Low Carbon Scenario for the Power Sector of Vietnam: Externality and Comparison Approach

H.A Nguyen-Trinh*, M. Ha-Duong

Abstract**—*In this paper, BAU (a scenario based on current trends) and ALT (a greener alternative with more renewables, higher energy efficiency) are developed. The external costs of CO_2, NOx, SO_2 and PM10 in the Vietnamese power sector are estimated at 20, 1328, 2047 and 1460 US$/ton, respectively. The authors find the electricity price and the domestic trade balance in ALT less sensitive to fluctuations in the international price of coal than in BAU. The total costs accumulated between the period of 2010-2040 would be lower in ALT: 632 billion US$ compared with 974 billion US$. This difference arises from several factors: lower investment in new capacity (226 vs 306 billion US$); lower local pollution costs (73 vs 137 billion US$); and lower expenditures on imported fuels (57 vs 115 billion US$). The outcomes of ALT are in accord with the targets in the most recent Green Growth Strategy of Vietnam and the Intended Nationally Determined Contributions (INDCs) of the country to UNFCCC and COP21.*

Keywords **— energy modeling, energy efficiency, external costs, LEAP, Vietnam.**

1. INTRODUCTION

Over the last twenty years, Vietnam has been pursuing a high-growth rate economic strategy with industrialization and urbanization [1], this strategy encompasses a rapid increase in the national need for energy. Under this pressure, the national energy mix has shifted to develop a secure and affordable energy supply quickly enough to support socioeconomic development. Fossil-based energy sources, such as coal, have been mobilized faster than renewable sources, such as hydropower. The environmental and energy security impacts of the development of the power sector have become issues of national concern.

This manuscript explores the sustainability of the development pathways for electricity supply and use in Vietnam over the period from the 2010 to 2040. The manuscript is organized as follows: The next section presents the method used to simulate the power system and to estimate external costs of electricity generation; we quantify two scenarios with the bottom-up energy-planning model LEAP [2]. We then present the results in Section 3 including results in energy security and in externality. In Section 4, we discuss the role of internalizing external costs in the power sector and low carbon electricity development, and the allocation of external costs. Section 5 summarizes and gives main conclusions of this paper.

2. MATERIALS

2.1 Simulation model

To describe different possible evolutions of the power sector in Vietnam, scenarios are simulated with the LEAP (Long-range Energy Alternatives Planning) model. LEAP [2] is a computer tool for energy planning that has been used in numerous countries to enhance national communication on the inventory of green house gases (GHG) emissions to the UNFCCC. LEAP is generally accepted to be an efficient tool for non-Annex I countries implementing their GHG mitigation assessment [3]. Fig.1 shows research model and boundary that will be simulated by LEAP.

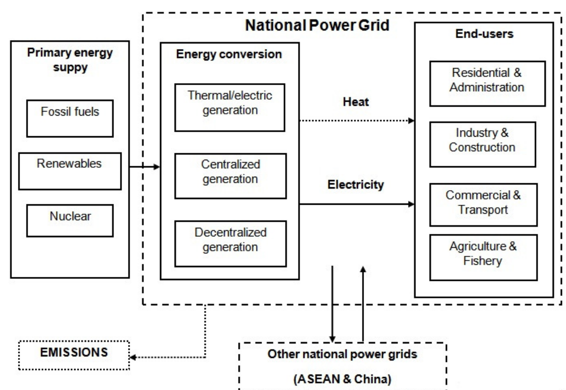

Fig.1. Geographic Boundary of the Scenarios

2.2 Scenarios

Sustainable development of the electric power sector is a balancing act between rising demand, pollution control and national security under a budget constraint. Although a complete policy analysis may explore the feasibility space in all four of these dimensions, this study aims at a more modest goal. We assess the extent to which managing the demand opens up opportunities in the other

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three terms of the balance. To this end, we compare two scenarios. Both scenarios are derived from the baseline scenario in the latest master plan for power development in Vietnam, abbreviated PDP VII [4]: (1) Business As Usual scenario (BAU): Demand side is based on the Medium demand forecast by the PDP VII, and Supply side is based on the Continuation of current energy policies in Vietnam; (2) Alternative scenario: Demand side Reduced power intensity (as compared with the Medium demand forecast in PDP VII), Supply side is with reduction of electricity generation from nuclear, imported coal relative to BAU.

2.3 Assumptions

Population: The projection of the Vietnam General Office for Population and Family Planning is selected in this study because it is the most suitable with current trend of population development and family planning policy in Vietnam. By 2040, the population would reach 112 million people.

Economic growth: In the ALT scenario, the projected annual GDP growth rate is 7.2 percent from 2011-2020 and 7 percent afterwards. The BAU scenario has faster GDP growth rates over the selected period: 8.5 percent from 2015 to 2020 and 8.0 percent afterwards. Those forecasts are merged from IEA and IMF's studies and the official reports of Vietnam.

Power demand: Using a comparison analysis, we find that Vietnam is a high power intensity country compared its neighbouring countries in both current status and over the next few decades.

Vietnam needs energy to speed up its socio-economic development. Moreover, low-technological advancement and non-synchronism infrastructure in the country could be a likely reason for the high power intensity. Its economy lags far behind those other countries. For a more competitive economic development in the region, Vietnam is expected to decrease its power intensity over the years. Fig.2 shows historical and current GDP per capita values of selected countries over the period 1995-2015.

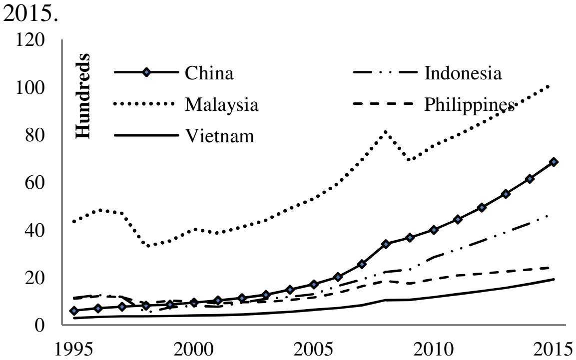

Fig.2. GDP per capita, 1995-2015

Hence, it is challenging for Vietnam to achieve the same power intensity level as the other countries in the region. Based on the current development trends of power intensities of the countries and correlations of their economics, by the year 2050, power intensity of Vietnam is assumed to be at par with that of Malaysia, which has the highest power intensity amongst the other ASEAN countries, in 2030 (about 60 TOEs per million US$.GDP). This could be an acceptable case. Fig.3 presents projections of energy intensity in selected countries to do comparison analysis.

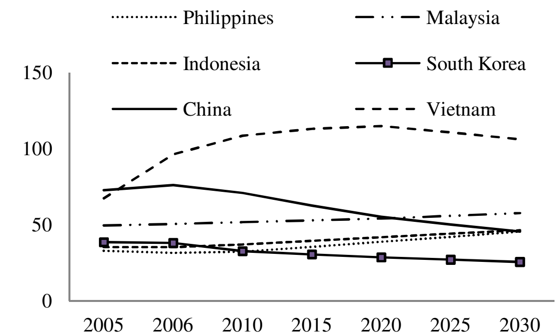

Fig.3: Energy intensity 2005-2030 (TOE/Million USD)

(Sources: Institute of Energy (Vietnam), Economic Research Institute for ASEAN and East Asia and extrapolating calculations of author)

Based on forecasts in the baseline scenario of the PDP VII, the ALT is developed. It is assumed that from 2016, when a number of energy efficiency programs will be completed [5], [6], Vietnam would have achieved substantial energy saving and reached its conservation targets. Annually, power intensity reducing rate of ALT from 2016 is 1.7 percent per year.

The data in the BAU scenario are from the baseline scenario of the PDP VII. However, the PDP VII provides only projected Vietnam's power demand up to 2030, thus the data from 2030 to 2040 is extrapolated by decreasing the power and economic growth rates annually.

Power losses: The total power losses in transmission and distribution grids are 10.8 percent -9.6 percent - 8.5 percent and 7.5 percent by 2010-2015-2020 and 2025, respectively. After 2025, the power losses rate is assumed to remain the same until the end of the selected period. For power self-consumption of power plants in the system, this rate increases from 3 percent by 2010 to 4.5 percent by 2040 due to a higher share of fossil fuel-based power plants which consume more electric power during generation process themselves.

Reserve margin: In the ALT scenario, the reserve margin will increase regularly from 1 percent in 2010 to 15 percent by 2040 as referenced from other power system operators [7].

Power supply: Vietnam is located in Southeast Asia, with many hills and a long S-shaped coastline of over 3200 km. The continental shelf of 1 million km2 has natural gas and crude oil, and there are domestic coal reserves inland. In addition to fossil resources, the geography offers above average potential for hydro, solar and wind power. Although all future power plants in the BAU scenario are the same as in the baseline scenario in the PDP VII, the ALT scenario will open more room for power capacity from non-fossil fuels as presented in Table.

Table 1. Power capacity potential by 2040 from renewables

Energy Type	GW	Energy Type	GW
Laerge hydro	17	Geothermal	2
Small hydro	4	Biomass	0.5
Wind	3	Solar	0.5

(Source: Combined from Master plan for renewable energy development in Vietnam [8] and other relevant studies from GTZ, WB, ADB)

In the two proposed scenarios, we examine energy security and pollution aspects. The concept of energy security is often understood to be the development and maintenance of a reliable energy supply with affordable costs and prices. According to the World Bank [9], three key elements of global energy security are the following: energy efficiency, proper diversification of the energy supply and the ability to deal with volatility in energy prices which should be considered as the long-term goals of the national energy development strategy. In this paper some of the most important energy-related indicators for the vulnerability analysis of sustainable development in Vietnam are proposed and are measured.

2.4 Estimation of external costs

Given the fact that estimation of external costs of electricity generation requires complex databases and integration of simulated models, externality-related studies face a number of uncertainties, unpredictability and controversial conclusions across the selected countries. In spite of these challenges, the methodologies and results of the ExternE [10] project have been applied worldwide and become a well-recognized source. Thomas Sundqvist [11] did a review of 132 studies about external costs of power generation, including coal, oil, gas, nuclear, hydro, wind, solar and biomass power. The study found a huge disparity of external costs estimates. For instance, the maximum external cost of coal power plants is 72 US cents/kWh while the minimum value is only 0.06 US cents/kWh and the mean value is about 14.78 US cents/kWh. It is basically due to: (1) the site specific of power plants with uncertainties of cause and nature of health and environmental impacts; (2) Convergent validity: Applying different methodologies to estimate external costs of a power plant may lead to different final results; (3) Scope: the boundary of external cost studies can cause differences in the final results; and (4) Assumption: the initial and basic assumptions may affect the accurateness of estimates, lack of adequate and suitable socio-economic valuation studies.

Recently, Stefan Hirschberg et al. [12] has been researched and applied the methodologies of the ExternE to estimate externalities of the Chinese power system. Specific results for Shandong province are found and these are extrapolated to the whole country. Unlike China, Vietnam so far has not officially carried out any study of the issue. Due to lack of sufficient data and particular evaluations to calculate externality costs in the power sector, external costs factors are extrapolated from other relevant studies in China. Airborne emissions in the present study for estimates of external costs include: CO_2, NOx, SO_2 and PM10.

(1) External cost for NOx, SO_2 and PM10

$$\text{External cost of emission (i, j)} = \mathrm{CF_{i,j}} * \text{Total emission (i, j)}$$

External cost factors for NOx, SO_2 and PM10

$$\mathrm{CF_{i,j}} = \mathrm{CF_{ref}} \mathrm{x} \frac{\mathrm{D_i}}{\mathrm{D_{ref}}} \mathrm{x} \frac{\mathrm{PPP_i}}{\mathrm{PPP_{ref}}} \left[\frac{\mathrm{US\$}}{\mathrm{ton}}\right]$$

Where: D: population density (person/km^2), PPP: purchasing power parity (billion US$), i = region, j = pollutant

(2) External cost factors for CO_2

There are several existing cost values of CO_2. It could be 19 US$/ton that is an average cost of CO_2 control by European Commission (2003). It was also calculated at US$25/ton by Peter Rafaj and Socrates Kypreos [13] based on adjusting the outcome of the ExternE project at global level. Some studies on these issues in China, costs of CO_2 are 50 US$/ton [14]. In the present study, damage costs of CO_2 is calculated by CO_2 prices of CDM projects in Vietnam as it is estimated at US$7/ton which reflects monetary benefits that power producers could earn if they reduced CO_2 emission during electricity generating activities. For historical and near-term calculations, this value is acceptable and quite useful for both power producers and energy policy makers. In long-term projections, average CO_2 control cost of US$ 20/ton would be used.

3. RESULTS

3.1 Results on energy security

Electricity generation and intensity

Fig. 4 presents the annual electricity generation in both scenarios. This increase of the total power generation raises its total costs in the BAU scenario approximately 15-fold, and the costs reach 28 billion US$ in 2040 compared to 1.8 billion US$ in 2010.

Fig. 5 (a) and (b) graphically present the power intensity in terms of MWh per capita in selected Asian countries and for the two scenarios for power development in Vietnam over the period from 1971-2040. In the BAU scenario, Vietnam’s power intensity is in the lower group, with the Philippines and Indonesia. However, in the period from 2005-2015, Vietnam’s power intensity is growing very quickly and will overtake China by 2025. The pattern of the power intensity increase is the same as in Malaysia, but with slightly faster growth, and the power intensity is projected to equal that of China by 2025. In the ALT scenario, all countries would have approximately the same growth pattern for power intensity, and the correlations among the power intensities of the countries do not change during 2005-2030.

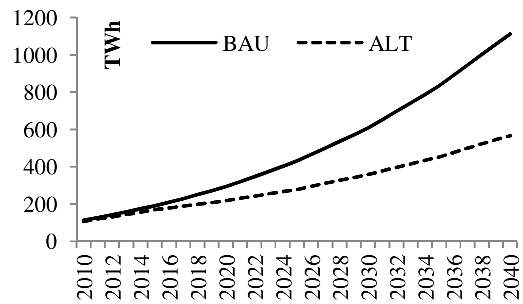

Fig.4. Electricity generation in Vietnam 2010-2040

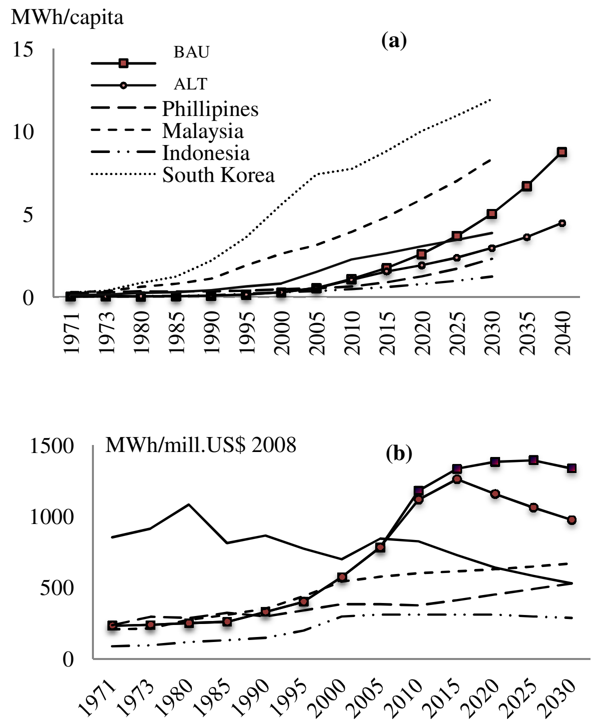

Fig.5. Power intensity: (a) MWh per capita and (b) MWh/Mill.USD.2008 of selected Asian countries, 1971-2030

The overall productivity of power use indicates the amount of power in MWh used by a country to produce a million US$ of its GDP. In the BAU scenario, Vietnam's power intensity is nearly twice as high as Malaysia's. Even in the ALT scenario with higher energy efficiency, the power intensity of Vietnam remains the highest among these countries. In fact, the unusual trends in the power intensity changes in Vietnam could be recognized. Although the patterns are an inverted-U-shape in the environmental Kuznets curve [15], the figures still lead to few concerns regarding the high power intensity in Vietnam from 2015 onwards.

Energy dependence

The net energy import dependence is an indication that assesses how much a country relies on energy imports to maintain its national energy balance. If a country heavily depends on energy imports, it definitely faces two risks: supply shortages and higher prices. Overall, the net energy import dependence increases gradually in both scenarios. The BAU scenario has a higher share of imported fuel-based power capacity. This higher share means that the domestic exploration of conventional energy for power generation is fully considered in all scenarios. The power system must mobilize imported fuel or electricity to satisfy each additional energy unit on the demand side.

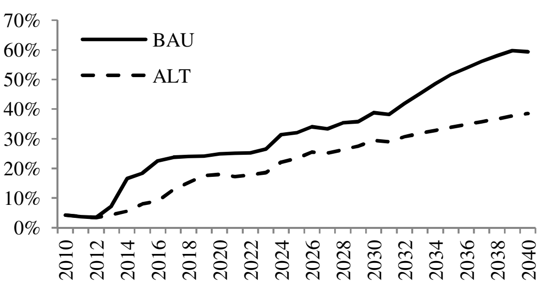

Fig.6. Percentage of imported fuel-based power capacity in Vietnam, 2010-2040

The results of the LEAP simulation (Fig.6) says that coal would account for the largest share of total primary energy imports in years to come. By 2030 in the BAU scenario, of the 32 percent of total electricity generation derived from imported fuels, including electricity and fossil fuels, 66 percent are from coal. Until 2040, power generation from imported coal accounts for 40 percent of the total generation.

Because of frequent fluctuations in fossil fuel prices and the recent worldwide economic crisis, the security of the energy supply has been the primary concern of any national energy development strategy. This indicator presents the effect of expenditure on a single fuel or one group of fuels in a country on its GDP. The higher the GDP, the higher the fuel bills for electricity generation. From a macroeconomic perspective, any change in the indicator could make a country more vulnerable.

Differences in the fuel mixes and power intensities in the scenarios lead to different levels of vulnerability for Vietnam's GDP. The BAU scenario is more vulnerable; the ratio of the imported fuel bill for power generation to GDP is approximately 2.3 percent by the year 2040. With the lowest power demand among the scenarios, this ratio is less than 1 percent by 2040 in the ALT.

In Vietnam, the domestic coal supply is currently sufficient to meet the demand for power generation. Accordingly, international coal prices do not much affect coal-based electricity generation costs. However, according to recent reports from official energy agencies, Vietnam started importing coal for power generation in 2013. Afterwards, the volume of imported coal will increase annually to meet the higher demand in the power sector. Being an imported-coal dependent country makes Vietnam easily vulnerable to any changes in the coal supply from foreign partners and to international coal prices.

Energy efficiency in generation and transmission sectors

The poor average heat rate of coal-fired power plants is another component of this vulnerability. The heat rate of a coal-fired power plant is the ratio of the energy from coal used for electricity generation to the electricity produced from the plant. Technically, the heat rate and the overall efficiency of a power plant are synonyms. The overall efficiency of a power plant is calculated by inverting its heat rate. In this study, the change in the average heat rate value is calculated and is analyzed by adjusting the average efficiency of the coal-fired power plants in the power system. As discussed earlier, the average current efficiency in Vietnam is approximately 36-38 percent because of the large number of technically backward coal-fired power plants in the power system. As recommended by the Institute of Energy Economics, Japan (IEEJ), the efficiency of coal-fired power plants should be benchmarked at 43 percent in Asian countries. Thus, Vietnam has a large technical margin to improve the efficiencies of its coal-fired power plants.

Efficiency of energy transformation process and transmission and distribution

This efficiency indicator is to measure the efficiency of the energy/power supply. Improving the efficiency is important to sustainable development objectives in general in a country in terms of reductions of primary energy consumption and negative environmental impacts. Yet there is not any one international target or recommended standard for energy efficiency.

Efficiency of energy conversion processes and power losses in transmission and distribution grids are important to technical and economic aspects of a power system. To technical aspect, high efficiency of energy processes could improve power supply quality and life-time of power devices. In economic aspect, primary energy resources for power generation can be reduced by improving efficiency of the system. Besides, reducing fossil-fuel consumptions could make remaining fossil-fuel reserves last longer and reduce the negative environmental effects caused by activities in the power sector. In detail, this indicator consists of two components: (1) efficiency of power plants and (2) self-consumption of power plants and power losses in transmission and distribution grids.

The first component examines average efficiency of fossil-fuel-based power plants in the power system by group of fuels. The average efficiencies are evaluated to present at which level of efficiency power plants in Vietnam are. In the current system, average efficiency of coal-fired power plants is 37-38 percent. For oil and gas-fired power plants, average efficiencies are 30 percent and 48 percent, respectively. These efficiencies are still quite low because of backward energy conversion technologies used in the power plants. In years to come, average efficiency of coal-fired power plants is promised to increase due to modern technologies applied and obligatory regulations on minimum efficiency of a thermal power plant. Oil based power plants will not be attractive to develop in Vietnam in the future because of its decreasing capacity. Recently, average efficiency of gas-based power plants has increased because most of the new power plants are combined cycle gas turbine plants that have average efficiency up to 55-56 percent. Average efficiency of thermal power plants, therefore will increase.

Power loss has been a real challenge to Vietnam's power system. The system has undergone situations of very high power losses of up to 25 percent in the late 1980s and 21 percent in the early 1990s (EVN and IEA). Recently, total transmission and distribution power losses decreased to 12 percent by 2005 and are projected to decrease to approximately 11 percent by 2010. It is expected to reduce to 7.5 percent in 2025 (TSD VI, Institute of Energy). Current, total network losses of European and North American countries are around 7 percent1. If the target of 7.5 percent could be reached in time, it is a great success of Vietnam's power system planners and operators.

On the other hand, average self-consumption of power plants is rising from about 3 percent in 2005 to more than 4 percent in 2025 because of the increasing share of thermal power plants that generally have higher power self-consumption as compared to non-fossil based power plants. The overall, total power loss in the power system is decreasing from nearly 15 percent in 2005 to less than 12 percent by 2025.

Investment, fuels and O&M costs

Because of the assumption of lower power demand, the total generation capacity of Vietnam in 2040 in the alternative scenario would also be 126 GW compared to 186 GW in the BAU scenario. In the BAU scenario, the cumulative investment cost for power generation from 2010 to 2040 is approximately 305 billion US$ and for most of the years during the planning period, the annual investment costs account for approximately 3 percent of Vietnam's GDP. Compared to the BAU scenario, the reduction in investment costs over the period from 2010-2040 in the ALT scenario is 80 billion US$.

3.2 Results for environmental externalities

Cumulative emissions

The cumulative CO_2 emitted in the BAU scenario is higher than that in the ALT scenario. Similar results are seen for the other three pollutants. In the BAU scenario, the total CO_2 emission from power generation increases by more than 16-fold to 711 million tCO_2 in 2040 relative to 44 million tCO_2 in 2010 whereas the total electricity production grows nearly 10-fold in the same period. Both scenarios present slightly increasing CO_2 emission intensities up to 2040; the ALT scenario has a lower CO_2 emission intensity of 524 tCO_2 per million US$ GDP while in the BAU scenario this figure is approximately 850 tCO_2 per million US$ GDP in the same year of 2040.

[1] Leonardo Energy Forum: A Leonardo Energy White Paper, Integrated energy planning, 2010

External costs

The external cost factors used to calculate these total costs of electricity generation in the power system are shown in Table 2, which includes the external cost of 20 US$/ton for CO_2. During the period from 2000-2009, the external costs per kWh generated in Vietnam decreased from 2.1 to 1.5 US$ cents per kWh. However, this value subsequently increases during 2010 to 2040 from 1.5 to 2.4 US$ cent per kWh. This increase occurs in both the BAU and ALT scenarios. In relative terms, the total cost increases continuously from 1.4 percent of Vietnam's GDP to more than 3.0 percent over the period from 2010 to 2040 in the two scenarios.

Table 1. External costs factors of emissions and renewable power in Vietnam

	US$/ton
NOx	1 328
SO_2	2 047
PM10	1 460
CO_2	7-20
	$US cent/kWh
Nuclear	0.88
Biomass	1.87
Hydro	0.61
Geothermal	0.09
Solar PV	0.11
Wind	0.27

The major challenge for the low penetration of renewables in power generation is the relatively high prices of these energy sources, not their physical availability. Currently the prices of fossil fuel-based electricity generation do not reflect their full social costs. How to attract more investments into the power sector, especially into non-fossil fuel-based power plants, is still a difficult question to the country.

Total costs of the scenarios

Fig.7 presents the total costs by break-down components (investment cost, domestic fuel cost, imported fuel cost, O&M cost, CO_2 cost, local pollutants cost and external costs of non-fossil fuels) and by scenarios (BAU and Alternative). The results present that applying energy efficiency measures and using more renewable energy sources in the electricity sector could bring considerable economic benefits for Vietnam during the simulation period from now up to 2040. The country would be less vulnerable to the international energy prices, emissions and increasing demand for power. When the burden of high investments for new power capacities to fuel the economy would be abated then Vietnam could have more financial sources for its other development targets such as infrastructure and living standard improvements.

Those results point to two issues in the future evolution of Vietnam's power sector: (1) the penetration level of non-fossil fuel-based power capacity and (2) the allocation of external costs to attain sound development in the power sector. The major challenge for the low penetration of renewables in power generation is the relatively high prices of these energy sources, not their physical availability. The prices of fossil fuel-based electricity generation do not reflect the full social cost of these fuels not only because the prices fail to include the costs of health and environmental damages but also because of the market organization. Vietnam's government sets upper limits for average electricity prices and does not give any direct subsidy to electricity utilities. The subsidy is given through the prices for coal and gas in the power sector. These prices are lower than market prices, from 50 to 20 percent, depending on the type of fuel and the ownership of the power plant. Normally, long-term fuel supply contracts are signed by EVN (Electricity of Vietnam) and TKV (Vietnam National Coal and Mineral Industries Group) or PVN (Petro Vietnam). For EVN, the biggest state-owned electricity company), the average electricity costs are currently lower than the electricity tariff from the government. However, the prices for electricity purchased from independent power producers could be higher than the tariff so EVN must fill the gap. To date, EVN is the only buyer in Vietnam's power market; thus, the power market in Vietnam is not a full competitive one. How to attract more investments into the power sector, especially into non-fossil fuel-based power plants, is still a difficult question to the country.

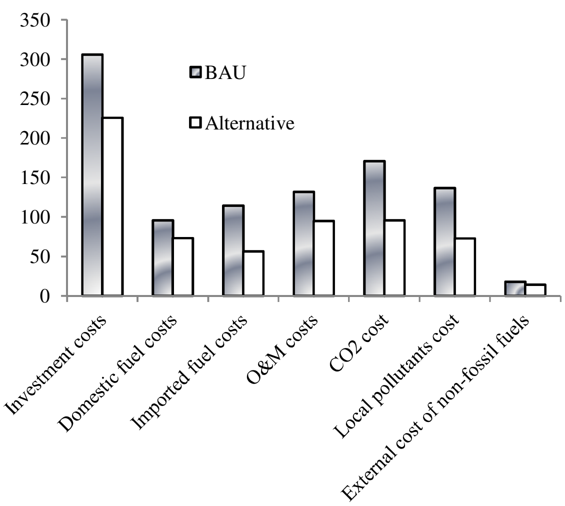

Fig7. Total costs (Investment costs, O&M costs, fuels costs (domestic & imported), external costs) by scenario (billion US$2008)

Even excluding external costs, the total costs for the generation sector in the ALT scenario are lower than those of the BAU. This is a point to tell us that at the moment as well as in few years to come, the external costs are not seriously under consideration of the power sector, Vietnam still should go for the green electricity development scenarios due to economic benefits that these scenarios could bring to the country.

4. DISCUSSIONS AND RECOMMENDATIONS

4.1 Externality and low carbon development

We would note three key features of the low carbon transition. First, the market prospects of low carbon technologies differ from those of most of the core technologies of previous industrial revolutions. Crucially, they primarily deliver a social benefit, i.e., the public good of mitigating climate change, rather than purely private benefits to the individuals or firms adopting them. In the language of economics, greenhouse gas emissions are 'externalities' that are not fully traded and priced in markets, because their reduction as yet lacks durable, credible market value. Hence, addressing climate change is an issue for society in general and cannot be achieved solely through the responses of private markets, buyers and sellers. This point suggests a more prominent role for public policy in 'managing' this transition than in many, although not all, previous energy transitions. It also raises major questions about the roles and influence of key societal actors, especially government, market and civil society actors.

Second, related to this, policy strategies, actions and instruments concerned with a low carbon transition are strongly influenced by the interplay and trade-offs between climate and other energy policy objectives, such as energy security, affordability and international competitiveness.

Third, the time scale for achieving a low carbon transition of the order needed to meet challenging carbon emission reduction targets by 2050 would be significantly shorter than previous comparable industrial transformations. These three significant contextual features influence whether and how a low carbon transition might also constitute an industrial revolution.

4.2 Technology learning curve and energy transition

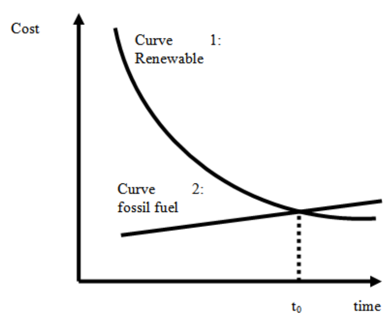

Fig.8. Energy technology options by type and cost

Based on Hohmeyer's approach in his study [16], the cost development of energy technology by time is illustrated in Fig.8. The curve 1 presents the costs development of renewable power technology. This decreases continuously because of reducing research and development (R&D) costs on renewable technologies and effects of increasing scale. On the contrary, the curve 2 presents an increasing trend of the cost development of fossil fuel based energy technology that is caused by increasing scarcity of fossil fuel energy. The curves present 'pure' cost development, without any externality considerations. Obviously, in the first stages of development before t_0, renewable energy is as not attractive as fossil energy in the term of costs. The moment t_0 differs from country to country. However, the current situation of Vietnam's power sector shows that it is quite far to reach the moment t_0 by itself. From the results of external costs in Vietnam's power sector, in which external costs of fossil fuel based electricity generation are much higher than those of electricity from renewable, for instance, 4 times in case of coal power as compared to hydro power. If external costs are taken into account, renewable energy would be more than attractive than its current trend. Fig.8 and Fig.9 illustrate more about the point.

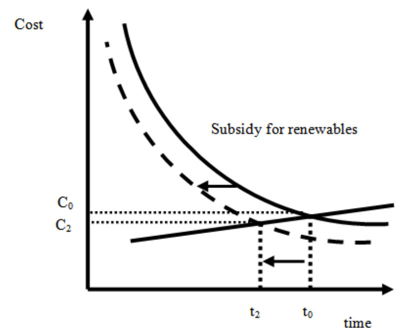

Fig.9. Policy option: Subsidy for renewables

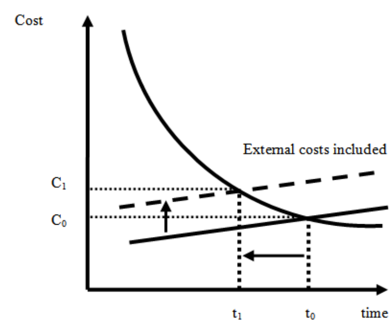

Fig.10. Policy option: external costs

The internalizing external costs into the power sector, "the equilibrium point" at which renewable energy could be as competitive as fossil energy will come earlier, from t_0 to t_1, because of the shifting up of the cost development of fossil fuel. Thus, it speeds up the penetration of renewable in power sector. However, "the equilibrium cost C_1" is higher than "the natural equilibrium cost C_0" and it requires a higher investment on 1MW installed power capacity at the point t_1 as compared to t_0. This to some extent could lower interest of investors on developing renewable energy. Another tool to prepone "the equilibrium point" is subsidy for power generation from renewable energy. The subsidy would be implemented by several methods, such as subsidy in tax, land, capital costs, low interest loan or feed-in tariff for electricity generated from renewable sources. The subsides could move the curve of cost development of renewable energy down then the equilibrium point will shift from t_0 to t_2. In this case, the equilibrium cost C_2 is lower than the natural equilibrium cost C_0. This lower cost may attract more investments on renewable energy. From the results of two cases, to reach high penetration of renewable energy in the power system with reasonable costs, it is very necessary to combine those tools, internalizing external cost and subsidizing renewable energy. It needs macro policies at the governmental level.

4.3 Allocation of external costs

The second external-cost-related issue in the future evolution of the power sector in Vietnam is the allocation of external costs. Particularly, it relates to total investment in the power sector. Presently these costs are not taken into account by both electric power utilities and the government. Although in recent national official reports in power sector, environmental concerns has to be presented, most of them are qualitative.

To date, no monetary valuation of externalities in power sector is implemented in Vietnam. Therefore, internalizing external costs into electricity generation sector is very controversial and challenging. Regardless type of performance, it definitely affects the investment on power generation sector. Assume that the government would expend a part of its public expenditure to compensate human health and environmental damages caused by power generation activities. If this amount is included in a fixed amount that government plans to invest in power sector, it will lower real MW capacity as promised. If not included, the expenditure on external costs could reduce investment opportunities in other sectors, thus economic growth of the country could be vulnerable. Evidently, the expenditure is for social benefits and to improve living and environmental quality. However, back to the ideas of the Kuznets' curves, at its current stage of development, Vietnam's government is not expected to compensate directly the total externality caused by the power sector

The second stakeholder in the external cost allocation scheme is the existing power plants operators or future investors in the sector. Additional investments in external costs would increase the total capital cost per MW installed power capacity, resulting in less new installed capacity in the power system. To some extent, pollution is "an unavoidable factor' of any industry, especially in power industry. If external costs are internalized, power producers have to deal with a cost/benefit analysis: more investment costs in high-quality human source, more efficient technology and pollutant control equipments vs. benefits from the reduction of social and environmental damage punishments. Therefore in the long term, the internalization of external costs may increase the efficiency of power generation and the cleaner energy conversion technologies used in the sector. Nevertheless, when compensation for the damages is obligatory to power producers, electricity production cost will increase as an inevitable result. If Vietnam's government would compensate for the electricity price differences to maintain affordable prices, it will bring us back to the first analysis mentioned already above. If not, power end-users will suffer these increases. Also power end-user is the last but very important stakeholder in "the external cost story".

The fact in Vietnam that electricity prices are fixed by power companies under regulations of the government. Vietnam's government has tried to control the prices at reasonable and affordable levels. Higher electricity prices could make electricity users more vulnerable to higher electricity bills. Moreover, it could negatively affect a number of vulnerable indexes as discussed earlier in this study, such as level of modern energy services; electrification, hunger eradication and poverty reduction processes, the consumer price index (CPI), etc. Recently, the Vietnam Energy Association proposed increasing average retail price of electricity about 50 percent, from 5.5 to 7.8 US$cents /kWh because with the current retail tariff, EVN have no profit and even get losses. The proposal is still controversial, especially facing opposite opinions of the public. This example shows that to successfully internalize external costs in practice, it needs a clear quantitative monetary evaluation and an appropriate scheme to go for. However, in the long term, the internalization of external costs could increase the efficiency of power use and reduce power intensity of the economy. Therefore, it could lead to a more sustainable development of the future power system in Vietnam.

4.4 A strategic log-frame for introducing external costs into electricity generation

To develop a strategy for internalizing of external costs in the power system of Vietnam, we propose a log-frame as presented in Table 5 (see Appendix). This logical framework describes both a general approach, in the form of a log-frame matrix, to programme planning, monitoring, and evaluation. It encourages policy makers to consider the relationships between available resources, planned activities, and desired changes or results. To achieve the main goal of successful internalizing of external costs in the power system, main activities are estimations of both internal and external costs of each type of electricity generated from different primary energy sources and in different regions. A number of indicators are calculated to measure the efficiency of the strategy in each stage and in different dimensions. This framework also gives means for monitoring and evaluating the outcomes of the programs. Currently, such steps are not paid high attentions and even ignored by the programs regarding energy efficiency and environmental assessment in developing countries like Vietnam.

Previous analysis by Larazic and Maréchal [17] has shown that adopting an evolutionary perspective in the policy process could help policy makers in dealing with energy- and climate-related issues such as internalizing external costs because traditional cost-efficient measures could fail to address structural barriers rather than bring about the required radical change in the field of energy. However, if Vietnam could explore appropriate measures for the internalization of external costs, it could increase the efficiency of power use and reduce power intensity of the economy. Therefore, it could lead to a more sustainable development of the future power system in Vietnam.

5. CONCLUSIONS

Our simulations show the extent of the sustainability challenges for the power sector in Vietnam, and describe one pathway to develop the power sector in a more sustainable way. Renewable resources –hydro, wind and solar– have a large potential capacity in Vietnam, but both our scenarios explored a power generation mix dominated by fossil fuels for the next three decades. In this context, energy dependence, pollution and costs are increasing sources of concern that can be alleviated.

- With the current development trends (BAU scenario), the power sector in Vietnam will become more vulnerable to the variability of international fossil fuel prices. With the share of imported fuels being more than 50 percent by 2035, the cost of electricity will depend critically on international markets. In the BAU scenario, the cost of fuel imported for power generation approaches 2.3 percent of the GDP by the year 2040. This result is not fatal. In the ALT scenario, this ratio remains below 1 percent at the same date. This difference is because the demand is lower, so imported fuel accounts for only 39 percent of the total generation in 2040, as opposed to 60 percent in the BAU scenario.

- The external costs, which are a measure of pollution, increase from approximately 1.5 billion US$ by 2010 to 8.3 billion US$ by 2025 in the BAU scenario. Most of these costs come from fossil fuel-based power plants. These plants would account for more than 90 percent of the total external costs in the power generation sector (with a CO2 cost of 20US$/t). In relative terms, the total external cost would increase from 1.4 percent of the GDP to more than 3.0 percent of the GDP over the period from 2010 to 2040 in the BAU scenario.

- Regarding costs, we find that the greener alternative, the ALT scenario, is also more sustainable than the current trend, the BAU scenario. The total generation capacity of Vietnam in 2040 in the ALT scenario would be lower, 126 GW relative to 186 GW. This difference results in lower total costs from 2010 to 2040, approximately 632 billion US$ relative to 974 billion US$. This difference arises from several factors: lower investment in new capacity to meet demand, 226 relative to 306 billion US$; lower local pollution costs, 73 relative to 137 billion US$; lower CO_2 emissions; lower expenditures on fuel imports of 57 relative to 115 billion US$ and not discounting the future fuel savings of renewables.

We believe that current trends will not be curbed much without additional policies. This manuscript is not the place to discuss the various methods and tools used by governments all over the world. These methods include regulation of power utilities, tax and subsidy schemes, emissions standards, tradable permits, or voluntary actions. We believe that the first consequence of pollution controls would be high penetration of advanced coal generation technologies. Improving the thermal efficiency of fossil fuel generation plants is always a priority. In an industrializing country, these advances do not mean CO_2 capture and storage, they mean less pulverized coal and more supercritical, high thermal efficiency plants.

Fortunately, there are signs of changes. The Green Growth Strategy of Vietnam (GGSV) was published in September 2012 [18]. Vietnam is one of the first developing countries in the Asia-Pacific region to develop such a green growth strategy. Power sector changes are expected to play an important role in the green growth strategy. Reducing emissions from the energy sector and promoting clean energy production and use are two strategic tasks in the GGSV. The GGSV aims to develop the infrastructure to improve the entire efficiency of the society. This improvement aligns with the key assumptions in our ALT scenario, which is that Vietnam catches up in the energy efficiency with neighbouring countries. Lower energy demand is the key to the greener growth scenario that is described in this study and simultaneously improves energy security, pollution and costs.

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APPENDIX

Table 3. Types of emissions and damages considered

No.	Impact category	Pollutants	Effects
1.	Human health	NO_x, SO_2, PM_{10}	Reduction in life expectancy, congestive heart failure
2	Impacts on crops and materials	NO_x, SO_2	Yield change for rice, potato, sugar cane, Aging of galvanized steel, limestone, mortar, sandstone, paint, rendering, and zinc for utilitarian buildings
3.	Global warming	CO_2	Wide effects on mortality, morbidity, coastal regions, agriculture, energy demand and economics.

(Source: ExternE project [10])

Table 2. Major factors to extrapolate external costs

Year 2003	Shandong	China	Vietnam
Population (1000 persons)	80,000	1,285,000	80,902
Area (1000 km2)	153	9,596	331
Population density (persons/km2)	523	134	244
PPP per capita (USD $/person)	2,869	3,237	1,781

(Source: [19], [20][2])

Table 5. A log-frame to develop a strategy for internalizing of external costs in the power system of Vietnam

	Objectives & activities	Indicators	Means of verification	Assumptions
Goals (impacts)	Successful internalizing of external costs in the power system	-Responsibilities for environmental and social damages by causers in power sector (through approximate payments for external costs)	-Monitoring and evaluating programs	-Availability of sufficient relevant database
Purpose (Outcome)	-Improve human health and environment quality -Promote clean energy conversion technologies -Reduce emissions	-Reduction of diseases/deaths related to pollutants -Increase of clean power share; -Reduction of emissions growth rates; -Higher efficiency of power production and usage	- Surveys; Statistical data -Energy and emission audit and measures	-The input-output table for sectors in economy is available -Good database of socio-economic status
Output	-Policy framework to internalize external costs in power sector -Financial scheme to allocate the costs	-Abilities to pay higher electricity prices of end-users -Adaptability of power producers to new policy framework -Performance of government's tax and subsidy	-Monitoring and evaluating programs	-Government's determination -Transparent power systems
Activities	-Estimate internal and external costs of each type of power plant by primary energy and region	-Internal and external costs factors in unit of US$ cent/generated kWh	-Analyze and compare to other relevant costs' estimates -Evaluating programs	-Availability of relevant specific economic evaluations

[2] Database of WorldBank and International Monetary Fund