from the national grid, higher than most countries with the same GDP in the region and in the world.

Viet Nam has a high potential for developing RE, such as small-scale hydropower, biomass energy, wind energy, solar energy, and others, which can be utilised to meet energy demand especially in areas far from the grid. However, due to limited budgets and lack of technology, most of the population must rely on biomass, a non-commercial energy. As a result, Viet Nam has low commercial energy consumption per capita compared to other Asian countries.

Fast-paced economic development and GDP growth led to high energy demand, especially the demand for natural gas, electricity, and coal for the manufacturing industries and residential activities and this trend is expected to be maintained in the future. Thus, energy generation and consumption is going to be the main source of GHG emissions in the coming decades.

2. Data and Methodology

2.1. Data and assumption

For consistency, the energy demand in Viet Nam for the next 25 years was estimated using the econometric approach with the historical energy data taken from the Energy Balances for Non-OECD Countries compiled by the International Energy Agency (IEA). Socio-economic data, such as GDP and industrial GDP used in the modelling work, were taken from the *Statistics Year Book of Viet Nam* and the *World Development Indicators* published by the World Bank. Other data, such as population and population growth rates, were obtained from national sources. Where official data were not available, estimates were obtained from other sources or the Institute of Energy.

In projecting future energy demand and GHG emissions, the assumptions used were based on population, GDP, crude oil price, changes in technology, and the context of existing energy-related policies as well as RE source potentials.

i. Population

In 2013, the total population in Viet Nam was 89.71 million and is projected to increase at an average annual rate of 0.66%, reaching 107.24 million in 2040. The urban population is expected to increase from 28.98 million in 2013 to 55.67 million in 2040, which accounts for 52.03% of the total population (see Viet Nam Population Forecasts, 2009–2049, GSO, 2011). It is assumed that there is no difference in population between the BAU scenario and the APS.

ii. GDP

GDP grew at an average annual rate of 7.01% during 2005–2010, slightly down to 5.91% during 2010–2015 due to the global economic crisis. GDP projection is around 7.0% for 2016–2020[3] and is estimated to be 6.5% for the period 2021–2025, 6.0% during 2026–2030, 5.5% during 2031–2035 and 5.0% during 2036–2040.[4] These projections are used for the development of both scenarios – BAU and APSs.

iii. Crude oil price

Future changes in crude oil prices remain highly uncertain. In this study, the crude oil price, as measured by Japan's average import price (nominal dollars per barrel), is assumed to decrease

[3] See the socio-economic development plan for 2016-2020 (March 2016).
[4] See the ERIA-Working Group estimation in 2016.

from US$105 a barrel in 2013 to US$84 in 2020 and then increase to US$137 a barrel in 2030 and US$209 a barrel in 2040 (IEEJ, 2015).

iv. Technology development

Technology development is an important factor to impact on energy demand. Along with GHG emissions, these have been included in BAU.

On the demand side, technology substitutions and changes in energy efficiencies were considered based on existing technologies and the trend of changes in the past.

In power generation, thermal efficiencies by fuel (coal, gas, and oil) were projected based on future power plant technologies as forecast by the US Department of Energy's *Annual Energy Outlook, 2008.* Thermal efficiency is expected to improve considerably over time in the BAU scenario as more advanced generation technologies, such as natural gas combined cycle and supercritical coal plants become available.

v. Electricity generation fuel mix

The share of electricity generated at coal-fired power plants is projected to increase considerably, at the expense of other energy types (thermal and hydro). Viet Nam is expected to increase its imports of coal for power generation and electricity, particularly from the Lao PDR and China. The use of nuclear energy is assumed to start in 2028 in line with Viet Nam's nuclear power development plan. In the BAU scenario, it is assumed that the first unit of nuclear power, with a capacity of 1,200 MW, will be installed in 2028 and the following units of nuclear power with capacity of 1,100 MW will be installed in 2029 and 1,200 MW in 2030.

vi. Costs of power generation

Data on capacity, efficiency, capital, operation and maintenance (O&M) costs, and maximum availability (or maximum capacity factor) were obtained from the PDP VII and other published documents, as listed in Table 18.

Table18: Existing Power Sources and Costs of Power Generation, 2013

	Capacity (MW)	Capital Cost (US$/kW)	Fixed O&M Cost (US$/kW)	Variable O&M Cost (US$/MWh)**	Efficiency (%)	Maximum Availability (%)
Thermal coal	7,058	1,300	45.5	4.5	35	80
Hydro	13,336	1,700	13.6	2.5	100	60
Thermal gas	93	1,200	42	3.0	37	80
CCGT	7,074	1,020	45.9	3.0	49.5	80
Nuclear	0	4,000	130*	0.5	33	80
DO fired GT	264	900	31.5	4.4	49.5	80
FO	1,050	1,200	42	1.48	30	80
Small hydro	1,589	1,700	42*	2.5	100	45
Biomass	81	1,800	70*	6.7	32	60
Wind	52	2,000	40*	5.0	100	25

CGT = combined cycle gas turbine, GT = gas turbine, DO = diesel oil, FO = fuel oil.

Sources: Power Development Plan VII; *International Energy Agency (2014); **National Renewable Energy Laboratory (2010).

vii. Fuel costs

Table 19 presents the cost of fuel energy by type, which was derived from the 2012 energy statistics of Viet Nam.

Table 19: Cost of Fuel Energy

	Unit	Indigenous Cost	Import Cost	Export Cost
Anthracite coal	US$/tonne	45		
Bituminous coal*	US$/tonne	96		
Crude oil	US$/tonne			887.6
Electricity	US$/kWh		0.06	
Diesel oil	US$/tonne		958.4	991.4
Gasoline	US$/tonne		1,058	1,103
Kerosene	US$/tonne		1,035	1,071
Fuel oil	US$/tonne		7,13.4	749.2
Jet kerosene	US$/tonne		1,023	1,045
Liquid petroleum gas	US$/tonne		939	942
Natural gas	US$/million British thermal unit	4.75		

* With an average calorific value of 6,500 kcal/kg, compared to anthracite coal with 5,500 kcal/kg.
Source: Vietnam-National Energy Efficiency Program (2013).

Changes in these fuel prices over time are based on changes in the international crude oil price. The crude oil price is assumed to increase to US$137 a barrel in 2030 and US$209 a barrel in 2040 (IEEJ, 2015).

3. Methodology

Currently, there are many types of models such as optimisation models (e.g. MARKAL), simulation models (e.g. ENPEP), and accounting frameworks (e.g. Long-range Energy Alternatives Planning or LEAP). These models were accepted for integrated energy planning as well as mitigation analysis in the context of the United Nations Framework Convention on Climate Change (UNFCCC).

Unlike complex tools such as ENPEP or MARKAL, LEAP is a simple tool that does not require a great number of data and this makes it easy for users to develop different policy scenarios and to select the best solutions based on cost–benefit analysis.

LEAP is also flexible and can be used to create models of different energy systems based on available data, ranging from bottom–up, end-use techniques, to top–down approaches.

Moreover, LEAP has been widely applied in more than 190 countries worldwide and 10 member ASEAN countries also are using the LEAP model to analyse the energy saving potential in East Asia under the energy project of the Economic Research Institute for ASEAN and East Asia (ERIA). Hence, this study uses LEAP as a tool for this analysis.

In this study, LEAP was used to develop a baseline scenario (or BAU) to outline future energy demand during 2013–2040 based on GDP and population projections, changes in technology, and existing policies regarding the LEAP files from existing studies[5] by ERIA. Emission factors for each technology and fuel type are selected based on the values identified by the Intergovernmental Panel on Climate Change or IPCC (available in LEAP).

The APSs were based on the accessible potential of all types of RE sources, assuming that additional action plans or policies would be developed or likely to be considered. The differences between the BAU and APSs represent the additional RE consumption and potential fossil energy savings as well as potential GHG reduction. In estimating the primary energy requirements, an accounting model is used in which the future choice for technology and fuels are based on the programmes of the country and the most likely available supply in the future.

The assessment and selection of the prioritised RE technologies were carried out based on multiple criteria, including social, economic, and environmental aspects, which need to be evaluated for decision-making for setting up the strategy and action plans for RE development. The difficulty here is that not all criteria can be valued in monetary terms. In this case, the technique of multi-criteria analysis (MCA) was used – an approach widely used for decision-making that requires making choices between and examining trade-offs across multiple objectives of policy, such as growth, inclusion, and environment.

[5] See LEAP file of Viet Nam, 2016.

Analytic Hierarchy Process (AHP) is one of the more widely applied MCA methods, which is a method for converting subjective assessments of relative importance to a set of overall scores or weights. The fundamental input to the AHP is the decision maker's answers to a series of questions of general form, such as 'How important is criterion A relative to criterion B?'. Although AHP has been used in many applications in both the public and private sectors, AHP still has several limitations. First, AHP was criticised for not providing sufficient guidance on structuring the problem to be solved, forming the levels of the hierarchy for criteria and alternatives. Second, the critique of AHP is the 'rank reversal' problem, i.e. changes in the importance ratings whenever criteria or alternatives are added to or deleted from the initial set of alternatives compared (Alexander, 2012).

Other use of MCA is a 'co-benefits approach' that was developed and applied by the National Action Plan on Climate Change for India's climate policy challenge. The co-benefits approach is a useful way for developing countries to address the issue of climate mitigation, but in a manner consistent with development objectives. The co-benefits analysis is intended to provide a framework for analysing the impacts of any policy objective under consideration on the full range of outcomes across economic, social, and environmental goals. Therefore, MCA with co-benefits approach was chosen as the tool for this study to prioritise RE technologies.

To support these strategies and action plans, the RE policy instruments applied effectively in other countries were reviewed and analysed based on the country-specific financial conditions to get the effective policies that could reduce the project costs of RE technologies.

4. Potentials on Renewable Energy Sources and Assumptions

Viet Nam has achieved a remarkable progress in economic development in recent decades. Together with rapid economic growth and implementation of rural electrification programme, electricity demand in recent years during 2001–2010 increased at a higher rate of 14.5%, and 10.3% during 2011–2015. Higher GDP growth over the same period caused the difficulties in the development of power generator sources. Due to increasing electricity demand, Viet Nam is expected to become an importer of electricity and coal for power generation in the coming years.

Though Viet Nam possesses significant natural resources, including RE such as biomass, solar energy, small hydropower, and reserves of crude oil, coal, and natural gas, its energy resources, as forecast, are unlikely to sustain economic growth at previous levels without imports and/or new sources of energy.

To meet such rapidly increasing electricity demand, the revised PDP VII envisages increasing the share of renewables in the energy mix to 6.5% of the total power generation in 2020, 6.9% in 2025, and 10.2% in2030. The bulk of this renewable capacity will come from small hydropower, solar PV, and wind power generation. In particular, the total solar PV power capacity is expected to increase from the current level, which is negligible, to around 850 MW by 2020, 4,000 MW in 2025, and 12,000 MW by 2030. Wind power capacity is estimated to increase to around 800 MW by 2020, 2,000 MW by 2025, and to 6,000 MW by 2030.

As noted earlier, the revised PDP VII and the Strategy for RE Development in Viet Nam are aimed at realising these targets for RE development. Currently, however, there are no concrete measures that include technical and financial support, no specific action plans, nor are there indications of institutional reform (including regulation or legislation) to support the achievement of these targets.

This section assumes that the proposed RE development under APS scenarios are based on the accessible potential and maximum ability of exploitation for all types of RE and from additional action plans or policies to be developed, which will ensure that the targets are met.

5. Small hydropower

The potential for small hydropower (SHP) (with a capacity of less than 30 MW per site) is estimated to be about 7,000 MW. By 2012, 157 SHP projects with total capacity of 1,269.4 MW will be in operation and an additional 163 SHP projects with total capacity of 1,683.0 MW are under construction. Moreover, over387 SHP projects with total capacity of 2,688.9 MW are being planned for the period. Thus, the total capacity of SHP that could be exploited is around 5,640 MW.

By 2013, the total installed capacity of SHP was 1,589 MW and is expected to reach 3,100 MW by 2020, 4,600 MW by 2030, and 5,640 MW by 2040.

To support SHP development, the Minister of Industry and Trade has released a decision on the ‘Regulation on avoided cost electricity tariff and power purchase agreement’ for SHP plants. However, almost all profitable feasible sites had been developed. The existing regulation on avoided cost for SHP is not likely to attract investors. Therefore, in BAU only 2,000 MW is assumed to be installed in 2020.

For APS, it is assumed that additional policy measures will support SHP development while almost all the potential capacity of SHP is exploited, as shown in Table 20.

Table 20: Installed Capacity of SHP in BAU and APS

	Installed Capacity (MW)			
Scenarios	**2013**	**2020**	**2030**	**2040**
BAU	1,589	2,200	2,200	2,200
APS	1,589	3,100	4,600	5,600

APS = Alternative Policy Scenario, BAU = business-as-usual, SHP = small hydropower.
Source: Government of Viet Nam (2016).

6. Biomass power plant

The main biomass sources that can be used to generate electricity are sugarcane trash, rice husks, and rice straws. Based on the production of bagasse and paddy in 2010, this study estimates that 4.8 million tonnes of bagasse, 8.0 million tonnes of rice husks, and 48.0 million tonnes of rice straws are available.

Due to abundant bagasse resources, the Revised PDP VII has set up a plan to develop biomass power generation in sugar mills with capacity estimated at around 500 MW by 2020 and 2,000 MW by 2030.

At present, bagasse is used for combined heat and power production in 40 sugar mills. The total installed power capacity of all such system is around 150 megawatt electric (MWe), with factory capacities ranging from 1.5 MWe to 24 MWe. Produced heat and power from these factories are mainly used for their own demand for pressing and producing sugarcane. Currently, only six power plants sell their surplus power 81 MW) to the national power network with 70 million kWh at a selling price ranging from US$3.0 to US$4.8per kWh. The opportunity to sell surplus from sugarcane factories is quite big due to expanding capacity that is also increasing. However, currently, the selling price is still low and proves to be a big constraint to further expansion.

So far, no biomass power plant is installed in Viet Nam due to high investment and production costs and the low selling price of electricity. However, 10 rice husk power plants with an average capacity of 10 MW per site are preparing investment reports. Almost all sites are in Mekong River Delta, where the rice husk resource accounts for 55% of total sources in the country.

So far, the current support mechanisms are not strong enough to encourage investment in biomass power plants. Therefore, in the BAU, it assumed that the installed capacity would increase from 81 MW in 2013 to 100 MW in 2020.

For APS, it is assumed that there would be additional policy measures to support biomass power plants; therefore, the total installed capacity is estimated to increase to 500 MW in 2020, 1,600 MW in 2030, and 4,000 MW in 2040.

Table 21: Installed Capacity of Biomass Power Plants in BAU and APS

	Installed Capacity (MW)			
Scenarios	2013	2020	2030	2030
BAU	81	100	100	100
APS	81	500	1,600	4,000

APS = Alternative Policy Scenario, BAU = business-as-usual, MW = megawatts.
Source: Government of Viet Nam (2016).

7. Wind power plants

With more than 3,000 kilometres of coastline and plenty of islands, the total potential wind energy in Viet Nam is estimated to be as high as 26,700 MW at speeds of over 6 metres per second (World Bank, 2001).

Currently, 48 projects on wind power development are registered in the whole of Viet Nam, concentrated in the central and southern provinces with a total registered capacity of 5,000 MW. Capacity per project ranges 6–250 MW.[6]

The first phase of a project located in Binh Thanh commune, Tuy Phong district, Binh Thuan province has just been completed with an installed capacity of 30 MW, including 20 wind turbines, each at 1.5 MW. The second phase was initially planned for construction in 2011–2015, and there were plans to increase its capacity to 120 MW. The first phase of the wind mill project was connected to the national grid in March 2011.

The second wind power project was implemented in the Mekong Delta, Bac Lieu Province. The first phase of 10 turbines of 16 MW was completed and connected to the national grid in September 2013. The second phase, completed during 2012–2015 increased its capacity to 99.2 MW.

Wind energy for power generation is one prioritised area as planned in the Revised PDP VII with the aim to achieve installed capacity of 800 MW in 2020 and 6,000 MW by 2030. The PDP VII is very ambitious and the target will be difficult to achieve because wind power is still not attractive to national and international investors. Investment is high and the price of electricity is too low at 7.8 US cents/kWh.

The low purchasing price at 7.8 US cents/kWh is considered the biggest obstacle facing investors. Hence, the second phase of wind power plant in Binh Thuan Province as mentioned above has not yet started.

[6] Based on data from the Provincial Department of Industry and Trade where documents were updated until May 2011) (in Vietnamese).

Due to these reasons, in BAU, the installed capacity was assumed to increase from 52 MW in 2013 to 130 MW in 2015 if the purchase price of electricity from wind power did not change.

For APS, it is assumed that the total installed capacity would increase to 800 MW in 2020 and 5,000 MW in 2030, and 10,000 MW in 2040 – provided additional policy measures would support the wind power plants.

Table 22: Installed Capacity of Wind Power Plants in BAU and APS

	Installed Capacity (MW)				
Scenarios	**2013**	**2015**	**2020**	**2030**	**2040**
BAU	52	130	130	130	130
APS	52	130	800	5,000	10,000

APS = Alternative Policy Scenario, BAU = business-as-usual, MW = megawatts.
Source: Government of Viet Nam (2016).

8. Biogas energy

At present, biogas technology has developed in two directions – family size biogas plants and large-scale plants. Large-scale plants often use in big farms and foodstuff processing plants for replacing a part of on-grid power.

In Viet Nam, biogas has been used for electricity generation, contributing to saving energy and improving people's livelihood. Electric generators run by biogas have been installed in several provinces, such as Thai Binh, Bac Giang, Phu Tho, Da Nang, and Tien Giang, with good results. Almost all these power generation projects are small-scale and are connected to the grid.

In 2009, a biogas power generation project was installed at the pig farm of San Miguel Food Company in Ben Cat district, Binh Duong province. The project's total capacity is 17,000 cubic metres (m^3) and its power generation is 3.5 MW. Currently, four units with a total capacity of 2.0 MW (at 500 kW per unit) were put into operation in April 2011 but only for internal use.

Another grid-connected project with a capacity of 9 MW is being operated by the TH-True Milk Company. The plan is to install the plant in 2020 to deal with cow's waste in Nghia Dan district, Nghe An province.

To date, no biogas power plants are connected to the national grid due to high investment. There are also no support mechanisms for the development of biogas power plants.

For the BAU case, it assumed that there is no electricity from biogas while for APS case, it is assumed that the total installed capacity of biogas is30 MW in 2020, 150 MW in 2030, and

200 MW in 2040 provided there are policy support measures to incentivise the generation of biogas power.

Table 23: Installed Capacity of Biogas Power Plants in BAU and APS

	Installed Capacity (MW)			
Scenarios	**2013**	**2020**	**2030**	**2040**
BAU	0	0	0	0
APS	0	30	150	200

APS =Alternative Policy Scenario, BAU = business-as-usual, MW = megawatts.
Source: Government of Viet Nam (2016).

9. Solar energy

Viet Nam has a stable high solar radiation in the southern and central regions but it fluctuates by season in the northern region. Average solar in the south and central is about 5 kWh per square metre per day, fluctuating from 4.0 to 5.9 kWh per square metre per day. The solar radiation in the North fluctuates from 2.4 to 5.6 kWh per square metre per day.

Solar photovoltaic (PV) has been studied in Viet Nam since the start of the 1990s. The telecommunication and marine assurance sectors are pioneers in this field. Since 1992, solar PV has supplied electricity to households in rural remote mountainous areas.

Currently, the total capacity of solar PV units installed in Viet Nam is1.6 megawatt peak (MWp) and is mainly used for telecommunications, rural health services, population centres, battery-charging stations, and household systems. Only a small number are connected to the grid projects. The biggest grid-connected PV system was installed at the National Convention Center in Ha Noi in 2006 with a capacity of 154 kilowatt peak. Another 12 kilowatt peak was installed at the building of the Ministry of Industry & Trade (MOIT) in 2010. These projects are operated as demonstration projects (not commercial) – mainly for their own use.

So far, no large ground-mounted PV systems are in operation. However, there have been some announced investments in utility-sized PV power plants. Based on media reports in January 2015, a 30 MWp PV plant with an investment of US$60 million is being developed and planned to be grid-connected in the Quang Ngai province. Another announcement was a planned 100 MWp PV plant in central Viet Nam Quang Nam province. In March 2015, a Russian energy company with Singaporean and Vietnamese investment partners was planning to invest US$140 million but negotiations with EVN about 'market prices' are still ongoing.

The current costs of small PV systems in Germany fell to just US$2,200/kW in the second quarter of 2012 from an average of US$3,800/kW in 2010. The European Photovoltaic Industry Association forecasts that cost for small-scale rooftop PV system in the most competitive markets could decline between US$1,750 and US$2,400/kW by 2020. Large utility-scale PV projects could see their average costs decline to between US$1,300 and US$1,900/kW by 2020 (IRENA, 2013).

In this study, the average price of PV systems in Viet Nam is estimated to be US$3,500/kW in 2013 and projected to reduce to US$2,000/kW by 2020, and to US$1,000/kW by 2040. This trend of cost reduction could make PV systems competitive in the future.

An average total solar radiation of 5 kWh/m^2/day in most of the middle and the southern provinces of Viet Nam, could be exploited to meet increasing electricity demand and market for power generation.

As noted earlier, it is assumed that there are no solar PV power plants in the BAU scenario.

In an APS scenario, based on the Revised PDP VII, it is estimated that grid- connected PV could achieve 800 MWp in 2020, 10,000 MWp in 2030, and 16,000 MWp in 2040 – provided there are support polices.

Table 24: Installed Capacity of Solar Power Plants in BAU and APS

	Installed Capacity (MW)			
Scenarios	2013	2020	2030	2040
BAU	0	0	0	0
APS	0	800	10,000	16,000

APS =Alternative Policy Scenario, BAU = business-as-usual, MW = megawatts.
Source: Government of Viet Nam (2016).

10. Outlook Results: Business-as-Usual

The BAU scenario was developed based on assumptions that Viet Nam's demand for energy will continue to increase based on historical trends where GDP will continue to increase, and there will be lack of additional policies to promote RE development.

In view of a changing energy mix, the use of RE technologies will be considered based on previous trends in the absence of additional policies to encourage and support investors.

10.1. Final energy demand

Based on the input data and key drivers, such as GDP, population, and historical trends in energy consumption, the energy demand per sector and fuel type is projected as follows:

Final energy demand by sector

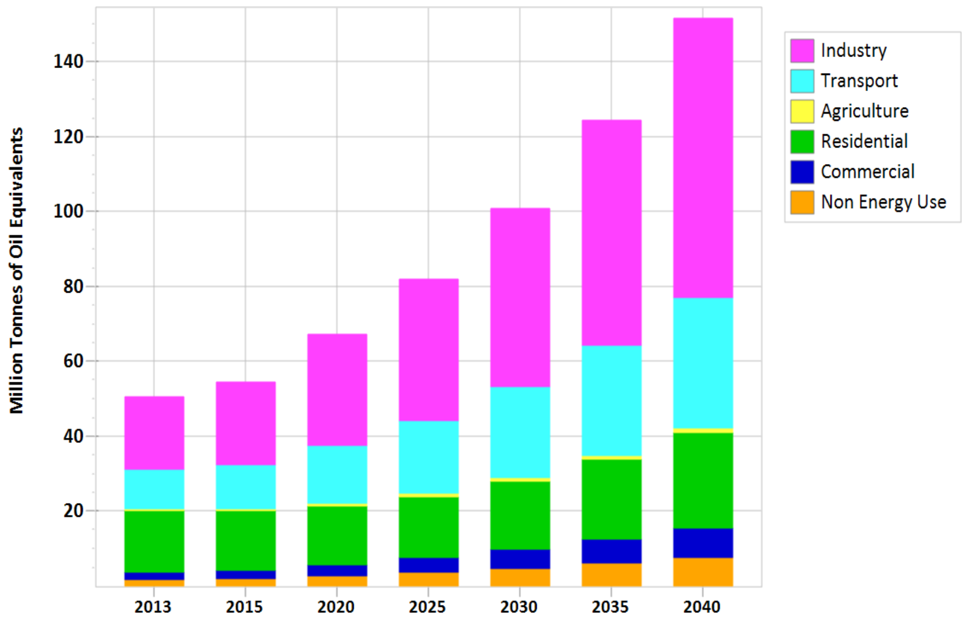
Under the BAU scenario, driven by assumed economic growth and a growing population, final energy consumption is projected to increase at an average rate of 4.2% per year between 2013 and 2040, with strong differences between sectors. On a per sector basis, the strongest growth in consumption is projected to occur in the commercial sector, increasing by 5.5% per year. This is followed by the industrial sector (5.1% per year), the transport sector (4.6% per year), the agricultural sector (2.0% per year), and the residential sector (1.7% per year). The non-energy use is expected to increase at growth rate of 5.7% per year.

Table 25: Final Energy Demand by Sector (Mtoe)

Sector	2013	2015	2020	2025	2030	2035	2040	AAGR (2013–2040) (%)
Industry	19.4	22.1	29.6	37.7	47.8	60.1	74.4	5.1
Transport	10.5	11.6	15.5	19.5	24.1	29.3	34.9	4.6
Agriculture	0.6	0.7	0.8	0.9	1.0	1.1	1.1	2.0
Residential	16.4	16.0	15.6	16.3	18.3	21.5	25.6	1.7
Commercial	1.9	2.1	3.0	3.9	5.0	6.4	7.9	5.5
Non-energy use	1.7	1.9	2.7	3.6	4.7	6.0	7.5	5.7
Total	**50.5**	**54.4**	**67.3**	**81.9**	**100.9**	**124.3**	**151.5**	**4.2**

Source: Calculation results derived from LEAP model.

Figure 13: Final Energy Demand by Sector



Mtoe = million tonne of oil equivalent.

Source: Calculation results derived from LEAP model.

Based on fuel types, under the BAU scenario, natural gas in final energy consumption is projected to grow rapidly, increasing by 7.4% per year between 2013 and 2040. Electricity demand is projected to exhibit the second highest growth, increasing by 6.1% per year between 2013 and 2040. Oil products are projected to grow at 5.0% per year, followed by coal at 4.5%.

Meanwhile, biomass fuels, such as wood, are projected to decline by 6.7% per year between 2013 and 2040 due to the impact of economic growth, which will translate into improved standards of living. As a result, energy consumers are expected to switch from biomass fuels with a low level of efficiency to alternative fuels (such as liquefied petroleum gas and electricity) with higher efficiency.

Table 26: Final Energy Demand Fuel Type (Mtoe)

Fuels	2013	2015	2020	2025	2030	2035	2040	AAGR (2013–2040) (%)
Coal	9.6	11.0	14.6	18.0	22.0	26.5	31.4	4.5
Natural Gas	1.3	1.6	2.5	3.6	5.1	6.9	9.2	7.4
Biomass	13.8	12.1	8.4	5.7	4.0	2.8	2.1	-6.7
Electricity	9.8	11.8	17.4	23.3	30.3	38.9	48.8	6.1
Oil Products	15.9	17.9	24.3	31.3	39.5	49.1	59.9	5.0
Total	**50.5**	**54.4**	**67.3**	**81.9**	**100.9**	**124.3**	**151.5**	**4.2**

AAGR = average annual growth rate, MTOE = million tonne of oil equivalent.
Source: Calculation results derived from LEAP model.

On the relation between GDP growth and energy demand, Viet Nam's energy intensity is projected to decrease during 2013–2040. Energy intensity of the country is to decrease from 547 tonnes of oil equivalent (toe)/million in 2005 US$ in 2013, to 338 toe/million in 2005 US$ in 2040. This is a good indication that energy will be used efficiently in the future for economic development.

Table 27: Energy Intensity

	2013	2015	2020	2025	2030	2035	2040
GDP (in 2005US$ billion	92.3	104.3	146.3	200.5	268.3	350.6	447.5
Total energy consumption (Mtoe)	50.5	54.4	67.3	81.9	100.9	124.3	151.5
Energy intensity (TOE/million in 2005US$)	547.0	522.0	460.0	409.0	376.0	354.0	338.0

GDP = gross domestic product, Mtoe = million tonne of oil equivalent.
Source: Calculation results derived from LEAP model.

10.2. Primary energy supply

Under the BAU scenario, Viet Nam's primary energy demand is projected to increase at an annual rate of 4.8% from 60.1 Mtoe in 2013 to 212.9 Mtoe in 2040, which is higher than the growth rate of the total final energy demand (4.2%). The reason is that the share of gas and hydro-based power generation up to 2040 is expected to decline due to the limitation of supply. These reductions are supplemented by coal fuel-based generation, which has lower than natural gas and hydropower plants.

Natural gas is expected to grow rapidly, increasing at an annual average rate of 6.5% between 2013 and 2040, followed by coal (at 6.3%), oil (at 5.1%) and hydropower (at 3.1%). Other supply sources (mostly biomass fuel) are projected to decline at an annual rate of 4.2% during 2013–2040 due to demand shifting towards commercial energy.

Table 28: Primary Energy Supply, BAU (Mtoe)

Fuels	2013	2015	2020	2025	2030	2035	2040	AAGR (2013–2040) (%)
Coal	16.2	17.7	30.3	38.4	48.9	64.9	83.6	6.3
Oil	16.4	18.3	25.4	33.0	41.8	51.2	62.8	5.1
Natural gas	9.0	9.5	10.9	18.6	26.4	37.1	49.2	6.5
Nuclear	0.0	0.0	0.0	0.0	2.8	2.9	2.9	-
Hydro	4.5	5.9	8.1	9.1	9.9	10.0	10.1	3.1
Others	14.1	13.0	9.8	7.3	5.8	4.9	4.4	-4.2
Total	**60.1**	**64.4**	**84.5**	**106.4**	**135.5**	**171.0**	**212.9**	**4.8**

AAGR = average annual growth rate, BAU = business-as-usual, Mtoe = million tonne of oil equivalent.
Source: Calculation results derived from LEAP model.

10.3. Power generation

Under the BAU, fuel inputs for power generation are projected to increase at an average rate of 6.5% per year between 2013 and 2040. The fastest growth will be in coal power generation (8.0% per year) followed by natural gas (6.4% per year), hydro (3.1% per year), and RE (2.2% per year).

Table 29: Power Generation Inputs by Type of Fuel, BAU (Mtoe)

Fuels	2013	2015	2020	2025	2030	2035	2040	AAGR (2013–2040) (%)
Coal	6.6	6.7	15.7	20.4	26.9	38.5	52.2	8.0
Oil	0.1	-	0.0	0.1	0.2	-	-	0.0
Natural gas	7.5	7.7	8.2	14.7	20.9	29.8	39.5	6.4
Nuclear	-	-	-	-	2.8	2.9	2.9	-
Hydro	4.5	5.9	8.1	9.1	9.9	10.0	10.1	3.1
Renewables	0.5	0.6	0.8	0.8	0.8	0.8	0.8	2.2
Total	**19.1**	**20.9**	**32.9**	**45.1**	**61.6**	**82.0**	**105.5**	**6.5**

AAGR = average annual growth rate, BAU = business-as-usual, Mtoe = million tonne of oil equivalent.
Source: Calculation results derived from LEAP model.

11. Evaluation of APS Scenarios for RE

As noted earlier, the APSs are designed based on the potential of RE sources under the assumption that additional action plans or policies are developed or considered. The outputs of the APSs will be used as the basis for assessing the impact of RE policies on energy saving, energy security, and GHG emission.

11.1. Input fuels demand for power generation

Under the APSs, new policies to encourage the exploitation of RE sources for power generation have significantly reduced fossil fuels as input fuels for power generation. RE sources are expected to grow at 12.6% per year, which is higher than 10.4% per year compared with BAU (2.2% per year). The increase in RE sources resulted in the reduction of other fossil fuels. Coal is expected to grow at 7.3% per year, which is lower than 0.7% per year compared with BAU (8.0% per year). Natural gas is expected to grow at 5.4% per year, which is lower than 1.0% per year compared with BAU (6.4% per year).

Table 30: Power Generation Inputs by Type of Fuel, APSs (Mtoe)

Fuels	2013	2015	2020	2025	2030	2035	2040	AAGR (2013–2040) (%)
Coal	6.6	6.7	14.4	17.4	21.5	31.2	43.8	7.3
Oil	0.1	0.0	0.0	0.1	0.2	0.3	0.3	2.8
Natural gas	7.5	7.7	8.1	14.4	18.4	24.5	31.0	5.4
Nuclear	-	0.0	0.0	0.0	2.8	3.0	3.2	-
Hydro	4.5	5.9	8.0	8.9	9.6	9.8	10.0	3.0
Renewables	0.5	0.6	1.8	3.0	5.6	8.4	11.2	12.6
Total	**19.1**	**20.9**	**32.4**	**43.7**	**58.2**	**77.3**	**99.5**	**6.3**

AAGR = average annual growth rate, APSs = alternative policy scenarios, Mtoe = million tonne of oil equivalent.
Source: Calculation results derived from LEAP model.

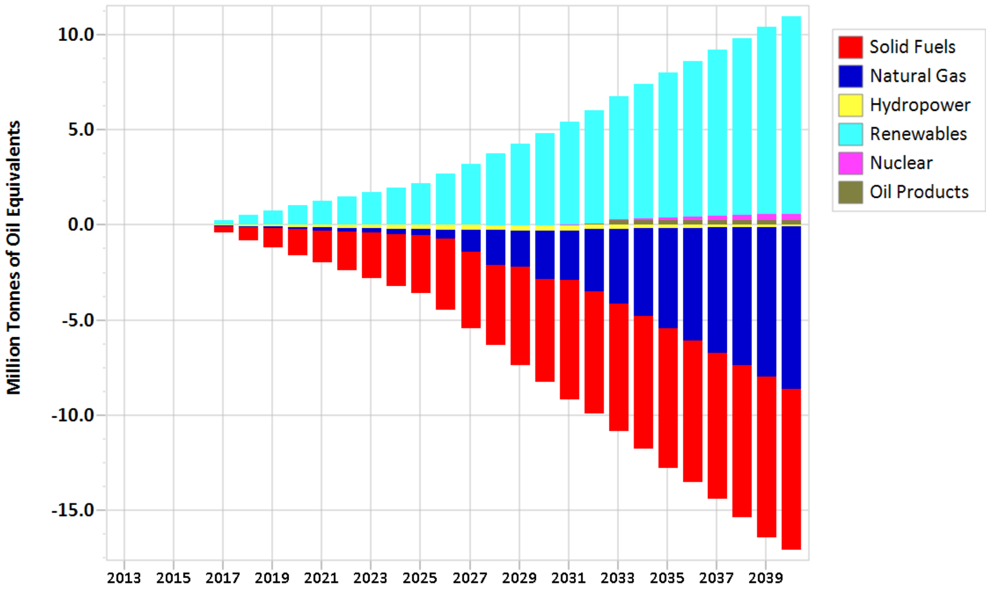
By 2040, power generation inputs of RE sources are expected to increase at an additional amount of 10.3 Mtoe, which corresponds to the reduction of inputs of traditional fuel energy types, mostly from coal (8.4 Mtoe) and natural gas (8.6 Mtoe).

Table 31: Power Generation Input by Technologies, APS vs BAU (in Mtoe)

Fuels	2013	2015	2020	2025	2030	2035	2040
Coal	0.0	0.0	-1.3	-3.0	-5.4	-7.3	-8.4
Oil	0.0	0.0	0.0	0.0	0.0	0.3	0.3
Natural gas	0.0	0.0	-0.1	-0.3	-2.6	-5.3	-8.6
Nuclear	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Hydro	0.0	0.0	-0.1	-0.2	-0.3	-0.2	-0.1
Renewables	0.0	0.0	1.0	2.2	4.8	7.6	10.3
Total	**0.0**	**0.0**	**-0.5**	**-1.4**	**-3.4**	**-4.7**	**-6.1**

Source: Calculation results derived from LEAP model.

Figure 14: Power Generation Input by Technologies, APS vs BAU



Source: Calculation results derived from LEAP model.

11.2. Power generation output

Moreover, RE-based power generation technologies such as small hydropower, wind power, solar PV, biomass, and biogas power plants were promoted to substitute for traditional power generation technologies, which resulted in significant increases in the share of RE power generation.

Table 32: Power Generation Output by Technologies, APS (billion kWh)

	2013	2015	2020	2025	2030	2035	2040
Coal	26.9	27.4	59.5	72.6	90.9	132.8	188.5
Natural gas	42.8	44.6	47.3	84.4	109.2	147.0	187.4
Hydropower	52.0	68.7	92.9	103.5	112.2	114.4	115.9
Nuclear	-	-	-	-	10.7	11.5	12.4
Oil products	0.5	-	0.1	0.5	0.6	1.3	1.3
Renewables	5.1	6.1	15.6	25.2	46.9	64.9	83.1
- Small Hydro	5.0	5.5	10.3	11.8	15.3	17.4	19.3
- Wind	0.1	0.2	1.7	4.1	10.4	15.9	21.5
- Solar	-	-	1.0	4.9	12.5	16.6	20.7
- Biomass	0.1	0.4	2.5	3.9	8.0	14.3	20.7
- Biogas	-	-	0.1	0.4	0.6	0.7	0.9
Total	**127.3**	**146.8**	**215.4**	**286.2**	**370.4**	**472.0**	**588.4**
Share of RE (%)	**4.0**	**4.2**	**7.2**	**8.8**	**12.7**	**13.8**	**14.1**

APSs = alternative policy scenarios, kWh = kilowatt-hour.
Source: Calculation results derived from LEAP model.

By 2040, the share of RE increases from the negligible rate (1.4%) in BAU to 14.1% in APSs. Wind contributes the highest share at 3.7%, followed by solar and biomass (3.5%), small hydro (3.3%), and biogas (0.1%).

Table 33: Share of Renewable Energy by Types of Technology (%)

	2013	2015	2020	2025	2030	2035	2040
Small hydro	3.9	3.8	4.8	4.1	4.1	3.7	3.3
Wind	0.0	0.1	0.8	1.4	2.8	3.4	3.7
Solar	0.0	0.0	0.5	1.7	3.4	3.5	3.5
Biomass	0.1	0.3	1.2	1.4	2.2	3.0	3.5
Biogas	0.0	0.0	0.1	0.1	0.2	0.2	0.1
Total	**4.0**	**4.2**	**7.2**	**8.8**	**12.7**	**13.8**	**14.1**

Source: Calculation results derived from LEAP model.

The above study results have been implemented based on the accessible potential of each type of RE with the assumption that there will be additional support policies for promoting RE. However, priority in the selections will be given to RE technologies, which have lower energy production cost and high potential on GHG emission reduction.

11.3. GHG reduction potential

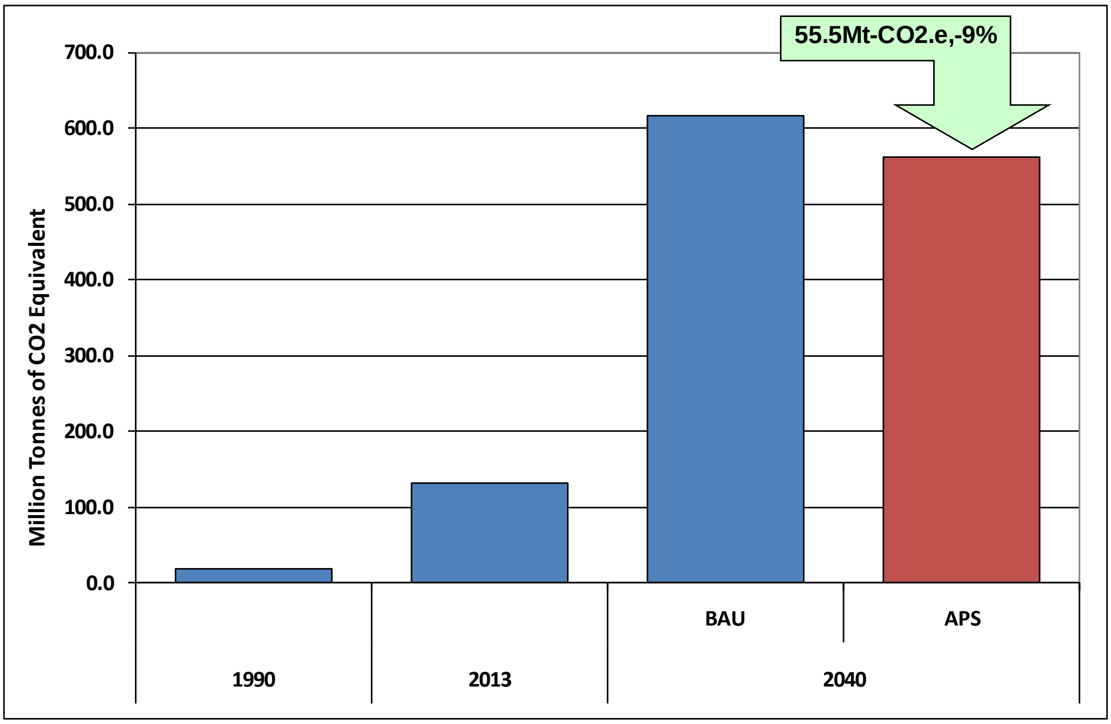
GHG emissions under the BAU scenario are projected to increase by 5.9% per year from 131.6 million tonnes of CO_2 equivalent in 2013 to 616.8 million tonnes of CO_2 equivalent in 2040. Under APS, the annual increase in GHG emissions between 2013 and 2040 is projected to be 5.5% yearly, which is 0.4 percentage points lower than the BAU scenario. Improvement in reducing GHG emissions under the APS will be 55.5 million tonnes of CO_2 equivalent (or 9 % reduction) in 2040, indicating that the goal to promote RE development in Viet Nam is very effective in reducing GHG emissions (Figure 15).

Table 34: CO_2e Emissions by Scenarios Up to 2030 (in million tonnes of CO_2 e equivalent)

Scenarios	2013	2015	2020	2025	2030	2035	2040	AAGR 2013–2040 (%)
APS	131.6	144.1	209.0	272.3	340.1	441.7	561.3	5.5
BAU	131.6	144.1	214.5	285.2	368.4	483.9	616.8	5.9
Reduction	-	-	-5.5	-12.9	-28.3	-42.3	-55.5	

AAGR = average annual growth rate, APS = alternative policy scenario, BAU = business-as-usual.
Source: Calculation results derived from LEAP model.

Figure 15: Evolution of CO_2e Emissions, BAU and APS



APS = alternative policy scenario, BAU = business-as-usual.
Source: Calculation results derived from LEAP model.