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Energy Reports

Provided in Cooperation with:

Elsevier

Suggested Citation: Do Thi Hiep; Hoffmann, Clemens (2020) : A power development planning for Vietnam under the CO₂ emission reduction targets, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 6, Iss. 2, pp. 19-24, https://doi.org/10.1016/j.egyr.2019.11.036

This Version is available at: https://hdl.handle.net/10419/243852

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Energy Reports 6 (2020) 19-24

The 6th International Conference on Power and Energy Systems Engineering (CPESE 2019), 20–23 September 2019, Okinawa, Japan

A power development planning for Vietnam under the CO2 emission reduction targets

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Received 2 October 2019; accepted 22 November 2019

Abstract

The paper guides three scenarios of power planning for Vietnam for the 2018–2030 period under CO2 emission targets. The analysis employs a model of energy expansion in the form of an optimization problem with the objective of the discounted entire system cost minimization. With each CO2 emission allowance, a scenario of the newly installed capacity structure will be carried out. The results indicate that instead of 42.6% coal-fired installed capacity as indicated in the National Power Development Master Plan for the 2011–2020 period with the Vision to 2030 (known as PDP VII), by 2030 the share of this power source will be around 29% (8% CO2 reduction scenario) and 19% (25% CO2 reduction scenario). Also, the lower emission sources such as hydro, wind, and solar power will be a priority for investment in the next decade. There is an existence of coal-fired power plants replacement by natural gas stations.

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Peer-review under responsibility of the scientific committee of the 6th International Conference on Power and Energy Systems Engineering (CPESE 2019).

Keywords: Power planning; Optimization problem; CO2 reduction target

1. Introduction

Vietnamese government currently faces the controversial topic of coal-fired or wind, solar power source development. Some argue that electricity generation from renewables is not only expensive for Vietnamese but also does not ensure the security of electricity supply while others advocate integrating wind and solar power sources into electricity market because of their environmental benefits. There has been an existence of cost reduction trend of wind turbines and solar panels in recent years. The photovoltaic module price for ground-mounted PV systems in the world decreased 70% after only 15 years from 1.85 USD/Wp (in 2000) to 0.57 USD/Wp (in 2015) [Bloomberg New Energy Finance]. More references on the reduced cost of solar power technologies, see in [1,2]. In contrast, because of the limited coal sources, the cost of electricity generation from this fuel is predicted to increase significantly in the upcoming years [3].

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https://doi.org/10.1016/j.egyr.2019.11.036

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Responding to the goal of the 21st Conference of the United Nations Framework Convention on Climate Change (COP21), Vietnam commits that by 2030, this nation will reduce 8% (with unconditional objectives) and 25% (with international support of finance, capacity building, and technology transfer) of greenhouse gases (GHGs) emission compared to the BAU scenario (787 MtCO2e by 2030) [4]. In Vietnam, in 2012, the emission share of the energy sector was 66%, in which the power sector made up about 16% [5]. In recent years, with the fast growth of new coal-fired power plants, more and more CO2 has been emitted into the air [6]. In order to achieve the goal of GHGs emissions, the reduction of emissions in this electricity area would contribute to the overall decrease efforts undoubtedly. Among technologies for power generation, coal-fired power plants have the highest emission factors between 740 and 910 gCO2eq/kWh. The other fossil fuels, including oil and natural gas, also have significantly higher emission factors than the ones of hydropower, solar, and wind power [7,8].

In Vietnam, coal-fired accounted for the highest share of electricity generation (37% in 2016, equivalents to around 70% CO2 emission from the electricity sector) [NLDC, 2017]. According to the revised National Power Development Master Plan for the 2011–2020 period with the Vision to 2030, the Vietnamese government aims to achieve 25,620 MW (42.7%) in 2020, 55,167 MW (42.6%) in 2030 of coal-fired installation [3]. With those targets, the electricity generation from coal is estimated at around 130 TWh in 2020 (equivalents to 123 MtCO2), 306 TWh in 2030 (equivalents to 245 MtCO2) [9]. It is precisely that existing a significant conflict between the CO2 reduction targets and the master plan for the development of power sources in Vietnam. The Vietnamese government sets the ambitious targets of CO2 reduction [4], and at the same time, approves the significant expansion of coal-fired power source [3].

To carry out an energy expansion that is consistent with the CO2 reduction targets, a suitable power planning model is essential. There is the existence of several power planning models focusing on the Vietnamese electricity market. Ha-Duong [10] introduced carbon capture and storage (CCS) technology for coal-fired, gas-fired, and biopower plants. A national energy mix simulation model has been carried out for the planned years 2030, 2050. Nguyen [11] offered a model of Vietnam power system with the objective of least cost expansion. The shares of coal, natural gas, renewables energy in the installed capacity structure were proposed at 24.4%, 22.8%, and 30% by 2030, respectively. Other researches focusing on the integration of wind and solar power with relation to transmission grid capacity can be found out in [12,13].

Looking further into the community of energy planning in the world, variety, and diversity energy planning models have been studied and achieved specific results. Hashim et al. [14] constructed a model for energy planning under three operating modes: economic mode, environmental mode, and mixed-mode, which was applied for the Ontario power grid. The results show two effective ways of the energy transition, including fuel balancing and fuel switching. Recent research on a dynamic investment and dispatch model for the future European electricity market (dynELMOD) has provided a tool to determine future scenarios of the European electricity system under CO2 constraints [15].

The present study is designed to catch sight of the system cost as well as the pathways of power plant expansion in the upcoming decade, in which CO2 emission target is one of the main drivers of the investment plan. The paper is organized as follows. In Section 2, we construct a mathematical image of an energy planning model in the form of a cost minimization problem. Section 3 is to investigate the future pathways of power mix for Vietnam under the CO2 targets. Section 4 is to present some conclusions and policy implications.

2. Proposed model

The model aims to deal with the investment options in electricity generation technologies which support the lawmakers to decide on the targeted installation structure of power in the future. The problem is formulated as linear programming and designed as optimization with the objective of the total discounted system cost minimization under economic and technical constraints. The system costs comprise (1) investment cost, (2) operation and maintenance cost, (3) fuel cost, (4) environment cost, and (5) electricity buying cost. The model has to satisfy demand–supply balance, power system security, CO2 emission limitation. The base year is the year 2017, and the horizon period is from 2018 to 2030. The model formulation is as follows:

$$Objective \ function: TSC = TC_{inv} + TC_{om} + TC_{fu} + TC_{env} + TC_{buy} \Rightarrow Min$$
(1)

The discounted investment cost of new power plants is as follows:

$$TC_{inv} = \sum_{t,i} IC_{i,2017} * (1+\alpha_i)^{t-2017} * CAPnew_{i,t} * (1+r)^{-(t-2017)} * [r/(1+r)/1 - (1+r)^{-Lc_i}]$$
(2)

The discounted operation and maintenance cost is as followed:

$$TC_{om} = \sum_{t,i} OMC_{i,2017} * (1+\beta_i)^{t-2017} * GEN_{i,t} * (1+r)^{-(t-2017)}$$
(3)

The discounted fuel cost is estimated as follows:

$$TC_{fu} = \sum_{t,i} FUC_{i,2017} * (1+\gamma_i)^{t-2017} * GEN_{i,t} * (1+r)^{-(t-2017)}$$
(4)

The environmental cost is the amount of money paid for CO2 emission:

$$TC_{env} = \sum_{t,i} CP_t * GEN_{i,t} * ef_i * (1+r)^{-(t-2017)}$$
(5)

The buying cost of electricity from outside a country is estimated as follows:

$$F_{buy} = \sum_{t} BE_t * EC_t * (1+r)^{-(t-2017)}$$
(6)

The objective function (1) *has to satisfy the following constraints:*

demand–supply balance:
$$\sum_{i} GEN_{i,t} + BE_t \ge PD_t$$
(7)

Installed capacity:
$$CAP_{i,t} = CAP_{i,2017} + \sum_{t} CAPnew_{i,t}$$
 (8)

The upper boundary of newly installed capacity: $CAPnew_{i,t} \leq CAPmax_i$ (9)

Generation and installed capacity relation: $GEN_{i,t} \le CAP_{i,t} * FLH_i$ (10)

Power system security operation:
$$\sum_{i} CAP_{i,t} + BP_t \ge (1+p) * PL_t$$
(11)

Electricity and power purchased:
$$a * ED_t \ge BE_t$$
; $b * PL_t \le BP_t$ (12)

CO2 emission limitation:
$$\sum_{i} GEN_{i,t} * e_i \le CO2_t$$
(13)

Nomenclature Power planning horizon t 2018-2030 i Types of power plants Coal, CCGT, OCGT, diesel, hydro, wind, solar $CAP_{i \ 2017}$ The total installed capacity of power plant i by the year 2017 (MW) The specific investment cost of power plant i in the year 2017 (\$/MWh) $IC_{i \ 2017}$ The OM, fuel costs of power plant i in the year 2017 (\$/MWh) $OM_{i,2017}, FUC_{i,2017}$ The life cycle of power plant i (years) Lc_i Average full-load hours of power plant i (hours) FLH_i The change rates of investment, OM, fuel costs of power plant i (%/year) $\alpha_i, \beta_i, \gamma_i$ The emission factor of power plant i (ton CO2/MWh) ef_i CAPmax_i Maximum annual growth of installed capacity of power plant i (MW) ED_t, PL_t Electricity demand, peak load in year t (MWh, MW) EC_t External purchased electricity price in year t (\$/MWh) CO2 price in year t (\$/ton CO2) CP_t CO2 emission limitation in year t (ton CO2/year) $CO2_t$ Discount rate (%) r Load margin coefficient (%) р The rate of purchased electricity purchased power from neighbors (%) a, b The newly installed capacity of the power plant i in year t (MW/year) CAPnew_{it} The total installed capacity of power plant i by year t (MW) $CAP_{i,t}$ Annual electricity generation from power plant i in year t (MWh) GEN_{it} The amount of electricity purchased in year t (MW) BE_t The amount of power purchased in year t (MW) BP_t

3. Application of the model to power planning in Vietnam

The capacity structure of power plants is collected from different sources [NLDC, 2017], [16,17]. The costs, future development of costs, full-load hours, are referenced from the surveys and researches by Dapice [18], Nguyen [11] and The Vietnamese government [3].

Because of source limitation, government's orientation, economic effectiveness, as well as electricity supply security, the newly installed capacity per year of technologies is limited [3]. The potential of hydropower for future exploitation is limited notably. Meanwhile, existing the high potential exploitation of wind and solar power [19,20]. The economic and technical specifications of power plants are presented in Table 1.

Table 1. Data of power plants.

Technology	CAP17 MW	IC17 \$/MW	OMC17 \$/MWh	FUC17 \$/MWh	Lc years	FLH hours	α *100(%)	β *100(%)	γ *100(%)	ef tCO2/MWh	CAPnewmax MW/year
Coal-fired	15,983	1,200,000	10	28	30	4500	0.015	0.07	0.012	0.82	3000
CCGT	5,000	800,000	4	67	20	6000	0.01	0.03	0.035	0.49	2000
OCGT	2,539	600,000	7	90	15	5000	0.01	0.03	0.035	0.45	2000
Diesel oil	1,229	200,000	10	225	10	200	0.01	0.03	0.062	0.733	500
Hydro	18,123	1,700,000	2.5	0	40	4000	0.015	0.007	0	0.024	1000
Onshore Wind	159	1,980,000	3.5	0	20	2540	-0.01	0	0	0.011	1000
Solar PV	1	1,000,000	1.8	0	20	1500	-0.02	0	0	0.048	3000

The annual electricity generation growth rate is estimated at around 10.5% (2016–2020), 8.6% (2021–2025), and 7.4% (2026–2030) [3]. Vietnam is going to develop CO2 caps regulation on all sectors of the economy and possibly on individual emitters [4]. It is assumed that Vietnam will introduce the CO2 price in 2020 at 7 USD/ton CO2 in 2020 and 20 USD/ton CO2 after that [21]. In this research, we consider three assumptions of CO2 emission limitation (Fig. 1) to finding out the future expansion scenarios: BAU scenario, 8%, and 15% reduction of CO2 emission compared to the BAU case.



Fig. 1. CO2 emission scenarios.

Refer to the current values, the parameters of interest rate, load margin coefficient, the rate of purchased electricity, purchased power are assumed to remain at 7%, 20%, 2%, and 2% over the power planning horizon, respectively.

Using the tool GAMS (The General Algebraic Modeling System), the model outcomes provide insights into the future pathways of the power structure in Vietnam.

Fig. 2 reveals that with the lower emission factors, the investment is a priority with the maximum annual values for hydro, wind, and solar power, respectively. No newer coal-fired power plants are constructed from 2029 in the 8% scenario, from 2023 in the 25% scenario. Instead, more investment in gas turbine technologies will be added.

Table 2 compares the shares of installed capacity of coal-fired, gas turbine, wind, and solar PV in two CO2 reduction scenarios and the PDP VII scenario. Instead of more than 42% coal-fired installed capacity in 2030 as indicated in PDP VII, this power source will account for only around 29% (8% scenario) and 19% (25% scenario). In contrast, the gas turbine technologies will play an essential role and reach 20% (8% scenario) and 29% (25% scenario) instead of 14.7 as in PDP VII. Furthermore, with the maximal installation, the shares of wind and solar are expected to increase from 17% in 2020 to 32% after a decade.



Fig. 2. The installed capacity of different technologies between 2018 and 2030, (a) 8% scenario, (b) 25% scenario.

Table 2. The share of coal-fired, wind and solar PV installation based on different CO2 scenarios.

Year	Coal-fired			Gas turbin	e		Wind and Solar PV		
	PDP VII	8% scenario	25% scenario	PDP VII	8% scenario	25% scenario	PDP VII	8% scenario	25% scenario
2020	42.70%	35%	34%	14.9%	16%	19%	9.90%	17%	16%
2025	49.33%	33%	26%	15.6%	17%	24%	12.50%	27%	27%
2030	42.60%	29%	19%	14.7%	20%	29%	21%	32%	32%

Fig. 3 shows the contribution of each technology into the CO2 emission. Under the 25% scenario, electricity generation from coal is the primary source of CO2 until 2028 before gas technologies become the main emitters after that.



Fig. 3. CO2 emission by fuel between 2018 and 2030, (a) 8% scenario, (b) 25% scenario.

Regarding the discounted system cost, the expenditure is estimated at around 142 billion (8% scenario) and 160 billion (25% scenario). In which, the fuel cost accounts for a considerable portion of the total system cost (61%–66%) while the investment cost makes up only 5%. If the CO2 price is introduced in 2020, the environmental cost is also a significant part of the cost system.

4. Conclusions and policy implications

This paper has developed an optimal energy planning model to discover the power expansion path for Vietnam until 2030 with the consideration of CO2 reduction targets. The costs of power plant investment, operation and maintenance, fuel, environment, and external electricity procurement have been investigated. The designed model is applied to the Vietnamese electricity market, with the assumptions on the future development of electricity demand, peak load, the existence of CO2 price mechanism, and the change rates of costs. The most important constraint is the CO2 emission allowance, which is expected to decrease from 8 to 25% compared to the BAU scenario by 2030.

Through the study, some meaningful conclusions are carried out. Firstly, there is a replacement trend of coal-fired power plants by gas turbine technologies in the next decade. From the years 2028 (8% scenario) and 2023 (25% scenario), more electricity from CCGT and OCGT are generated than the one from coal-fired stations. In other words, the research results show that fuel switching is a useful option to reduce CO2 emissions. Secondly, wind and solar power play a more and more critical role in the electricity supply system, from 17% in 2020 to 32% after a decade. Also, integrating wind and solar farms into the electricity supply system is the necessary condition to achieve the CO2 targets. Besides, the outcomes of the research also reveal the different structures of electricity generation technologies until 2030, compared to the PDP VII (as shown in Table 2).

As planned, the next power development planning for Vietnam (PDP VIII) will be developed in 2019; this research provides a suggestion to the energy policymakers to adjust the targeted installed capacity to get the development of electricity in line with the Paris Agreement.

References

- [1] Wirth H. Recent facts about photovoltaics in Germany. Fraunhofer ISE 2015;1(89):92, doi: Fraunhofer ISE.
- [2] ITRPV working group. International technology roadmap for photovoltaic 2014 results, itrpv. 2015.
- [3] The Vietnamese government. Decision on the approval of the revised national power development master plan for the 2011-2020 period with the vision on 2030. 2016.
- [4] The Vietnamese government. Plan for the implementation of the Paris agreement. 2016.
- [5] Ministry of Natural Resouces and Environment. The second biennial updated report of Vietnam to the united nations framework convention on climate change. 2017.
- [6] Ha-duong M, et al. Synthesis report on socio-environmental impacts of coal and coal-fired power plants in Vietnam. HAL; 2017.
- [7] Hardisty PE, et al. Life cycle greenhouse gas emissions from electricity generation: A comparative analysis of Australian energy sources. Energies 2012;5:872–97. http://dx.doi.org/10.3390/en5040872.
- [8] World Nuclear Association. Comparison of lifecycle greenhouse gas emissions of various electricity generation sources. 2011.
- [9] Bui HP. Coal-fired power, waste, and cooling water. Energy J Vietnam 2017;142:12-4.
- [10] Ha-Duong M. Two scenarios for carbon capture and storage in Vietnam. Energy Policy 2017;110(May):559–69. http://dx.doi.org/10. 1016/j.enpol.2017.08.040, Elsevier Ltd.
- [11] Nguyen QK. Analysis of future generation capacity scenarios for Vietnam. 2017.
- [12] Viet DT, et al. A cost optimal pathway to integrate renewable energy into the future Vietnamese power system. In: 2018 4th international conference on green technology and sustainable development (GTSD). IEEE; 2018, p. 144–9.
- [13] Kies A, et al. Large-scale integration of renewable power sources into the Vietnamese power system. Energy Procedia 2017;125:207–13. http://dx.doi.org/10.1016/j.egypro.2017.08.188, Elsevier B.V.
- [14] Hashim H, et al. Optimization model for energy planning with CO 2 emission considerations. Ind Eng Chem Res 2005;879-90.
- [15] Clemens Gerbaulet CL. DynELMOD: A dynamic investment and dispatch model for the future european electricity market. 2017.
- [16] GIZ. Province with wind power development plan. 2018.
- [17] Ministry of Industry and Trade. The development of solar power projects. 2018.
- [18] Dapice D. Counting all of the costs : Choosing the right mix of electricity sources in Vietnam to 2025. 2017.
- [19] Truepower a WS. Wind resource atlas of Vietnam. 2011.
- [20] Bernardos A, et al. Maps of solar resources and potential in Vietnam. 2015.
- [21] Danish Energy Agency. Vietnam energy outlook report 2017. 2018.