# Programming Sustainable Development in a Developing Country: A Social Optimization of the Vietnamese Power Sector A

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# Programming Sustainable Development in a Developing Country: A Social Optimization of the Vietnamese Power Sector

A Dissertation submitted to the School of EHESS in fulfilment of the requirements for the degree of Doctor of Philosophy in Energy and Environmental Economics

by

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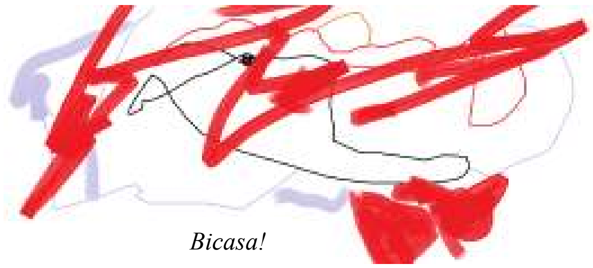
**March, 2011**

**To my son: Hieu An Nguyen (Bi)**



*Bicasa!*

*I wish to dedicate my beloved son, Hieu An, all the words within this dissertation. A number of words I wrote down are as much as the love, the nostalgia, and the torment that I have felt about him during the past 3 years.*

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Finally, I wish to dedicate this work to my beloved son, Hieu An Nguyen (Bi), who has starved for daily care from his father since the past three years.

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## General introduction

Vietnam is confronted to the challenges of sustainable development in its three dimensions: balanced economic development, equity in its social development and environmental protection. In fuelling the economic and demographic growth in Vietnam, energy has a critical role to guarantee this sustainable development. Over the last decades, a number of reforms in the central planning economy have led Vietnam to faster economic growth with annual rates of 7-8%. The demand for electricity has increased twice as fast as the Gross Domestic Product (GDP) during the same period, and annual growth rates of about 17% has been predicted for the electricity demand for the period from 2010 to 2030 (Institute of Energy, 2009). However, the development of energy for fulfilling material needs to the economy growth has also been accompanied by a number of challenges.

Economically, there arises changes in primary energy resource base thereby the increasing reliance on energy supplies from aboard is foreseen for the years to come (Institute of Energy, 2009; World Bank, 2010a). Although the availability of indigenous primary energy resources is not going to be an immediate threat to the security of energy supply, a question arisen is that can Vietnam afford to allow the current patterns of energy production and consumption to continue in the context of uncertain fossil fuels prices at global level? According to World Bank (2010a), the expected development of electricity production using large-scale coal and electricity imports, and increase in international oil prices will only make energy costs rising to Vietnam's consumers and could lead the power sector to potential vulnerability of international energy price fluctuations. Such volatile energy costs in the power sector could further contribute to increased poverty, political pressures, and instability. Changing these unsustainable patterns is, thus, the major challenge for the Vietnamese power sector.

Financially, the energy infrastructure development in Vietnam in particular in electricity distribution and commercial fuel supply lags the demand growth due to a major barrier of insufficient access to financing sources (MOIT-JICA, 2008; World Bank, 2010b). In practice, the electricity price is administered in Vietnam and policy makers lean toward controlling the price at a level moderate enough to enable the domestic products to be competitive in the global market. Besides, the fuel and electricity prices tend to be widely subsidized, creating large deficit in the public companies. This low and inadequate electricity pricing scheme makes it less attractive to investors to lay down their funds for electricity supply projects. Moreover, global economic downturn also slows down new investment in energy as it is the largest capital-intensive sector. Thus, the country is extremely facing the pressure on obtaining the necessary finance for the request of expanding the electricity generation industry while government resources should be also requested for investment in other socioeconomic areas.

Technologically, increasing supply efficiency and passing efficiency gains to consumers has been always a real technical challenge in Vietnam. The energy supply loss, within the power sector, was about 10.8% in 2010 (NLDC, 2010a). Very high energy intensity suggests also that inefficient energy use, in terms of energy technology and behaviour, should exist within the given absence of price incentive. This contributes to the rapid but uncertain increase in electricity demand and affects the stability of the supply system. As a consequence, the chronic problems of power shortages and poor security of electric power supply often occur hampering the economy and daily life of Vietnamese people, especially the medium- and low-income people and people in rural areas.

Socially, there exist three basic features related to sustainable electricity supply goals: accessibility, affordability, and acceptability. Particularly for rural areas, the electrification aims to bring people to modern health and education services, poverty alleviation and gender equality. In fact, though Vietnam has achieved significant electrification rates in recent years, the access to electricity and modern services is still limited in many rural places, even impossible for people living in mountainous and very-remote areas. Besides, some rural areas have grid-connected systems, but people still suffer many handicaps and hardly affordable to access because: the local electricity grids are very poor and very unreliable, expensive costs of connecting grids, electricity tariff somewhere is higher than that in urban areas due to very poor system management locally and high power loss. Given a high economic growth, the power sector is likely to expand based on large-scale coal fuel in the years to come. Yet increasing the use of fossil fuels to meet growing worldwide demand for electricity, especially in developing countries, goes against the need to prevent dangerous climate change globally, by which Viet Nam is estimated as one of the most vulnerable countries to global warming. Moreover, Vietnam's geography makes it one of the most disaster-prone countries in the world, suffering from typhoons and tropical storms, floods, drought, and landslides. An inappropriate exploitation of hydropower resource for expanding the electricity supply industry may also become environmentally and socially unsustainable such as: deteriorating the watershed forests, causing effects on biodiversity and ecosystems, increasing floods, etc.

Environmentally, rapid economic growth based on heavy use of fossil fuels along with the expansion of power sector over the last decade is responsible for an alarming increase of air pollution and deterioration of local air quality in Ha Noi and Ho Chi Minh cities. For example, air pollution brought about 22% of chronic pneumonia cases and one-third of respiratory inflammations in Vietnam from 2001 to 2003 (Cofala et al., 2004; USAID, 2007; IEA, 2010a). In terms of increasing $CO_2$ emission inventory, we estimate a large amount of 7.2 Gt of $CO_2$ cumulative emissions would be emitted by the power sector from 2010 to 2040 because of the dependence on burning coal fuel. This  figure is about 70 times larger than the total 103 Mt of $CO_2$ emissions emitted from fossil fuels combustion in Vietnam in 2008 (IEA, 2010b). Moreover, the sector could become a large emitter of local pollutants, with cumulative emissions of up to 15 Mt of $SO_2$ and 8 Mt of $NO_X$ over the same period. These figures are 80 folds larger than the 128.2 Kt of SO2 and 102 Kt of $NO_X$ emitted by the sector in 2006 (Nguyen and Ha-Duong, 2009).

Structurally, like most parts of the developing world, the Vietnamese power sector still be of the structure of vertically integrated (quasi-) monopolist and state entities keep a central role in the sector. Given the increasing pressure on the current unstable situation of the power sector and its poor performance, the need of sector reform is recognized by Vietnamese Government and becomes an imperative action in order to attract a broader cluster of participants to invest in the sector, improve its performance in terms of quantity and quality to support economic growth, while ensuring reasonable and fair costs to consumers, and efficiency. However, how to implement the reform effectively so that it could achieve the desired outcomes and be adequate to the specific circumstances of the country still exists as a practical challenge.

Today, a strategy for sustainable energy development is set up with the four lines of business: direct poverty alleviation, macroeconomic equilibrium governance and private sector development, and environmental sustainability (World Bank, 2009a). In fact, these goals are not new, but circumstances change: we have to consider urgently the climate change-related challenges and look for opportunities of increased sustainable development in conjunction with international carbon emission mitigation.

But the right moment has come for Vietnamese Government to review the past progress of the development road and have stronger and proper policies towards future sustainability. Specially, the issues of energy development related to sustainable future should be taken a larger part in the development agenda of Vietnamese policy decision-makers.

The objectives of the dissertation: The kernel of this dissertation aims to exploit by optimisation methods and empirical studies the issues of sustainable development in the Vietnamese power sector for the next thirty years. It then examines the ways to implement sustainable energy options for the power sector in practice. To accomplish these two objectives, the study focuses on different, but related, issues with these two methodologies:

(i) In the first part, we develop the bottom-up Integrated Resource Planning (IRP) model to provide a more exhaustive assessment of the current state and future prospects for the Vietnamese power sector in next three decades. Then, using a comparative analysis and a vulnerability analysis that is based on the IRP simulation, we analyze energy-development-related vulnerabilities that the sector could face, in terms of economic and socio-environmental dimensions. We further develop the IRP model, in such a way representing realistically the marginal abatement costs of carbon emission reduction by considering non-zero carbon values and carbon emission constraints, in order to simulate sustainable energy supply options for the power sector.

(ii) In the second part, we study the major barriers against the wider adoption of sustainable energy development options in practice by using analytical hierarchy process-based formal surveys among national experts. Then, we use an empirical analysis approach to examine different appropriate policy means including incentive instruments/schemes and sector reform for such sustainability of the power sector. To the end, we analyze the access to feasible financing sources for sustainable development in the Vietnamese power sector.

In electricity industry, utility planners often use simulation and optimization tools to address the dynamic process of electricity energy planning according to changing conditions. To response to increasing concerns about energy supply costs, the environment degradation, and related risks, the traditional electricity energy planning has been redesigned thereby planners have moved towards the so-called integrated resource planning (IRP). Today, in spite of the increasing irrelevance of the IRP in many developed countries, where one exploits the efficiency of private sector, and other viable and potentially valuable resources that may further reduce the costs, and relieves the debt-ridden public utility sector of financial burden for new investments, this is not the case in most parts of the developing world, especially in Asia where power sectors still remain the structure of vertically integrated (quasi-) monopolists with or without Independent Power Producers (IPPs) and state electric power utilities keep a central role in the sector. The principles of the IRP still remain a valuable tool for power sectors to address their existing problems and ongoing reforms. The present study develops the bottom-up IRP model using the principles of the integrated resource planning. This model uses mixed-integer linear programming (MILP) to compute a lowest-cost electricity generation capacity expansion plan. Specifically, the IRP model is used to simulate programming sustainable development options for the Vietnamese power sector and analyze potential vulnerability that the sector could face under the current energy development policy. These sustainable energy options include energy efficiency improvements, renewable energy (renewables), and carbon capture and storage (CCS).

The organisation of the dissertation: This dissertation is organized with the two major parts: namely A and B. The introductive chapter 1 explains the main issues of sustainable development related to the energy system situation in Vietnam. In follows, the Part A examines successively three technological options possibly contributing to a more sustainable development. Chapter 2 discusses about energy efficiency improvements including demand-side management (DSM). Chapter 3 is about renewable energy (renewables), and chapter 4 about carbon capture and storage (CCS). Chapter 5 provides the overall technical potential for $CO_2$ mitigation in Vietnam's power sector with carbon caps and carbon prices using the IRP simulation. The Part B takes a more holistic stance to address three pragmatic issues. Chapter 6 analyses the social barriers to the adoption of renewables and higher efficient coal-based generation technologies, based on a domestic expert survey. Then, it analyses different appropriate policy means including incentive instruments/schemes and sector reform for solving the major barriers towards a sustainable development for the sector. Chapter 7 discusses financing for sustainable energy development in the Vietnamese power sector. To the end of the dissertation, the Chapter 8 summarizes and concludes. The electronic supplements are also annexed to the dissertation. They include a details presentation of the IRP model and its parameters, and copies of the published articles/chapters.

# Chapter 1. Socio-economic development and energy system situation in Vietnam

## 1.1 Socio-economic development and energy system situation

### 1.1.1 Socio-economic development situation

*Geographical and social features*

*Figure 1-1: Vietnam lies in the center of South East Asia.*


Located in the region of South East Asia, Vietnam owns a long coastline of over 3,200 km, and approximately 331,212 $km^2$ area. The country borders with China in the North, Laos PDR in the West, and Cambodia in the South (Figure 1-1).

Vietnam experiences typical tropical monsoon climate in the Southern part with two seasons: rain season (from May to September), and dry season (October to April) while the Northern has monsoon climate with four distinct seasons: spring, summer, fall, and winter.

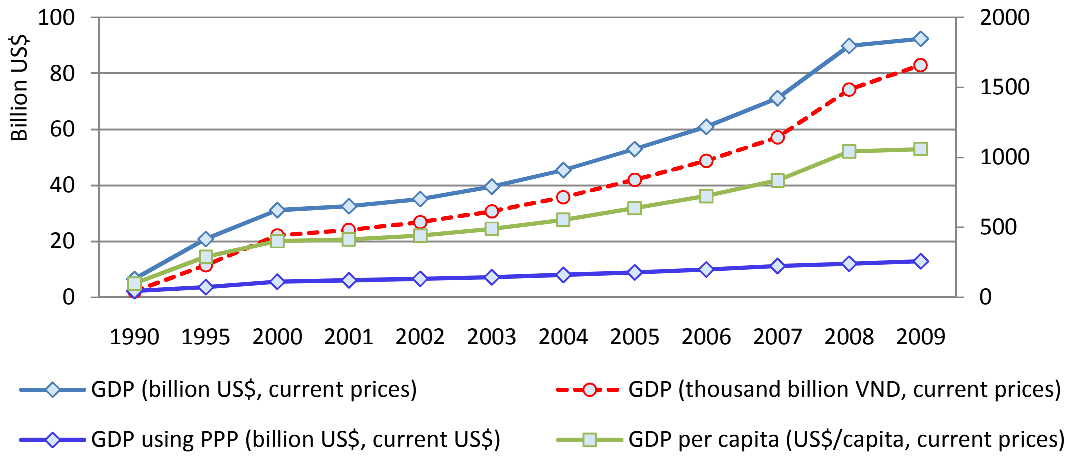
Source: Khanh Toan, P., (2010).

Vietnam is ranked as the thirteenth most populous country in the world. By 2010, Vietnam's population is over 88 million, growing about 1.3% annually over 2000-2009. The population density grew at 1.7% per annum (199 capita/$km^2$ in 1990 and 263 capita/$km^2$ in 2009). The fraction of the urban population was 19.5% in 1990. This rose faster to 24% and 29% for the following years 2000 and 2009, respectively (VGSO, 2010). The growth rate in urban population implies a fast urbanization an on-going industrialization process in Vietnam.

*Historical economic growth*

Vietnam has experienced remarkable economic development since 1986 through the performance of the reform policy "Doi Moi", implementing several plans of socio-economic development. Over the period 1990-2009, Vietnam's economy achieved a rapid Gross Domestic Product (GDP) growth with an average increasing rate of 8% (Figure 1-2). However, in term of nominal GDP and nominal GDP/capita, Vietnam still lies at low-income level by 2009. In 2009 Vietnam achieved US$ 1,060/capita, being positioned in the late developing group of ASEAN and behind other neighbours such as Indonesia, Thailand, Malaysia, Singapore, Philippine, etc (IMF, 2010).

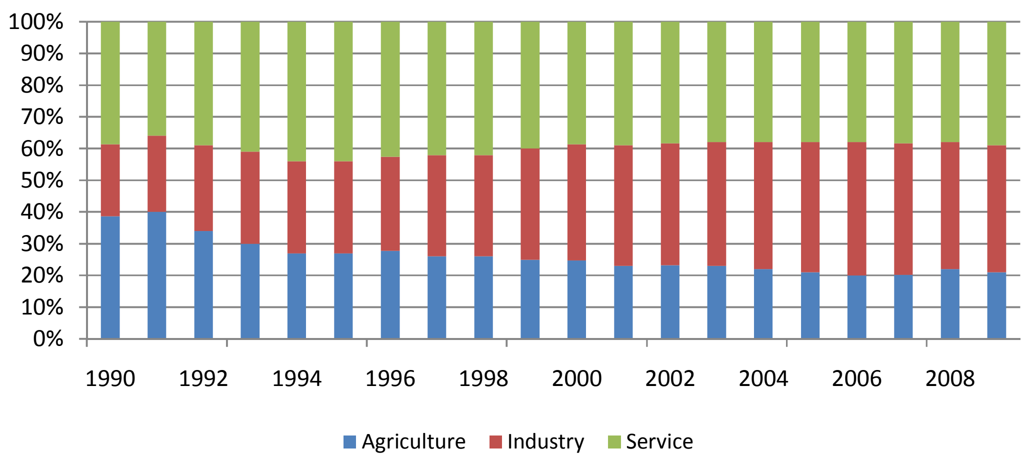
*Figure 1-2: The historical fast growth of GDP in Vietnam over the period 1990-2009.*




Source: IMF (2010) and VGSO (2010).

As an exporting country of agricultural products, Vietnam is currently the second biggest rice-exporter in the world. The revenue from exporting other principal agricultural products (coffee, cashews, maize, pepper/spice, sweet potato, pork, peanut, cotton, fresh vegetables & fruit, rubber, etc.), plus extensive aquaculture of both fish and shellfish species also gives significant contribution to the national GDP. The agricultural sector has contributed over 20% of the country's GDP during the last two decades. In apparel with economic growth and global integration, Vietnam's economy structure has gradually moved forward industrialization and urbanization (Figure 1-3). Since 2000, the fraction of the country's GDP accounted by agricultural sector has continuously reduced from 24.5% in 2000 to 20.3% in 2007 whilst GDP share of industrial sector has increased from 36.7% to 41.6% over the same period.

*Figure 1-3: Sectoral shares of the national Gross Domestic Product over 1990-2009.*




Source: VGSO (2010).

*Expected future economic growth*

There are 3 scenarios of economic growth predicted for the next 30 years. The forecast is built-up upon the following key parameters: (i) economic-development scenarios and modes of other countries locating in the area of active-economic-development nations including South Korea, Taiwan, and China; (ii) factors that mainly affect economic growth including attract-ability of foreign investment inflows such as Foreign Direct Investment (FDI), Oversea Development Assistance (ODA) source, impacts of technology innovation, deflation of GDP, basic hypotheses of economic growth, etc. (Institute of Energy, 2009).

As a result of the forecast, Vietnam would become an industrialized country, in a low economic development scenario, by 2020, in which the country's GDP growth rate of 6.2% reached over 2006-2010 yet, expected to increase up 7.0% over 2010-2020, remaining 7.0% over 2020-2030, and gradually decreasing to 6.5% over 2030-2040. However, even this scenario of low economic growth seems optimistic and challenging to achieve in the current context of global economic crisis. Table 1-1 presents the prospects of economic development in Vietnam for the next 30 years under different conditions predicted by Vietnamese agencies.

*Table 1-1: Scenarios of future economic growth predicted by Vietnamese agencies*

| **Economy growth (%) predicted in a high growth scenario** | | | | | |
|---|---|---|---|---|---|
| No. | Sector | 2006-2010 | 2011-2020 | 2021-2030 | 2031-2040 |
| 1 | Industry&Construction | 11 | 10 | 8.5 | 7.0 |
| 2 | Agriculture | 3.5 | 3.0 | 2.5 | 2.0 |
| 3 | Service | 8.0 | 8.4 | 8.3 | 7.5 |
| 4 | Total GDP growth (%) | 8.5 | 8.5 | 8.0 | 7.0 |
| **Sectoral shares of GDP predicted in a high growth scenario** | | | | | |
| No. | Sector | 2010 | 2020 | 2030 | 2040 |
| 1 | Industry&Construction | 45.0 | 50.1 | 51.1 | 49.7 |
| 2 | Agriculture | 17.1 | 10.8 | 6.9 | 4.6 |
| 3 | Service | 37.9 | 39.0 | 42.0 | 45.8 |
| **Economy growth (%) predicted in an average growth scenario** | | | | | |
| No. | Sector | 2006-2010 | 2011-2020 | 2021-2030 | 2031-2040 |
| 1 | Industry&Construction | 10.0 | 8.2 | 7.5 | 6.5 |
| 2 | Agriculture | 3.0 | 3.0 | 2.5 | 2.0 |
| 3 | Service | 7.2 | 7.3 | 7.3 | 7.1 |
| 4 | Total GDP growth (%) | 7.6 | 7.2 | 7.0 | 6.5 |
| **Sectoral shares of GDP predicted in an average growth scenario** | | | | | |
| No. | Sector | 2010 | 2020 | 2030 | 2040 |
| 1 | Industry&Construction | 44.7 | 47.8 | 48.7 | 47.3 |
| 2 | Agriculture | 17.3 | 12.5 | 8.7 | 6.0 |
| 3 | Service | 38.0 | 39.7 | 42.6 | 46.7 |
| **Economy growth (%) predicted in a low growth scenario** | | | | | |
| No. | Sector | 2006-2010 | 2011-2020 | 2021-2030 | 2031-2040 |
| 1 | Industry&Construction | 8.0 | 8.5 | 8.5 | 7.0 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | Agriculture | 3.5 | 3.0 | 2.5 | 2.0 |
| 3 | Service | 5.5 | 6.5 | 6.0 | 6.5 |
| 4 | Total GDP growth (%) | 6.2 | 7.0 | 7.0 | 6.5 |
| **Sectoral shares of GDP predicted in a low growth scenario** | | | | | |
| No. | Sector | 2010 | 2020 | 2030 | 2040 |
| 1 | Industry&Construction | 43.6 | 48.9 | 55.0 | 56.5 |
| 2 | Agriculture | 19.0 | 13.9 | 9.8 | 6.8 |
| 3 | Service | 37.4 | 37.1 | 35.2 | 36.7 |

Source: Institute of Energy (2009)

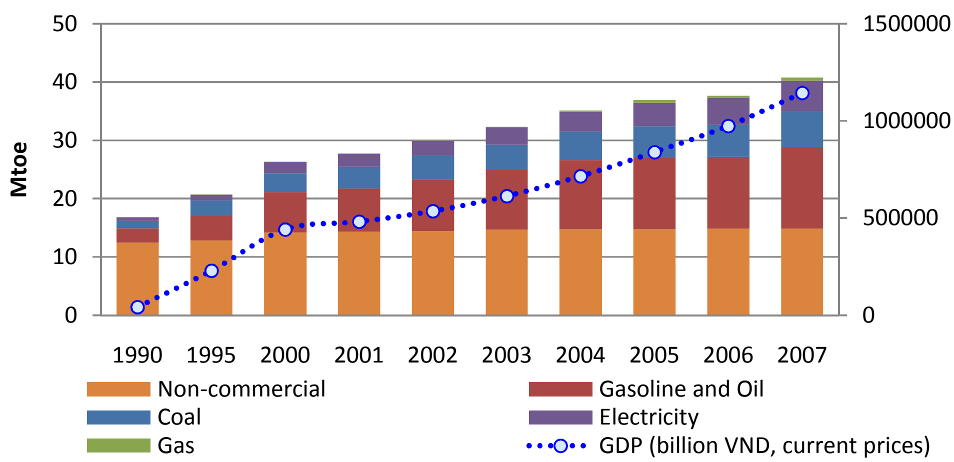
### 1.1.2 The energy system and its development prospects

*Energy demand grew very fast over the last two decades*

Energy has contributed largely to the Vietnamese recent industrialization and export earnings. To sustain the country's economic development over the last two decades, the demand for energy has been extremely growing, even grew faster than the growth of GDP.

The total final energy consumption was about 16.76 Mtoe in 1990, and increased by 143% to 40.75 Mtoe in year 2007. The share of coal fuel doubled over the same period, from 7.9% in 1990 to 14.9% in 2007, while the share of electricity consumption soared from 3.2% in 1990 to 12.9% in 2007 (Figure 1-4 ).

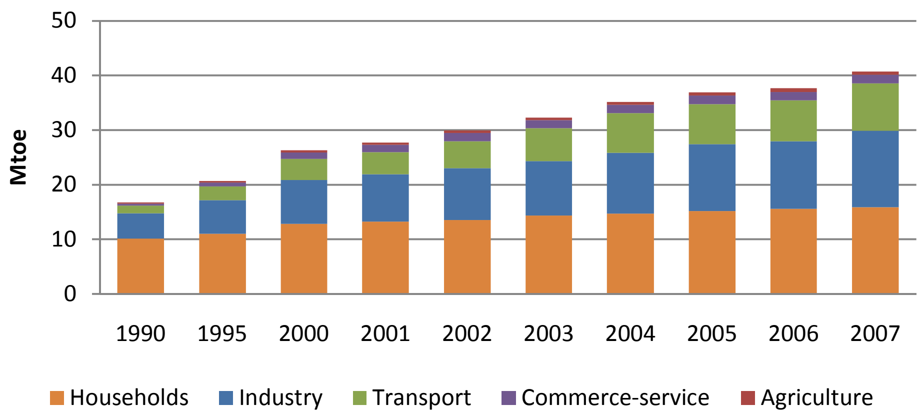
*Figure 1-4: Final energy consumption mix by fuel types in Vietnam over 1990-2007.*




Source: Institute of Energy (2009); VGSO (2010).

In the energy consumption mix by sectors over 1990-2007 as showed in the Figure 1-5, the energy consumption share of transport and industry sectors increased quicker than that of the residential sector while those of agriculture and trade-service sectors have not much changed.

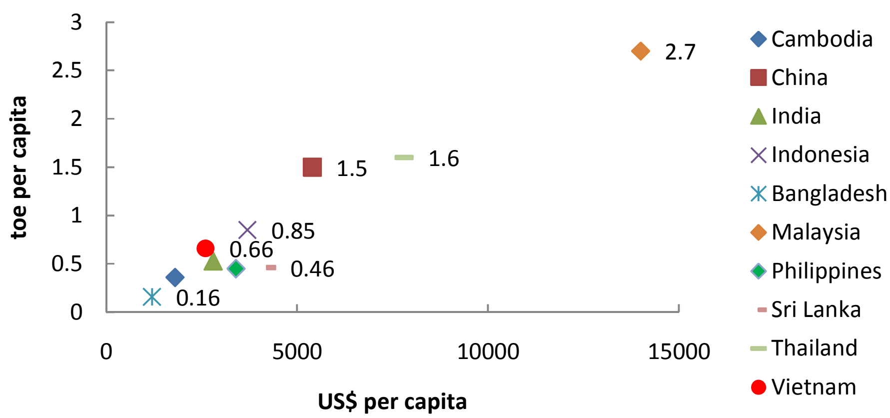
*Figure 1-5: Final energy consumption by sectors in Vietnam over 1990-2007.*




Source: Institute of Energy (2009).

As a still-low income developing country, Vietnam is ranked among the regional countries with low-level of energy production and energy consumption per capita (Figure 1-6). By the end of 2007, the final energy consumption per-capita reached at 0.66 (ktoe/capita). Table 1-2 further provides some typical energy-economy indicators in Vietnam from 1990 to 2007.

*Figure 1-6: List of selected Asian countries by final energy consumption per capita, 2007.*




Source: the author's own combination from World Bank Database (2010).

*Table 1-2: Energy-economy indicators in Vietnam during the period from 1990 to 2007.*

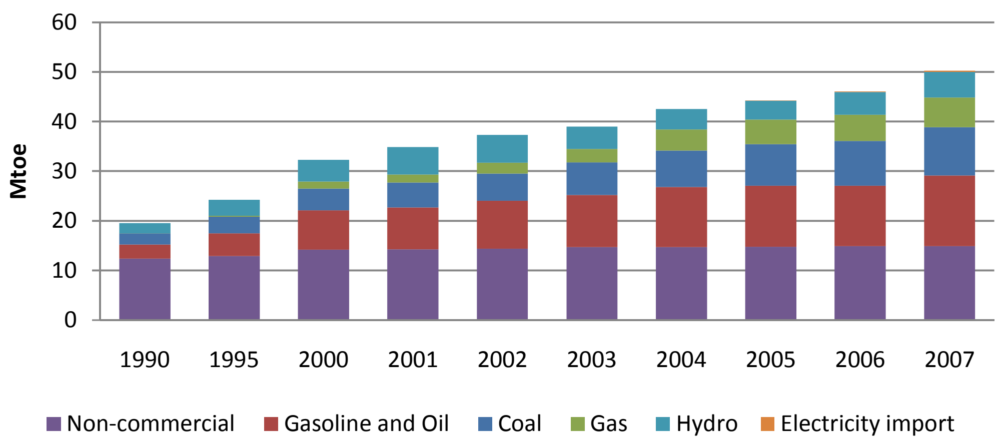
| Indicators | 1990 | 2000 | 2007 |
|---|---|---|---|
| GDP (US$2008) per capita | 283 | 504 | 835 |
| Commercial energy consumption (KgOE/capita) | 66 | 156 | 304 |
| Energy intensity (TOE/mill. US$2008) | 330 | 402 | 600 |
| | | **1990-2000** | **2000-2007** |
| Energy elasticity factor | | 1.43 | 1.48 |

Source: the author's own combination from Institute of Energy (2009); IMF (2010).

*Energy supply resources were also increasingly explored*

Vietnam has speeded-up the exploitation of national primary energy resources for economic growth. As we can observe in the Figure 1-7, the non-commercial energy[1] is kept stable all along the period 1990-2007 but its share in the total primary energy supply in the system abruptly decreased from 63.5 % in 1990 to 29.6 % in 2007. Coal fuel has increased its share from 11.3 % in 1990 to 19.4 % in 2007 whereas the share of gas increased continuously from 0.04 % in 1990 to 11.9 % in 2007. This highlights the development progress of gas industry in Vietnam since early 1990s, becoming a large-scale industry now. With 76% of population living in rural areas by 2007, the non-commercial energy has taken a large share in total energy demand in Vietnam, in which biomass energy accounts for 99% of the total non-commercial energy whilst only a very small contribution from other renewables. However, the share of non-commercial energy consumption trends to fall plainly from 74.1% in 1990 to 36.4% in 2007 indicating the urbanization and industrialization progress since early 1990s.

*Figure 1-7: Primary energy supply by fuel types in Vietnam over the period 1990-2007.*




Source: Institute of Energy (2009).

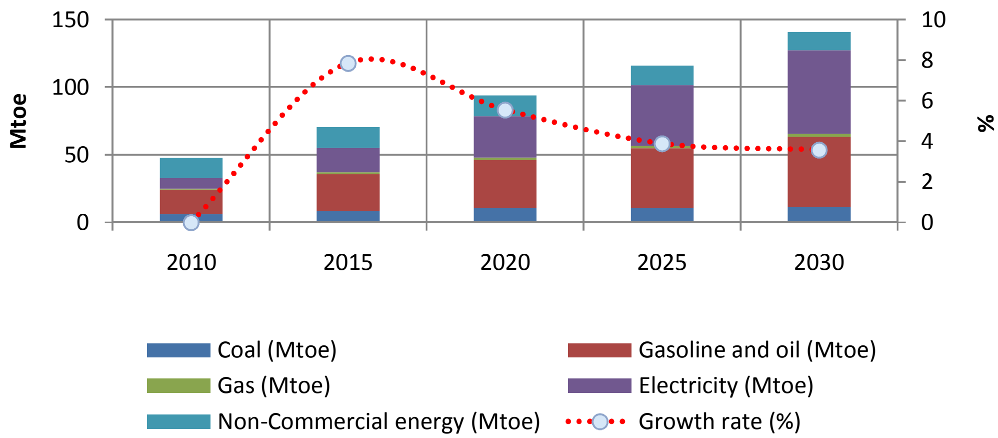
*Future outlook and challenges of Vietnamese energy system*

To support future the economic development, Vietnamese energy system is likely to be facing the challenge of energy security. There are many national/international reports estimating that Vietnam is foreseen to be dependent on energy/fuel imports for economic growth. Institute of Energy (2009) showed that to sustain an expected average economic growth as indicated in the Table 1-1, Vietnam could soon become a country of energy-scarcity. The need for total final energy consumption in Vietnam could achieve about 48 Mtoe in 2010, increasing to 141 Mtoe

[1] Non-commercial energy, in this study, includes from wood, wood charcoal, agricultural residues (biomass), new and renewable energy such as solar, wind, geothermal, hydro power, etc. The meaning of "non-commercial" is that these types of energy were exploited, processed then consumed locally without any trading activities involved. These did not contribute to the gross domestic products of the economy.

by 2030. By this expectation of economy growth, the average growth rate of final energy consumption is expected to increase extremely over 2010-2015 by 7.85% (Figure 1-8).

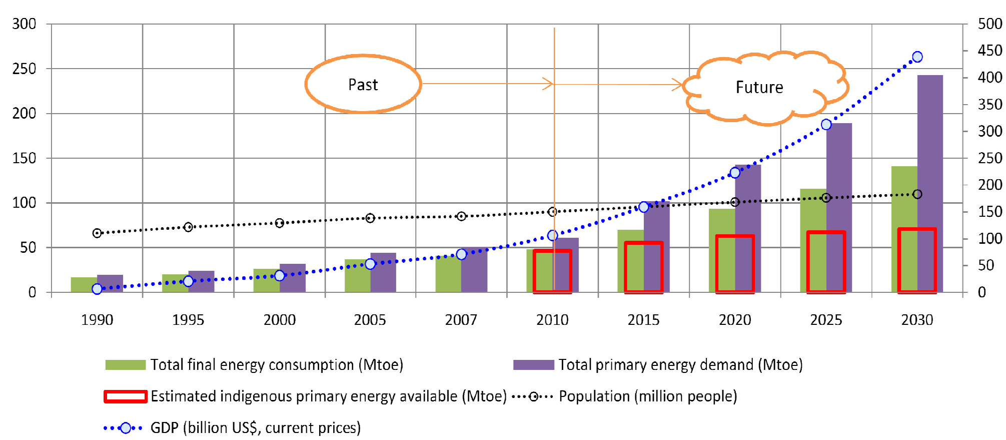
*Figure 1-8: Projection of future final energy demand in Vietnam over 2010-2030.*




Source: Institute of Energy (2009).

To meet the projected demand for energy in the next 20 years, the outlook of primary energy supply is drawn out as the Figure 1-9. Though, Vietnam is endowed with diverse fossil-fuel energy resources (oil, coal and gas) the signal on increased uses of indigenous fossil-fuels has been turning from green to yellow. Thus, fuels and energy imports would be needed for fuelling the future economy growth (MOIT-JICA, 2008; Institute of Energy, 2009). *Therefore, proper policies need to be employed by Vietnamese Government so that the country's economic development could be sufficiently fuelled for the forthcoming period of energy-scarcity*.

*Figure 1-9: Situation of energy supply system and demand balance in next 20 years*




Source: Institute of Energy (2009).

## 1.2 Overview of the power sector development and its challenges

### 1.2.1 The current unsustainable situation of power sector

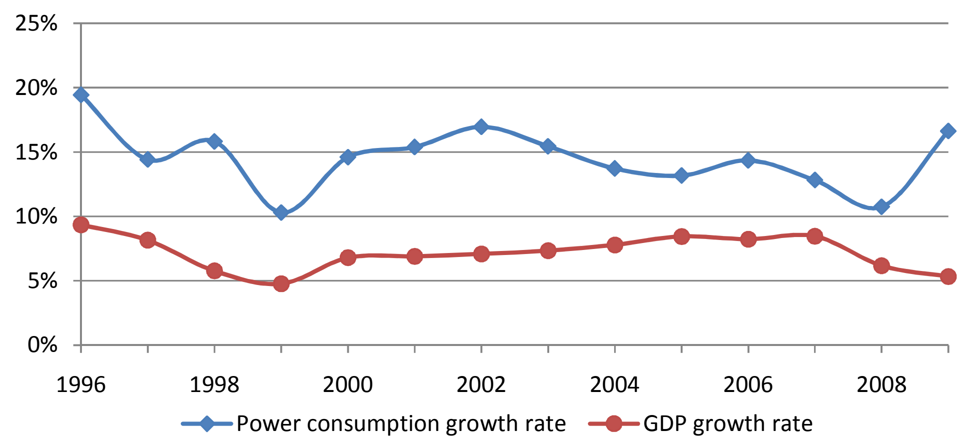
*The Electricity of Vietnam*

The electric power sector is a growing market and represents one of the most promising areas for domestic and foreign service prospects in Vietnam. Currently Electricity of Vietnam (EVN), a state-owned utility established in 1995 with more than 50 subsidiaries under the Ministry of Trade and Industry (MOIT), is the established leader in electricity generation and still holds a monopoly in transmission and distribution for electricity.

*Power demand and supply system*

Electricity consumption in Vietnam grew at 14.9% annually over 1996-2000 and at 15% over 2000-2009, that is 2.14 faster than the GDP which grew at 7.2% over 1996-2009 (Figure 1-10). This results in a very high power intensity of the GDP at 2.14. The share of households in total electricity consumption has decreased from 49% in 2000 to 40.9% in 2007, while that of the industry sector increased from 40.6% to 49.9% (Table 1-3). The electricity consumption per capita also increased from 289 kWh/capita/yr in 2000 to 718 kWh/capita/yr in 2007 (Institute of Energy, 2009; World Bank, 2010c).

*Figure 1-10: Electricity demand grew double faster than GDP growth, 1996-2000.*




Source: ADB (2007); World Bank (2010c); Institute of Energy (2009); IMF (2010).

*Table 1-3: Structure of electricity consumption in Vietnam, 1990-2007, (TWh).*

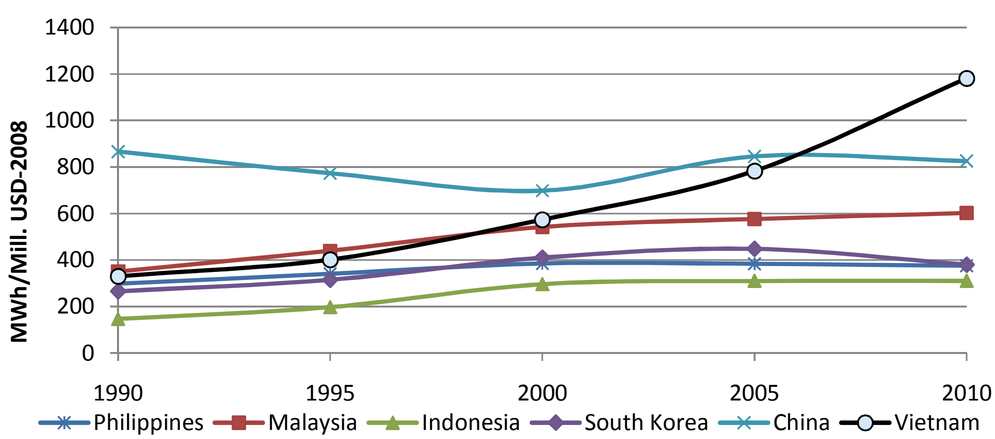
| No. | Sector | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Industry | 2.85 | 9.1 | 10.4 | 12.7 | 15.2 | 17.9 | 21.3 | 24.3 | 29.2 |
| | Share (%) | 46 | 40.6 | 40.4 | 42.0 | 42.0 | 45.0 | 47.0 | 47.4 | 49.9 |
| 2 | Agriculture | 0.6 | 0.43 | 0.48 | 0.51 | 0.56 | 0.55 | 0.57 | 0.56 | 0.57 |
| | Share (%) | 9.5 | 1.9 | 1.9 | 1.7 | 1.7 | 1.4 | 1.3 | 1.1 | 0.9 |
| 3 | Residential | 2.04 | 11 | 12.7 | 14.3 | 16 | 17.7 | 19.8 | 22.1 | 23.9 |
| | Share (%) | 32.9 | 49.0 | 49.1 | 47.4 | 47.4 | 44.6 | 43.4 | 42.9 | 40.9 |

| No. | Sector | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Non-industry | 0.72 | 1.9 | 2.23 | 2.71 | 3.1 | 3.5 | 3.9 | 4.43 | 4.77 |
| | Share (%) | 11.6 | 8.5 | 8.6 | 9.0 | 9.0 | 8.8 | 8.5 | 8.6 | 8.0 |
| 5 | Electricity sales | 6.2 | 22.4 | 25.9 | 30.2 | 34.8 | 39.6 | 45.6 | 51.3 | 58.4 |
| 6 | Electricity per capital (kWh/capita/yr) | 93 | 289 | 338 | 382 | 435 | 478 | 567 | 640 | 718 |
| 7 | Self-consumption and T&D losses (%) | 25.4 | 15.3 | 15.1 | 15.0 | 14.1 | 14.3 | 13.2 | 12.9 | 12.5 |
| | | **1990-2000** | | | | **2000-2007** | | | | |
| 8 | Electricity elasticity factor | 1.8 | | | | 2.0 | | | | |

Source: Institute of Energy (2009).

Looking at the power intensity of Vietnam's economy, it grew very fast during the period 1990-2009, starting from 330 MWh/million US$ of GDP in 1990, increased to 574 MWh/million US$ in 2000, and reaching 941 MWh/million US$ of GDP in 2009 (all GDP based on 2008 price). Compared to other economies in the region, Vietnam has become high intensive power economy, especially since 2005 (Figure 1-11). *This indicates that the usage of electricity energy in Vietnam's economy recently is less effective than that of other countries in the region and large wasteful energy in uses should exist within the country.*

*Figure 1-11: Comparative analysis of power intensity in selected Asian countries, 1990-2010.*

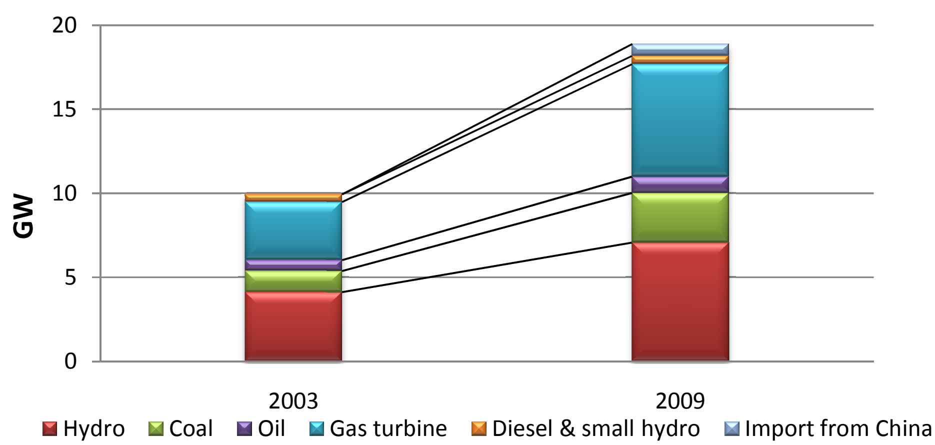



Source: author's own combination from Institute of Energy (2010); IEEJ (2010); ERIA (2010).

Now, let's have a glance at the electricity supply system in Vietnam. At the end of 2009, the total energy capacity installed was 18.9 GW, in which EVN facilities accounted for about 71.9%. Compared to the system in 2003, this is double larger resulting from an average annual growth in energy capacity by 14.2% between 2003 and 2009 (Figure 1-12). More particularly, the present system consists of 37.5% of hydro, 35.4% of gas-fired, 15.7% of coal-fired, 5.1% of oil-fired, 3.7% of electricity imported, and 2.6% from small hydro and diesel plants (NLDC, 2010a, 2010b). At this time, coal-fired capacity has a relative modest contribution but it is foreseen to take an increasing important role in the system after 2015.

In energy production, the generation of electricity increased from about 17 TWh in 1996 to approximate 85 TWh in 2009, representing an annual average growth rate of 14% during the period. In 2009, 34.4% of the sector's total production was provided from hydro generation sources (including a small fraction of small hydro energy), 43.2% from gas-fired generation, 14.4% from coal-fired, 4.7% from electricity imported, and only 3.2% from oil-fired source. Electricity generation from diesel plants was thus negligible. Overall, the current electricity generation contributed from renewables (mainly from small hydro) is still very small, only around 1.5% of the sector's total electricity production. *It must be stressed that the production of electricity supplied from thermal generation grew very fast from 1996 to 2009 with an average growth rate of 27.7%, nearly twice the average annual growth rate of the total electricity generation during the same period* (NLDC, 2010a).

*Figure 1-12: The generation capacity in Vietnam is doubled over 2003-2009 with an average growth of 14.2% per annum.*




Source: NLDC (2010a).

*Electricity system losses and thermal generation efficiency*

The Vietnamese electricity transmission network comprises of three high-voltage levels including 500kV, 220kV and 110kV. By the end of 2005, the 500kV double-line transmission infrastructure has been extended to more than 3,000 km connecting between the two central loads in the North and South of Vietnam. The 220kV transmission system includes 5,257 km of lines and the 110kV network has 10,290 km of lines. The current distribution network consists of five medium voltage levels 6-10-15-22-35 kV existing together, in which the 22kV level is mainly used for the urban areas and 35kV level used for the rural areas (Electricity of Vietnam, 2007a; Khanh Toan, P., et al., 2010).

The loss of electric power has been always a real challenge to the Vietnamese power sector. The loss including transmission and distribution was 25% of the total electricity production in the late 1980s and 21% in the early 1990s. However, the loss has been also remarkably reduced by 12% in 2005 and expected to decrease to 10.8% by 2010. Compared to the power loss in developed countries, this figure is still very high. Thus, Vietnamese Government is now planning to take technical and manageable measures to reduce the loss down to 7.5% by 2025 (Electricity of Vietnam, 2007a; Institute of Energy, 2009; NLDC, 2010b).

The average efficiency of coal-fired generation plants stands between 37 and 38%[2]. For oil and gas-fired plants, the average efficiencies are 30% and 48%, respectively. In fact, there exist some coal and oil-fired generation units having efficiency below 27% due to backward energy conversion technologies. These efficiencies are quite low, compared to the average efficiency performance (around 42%) of coal-fired generation system in the region of Asia such as Malaysia, Japan (World Bank, 2010d).

*Power supply security*

Power shortage and quality have been two very critical challenging problems to the sector. Since 2008 load shedding has been occurring frequent in Vietnam with deep power cut. In early 2010, the total installed capacity of generation power plants is 19 GW but the usable capacity should be smaller. Therefore, the system could not reliably satisfy the peak demand (about 18.5 GW). Over the first six months in 2010, the power shortage accounts for 5-7% of the total power demand (NLDC, 2010a) causing serious impacts on the economy and society. Customers, especially in rural areas, were the most vulnerable to the power cuts causing negative effects to their daily life and agricultural activities. *The investment in energy development is always lower than required, progress of many projects is delayed, less diverse generation sources and high dependence on hydro power, poor maintenance schedules, and low energy efficiency of the sector are identified as the major reasons.*

*Electricity tariff and financial issues*

According to a new circular No. 08/2010/TT-BCT issued by MOIT, the electricity tariff in 2010 has a weighted average price of 1,058 VND per kWh, it equals to 5.4 US cents per kWh[3] (MOIT, 2010b). Though this price has been increased by 6.8% from 971 VND/kWh in 2009 but it is still far below than the price in neighbouring countries such as: Malaysia (7.6 US cents/kWh), Thailand (8.5 US cents/kWh), Singapore (13.5 US cents/kWh) (VietNamNet, 2010). It also notes here that the electricity tariff in Vietnam has even decreased during the period 1994-2010, in term of constant 1994 price (Figure 1-13 and Figure 1-14). In practice, the electricity price is administered in Vietnam and policy makers lean toward controlling the price at levels moderate enough to enable the domestic products to be

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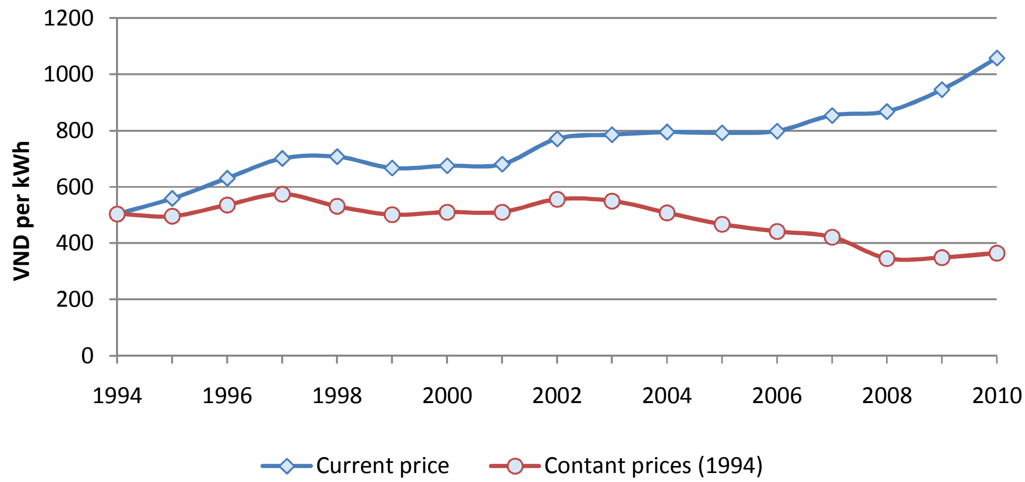
[2] This is based on the author's own calculation from the performances of the existing generation plants.

[3] Exchange rate: 1 US$ = 19,500 VND.

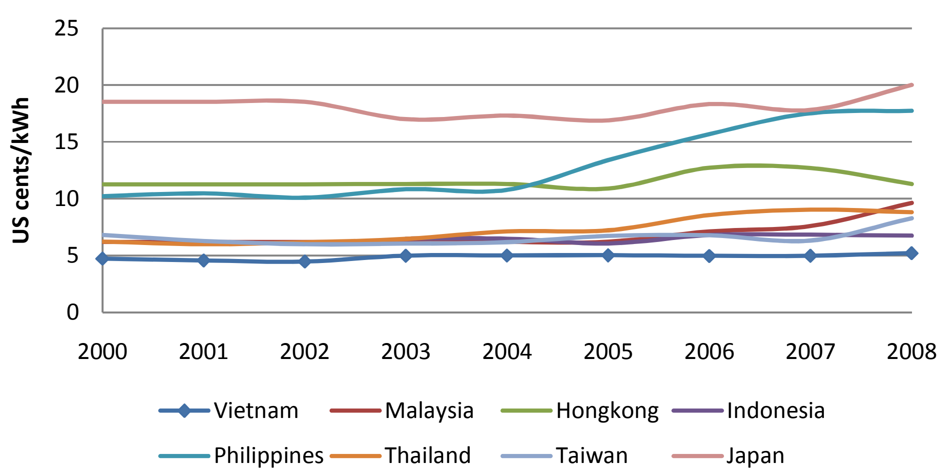
competitive in the global market. Besides, the energy prices including electricity still contain loss compensation and cross subsidies in the economy. *This low and inadequate electricity pricing scheme leads to energy wasting usage and makes it less attractive to investors to lay down their funds for electricity supply projects.*

*Figure 1-13: Electricity prices in Vietnam over the period 1994-2010.*




Source: Nguyen Duc Thanh et al., (2008); MOIT (2010a).

*Figure 1-14: Electricity price in Vietnam is the lowest among regional countries*




Source: Nguyen D. Thanh et al., (2008); MOIT (2010a).

*Rural electrification*

Though Vietnam achieves a significant success in electrification, the country still faces challenges to improve access and affordability to electricity services for the poor in remote areas. In 2008, Vietnamese rural electrification rate was 94.5%, compared to a mere 14% in 1993 but mountainous and very-remote areas have still no access to electricity network (GTZ, 2009). In addition, rural electricity grids are very poor, very unreliable, and high losses (ITVN, 2010; World Bank, 2010d). Recent years, the Government has been implementing a number of policy measures for poverty reduction and hunger eradication, providing subsidy to rural electricity consumption. Nevertheless, the access to electricity services is still limited. This is partly due to high poverty rate and low income in the areas. In spite that rural electricity tariff is regulated by the Government, rural people still cannot afford to pay the real high price imposed, even 1.5 times higher than the regulated one in many places (San and Thanh, 2010), due to a very poor management system at local level (Figure 1-15).

*Figure 1-15: The electricity distribution systems exist in rural areas.*

Source: San and Thanh (2010).

### 1.2.2 Power sector in the next 30 years: the baseline scenario

The Vietnamese Government manages the development of the power sector using a Power Development Master Plan, which anticipates the need for electricity services and schedules the sector's overall development in a ten-year period, taking into account the following ten years period. According to the current sixth Power Development Master Plan (MP-VI), the electricity demand is projected to increase by 16.8% and 6.9% per annum in a low demand scenario over the period of 2010-2030 and 2030-2040 respectively, and by 21.4% and 8.2% per annum in a high demand scenario over the period of 2010-2030 and 2030-2040 respectively. Table 1-4 presents the projections of electricity demand for the next 30 years in Vietnam, by Vietnamese agencies. However, many Vietnamese energy experts argue against the agencies' projections that they consider over-estimated even in the low scenario case (Pham D. Hien, 2009a; Nguyen Khac Nhan, 2009). All these implied a political will for the large-scale nuclear energy capacity development plan supported by the expected soaring demand of electricity for the next decades.

*Table 1-4: Projected electricity demand in Vietnam, 2010-2040, by Vietnamese agencies.*

| Year | Low scenario | | Moderate scenario | | High scenario | |
|---|---|---|---|---|---|---|
| | Electricity (TWh) | Peak demand (GW) | Electricity (TWh) | Peak demand (GW) | Electricity (TWh) | Peak demand (GW) |
| 2010 | 91.95 | 18.51 | 97.11 | 18.51 | 101.15 | 20.37 |
| 2020 | 216.43 | 40.92 | 257.26 | 48.64 | 267.56 | 50.59 |
| 2030 | 417.02 | 76.91 | 537.83 | 100.97 | 556.50 | 104.48 |
| 2040 | 703.07 | 126.29 | 981.26 | 186.91 | 1015.31 | 193.40 |

Source: Electricity of Vietnam, 2007a and NLDC, 2010b.

With regards to the indigenous energy supply resources, they will become scarce after 2015. Recently, the Vietnamese Government has approved an optimistic plan to develop nuclear energy for meeting the increase of energy demand between 2020 and 2030. This plan consists of 15-16 GW in generation capacity. The first nuclear generator is planned to produce electricity in 2020 (GOV, 2010). *However, there are many concerns and doubts from energy experts about such a large development plan considering the country's current limitations in human resources, essential technical and regulatory infrastructures, financing resources, public acceptance, etc.*

In follows, the study presents a more realistic overview and a more reliable assessment of the prospective evolution of Vietnamese power sector with attendant challenges, using the IRP simulation model.

#### *1.2.2.1 Large capacity expansion changing the electricity generation mix*

The IRP simulation meets the projected demand for energy services during the next three decades by a hugely expanded coal-fired generation capacity. In the baseline development or Business-As-Usual (BAU) scenario, the expansion of energy capacity requires a great average growth rate of 10% per annum over the period from 2010 to 2040, reaching about 158 GW by 2040. This includes 109 GW of fossil fuels, 16.8 GW of large-hydro, 10.2 GW of hydro pump-storage, 10 GW of nuclear, 6.3 GW of renewables, and 5.8 GW of electricity imports.

With such a large expansion of energy capacity, the energy generation mix would be significantly changed by periods of time. The proportion of electricity generation from large hydro grows fast from 28% (37 TWh) in 2010 to 33 % (66.4 TWh) by 2015, but then declines to 8% (69.1 TWh) by 2040 due to a restriction of resources. Whereas the share produced, using coal fuels would hold a drastic growth during this period. In this case, the share of coal-fired generation increases from 32% (66.8 TWh) in 2015 to 68.3% (634.3 TWh) by 2040.

Moreover, the proportion of electricity production from domestic gas-fired sources would decrease from 26% (53.4 TWh) by 2015 to 8% (77.1 TWh) by 2040 because of depletion in indigenous resources. As a political will, nuclear power will engage an important part of the electricity energy supply since 2020 onwards. The share of electricity produced by nuclear plants would enlarge from 2.5% (7.1 TWh) by 2020 to 8% (71 TWh) by 2040. In contrast, the share produced from renewables would decrease remarkably from 8% (21.8 TWh) by 2019 to 2.8% (26.1 TWh) by 2040.

In overall, over the period from 2010 to 2040, fossil fuels are expected to dominate the energy generation mix, and may account for 67.7% of the total cumulative electricity production of 14,106 TWh. Of this production from fossil fuels: coal, natural gas, and oil would account for 71.6%, 28%, and 0.4%, respectively. Whereas hydro and nuclear energy would account for 18.6% and 5.6%, respectively, and the remaining 5.3% comes from electricity imported. Focusing on renewables, the study suggests that with the current renewables development strategy, renewables would contribute remarkably to the electricity energy supply from 2010 to 2020, in which its share of energy capacity grows from 2.5% (575 MW) in 2010 to 10.2% (5,566 MW) by 2020. However, as a broader cluster of investigated renewables sources is not yet strategically integrated in the baseline development, the share will decrease from 10.2% in 2020 to 4% by 2040. In energy production, renewables would contribute 4.1% of the total electricity generation during the period from 2010 to 2040. This finding provides that without further incentive policies, the target for renewables deployment could be hardly achievable at 11% of the total commercial primary energy supplied by 2050[4]. Table 1-5 summaries the prospective outlook of Vietnamese power sector in the next 3 decades.

*Table 1-5: The energy capacity (GW) and generation mix (TWh) of Vietnamese power sector over the period 2010-2040. The IRP simulation.*

| Items | Nuclear | Renewable sources | | | Fossil fuel sources | | | | Imp. Elec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RETs | Large Hydro | Pump Storage | Dom. Coal | Imp. Coal | Dom. Gas | Oil | | |
| Energy capacity by 2040 | 10 | 6.3 | 16.8 | 10.2 | 37 | 54.1 | 17.2 | 0.6 | 5,8 | 158 |
| Percentage (%) | 6.3 | 4.0 | 10.6 | 6.5 | 23.4 | 34.2 | 10.9 | 0.4 | 3.7 | 100.0 |
| Total electricity over 2010-2040 | 788 | 585 | 2,045 | 390 | 3,729 | 3,117 | 2,674 | 36 | 743 | 14,106 |
| Percentage (%) | 5.6 | 4.1 | 14.5 | 2.8 | 26.4 | 22.1 | 19.0 | 0.3 | 5.3 | 100.0 |

#### *1.2.2.2 Greater dependence on large-scale coal and electricity imports for future expansion, even with newer technologies*

As the demand for electricity exceeds the expected supply capability of domestic energy sources, the country would start to import coal fuel since 2012 and while electricity is already imported since 2004. Especially, the shift from hydro-to-coal-based generation capacity since 2015 causes a strong demand for coal fuels (domestic and imported), growing from 26.4

[4] On 27 December 2007, the Prime Minister signed a Decision No. 1855/QD-TTg to approval the Vietnam's national energy development strategy up to 2020, with 2050 vision. Particularly for renewables development, it aims for a share of 3% in 2010, 5% by 2020 and 11% by 2050 over the total commercial primary energy.

million tons by 2015 to 98 million tons by 2030, reaching 217 million tons by 2040. Of this demand, the domestic coal could meet 17.2 million tons (equals to 299 PJ) by 2015, 70 million tons (1,599 PJ) by 2030, and accelerating to 99 million tons (2,289 PJ) by 2040 (Table 1-6).

*Table 1-6: The future fuel requirements for the expansion of electricity generation system over 2010-2040, the IRP simulation.*

| | Fuel types | Unit | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|---|
| Fossil fuels | Domestic Coal | Million tons | 14.3 | 17.2 | 16.6 | 41.4 | 69.8 | 84.8 | 99.2 |
| | | PJ | 299.4 | 360.5 | 347.0 | 929.1 | 1598.7 | 1949.8 | 2288.6 |
| | Imported Coal | Million tons | 0 | 9.2 | 11.3 | 15.3 | 27.8 | 63.4 | 117.4 |
| | | PJ | 0 | 249.2 | 308.9 | 416.5 | 757.0 | 1726.7 | 3195.2 |
| | Domestic Gas | Cubic meters | 10.1 | 9.6 | 14.1 | 18.7 | 19.8 | 18.0 | 13.4 |
| | | PJ | 392.4 | 384.7 | 562.7 | 749.3 | 795.7 | 725.6 | 540.0 |
| | Oil (FO/DO) | Million tons | 0.929 | 0.528 | 0.209 | 0.209 | 0.115 | 0.116 | 0.153 |
| | | PJ | 38.94 | 22.50 | 8.59 | 8.59 | 4.73 | 4.78 | 6.27 |
| Renewables | Bagasse | Million tons | 0.51 | 3.40 | 4.07 | 4.07 | 4.07 | 4.07 | 4.07 |
| | | PJ | 3.94 | 26.29 | 31.55 | 31.55 | 31.55 | 31.55 | 31.55 |
| | Rice husk | Million tons | 0.08 | 0.53 | 0.87 | 0.87 | 0.87 | 0.87 | 0.87 |
| | | PJ | 0.90 | 6.05 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 |
| | Wood residues | Million tons | 0 | 0.18 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | | PJ | 0 | 2.68 | 13.42 | 13.42 | 13.42 | 13.42 | 13.42 |
| | Municipal solid wastes | Million tons | 0 | 1.31 | 2.09 | 2.37 | 2.37 | 2.37 | 2.37 |
| | | PJ | 0 | 8.29 | 13.26 | 15.03 | 15.03 | 15.03 | 15.03 |

In the point of a macro-view, the expected increase on imports including steam coal, net oil, and electricity for the future development of electric power industry would be raising future issues of energy supply security and large increases in power sector costs for Vietnam. The study findings show that imported energy sources (coal, oil and electricity) would provide 43.8% of the total electricity production, of which 3% for power imports, by 2040 (Figure 1-16). More specifically, coal imports would account for 40% of the total coal material needed for producing electricity during the period from 2010 to 2040 (Figure 1-17). These figures clearly prove that the increasing reliance on large-scale imports for electricity production in the future could lead Vietnamese power sector to be dependent on international energy price fluctuations and potentially large increases in energy costs. Such vulnerability could further contribute to increased poverty, political pressures, and instability.

*Figure 1-16: Greater dependence on imported fuels including electricity for electricity generation in Vietnam, 2010-2040. Simulation by IRP.*

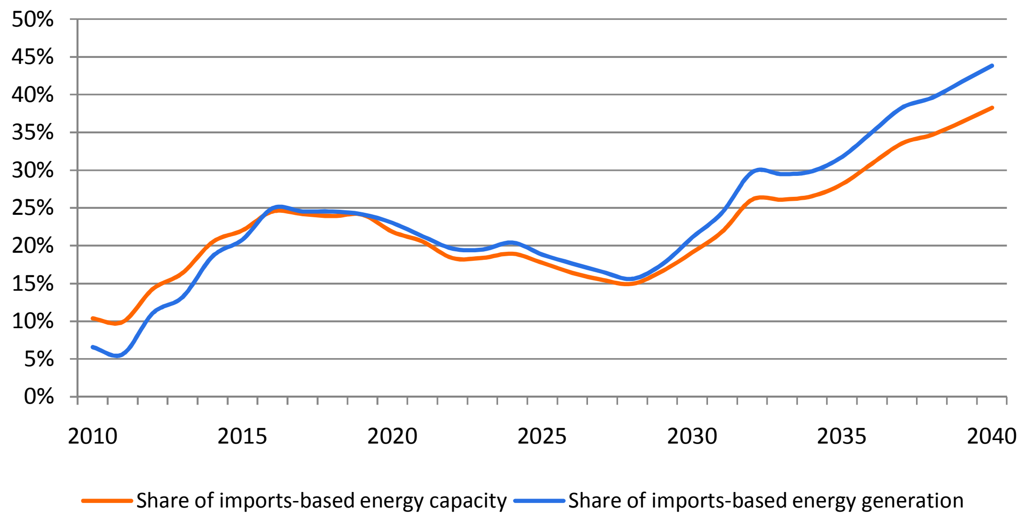
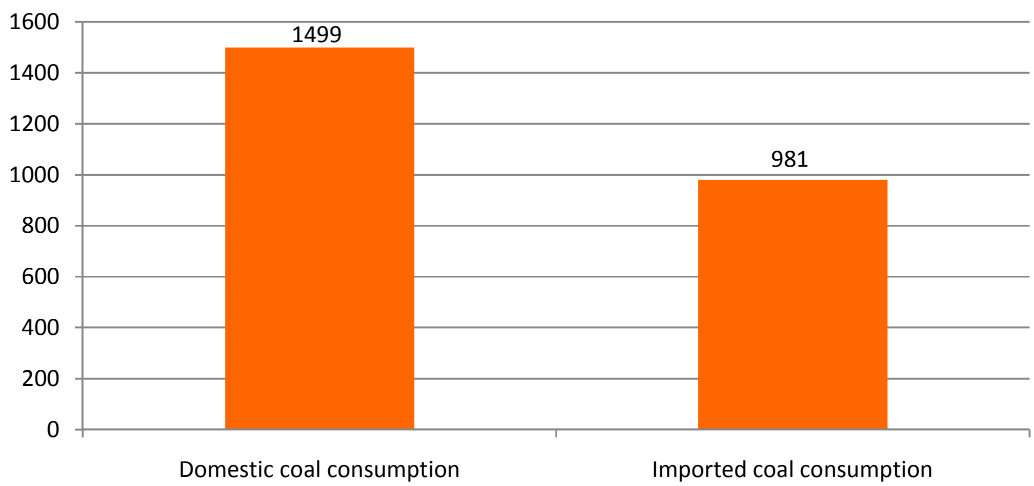



*Figure 1-17: Coal consumption (million tons) for electricity generation in Vietnam, 2010-2040. Simulation by IRP.*



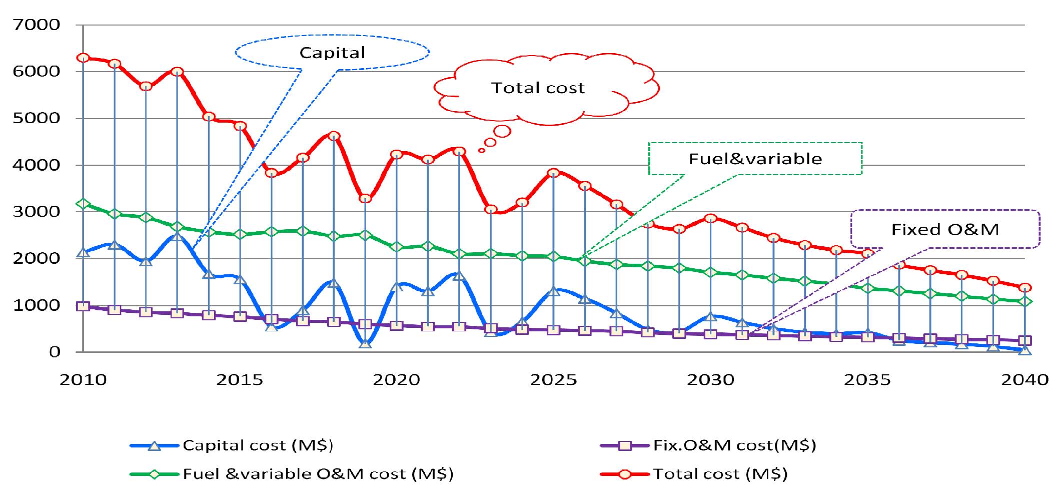

Technologically, the simulation presents a large array of electricity generation technologies based on both conventional and non-conventional energy sources for the next 30 years. This technological application varies from hydro (large, medium, and pump storage) and fossil fuel options (coal-, gas-, and oil-fired) to renewables (small hydro, biomass including bagasse, rice husk, wood residues, and municipal solid waste, geothermal, wind, and solar). Among six coal-fired generation technologies considered in the IRP model, the IGCC technology would not be cost-effective for the future electricity generation in Vietnam due to its still-high production cost. The electric power industry would continue to rely on conventional pulverized coal (PC) or sub-critical coal-fired technology, at least for the next 15 years. However, it would be interesting to find that the super-critical coal-fired technology (SPC) would become cost-competitive for providing electricity energy since 2025. The generation system would be integrated with 16 GW in energy capacity-based SPC using domestic coal (anthracite), and 9 GW in energy capacity-based SPC using imported coal (bitum) by 2040. Inversely, most of power plants using oil fuels (DO, FO, and diesel) will be deconstructed since 2020. Only a few oil-fired units (600 MW) will remain dispatched to the grid up to 2040.

#### *1.2.2.3 Cost and financing issues*

To expand the electricity generation industry during the period from 2010 to 2040, the Vietnamese Government is facing a pressing need of financial resources. A total of 107.5 billion $ would be necessarily on the need. Of this total cost, 26.8% needs for constructing new generation plants, 58.2% is used for fuels and O&M expenses. The remaining 15% is required for fixed O&M expenses. Figure 1-18 illustrates the annual expenditures that would be needed for the expansion plan from 2010 to 2040.

Specifically, the study showed that the Government would have to finance around 2 billion US$ per year for investment in new energy capacity during the short-term of 2010-2015. But Vietnam is still among the countries of lowest electricity price (5.4 US$/kWh) in the region. The EVN sales totalled 90,877 billion VND in 2010 (equals to 4.66 billion US$),[5] and lost 8,000 billion VND (VINAFINS, 2011). Thus, it is insufficient a revenue for EVN to cover such investments with its own budgets. How to raise enough funds for new investment in the power sector keeps being a great challenge otherwise financial constraint may slow down new investment. Moreover, a financing architecture will, sooner or later, have to be designed to address the funding of climate change mitigation and adaptation issues in the electric power industry.

*Figure 1-18: Annual component costs of electricity generation, 2010-2040. IRP simulation.*

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[5] Exchange rate: 1 US$ = 19,500 VND.

It should take here an interpretation for the observation that the total planning cost is falling from 2030 to 2040 as indicated in the Figure 1-18. Though the electricity demand is estimated to increase by 16.8% per annum from 2010 to 2030, the increasing rate of peak load demand in the period from 2030 to 2040 is rather lower, only by 7%. In addition, the T&D loss was simulated decreasing gradually from 10.8% in 2010 to 7% by 2040 in the IRP model. These lead to a decrease in both additional energy capacity and fuels required for generating electricity, i.e. capital costs and expenditures for fuels would be reduced over the period from 2030 to 2040, accordingly. Moreover, during this period, some of existing less efficient plants with higher fuel consumption rates are retired and replaced by more efficient units. This also results in reducing fuel costs at the later part of the planning period.

In terms of electricity production costs, the study finds that the long run average cost (LRAC) would be 4.32 $cent/kWh, whereas the average incremental cost (AIC) would be 4.59 $cent/kWh (all costs are based on 2008 prices). Adding the cost components related to transmission and distribution and management, the total average cost for delivering a kWh of electricity to the end user would charge about 6.82 $cent/kWh. This is even higher than the present average retailed electricity tariff of 5.4 $cent/kWh (VAT exclusive). Therefore, this could technically prove for the Vietnamese Government plan of further raising the present tariff, to a long run marginal cost of 7.5 US cent/kWh (Khanh Nguyen, 2008a; MOIT-JICA, 2008), to secure financing to EVN and aim at necessary investment. Economically, this fiscal instrument could be implemented under an appropriate roadmap being consistent with the corresponding socio-economic circumstances, otherwise surcharges would raise complexities.

#### *1.2.2.4 Relevant environmental and sustainable issues*

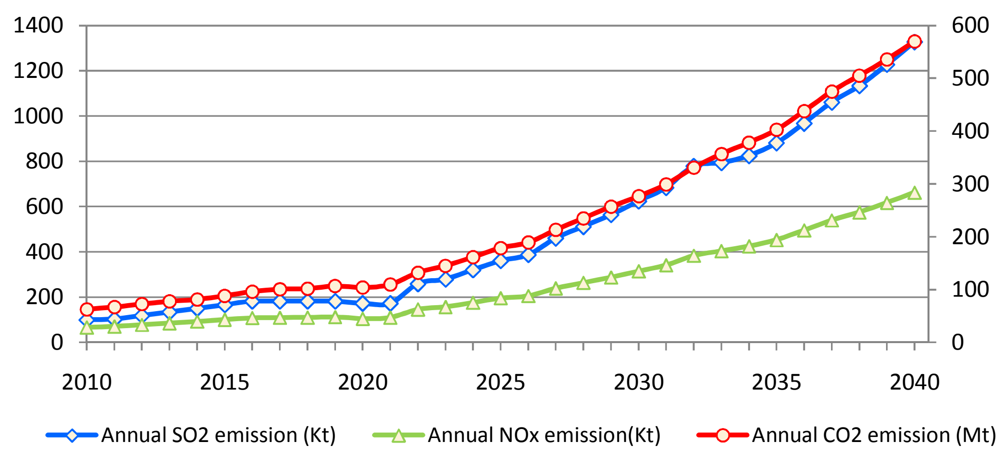
Over the last decades, Vietnam has focused its concerns more on economic development than on local environmental degradation. The rapid expansion and intensification of energy production from fossil fuel burning processes have been placing not only high pressures on the depletion of natural resources but also negative health impacts and dangerous environmental effects locally (USAID, 2007; IEA, 2010a). IEA (2009a) estimated that the total $CO_2$ emissions from fuel combustion in Vietnam experienced an extreme increase from 1990 to 2007 with a percentage change of 441.5%, from 17.2 million tons in 1990 to 93.6 million tons in 2007. This has the largest growth rate of $CO_2$ emissions in the world. Though the country's per capita emissions in 2007 (1.1 $tCO_2$/capita) are still below that of 7 countries listed by IEA (2009a), the gap would be soon narrowed when the country is extending severe dependence on burning coal fuel for future development. More environmental locally, USAID, (2007) argued serious air pollution, resulting from economic growth based on heavy use of fossil fuels along with the expansion of power sector over the last decade, brought about 22% of chronic pneumonia cases and one-third of respiratory inflammations in Vietnam during the period from 2001 to 2003. Though the concentrations of sulphur dioxide ($SO_2$), carbon monoxide (CO), and nitrogen oxides ($NO_X$) in Ha Noi and Ho Chi Minh between 1997 and 2002 were generally below national standards, given the increasing use of fossil fuels they are likely to soar and soon exceed the standards.

In recent years, the Vietnamese people have witnessed the Government's authorities, at both central and local levels, have undertaken its best efforts to overcome the negative environmental consequences and limit damages but their achievements are still limited and it remains a basic challenge (World Bank, 2010c; Parkes, 2010).

As suggested by our simulation, the potential environmental consequences of the future expansion of Vietnamese electricity generation industry, which bases on burning coal fuels, would be at levels never witnessed in Vietnam before. About 7.2 Gt of $CO_2$ cumulative emissions would be discharged into the atmosphere between 2010 and 2040, representing a 26% annual growth in $CO_2$ emissions during the period. This  figure is about 70 times larger than the total 103 Mt of $CO_2$ emissions emitted from fossil fuels combustion in Vietnam in 2008 (IEA, 2010b). Therefore, the stabilization of atmospheric carbon emissions may require proper policies to cut down the sector $CO_2$ emissions during the future development stages.

Moreover, the sector could become a large emitter of local pollutants, with cumulative emissions of up to 15 Mt of $SO_2$ and 8 Mt of $NO_X$ over the same period. These figures are much larger than the 128.2 Kt of $SO_2$ and 102 Kt of $NO_X$ emitted by the sector in 2006 (Nguyen and Tran, 2005). Figure 1-19 presents how the Vietnamese power sector's environmental consequences evolutes in the next 3 decades, especially between 2020 and 2040 when a stronger switch from non-fossil-fuels-based power plants to coal fuels comes out.

*Figure 1-19: Annual emissions of $CO_2$ and local pollutants ($SO_2$ and $NO_X$) emitted during 2010-2040. IRP simulation.*




Vietnam geography makes it one of the most disaster-prone countries in the world, suffering from typhoons, tropical storms, floods, drought, seawater intrusions, and landslides. An inappropriate exploitation of hydropower resource for expanding the electricity supply industry may even become more environmentally and socially unsustainable. For example, there are many hydropower projects (Cua Dat, Khe Mo, Ho Ho, Binh Dien Ke, Thau Dau) that changed the natural water flows of the rivers and deteriorated the watershed forests, thus, causing effects on the biodiversity and ecosystems and intensifying floods. In addition, erosion, flooding of valuable farmland and destruction of fish breeding habitats has been typical problems. Therefore, this gives a pressure to the Vietnamese authorities in taking proper measures to control and mitigate the potential impacts from the use of hydropower for electricity generation.

More seriously, climate change is now already a major global threat to human development and Vietnam must take parts in the effects and causes. Today, climate change related impacts are visible to most Vietnamese people and have been affecting directly human life and socioeconomic development in many residential quarters.

Specific scientific research reports of international organizations suggest that Vietnam is very sensitive to rising sea-levels bound to be caused by global warming. According to World Bank (2008a), a sea-level rise of 30cm to 1m over the next 100 years is anticipated by IPCC (2007), it could cause a capital value loss every year of up to 17 billion USD and the country could lose over 12% of territorial area, where presently 23% of the 84 million people live. In Ho Chi Minh City alone, 9 million people could be exposed to floods by a sea-level rise of 50cm by 2070. Increased temperature in the Mekong River Delta could raise evaporation and transpiration by 10-15%, affecting the Mekong's water supply to many cities in Vietnam.

UNDP (2007) estimated that the rise in seawater level will worsen saline water intrusion in coastal zones in Vietnam. The Mekong River Delta will be the most affected region with 1.77 million ha of salinised land, accounting for 45% of the delta surface. A scenario of 30cm sea-level rise in year 2050 would enlarge the salinity of the main tributaries of the Mekong River as far as 10 kilometres inland. Inundation and its consequence of land loss, saline water intrusion in the Mekong Delta and parts of Red River Delta are serious threat to farmers as well as to exports such as rice, and possibly to national food security.

Climate change could also increase the country exposure to extreme weather events. Flood damage is expected to be aggravated by an increase in daily rainfall of 12-19% by 2070 in some areas and drought problems will intensify through increased variation in rainfall and increased evaporation (3% in coastal zones and 8% in inland areas) by 2070. The typhoon activity and the intensity of storms will grow, especially in coastal zones that pose greater threat to people's lives, livelihoods, infrastructure and agricultural production. As estimated, 80-90% of the Vietnamese population is potentially directly affected by typhoons.

Last but not least, climate change could have detrimental health impacts in Vietnam as increasing temperature facilitates the growth and development of various viruses and disease carriers, resulting in wider incidence of infectious diseases such as malaria and dengue.

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# Part A: Programming sustainable development options for Vietnam's power sector

# Chapter 2. Energy efficiency: the best energy option to reduce any potential vulnerability

## 2.1 Introduction of Chapter 2

Energy efficiency is considered as the most critical step and requires widespread implementation if a country is to pursue a sustainable energy path (IEA, 2008c). Improving energy efficiency can firstly deliver a part of the largest but cheapest carbon emission reduction. Secondly, given the turn-down global economic conditions while an energy revolution is possible (IEA, 2009b), improving energy efficiency can offer a fast but effective way bringing more benefits than any other alternatives of energy technology. Thirdly, energy efficiency achieved today gives a significant avoidance of new energy capacity required for tomorrow, lowering costs of energy use, conserving indigenous energy resources and extending time for new low-carbon technologies to be mature (IEA, 2009b; IEA, 2009c).

In this chapter, we firstly focus on the current unsustainable pattern of energy use in Vietnam by using a comparative analysis to address that Vietnam has very high level of inefficient energy use among Asian countries and the potential energy savings across the economy remain largely untapped. In the core of the chapter 2, we aim to argue that more aggressively pursuing policies and measures to improve the efficiency of energy use are now an urgent imperative for Vietnam. The argument will be carried out by analyzing the trends of energy use and rising energy costs in Vietnam and the increasing pressures on ensuring energy security in the context of domestic energy resource constraints. Potential environmental consequences of increases in energy supply, which will be largely dependent on fossil fuels and energy use for the decades to come, are also analyzed to suggest a necessary change of the current unsustainable pattern of energy use. Changing this pattern, the Vietnamese power sector could reduce any potential vulnerability related to economy, energy and environment. Otherwise, potential vulnerability could even further contribute to increased poverty, political pressures, and instability. To the end, a case-study of improving the efficiency of energy use in the Vietnamese household sector will be quantitatively simulated in the IRP model to provide the insights that how energy efficiency could potentially offer more sustainable benefit values than any other alternatives of energy technology in the power sector.

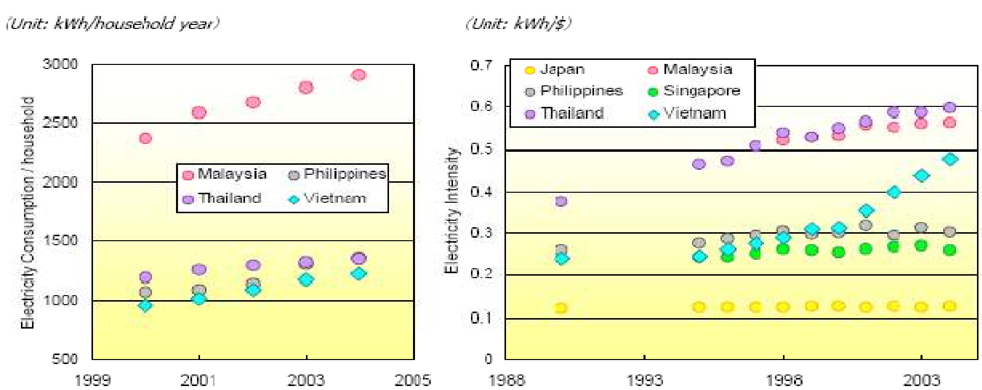
## 2.2 The importance of energy efficiency: a comparative and vulnerability analysis

### 2.2.1 The increasing power intensity: a comparative analysis

Energy intensity is the amount of energy used per unit of activity. It is usually calculated as the ratio of energy use to GDP. Energy intensity is often taken as a proxy for energy efficiency, although this is not entirely accurate as changes in energy intensity are a function of changes in several factors including the structure of the economy and energy efficiency (IEA, 2007b; IEA, 2009d). Moreover, it is commonly used as it affects future trends of development of all economies; especially it brings discussions on the issue of sustainability.

The section 1.2.1 already showed a very high power intensity suggesting inefficient energy use in the Vietnamese economy. To further prove for this issue of energy waste, we now examine how the increase in electricity consumption per capita interplayed with the change in GDP per capita among reference Asian countries in 2005. Though the GDP/capita in Vietnam just reached 670 US$/capita in 2005, the electricity consumption per capita (556 kW/capita) almost passed those of the Philippines (535 kW/capita) and Indonesia (484 kW/capita) whereas their GDP/capita were 1,395 US$/capita in the Philippines and 1,176 US$/capita in Indonesia. For the residential sector, accounting for almost 50% of total energy consumption over the period 2000-2005, the electricity consumption per electrified household has closely reached the consumption levels of the Philippines or Thailand whereas the GDP/capita in Vietnam only equalled as 1/2 or 1/4 as those of the respective countries in 2005 (Figure 2-1). All the GDPs are based on US$ 2008 (MOIT-JICA, 2008; Institute of Energy, 2010).

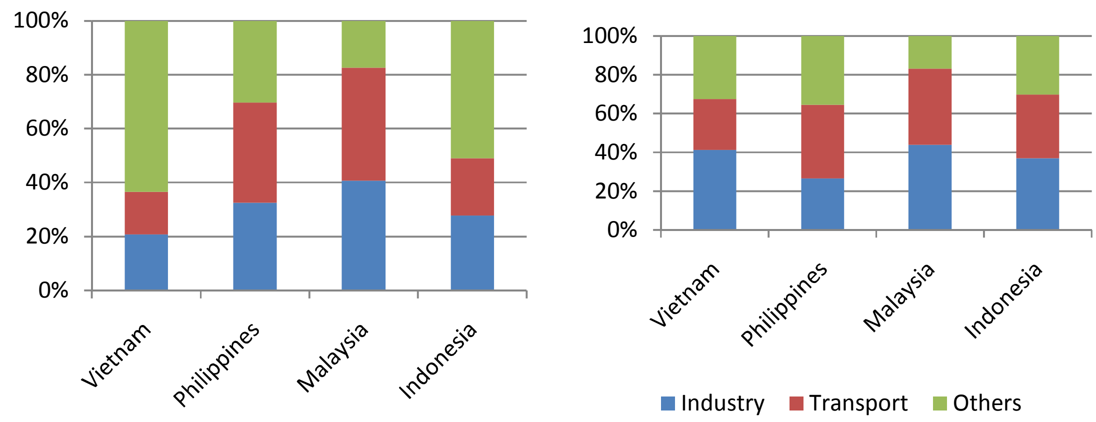
*Figure 2-1: Residential electricity consumption per electrified household (left) and electricity intensity of industrial sector (right) among some Asian countries, 1990-2005.*




Source: MOIT-JICA (2008).

Since 2005, the energy consumption in the Vietnamese residential sector has declined but it will remain a dominant proportion of total final energy consumption until 2020. The sector's share in energy consumption is estimated about 39% in 2010, decreasing to 30% by 2030 while that of industry sector would increase from 31% in 2010 to 40% by 2030 (Institute of Energy, 2009). Compared to other countries, Vietnam has experienced a quite similar structure of final energy consumption in Indonesia where the other sectors, different from industry and transport, took the largest proportion of energy consumption in 2005, and their share tends to shrink whereas that of industry sector tends to enlarge up to 2030 (Figure 2-3).

*Figure 2-2: Comparison of final energy consumption by sectors, in 2005 and by 2030.*




Source: Institute of Energy (2010), IEEJ (2009), IEEJ (2010).

But surprisingly, the power intensity in Vietnam economy tends to extremely increase for the coming decades while those of the reference economies in the Asian region (like China, Malaysia) tend to decrease or grow slightly like Indonesia, and the Philippines (Table 2-1). This virtually reflects a very low efficient energy use for future economy growth in Vietnam if the current scenario of development policy is continued. In other words, our argument agrees with JICA (2009) and World Bank (2010a) in that the potential energy savings across the economy remain largely untapped. For instance, the potential of energy savings could offer a reduction of 50-60% in total energy demand in the building sector, while a potential reduction of 30% could be attainable in the household sector, 20% in the textile, and 10% in the iron and steel (JICA, 2009). If stronger measures and policies for energy efficiency are put in place, about 20-30% of the business-as-usual energy demand for increased energy services could be reduced at costs typically being one-quarter as much as for additional energy supply (World Bank, 2010a).

*Table 2-1: Power intensity (GWh/Mill.US$2008) in Asian developing economies.*

| Country | 2010 | | 2030 | |
|---|---|---|---|---|
| | GWh/Mill.US$ 2008 | Index | GWh/Mill.US$ 2008 | Index |
| Vietnam | 1.12 | =100% | 1.29 | =100% |
| China | 0.83 | =74% | 0.53 | =41% |
| Malaysia | 0.60 | =54% | 0.67 | =52% |
| Indonesia | 0.43 | =38% | 0.54 | =42% |
| Philippines | 0.38 | =34% | 0.53 | =41% |

Source: the study's comparative results.

In the view of energy intensity, a number of empirical analyses already proved by using the principle of Kuznets' curves that the energy used per dollar of GDP produced would decline with rising income or even follow an inverted U-shaped path though the ratio of energy consumption to income does not appear to be constant in most developing countries (Galli, 1998; Cole et al., 1997; Suri and Chapman, 1998; Stern, 2004). But this is not the case in Vietnam where the power intensity tends to increase over time for the coming decades. This suggests that inefficient energy use, in terms of energy technology and behaviour, should exist within the given the absence of price incentive. Moreover, the Vietnamese power sector is projected to be in a position that will be more dauntingly challenging than before for the decades to come. The demand for electricity is anticipated to highly double the expected economic growth rate whereas the indigenous energy resources will become scarce after 2015. Much more of the required energy supply will need to be imported. Thus, the right moment has come for Vietnam to change the current unsustainable pattern of energy use otherwise the country could endure inevitable consequences of vulnerability affecting its power sector and the economy as well.

### 2.2.2 Why promote energy efficiency: a vulnerability approach

Vulnerability is the degree to which a system, subsystem, or system component is likely to experience harm (Turner et al., 2003), and the basic principle of vulnerability is the risks of being negatively affected by shocks (United Nations, 1999). There is a wide range of studies using this vulnerability concept for the analyses of socio-economic development (IMF, 1999; Whelan and Maitre, 2005; Goh, 2009), environmental science (Turner et al., 2003). More specific for energy issue, Loschel and Moslener (2010) discussed the issue of energy supply security in relation to changes in energy price and diversity of energy supplies. Bhattacharyya (2009) analysed the diversity of fuel mix for electricity generation in selected European countries and investigated how the fuel bill has changed as a share of GDP in these countries. For developing countries, Nakawiro and Bhattacharyya (2007) examined by analyzing the effect of changes in fuel prices on electricity tariff the economic impact of high dependence on natural gas for power generation in Thailand. Rakesh Ahuja (2007) estimated energy deficit as the greatest economic vulnerability in India.

We use in this study a number of energy-environment related indicators, as presented in Table 2-2, to take a measurement of potential vulnerability that the Vietnamese power sector could face if the power intensity in Vietnam remains increased as expected in the above Table 2-1.

*Table 2-2: Energy-related indicators for vulnerability analysis in this present study.*

| No. | Indicators | Unit |
|---|---|---|
| | **Economic dimension** | |
| 1 | Costs (capital, fuel, fixed/variable O&M) | Bill. US$ |
| 2 | Electricity per capita | kWh/person.year |
| 3 | Diversity of primary fuels for power generation | |
| 4 | Fuel import dependence | Percentage (%) |
| 5 | Imported fuel bill/GDP | Percentage (%) |
| 6 | Natural energy resource conservation | Mton |
| | **Environmental dimension** | |
| 7 | Quantities of $CO_2$ | Mton |

| | | |
|---|---|---|
| 8 | Quantities of $SO_2$ and $NO_x$ | kton |
| 9 | $CO_2$/capita | Ton per person |
| 10 | $CO_2$/GDP | kton/Mill. US$ |
| 11 | $CO_2$/kWh | g/kWh |
| 12 | Land use | ha |

Indicator 1: Costs (capital, fuel, fixed/variable O&M):

$$Total\ Cost = Capita\ Cost + Fuel\ Cost + Fixed/Variable\ O\&M\ Costs \quad (2.1)$$

Indicator 2: Electricity consumption per capita:

$$Electricity\ consumption\ per\ capita = \frac{Total\ electricity\ consumption}{Population}\ [kWh/capita] \quad (2.2)$$

Indicator 3: Diversification of fuels for power generation:

Herfindahl-Hirschman Index – HHI:

$$Fuel\ diversity\ index\ (HHI) = \sum x_i^2 \quad (2.3)$$

$x_i$ : share of electricity capacity from fuel *i* in the system

The Herfindahl-Hirschman Index (HHI), in power industry, can be used to measure the diversity of fuel mix for power generation or the level of fuel import concentration (Bhattacharyya, 2009).

Indicator 4: Net energy import dependence:

$$Net\ energy\ import\ dependence = \frac{Imported\ fuel\ based\ power\ capacity}{Total\ power\ capacity}\ [\%] \quad (2.4)$$

Indicator 5: The ratio of imported fuel bill to GDP:

$$\begin{aligned} Ratio\ of\ imported\ fuel\ bill\ to\ GDP &= \frac{Fuel\ bill\ for\ power\ generation}{Gross\ Domestic\ Product\ (GDP)} \\ &= \frac{Fuel\ bill\ for\ power\ generation}{GDP} x \frac{Gross\ \ GWh\ (GWh)}{Gross\ GWh\ (GWh)} \\ &= \frac{Fuel\ price * Average\text{-}heat\text{-}rate * GWh_f}{GDP} x \frac{GWh}{GWh} \\ &= \frac{Fuel\ price * Average\text{-}heat\text{-}rate * GWh_f}{GDP} x \frac{GWh}{GWh} \\ &= (Fuel\ price * Average\text{-}heat\text{-}rate) x \frac{GWh_f}{GWh}\ x \frac{GWh}{GDP} \end{aligned}$$

$$= (Fuel\ price * Average\text{-}heat\text{-}rate) x (Fuel\ dependence) x (Power\ intensity)\ [\%] \quad (2.5)$$

Where:

*$GWh_f$*: power generated from the imported fuels (under consideration the study) [GWh]

*Fuel price*: average price for buying the fuels in electricity generation [US$/GJ]

*Average-heat-rate*: Average heat rate of power plants used the fuels [GJ/GJ]

*Gross GWh*: total electricity generation in the country [GWh]

*GDP*: Gross Domestic Product [Bill. US$]

Indicator 6: Natural energy resource conservation:

$$Coal\ savings\ = Coal\ consumption\ in\ BAU\ \text{-}\ Coal\ consumption\ in\ EEF\ \left[million\ ton\right] \quad (2.6)$$

Indicator 7: Quantities of $CO_2$:

$$Total\ CO_2\ emission = \sum CO_2 Emission\ from\ fossil\ fuel\ power\ plants\ \left[million\ ton\right] \quad (2.7)$$

Indicator 8a: Quantities of $SO_2$:

$$Total\ SO_2\ emission = \sum SO_2 Emission\ from\ fossil\ fuel\ power\ plants\ \left[million\ ton\right] \quad (2.8a)$$

Indicator 8b: Quantities of $NO_x$:

$$Total\ NO_x\ emission = \sum NO_X\ Emission\ from\ fossil\ fuel\ power\ plants\ \left[million\ ton\right] \quad (2.8b)$$

Indicator 9: $CO_2$ emission per capita:

$$CO_2\ emission\ per\ capita = \frac{Total\ CO_2\ emission}{Population}\left[ton/capita\right] \quad (2.9)$$

Indicator 10: Ratio of $CO_2$ emission to GDP:

$$CO_2\ emission\quad intensity = \frac{Total\ CO_2\ emission}{GDP}\left[kton/Mill.US\$\right] \quad (2.10)$$

Indicator 11: Ratio of $CO_2$ emission of kWh electricity generated:

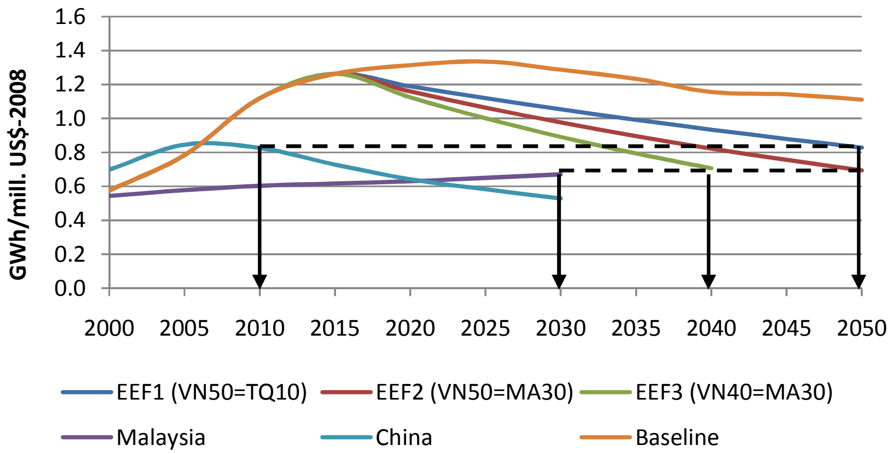
$$CO_2\ emission\ per\ kWh = \frac{Total\ CO_2\ emission}{Total\ Electricity\ Generation}\left[kCO_2/kWh\right] \quad (2.11)$$

Indicator 12: Land use:

$$Land\ saving = Specific\ land\ required\ for\ coal\ plant\ x\ Power\ capacity\ reduction\ \left[ha\right] \quad (2.12)$$

To reduce the vulnerability, we assumably suggest that Vietnam economy should aim to bring its power intensity at par with those of China and Malaysia, at least. They have a relatively high level of power intensity among the reference economies, and Vietnam should target the same level if stronger policies on energy efficiency improvements are put in place. Three scenarios of energy efficiency improvements (called hereafter EEF1, EEF2, and EEF3) are thus assumably suggested and graphically presented by the Figure 2-3. In this Figure, the legend "VN50=TQ10" indicates an assumption that power intensity of Vietnam in 2050 is at par with that of China in 2010, while "VN50=MA30" assumes power intensity of Vietnam in 2050 reaches that of Malaysia in 2030. Similarly, "VN40=MA30" assumes power intensity of Vietnam in 2040 reaches that of Malaysia in 2030.

*Figure 2-3: Assumptions of power intensity in Vietnam with reference to that in China and Malaysia, 2010-2050.*




Next, the study by using the IRP model simulates the development of electricity generation industry in Vietnam during the period 2010-2040 within these scenarios EEF1, EEF2, EEF3. These simulated outputs are then individually compared to those in the baseline development of the power sector (BAU scenario) in order to determine the vulnerabilities, in terms of economic and environmental dimensions, that the power sector could avoid by reducing the power intensity in the economy through promoting energy efficiency in the power sector.

#### *2.2.2.1 The results of analysis*

*Costs (capital, fuel, fixed/variable O&M)*

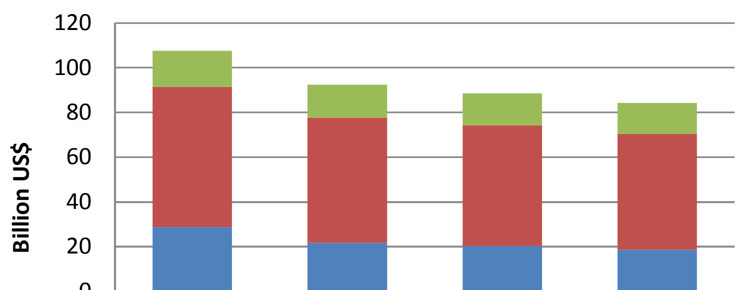
The IRP simulation provides that if energy efficiency improvements are deployed as suggested in scenarios EEF1, EEF2, and EEF3, the sector could significantly reduce the total new energy capacity required under the current development policy (the baseline scenario), by 19%, 26.6% and 36.1%, respectively. Thus the country could significantly benefit from great savings of 16.4%, 22.3%, and 28.9% in the total cumulative electricity generation over the period 2010-2040, respectively. In term of economic value, these savings could ease the country's pressures on the request of financing for expansion of energy supply infrastructure, and government resources can be freed up for investment in other socioeconomic areas. Figure 2-4 is telling us if the sector goes for the sustainable path suggesting from the three energy efficiency scenarios, the sector could gain avoided costs of 15, 19, and 23 billion US$, respectively over the planning horizon. Particularly, by the EEF3 scenario, the sector could avoid 0.76 billion

US$ per annum in new investments for expansion of electricity generation from 2010 to 2040, to which must be added the investment saving on electricity transmission and distribution. Because of unavailable necessary data, the demand-side investment costs for implementing these energy efficiency scenarios were not integrated for a full cost-comparative analysis between supply-side and demand-side investments. However, this figure of saving cost practically provides energy policymakers with a financial indicator for designing and managing energy efficiency programs in Vietnam.

*Electricity consumption per capita*

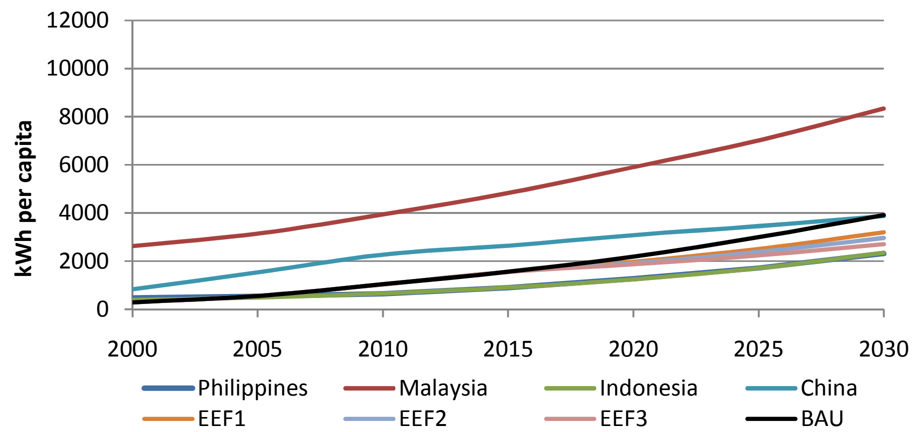
In the baseline development, the electricity-per-capita in Vietnam would accelerate increasing even higher than those of the Philippines and Indonesia since 2010. For instance, the electricity-per-capita in Vietnam would be 961 kWh/capita in 2010, higher than those of the Philippines (643 kWh/capita) and Indonesia (656 kWh/capita) in the same year. By 2030, it would be 4912 kWh/capita, even much higher than those of the Philippines (2312 kWh/capita) and Indonesia (2347 kWh/capita). But, if energy efficiency improvements are deployed as in scenarios EEF1, EEF2, and EEF3, the electricity-per-capita in Vietnam by 2030 would be reduced by 18%, 24%, and 31%, respectively (Figure 2-5).

*Figure 2-4: Cumulative cost components by various scenarios, 2010-2040. Vulnerability analysis based on IRP simulation.*




| | BAU | EEF1 | EEF2 | EEF3 |
|---|---|---|---|---|
| Fixed O&M | 16.1 | 14.7 | 14.3 | 13.9 |
| Variable O&M and fuel costs | 62.5 | 55.9 | 53.8 | 51.7 |
| Capital | 28.8 | 21.8 | 20.4 | 18.6 |

*Figure 2-5: Electricity-per-capita by country compared to energy efficiency improvements scenarios. Vulnerability analysis based on IRP simulation.*




*Diversification of fuels for power generation*

As we can see the calculated HHI index in the baseline development is above 3,000 indicating a rather highly concentrated fuel generation mix in the Vietnamese power generation industry. In this case, a drastic shift to imported energy supply especially large-scale coal imports, for electricity production is largely extended after 2015. Given that 40% of the total electricity production would be generated from coal imports by 2040, the Vietnamese power sector is likely to be unable to avoid a potential vulnerability to international energy price fluctuations. To reduce a possible volatility to international energy price, energy efficiency improvements are suggested as the single cost-effective solution, by which less-concentrated coal fuel generation mix could be significantly achievable. For instance, in the EEF3 scenario, the HHI index could be reduced below 3,000 presenting an electricity generation portfolio with more diversified fuel generation mix (Figure 2-6 and Figure 2-7).

*Figure 2-6: Diversification indexes of energy supplies by 2040. Vulnerability analysis based on IRP simulation.*

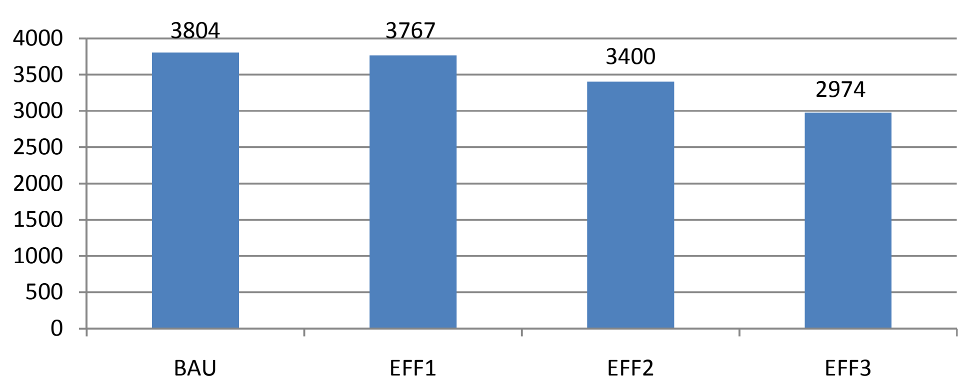
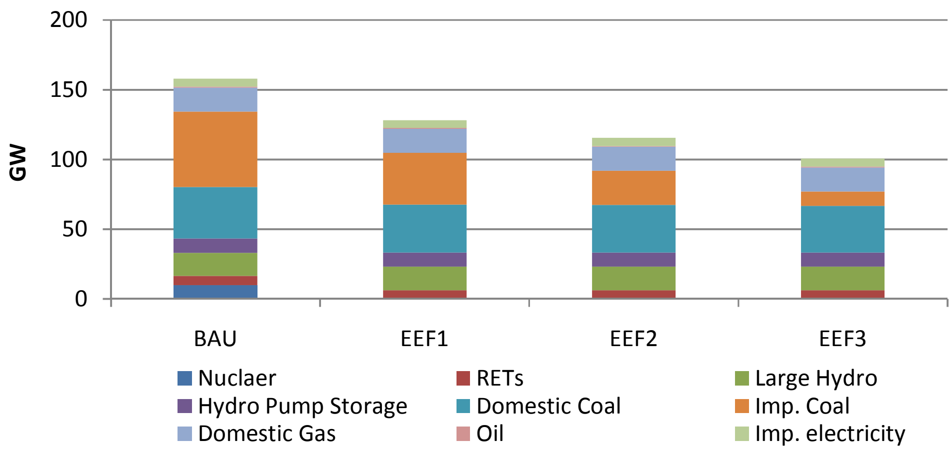


*Figure 2-7: More diversified fuel generation mix with energy efficiency improvements by 2040. Vulnerability analysis based on IRP simulation.*




*Net energy import dependence:*

As modelled in the baseline development, the energy capacity share of imported fuels (coal, oil and electricity) would increase from 19% to 38% during 2030-2040 and the share of energy generation from these sources would increase from 21% to 44% during the same period. These figures imply that the Vietnamese power sector would be greater dependent on imported fuels for the future electricity production. This could potentially, thus, make the sector vulnerable to international energy price volatility and cause large increases in power sector costs. With the rising issues of energy supply security and such a possible vulnerability, the study finding shows that aggressively pursuing measures to improve energy efficiency are better prepared for possible vulnerable circumstances in the future, by which the energy capacity share of imported fuels in the baseline scenario could be remarkably reduced by 4% to 22% (in the EEF3 scenario) during 2030-2040 (Figure 2-8) and the share of energy generation from imported fuels could be greatly reduced by 4% to 26% during the same period (Figure 2-9).

*Figure 2-8: Percentage of imported fuels-based energy capacity, 2010-2040. Vulnerability analysis based on IRP simulation.*

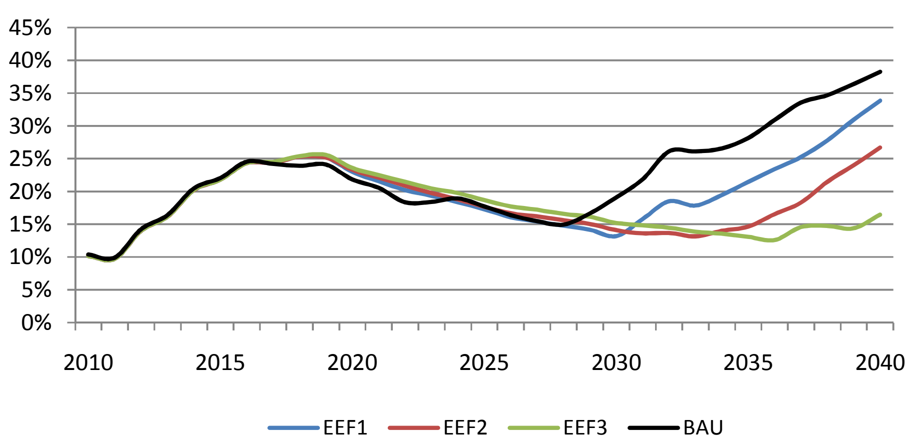
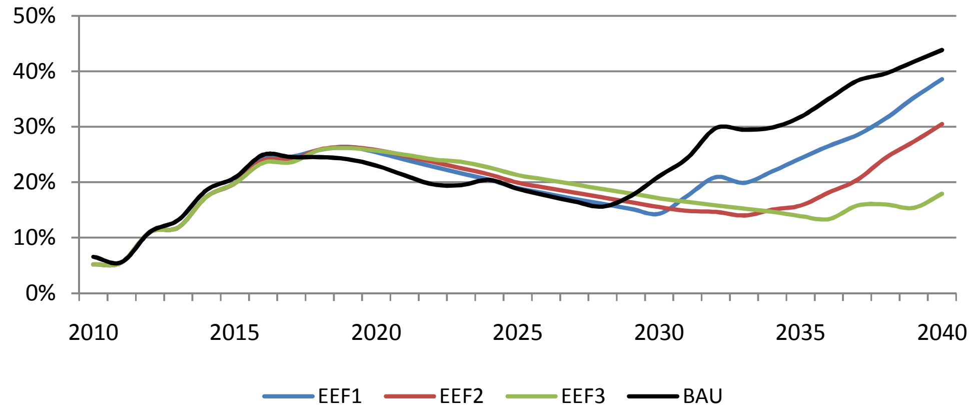


*Figure 2-9: Percentage of imported fuels-based electricity generation, 2010-2040. Vulnerability analysis based on IRP simulation.*

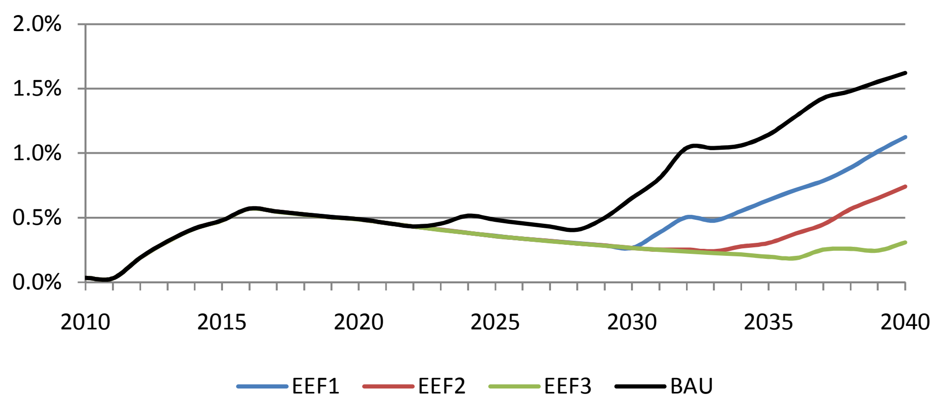



*The ratio of imported fuel bill to GDP:*

To assess a potential vulnerability to the Vietnamese economy by increasing reliance on imported fuels for the future electricity production, the study examines the ratio of imported fuel bill to GDP as expressed by the formulation 2.5. This indicator presents the effect of expenditure on a single fuel or one group of fuels in a country on its economy production (GDP). Within the present study, the imported coal is selected for analyzing.

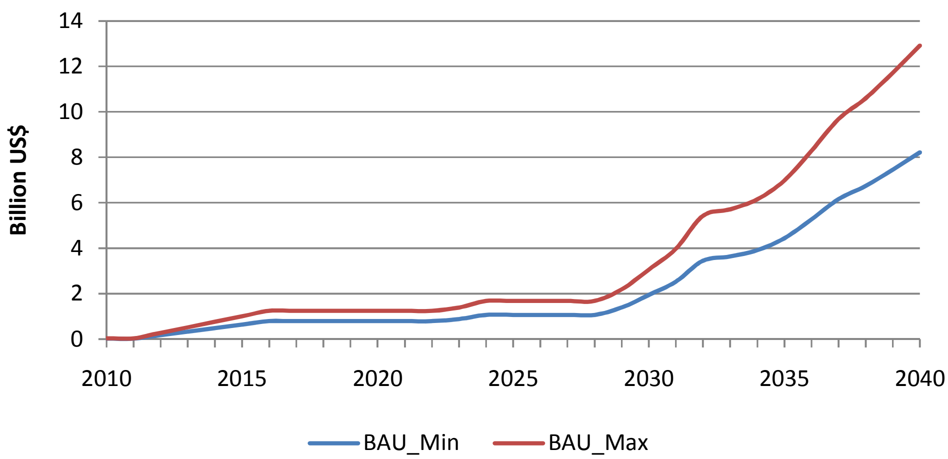
In fuelling the expansion plan, imported coal will account for a lion share of the total imported energy supply. By 2040, the total bill expensed for importing coal would account for 1.6% of the country's GDP in the baseline scenario. Though this figure is small in relative term but it would contribute a considerable absolute value to total net imports of the entire economy by 2040. So far, the finding here is that this figure could be greatly cut down to 1.1% in the EEF1 scenario, and to 0.3% in the EEF3 scenario (Figure 2-10).

*Figure 2-10: Percentage of the bill for coal importation in GDP, 2010-2040. Vulnerability analysis based on IRP simulation.*



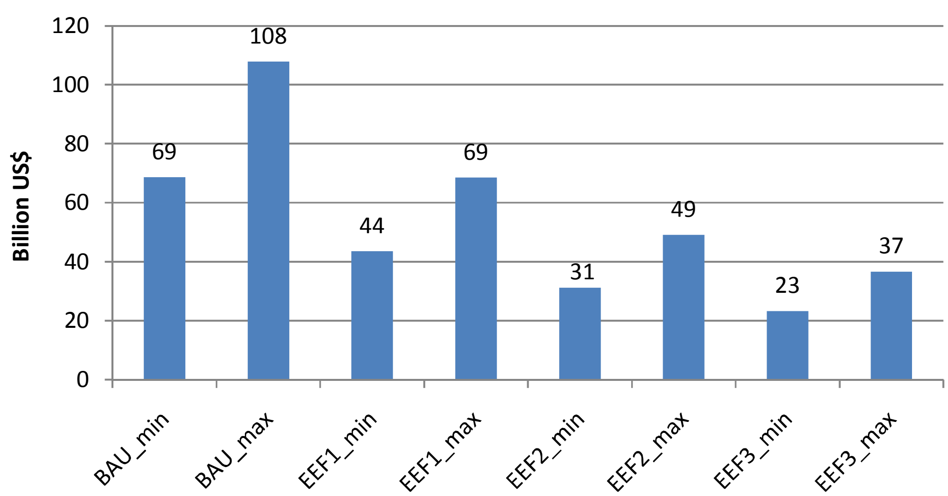
To further examine potential impacts of international coal price volatility on the bill for coal importation, the study carried out a sensitivity analysis, in which we assumed coal price would vary from a min value of 70 US$/ton to a max value of 110 US$/ton. Figure 2-11 shows that if the imported coal price is 70 US$/ton by 2040, the bill would charge 8.2 billion US$ by 2040, and the bill would charge 12.9 billion US$ if the price is 110 US$/ton by the same year.

*Figure 2-11: Annual bill for imported coal fuel in the BAU scenario assuming imported coal price varies in a range of (max=110US$/ton, min=70US$/ton), 2010-2040. Vulnerability analysis based on IRP simulation.*



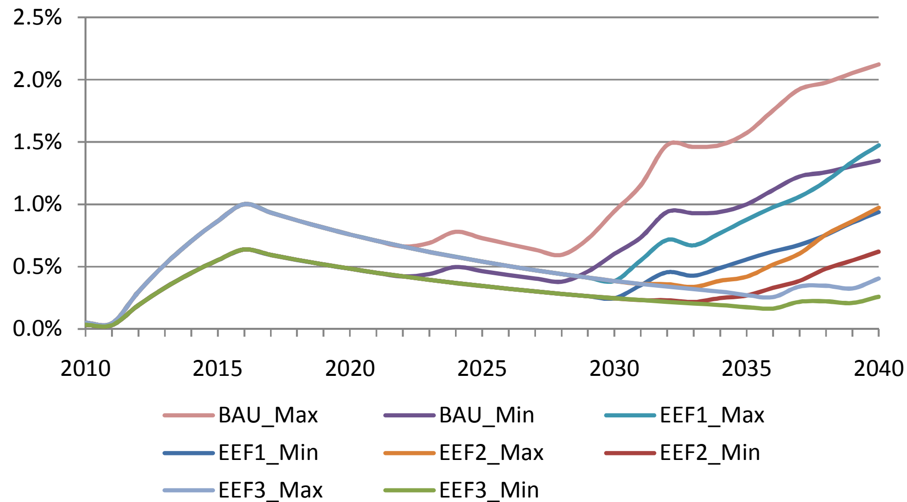

Moreover, Figure 2-12 presents the cumulative bill for coal importation used for electricity generation by various scenarios during the period from 2010 to 2040, assuming that imported coal price varies from a min value of 70 US$/ton to a max value of 110 US$/ton.

*Figure 2-12: Cumulative bill for imported coal fuel by various scenarios assuming imported coal price varies from a range of (max=110US$/ton, min=70US$/ton), 2010-2040. Vulnerability analysis based on IRP simulation.*



In term of imported coal bill to GDP, the study finds that if imported coal price is 110 US$/ton by 2040, the bill for coal importation would account for more than 2% of the country's GDP in the baseline. But, this figure could be significantly reduced to 0.4% in the EEF3 scenario (Figure 2-13).

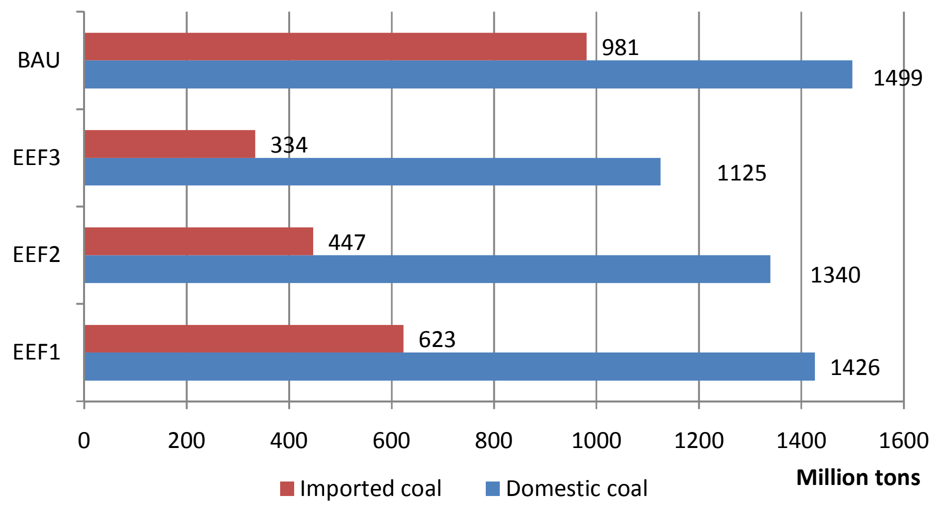
*Figure 2-13: Percentage of imported coal bill to GDP assuming imported coal price varies in a range of (max=110US$/ton, min=70US$/ton), 2010-2040. Vulnerability analysis based on IRP simulation.*




*Coal fuel conservation:*

In term of natural energy resource conservation, pursuing energy efficiency would also help the country attain a significant saving of indigenous coal resource while ensuring sufficient electricity production for meeting the energy demand for the next three decades. The cumulative coal consumption for electricity production over the period from 2010 to 2040 in the baseline development is estimated about 2,480 million tons, including 1,499 million tons of domestic coal and 981 million tons of imported coal. This cumulative figure equals to 57 folds of the domestic coal production in Vietnam by 2009 and is 130 folds larger than total coal consumption by the country in the same year. As a result of energy efficiency improvements, the total demand for coal fuel, over the period 2010-2040, would be largely reduced by 41% (1,021 million tons) in the EEF3 scenario (Figure 2-14). This reduction includes 647 million tons of imported coal and 374 million tons of domestic coal. The saving of domestic coal is triple larger than the estimated total coal production in Vietnam by 2030 (Institute of Energy, 2009) and it's importantly valuable in the context of the scarcity of indigenous energy resources after 2015.

*Figure 2-14: Cumulative domestic coal consumption by various scenarios, 2010-2040. Vulnerability analysis based on IRP simulation.*




*Environmental issues*

As a consequence of greater dependence on burning coal fuel for electricity production over the period from 2010 to 2040, the sector's $CO_2$ emissions tend to move to a very high level that has never witnessed in Vietnam before. The IRP results suggest that about 7.2 Gt of $CO_2$ emissions would be discharged into the atmosphere between 2010 and 2040 from the sector in the baseline development. This figure is around 70 times larger than the total 103 Mt of $CO_2$ emissions emitted from combustion of fossil fuels in 2008 in Vietnam (IEA, 2010b). In term of $CO_2$ emission intensity to population ($tCO_2$/capita), the study finds that the $CO_2$/capita is closely reaching 5.1 $tCO_2$/capita by the year of 2040 in the baseline. This value is 28 folds larger than the 2000 level of $CO_2$/capita in the Vietnamese society (IEA, 2010b).

However, potential environmental consequences of such the present unsustainable model of energy supply and use could be significantly alleviated if energy efficiency improvements are implemented. Particularly, it could cut down the power sector cumulative $CO_2$ emissions by 17% in the EEF1 scenario, and by 37% in the EEF3 scenario (Figure 2-15), and the $CO_2$/capita could be greatly reduced by about 50%, in the EFF3 scenario (Figure 2-16).

The ratio of $CO_2$ emission to GDP or the $CO_2$ emission intensity to GDP ($tCO_2$/ million US$) implies not only the penetration of cleaner power in economy growth but also the efficiency of energy use in the economy. Figure 2-17 shows this ratio would decrease gradually for the next 10 years, in all scenarios, owing to the increasing share of electricity generation from non-fossil fuels sources (large hydro and renewables) in the sector. Afterwards, while all other scenarios present an increase in this ratio until 2040, the EFF3 scenario provides an almost constant level of 502 $tCO_2$/ million US$. This represents a more sustainable economic growth with higher efficient energy use in the Vietnamese economy.

*Figure 2-15: The sector cumulative $CO_2$ emissions by various scenarios, 2010-2040. Vulnerability analysis based on IRP simulation.*

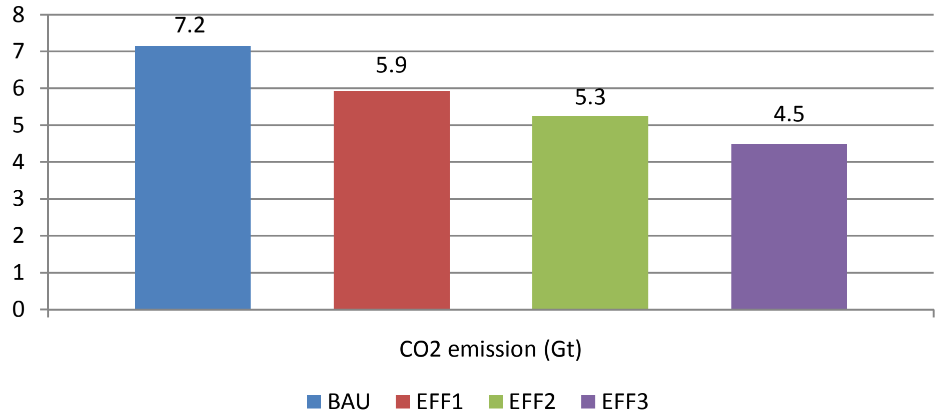



*Figure 2-16: $CO_2$ emission per capita by various scenarios, 2010-2040. Vulnerability analysis based on IRP simulation.*

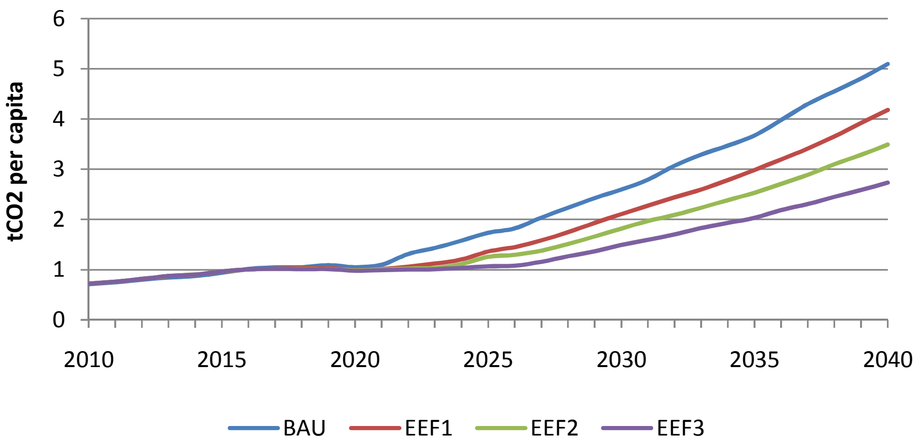
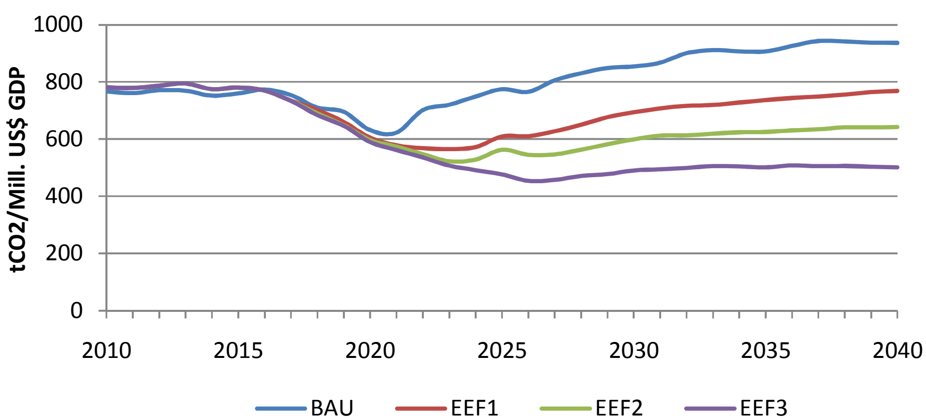
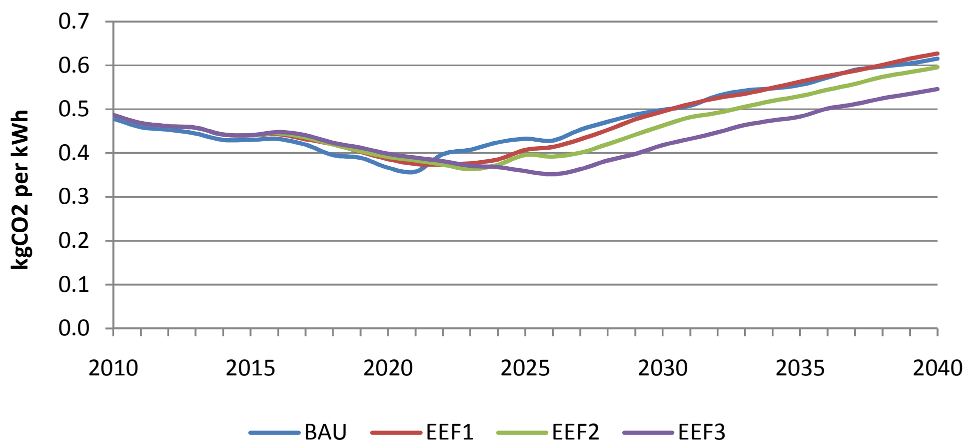



*Figure 2-17: $CO_2$ emission intensity of Vietnam's economy, 2010-2040. Vulnerability analysis based on IRP simulation.*



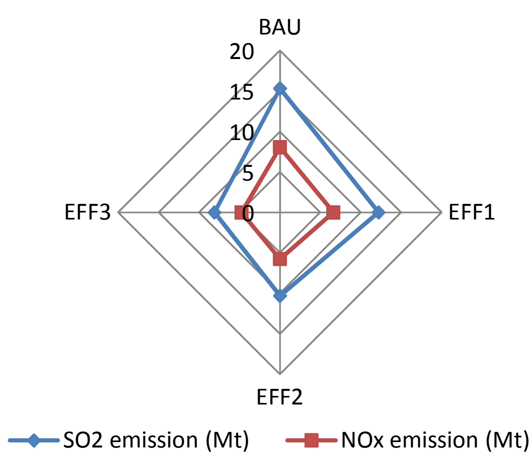
Similarly, the indicator of 600g $CO_2$/kWh in the BAU scenario for the latest years of the planning horizon implies for a future of high carbon intensive electricity generation industry in Vietnam, which is mainly based on combustion of coal fuels. As a result of changing the current unsustainable pattern of energy use, the $CO_2$ emission per kWh could be significantly reduced from 600g to 540g $CO_2$/kWh over the same period in the EEF3 scenario (Figure 2-18).

*Figure 2-18: $CO_2$ emission per kWh electricity production, 2010-2040. Vulnerability analysis based on IRP simulation.*




Specially, air pollution from electricity production based on firing fossil fuels always carries a large extent of socio-economic costs and dangerous public health impacts causing respiratory illnesses and premature death. To prevent this inevitable vulnerability, energy efficiency improvements are proven by the study as an ideal solution: 20% (in the EEF1 scenario) to 47% (in the EEF3 scenario) of total 15 Mt $SO_2$, and 18% to 41% of total 8 Mt $NO_X$ emissions could be greatly cut down, respectively over the period from 2010 to 2040 (Figure 2-19).

*Figure 2-19: Cumulative $SO_2$ and $NO_X$ emissions by scenarios, 2010-2040. Vulnerability analysis based on IRP simulation.*



*Land use:*

We further measure an avoidance of potential vulnerability in term of land use required for construction of power generation plants. Practically, the requirement of land use varies from one place to others depending on specific local features and technologies used. And as most of avoided energy capacity is from coal-fired generation, we only estimate the average area of land use required for constructing coal-fired generation plants based on the guideline of the (IAEA, 2003) and the practical project data in Vietnam. On this ground, the study compares in relative values the request of land use between the baseline (BAU) scenario and the EEF1, EEF2, and EEF3 scenarios, respectively.

In Vietnamese power project practice, for a typical coal-fired generation plant with a capacity of 1,800 MW, the need of total land area is about 195 ha. This means about 0.108 ha would be required for 1 MW of coal-fired generation capacity. Following the Japan Handbook for Thermal and Nuclear Power Engineers, IAEA (2003) recommended that a site area for coal-fired power plants could vary from 0.05-0.09 ha per MW. Using these reference values and the avoided new energy capacity among the scenarios, the potential saving of land use is shown out in the Table 2-3.

*Table 2-3: The cumulative land use savings of alternative energy efficiency scenarios, 2010-2040. Vulnerability analysis based on IRP simulation.*

| Items | Average rating | EEF1 | EEF2 | EEF3 |
|---|---|---|---|---|
| Avoided energy capacity (MW) | | 29,580 | 42,380 | 57,280 |
| Land savings (ha) | 0.05 ha/MW | 1,479 | 2,119 | 2,864 |
| | 0.108 ha/MW | 3,205 | 4,591 | 6,205 |

Last, the point of interest is that all selected nuclear generation plants (10 GW) would not be lowest-cost-optimally solved in the IRP simulation if energy efficiency improvements are deployed as suggested in scenarios EEF1, EEF2, EEF3. Particularly, even when only one nuclear generator (1 GW) is input as a committed generation plant in the IRP model, the model could not find out a lowest-cost-optimal solution for the generation capacity mix in any scenarios EEF1, EEF2, EEF3. This is prominent that implementing energy efficiency improvements in scenarios EEF1, EEF2, EEF3 together with the use of available primary energy supply sources (other than nuclear) would be already significantly lowest-cost-optimal to satisfy the baseline demand for electricity during the period 2010-2040. The nuclear energy development plan (10 GW) for electricity use during the period 2020-2040 may simply mean an inefficient energy capacity in this context, even potentially cause inefficient overcapacity if higher nuclear capacity of 15-16 GW (as ambitiously planned by the Vietnamese Government in the reality) are developed, during the same period. In other words, such a finding suggests that the current national energy development policy based on large capacity of nuclear energy for fulfilling the rapid but uncertain increase in electricity demand may not be the cost-effective way to ensure energy supply security as compared to the cheapest and simpler, safer and more cost-effective measures of improving energy efficiency. Moreover, if energy efficiency improvements are successfully implemented, the sector could limit the risks of radioactive wastes from this nuclear option.

## 2.3 Economic potential for demand-side management in the household sector

Energy efficiency improvements in the household sector are considered as a high priority in Vietnam (JICA, 2009). Currently, about 40% of total electricity use and 21% of total final commercial energy demand are from the household sector, which involve millions of small household-consumers along the country. As a tropical country, heating is not a critical load in Vietnam. The most electricity demand, in this sector, is for home electric appliances such as lighting lamps, air conditioners, refrigerators, electric water heaters, etc. The major concern for demand-side management (DSM) programs in the sector is, therefore, towards promoting energy efficiency of relevant technologies for these home electric appliances (Institute of Energy, 2008b; Institute of Energy, 2009; JICA, 2009; World Bank, 2010a).

### 2.3.1 Integrating the DSM into the IRP simulation model

Within this part of the study, we examine the importance of DSM programs involving the replacement of incandescent light bulbs (ILs) and fluorescent light bulbs (ILs) with compact fluorescent (CLFs) and high efficiency fluorescent light bulbs (EFLs) in the Vietnamese household sector (data is given in Table 2-4) by using the IRP simulation. The two energy efficiency options of replacing the current air-conditioners with higher efficiency air-conditioners (EEAC) in the sector are also considered (Table 2-5). All these are hereafter called as high efficient home appliances. The two scenarios below are defined in the IRP model:

*Table 2-4: Technical details and costs of existing and energy efficient light bulbs.*

| Conventional equipment to be replaced | | | | Energy efficient equipment | | | |
|---|---|---|---|---|---|---|---|
| **Sector/type of appliance** | **Ratings (Watt)** | **Cost (US$)** | **Life** | **Type of appliance** | **Ratings (Watt)** | **Cost (US$)** | **Life** |
| DSM1 | 40 | 0.52 | 1500 | CFL | 9 | 6.77 | 10000 |
| DSM2 | 60 | 0.57 | 1200 | CFL | 13 | 6.77 | 12000 |
| DSM3 | 75 | 0.57 | 800 | CFL | 18 | 7.67 | 12000 |
| DSM4 | 100 | 0.62 | 800 | CFL | 27 | 8.12 | 10000 |
| DSM5-Fluorescent | 40 | 1.56 | 8000 | EFL | 36 | 2.32 | 12000 |

Source: Nguyen and Ha-Duong (2010) and JICA (2009).

*Table 2-5: Technical details and costs of existing and energy efficient air-conditioners.*

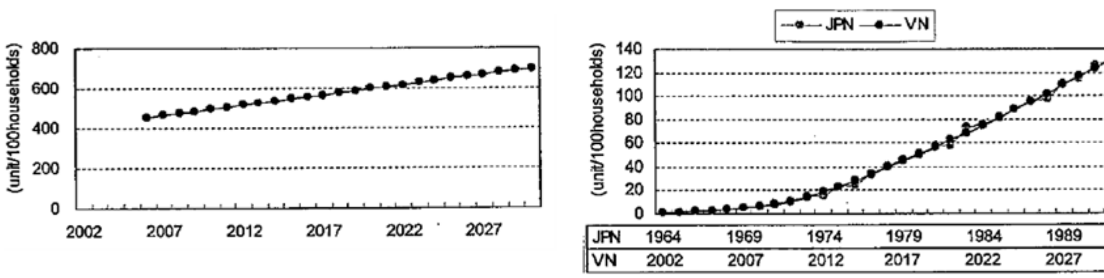
| Conventional equipment to be replaced | | | | Energy efficient equipment | | | |
|---|---|---|---|---|---|---|---|
| **Type of appliances** | **Ratings (Watt)** | **Cost (US$)** | **Life** | **Type of appliance** | **Ratings (Watt)** | **Cost (US$)** | **Life** |
| 9000 BTU | 950 | 419 | 10 years | EEAC | 750 | 842 | 10 years |
| 12000 BTU | 1300 | 530 | 10 years | EEAC | 1050 | 953 | 10 years |

Source: Nguyen and Ha-Duong (2010) and JICA (2009).

Baseline (BAU) scenario: all home electric appliances used in this scenario are conventional. The total electricity consumption in the household sector is a part of the total electricity demand anticipated of the baseline development scenario.

DSM scenario: all home electric appliances penetrating in this scenario are high efficient types. The annual stocks and penetration of these home electric appliances are mainly derived from JICA (2009) and Nguyen and Ha-Duong (2010). The Figure 2-20 illustrates the penetration for each kind of electric home appliances in Vietnam based on the estimated living standard in different periods of time. The two scenarios are otherwise identical in all other aspects.

*Figure 2-20: Number of penetration of high efficient lamps and room air-conditioners*




Source: JICA (2009).

Because of unavailable data, only the technical potential of the DSM programs is considered, i.e. the rebound effect[6] (also known as “feedback effect”) is not included in the study.

### 2.3.2 The DSM in the household sector: the free lunch option

As IRP is a bottom-up optimization model, optimizing over a broader array of energy technologies from demand-side can only improve results. Thus, it is no surprise that the model run with DSM programs (DSM scenario) performs better economically than the model run with no DSM (BAU scenario). What is more interesting, perhaps, are the quantitative differences between the two scenarios, which are summarized in Tables 2-6 and Table 2-7, and discussed in more detail below. We examine in turn the implications for electricity planning, the benefits of DSM programs from the perspective of domestic energy security, the cost improvements, and the environmental benefits.

Overall, the IRP simulation suggests that using high efficient home appliances in the Vietnamese household sector could potentially release the soaring demand for electricity and help the country avoid installing 9.3 GW of coal-fired generation capacity, which accounts for 7.2% of the total new energy capacity added from 2010 to 2040 in the baseline development. Moreover, by replacing conventional home appliances in this sector could also potentially save 791 TWh in electricity during the specified period.

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[6] Energy efficiency improvement results in a decrease in the effective price of services which would increase the service demand. As a result, actual energy savings due to the introduction of efficient appliances would be less than the savings based on engineering estimates.

*Table 2-6: Electricity generation in Vietnam, 2010-2040. Simulations of the Vietnamese power sector were carried out using the IRP model.*

| Cases | Nuclear | Renewable sources | | | Fossil fuel sources | | | | | Imp. power | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RETs | Large Hydro | Hydro Pump Storage | Dom. Coal | Imp. Coal | Dom. Gas | Imp. Gas | Oil | | |
| **Capacity installed by 2040 (MW)** | | | | | | | | | | | |
| DSM | 10000 | 6344 | 16761 | 10200 | 36689 | 45080 | 17182 | 0 | 600 | 5784 | 148640 |
| | 6.7 | 4.3 | 11.3 | 6.9 | 24.7 | 30.3 | 11.6 | 0.0 | 0.4 | 3.9 | 100.0 |
| BAU | 10000 | 6344 | 16761 | 10200 | 36989 | 54080 | 17182 | 0 | 600 | 5784 | 157940 |
| | 6.3 | 4.0 | 10.6 | 6.5 | 23.4 | 34.2 | 10.9 | 0.0 | 0.4 | 3.7 | 100.0 |
| **Electricity generation over 2010-2040 (TWh)** | | | | | | | | | | | |
| DSM | 788.2 | 587.3 | 2045.7 | 389.6 | 3596.6 | 2414.8 | 2715.9 | 0.0 | 35.2 | 742.2 | 13315.4 |
| | 5.9 | 4.4 | 15.4 | 2.9 | 27.0 | 18.1 | 20.4 | 0.0 | 0.3 | 5.6 | 100.0 |
| BAU | 788.2 | 584.6 | 2045.1 | 389.6 | 3729.1 | 3117.0 | 2674.0 | 0.0 | 35.6 | 743.1 | 14106.3 |
| | 5.6 | 4.1 | 14.5 | 2.8 | 26.4 | 22.1 | 19.0 | 0.0 | 0.3 | 5.3 | 100.0 |
| **Reduction in capacity (MW) and electricity generation (TWh)** | | | | | | | | | | | |
| MW | 0 | 0 | 0 | 0 | 300 | 9000 | 0 | 0 | 0 | 0 | 9300 |
| % | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 16.6 | 0.0 | - | 0.0 | 0.0 | 5.9 |
| TWh | 0.0 | -2.8 | -0.6 | 0.0 | 132.5 | 702.3 | -42.0 | 0.0 | 0.4 | 1.0 | 790.8 |
| % | 0.0 | -0.5 | 0.0 | 0.0 | 3.6 | 22.5 | -1.6 | - | 1.2 | 0.1 | 5.6 |

Compared to the BAU scenario, using high efficient appliances in the DSM scenario decreases lightly the total amount of electricity imported and reduces significantly the electricity generated from conventional coal-fired plants, whereas electricity production from renewables, large hydro and gas-fired plants are more exploited. In this case, the total electricity generation from coal-fired plants could be reduced by 26.1% (835 TWh) over the period from 2010 to 2040 (Table 2-6). Moreover, integrating DSM programs in the household sector could help increase lightly the average thermal efficiency as well as decrease the average expected energy not served (Table 2-7).

In term of natural energy resource conservation and energy security, Table 2-7 advises that implementing DSM programs is the most social-optimal solution to ensure energy security while conserving the natural energy resource. In this case, the country could save approximately 51 million tons of domestic coal and avoid a significant amount of imported coal of 219 million tons for producing electricity from 2010 to 2040. This difference is mainly contributing to a saving of 1.8 billion US$ in fuel and variable O&M cost. However, the simulation suggests that the country would slightly increase the use of natural gas: the demand for natural gas resource in the BAU scenario is only 471 billion $m^3$ compared to 479 billion $m^3$ in DSM scenario.

*Table 2-7: The benefits of energy-efficiency improvement from the perspectives of domestic energy security, the cost improvements, and the environmental benefits over2010-2040. Simulations of the Vietnamese power sector were carried out using the IRP model.*

| Implications | DSM | BAU | Avoided (absolute) | Avoided (%) |
|---|---|---|---|---|
| **1. Electricity utility planning** | | | | |
| Total generation capacity added over 2010-2040 (MW) | 119,627 | 128,927 | 9,300 | 7.21 |
| Total generation capacity installed up to 2040 (MW) | 148,640 | 157,940 | 9,300 | 5.89 |
| Average expected energy not served (GWh) | 11,221.8 | 11,638.8 | 417 | 3.58 |
| Average thermal efficiency (%) | 43.22 | 43.08 | 0 | -0.32 |
| **2. Implications for energy resource conservation and energy security** | | | | |
| Domestic fuel consumption over 2010-2040 | | | | |
| Coal (million tons) | 1,448 | 1,499 | 51 | 3.43 |
| Gas (billion m3) | 479 | 471 | -8 | -1.62 |
| Imported fuel consumption over 2010-2040 | | | 0 | |
| Coal (million tons) | 762 | 981 | 219 | 22.34 |
| Gas (billion m3) | 0 | 0 | 0 | |
| Oil (million tons) | 9.0 | 9.1 | 0.1 | 1.06 |
| Imported electricity during 2010-2040 (TWh) | 742.2 | 743.1 | 1 | 0.13 |
| **3. Financial and cost improvements** | | | | |
| Capital cost during 2010-2040 (million $) | 27,272 | 28,838 | 1,566 | 5.43 |
| Fuel and variable O&M costs during 2010-2040 (million $) | 60,696 | 62,539 | 1,843 | 2.95 |
| Fixed O&M costs during 2010-2040 (million $) | 15,744 | 16,142 | 399 | 2.47 |
| Total fuel and O&M costs during 2010-2040 (million $) | 76,440 | 78,681 | 2,241 | 2.85 |
| Total DSM cost (million $) | 605 | | | |
| Total discounted planning cost during 2010-2040 (million $) | 103,712 | 107,519 | 3,807 | 3.54 |
| Average incremental cost AIC ($cent/kWh) | 4.59 | 4.59 | 0 | 0.00 |
| Long run average cost LRAC ($cent/kWh) | 4.31 | 4.32 | 0.01 | 0.23 |
| **4. Environmental benefits** | | | | |
| Total emissions during 2010-2040 | | | | |
| $CO_2$ emission (Mton) | 6464 | 7156 | 692 | 9.67 |
| $SO_2$ emission (Kton) | 13354 | 15301 | 1947 | 12.73 |
| $NO_X$ emission (Kton) | 7170 | 8042 | 871 | 10.84 |

As simulation results in the Table 2-7, the avoidance of new energy capacity in the DSM scenario significantly reduces 1.6 billion US$ (5.43%) of capital investment for the expansion plan compared to the BAU scenario. In addition, the reduction in electricity production would additionally contribute to a saving of 2.2 billion US$ in total cost expenditures during the planning horizon from 2010 to 2040. In other words, improving energy use in the household sector could help Vietnamese Government release its pressure on financing the expansion of power sector and could also reduce the electricity production cost by 0.01 $cent/kWh, in term of long run average cost (LRAC), for the period of 2010-2040. Though this reduction is relatively small in absolute term, it would ease stresses on household budgets and Government energy bills in the context of increasing energy costs in Vietnam.

Furthermore, the Table 2-7 illustrates quantitatively how energy efficiency is suggested as the cost-effective way to reduce emission of $CO_2$ and the health and environmental effects causing by increased use of fossil fuels for electricity production in Vietnam. By replacing conventional appliances with high efficient ones in the household sector, the country could cut down the sector cumulative $CO_2$ emissions by 9.7% (over 7,156 Mt) and avoid 12.7% of total cumulative 15 Mt $SO_2$ and 10.8% of total cumulative 8 Mt $NO_X$ emissions emitted during the 2010-2040 period. This reduction decreases the baseline intensity of carbon emission from 0.51 $tCO_2$/MWh to 0.49 $tCO_2$/MWh on average.

Particularly, the IRP simulation suggests that improving energy efficiency in the Vietnamese household sector is a “no-regret” option. Financially, this would represent a “free lunch” for reductions in $CO_2$ emissions. With this “free lunch” effect, the cost of abatement is negative. However, while substantial opportunities clearly exist for improving energy efficiency on the demand side in Vietnam, the “free lunch” has not been significantly internalized by the market. There are a number of key barriers that have prevented the development of meaningful impacts to date. These include: (i) lack of information and scepticism, (ii) insufficient readily available expertise, (iii) energy pricing, (iv) high project development costs, (v) lack of affordable financing, (vi) poor customer creditworthiness, (vii) limited interest of end-users, (viii) limited local energy efficiency and high quality equipment, (ix) cost-consciousness, (x) a lack of supportive policies, (xi) behavioural inertia (World Bank, 2008b; JICA, 2009; World Bank, 2010a; Nguyen et al., 2010).

Last but not least, we find that with the baseline development scenario for the Vietnamese power sector simulated in the present study, the cost-effective penetration of high efficient appliances into the household sector would be very limited in the IRP simulation during the early years, from 2010 to 2015. This is because, in fact, a number of generation plants especially hydro power plants, are committed for being put into services for the period of 2010-2015. Therefore, a red message is given to energy policymakers that the expansion plan for electricity generation capacity should be, in practice, carefully planned and taken consistently with the penetration of energy efficiency programs, otherwise it potentially causes an overcapacity in the system.

## 2.4 Concluding remarks

The study already showed that Vietnam is a country of very high power intensity suggesting that inefficient energy use, in terms of energy technology and behaviour, should exist within the given absence of price incentive. So, now more than ever, Vietnam cannot afford to continue to waste energy otherwise the country could endure inevitable consequences of vulnerability affecting its power sector and the economy as well. To reduce the potential vulnerability, the country should aim to lower its power intensity by putting in place of stronger programs and policies for promoting energy efficiency.

The study proved that more aggressively pursuing measures to improve energy efficiency is the best single energy option to reduce any potential vulnerability and towards sustainability for the Vietnamese power sector. Particularly, it could help the country ease its budget pressures for the expansion of power sector, change the current pattern of energy use into a more sustainable one that is better prepared for possible vulnerable circumstances in the future, diversify the generation fuel mix while ensuring energy security. Specially, it could also help conserve indigenous natural energy resources and reduce the increasing dependence on imports for future electricity production over the next three decades. Last, energy efficiency improvements are the cost-effective way to combat the evolution of $CO_2$ emissions in the Vietnamese power sector and alleviate pollution emissions. Specially, improving energy efficiency in the Vietnamese household sector offers a “free lunch” for $CO_2$ emissions reduction in the power sector.

The point of interest is that the current national energy development policy based on large capacity of nuclear energy for fulfilling the rapid but uncertain increase in electricity demand may not be the cost-effective way to ensure energy supply security as compared to the cheapest and simpler, safer and more cost-effective measures of improving energy efficiency. Moreover, if energy efficiency improvements are successfully implemented, the sector could limit the risks of radioactive wastes from this nuclear option.

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## Chapter 3. Renewables can provide diverse energy supplies and environment preservation

### 3.1 Introduction of Chapter 3

Renewable energy is widely seen as an important option of energy supply, especially when the world is moving towards a sustainable energy path. Many scientific studies[7]have demonstrated renewables can play as a key driver towards clean, reliable, secure and competitive energy supply. For Southeast Asian countries, IEA (2010a) argued the urgent needs for broader deployment of renewables in order to debate attendant challenges: greater dependence on fossil fuels for ensuring energy supply security, concerned severe air quality problems, rising pressure on the request of electrification for rural development and poverty reduction.

In this chapter, we attempt to give new insights about what it is possible to do in terms of generating electricity and reducing carbon emissions in Vietnam. The originality of this study is to explore the potential of all renewable energy sources together for electricity generation in Vietnam towards sustainability. To this end, using the IRP model we analyze the optimized integration of a large array of grid-connected renewable energy technologies, i.e. small hydro, geothermal, biomass, wind, solar, etc., in the power electric generation system to meet the challenges of soaring electricity demand, growing environmental concerns, energy pricing climax, and energy security over the period 2010-2040.

### 3.2 National renewables resources: large but untapped technical potential

Vietnam has lots of diversified renewable energy sources. They include small hydro, biomass (bagasse, MSW, rice husk, paddy straw, wood residues, wood plantation), geothermal, wind power, and solar energy.

*Hydro energy:* As a country endorsed with renewables resource, Vietnam has an economic potential of approximately 84 TWh (20.5 GW) distributed over nine major river basins (*Lo-Gam-Chay, Da, Ma, Vu Gia-Thu Bon, Ba, Se San, Srepok, Dong Nai*) and others. Of this potential, above 4 GW and 16.5 TWh/year come from small (≤ 30 MW) and mini (≤ 1 MW) hydro sources (SWECO, 2005; PECC1, 2005; Electricity of Vietnam, 2007b; Institute of Energy, 2008a).

A recent estimation of the Institute of Energy (2008a) determined the economic potential of small hydro power in Vietnam, which is categorized in various ranges of capacity:

- Capacity range: 0,1÷ <1MW, above 378 stations with estimated capacity of 1,268 MW.
- Capacity range: 1÷ <5MW, above 394 stations with estimated capacity of 1,030 MW.
- Capacity range: 5 ÷ <10MW, above 145 stations with estimated capacity of 1,050 MW.

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[7] Sims et al., 2003; IEA, 2007; Martinot et al., 2007; Lund, 2007; IEA, 2008b; IEA, 2009e.

- Capacity range: 10 ÷ <15MW, above 52 stations with estimated capacity of 650 MW.
- Capacity range: 15 ÷ <20MW, above 21 stations with estimated capacity of 670 MW.
- Capacity range: 20 ÷ <25MW, above 13 stations with estimated capacity of 310 MW.
- Capacity range: 25 ÷ <30MW, above 10 stations with estimated capacity of 300 MW.

*Figure 3-1: Distribution of small hydro sources.*

Source: International Small-Hydro Atlas for Vietnam

Mostly, the potential of small hydropower spreads out over the mountainous areas in the North, South Central part, and Central highland territory of Vietnam (Figure 3-1). Table 3-1 summaries the proven potential of small hydro sources that could be exploited for electricity generation.

*Hydro pump storage energy:* It is estimated that Vietnam has a large potential of hydro pump storage energy and over 10 GW of hydro pump storage plants will be constructed by Electricity of Vietnam by 2018 in the northern and southern areas of the country (Electricity of Vietnam, 2007a).

*Table 3-1: Proven potential of small hydro power distributed over the provinces in Vietnam.*

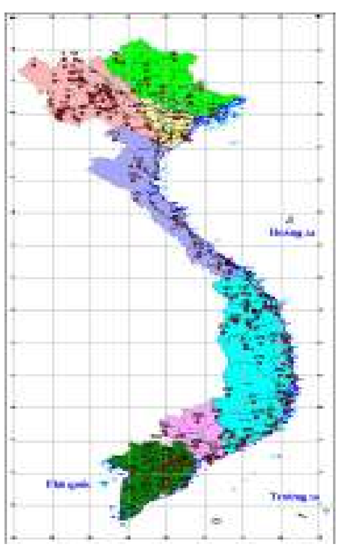
| No. | Provinces | Projects | Total installable capacity (MW) | Total annual energy (GWh) |
|---|---|---|---|---|
| 1 | Lai Chau | 14 | 64 | 295 |
| 2 | Dien Bien | 7 | 68 | 283 |
| 3 | Son La | 19 | 114 | 512 |
| 4 | Cao Bang | 16 | 31 | 155 |
| 5 | Lang Son | 9 | 28 | 133 |
| 6 | Bac Can | 4 | 12 | 66 |
| 7 | Lao Cai | 39 | 536 | 2,567 |
| 8 | Yen Bai | 25 | 231 | 1,056 |
| 9 | Ha Giang | 29 | 425 | 1,867 |
| 10 | Hoa Binh | 2 | 10 | 42 |
| 11 | Tuyen Quang | 5 | 17 | 75 |
| 12 | Quảng Ninh | 2 | 10 | 40 |
| 13 | Thanh Hoa | 8 | 17 | 74 |
| 14 | Nghe An | 16 | 131 | 551 |
| 15 | Ha Tinh | 8 | 102 | 436 |
| 16 | Quang Binh | 2 | 5 | 22 |
| 17 | Quang Tri | 3 | 10 | 45 |
| 18 | T. Thien Hue | 6 | 49 | 228 |
| 19 | Da Nang | 3 | 10 | 43 |

| No. | Provinces | Projects | Total installable capacity (MW) | Total annual energy (GWh) |
|---|---|---|---|---|
| 20 | Quang Nam | 27 | 107 | 875 |
| 21 | Quang Ngai | 10 | 72 | 315 |
| 22 | Binh Dinh | 11 | 60 | 257 |
| 23 | Phu Yen | 1 | 71 | 297 |
| 24 | Khanh Hoa | 5 | 62 | 477 |
| 25 | Ninh Thuan | 5 | 14 | 78 |
| 26 | Binh Thuan | 4 | 20 | 87 |
| 27 | Binh Phuoc | 10 | 38 | 171 |
| 28 | Dac Nong | 15 | 139 | 616 |
| 29 | Dac Lac | 12 | 82 | 335 |
| 30 | Gia Lai | 28 | 184 | 840 |
| 31 | Kon Tum | 27 | 141 | 657 |
| 32 | Lam Dong | 45 | 288 | 1,246 |
| | Total | 1,050 | 4,045 | 16,741 |

Source: Institute of Energy (2008).

*Geothermal energy:* This is one of the clean energy supply resources still-wasting even the country is listed as a country of potential on the world map of geothermal energy (Institute of Energy, 2008a). Six regions with proven potential are determined: the Northwest, Northeast, Bac Bo plain, North central part, South central part, and Southern plain (Figure 3-2).

*Figure 3-2: Location of geothermal energy sources.*



According to Hoang H. Quy (1998), and Hoang and Ho (2000) Vietnam has more than 300 hot streams ranging in temperature from 30 °C to 148 °C, in which approximately 1,000 MW could be developed for direct use and 400 MW for producing electricity by 2030. To date, there is no electricity generated from geothermal energy. There are few preliminary assessments performed by Government agencies identifying a potential capacity of 472 MW that could be used for electricity production (Institute of Energy, 2008a; Institute of Energy, 2009; MOIT, 2009). Table 3-2 defines 30 sites of geothermal energy sources that could be exploited at the industrial scale and Table 3-3 determines those potentially developed for electricity production in the near future.

Source: Institute of Energy (2008).

*Solar energy:* Vietnam is located in Southeast Asia. Its territory ranges from 23°23’ to 8°02’ North latitude and from 102°06’ to 109°28’ East longitude. Thus Vietnam possesses quite large constant solar sources spreading over the country’s territory. But it doesn’t allocate uniformly among regions due to different geographical and climate features. In the South and Central, solar radiation levels vary from 4.1 to 5.9 kWh/$m^2$/day uniformly distributed over the land throughout the year (Table 3-4). In contrast, the solar energy in the North fluctuates seasonally, varying from 2.4 to 5.6 kWh/m2/day over the course of the year (ESMAP, 2004; Institute of Energy, 2008a; MOIT, 2009). To date, there are no detailed reports to assess the overall potential of solar energy for producing electricity in Vietnam.

*Table 3-2: Characteristics of different exploitable geothermal energy sources in Vietnam.*

| No. | Name of sources | Provinces | Temperature ($^{o}C$) | |
|---|---|---|---|---|
| | | | Above earth surface | High depth |
| 1 | Pac Ma | Lai Chau | 66 | 200 |
| 2 | Sin Chai | Lai Chau | 74 | 165 |
| 3 | Ban Sang | Lai Chau | 56 | 19) |
| 4 | Pe Luong | Đien Bien | 57 | 194 |
| 5 | Pom Lot | Đien Bien | 74 | 168 |
| 6 | Pac Vat | Đien Bien | 62 | 186 |
| 7 | Na Hai | Đien Bien | 78 | 150 |
| 8 | Nam Pam | Lao Cai | 50 | 200 |
| 9 | Bo Đot | Ha Giang | 72 | 208 |
| 10 | My Lam | Tuyen Quang | 64 | 146 |
| 11 | Kim Đa | Nghe An | 74 | 164 |
| 12 | Son Kim | Ha Tinh | 78 | 178 |
| 13 | Bang | Quang Binh | 100 | 193 |
| 14 | Huyen Co | Quang Tri | 70 | 217 |
| 15 | Thanh Tan | Thua Thien Hue | 67 | 210 |
| 16 | Dương Hoa | Thua Thien Hue | 68 | 185 |
| 17 | Que Loc | Quang Nam | 58 | 210 |
| 18 | Que Phong | Quang Nam | 64 | 208 |
| 19 | Phu Ninh | Quang Nam | 71 | 146 |
| 20 | Thach Bich | Quang Ngai | 68 | 165 |
| 21 | Nghĩa Thắng | Quang Ngai | 78 | 152 |
| 22 | Mo Đuc | Quang Ngai | 80 | 184 |
| 23 | Hoi Van | Binh Đinh | 83 | 142 |
| 24 | Phu Sen | Phu Yen | 71 | 145 |
| 25 | Tu Bong | Khanh Hoa | 73 | 149 |
| 26 | Hoc Chim | Khanh Hoa | 71 | 178 |
| 27 | Đanh Thanh | Khanh Hoa | 72 | 135 |
| 28 | Ta Cu | Binh Thuan | 78 | 153 |
| 29 | Suoi Luong | Kon Tum | 63 | 136 |
| 30 | Binh Chau | Ba Ria Vung Tau | 82 | 160 |

Source: Institute of Energy (2008a).

*Table 3-3: Characteristics of different exploitable geothermal energy sources in Vietnam.*

| No. | Location | Provinces | Surface temperature (oC) | Tank temperature (oC) | Exploitable capacity (MW) |
|---|---|---|---|---|---|
| 1 | Bo Đươt | Ha Giang | 71.5 | | 20 |
| 2 | Pac Ma | Lai Chau | 63.5 | | 20 |
| 3 | Sin Choi | Lai Chau | 74 | | 20 |
| 4 | Ta Pin | Lai Chau | 60 | | 15 |
| 5 | Pom lot | Lai Chau | 74.5 | | 20 |
| 6 | Pac Vat | Lai Chau | 62 | | 15 |
| 7 | My Lam | Tuyen Quang | 64 | | 10 |
| 8 | Kenh Ga | Ninh Binh | 53 | | 5 |
| 9 | Cua Đat | Thanh Hoa | 50.8 | 156.6 | 15 |
| 10 | Kim Đa | Nghe An | 73.5 | 163 | 20 |
| 11 | Som Kim | Ha Tinh | 78 | 189 | 20 |
| 12 | Bang | Quang Binh | 105 | 184 | 23.3 |
| 13 | Huyen Co | Quang Tri | 70.5 | 189 | 20 |
| 14 | Thanh Tan | Thua Thien- | 67.3 | 160 | 15 |
| 15 | Duong Hoa | Thua Thien- | 68 | 189 | 15 |
| 16 | Ky Que | Quang Nam | 71.5 | 120 | 15 |
| 17 | Tay Vien | Quang Nam | 62 | 141 | 10 |
| 18 | Ta Vi | Quang Nam | 68 | 140 | 15 |
| 19 | Nghia | Quang Ngai | 80 | 150 | 18 |
| 20 | Mo Đuc | Quang Ngai | 81 | 187 | 21,1 |
| 21 | Vinh Thinh | Binh Đinh | 74 | 143 | 15 |
| 22 | Hoi Van | Binh Đinh | 84 | 150 | 18 |
| 23 | Đak Coi | Kon Tum | 65 | 133 | 10 |
| 24 | Lang Ria | Kon Tum | 65 | 133 | 10 |
| 25 | Triem Đuc | Phu Yen | 73 | 126.5 | 15 |
| 26 | Phu Sen | Phu Yen | 70.5 | 126 | 15 |
| 27 | Tu Bong | Khanh Hoa | 72 | 151 | 18 |
| 28 | Ninh Hoa | Khanh Hoa | 68 | 127 | 10 |
| 29 | Đanh Thanh | Khanh Hoa | 72.5 | 140 | 14 |
| 30 | Binh Chau | Ba Ria Vung | 83 | 138 | 15 |
| | | | | Total: | 472.4 |

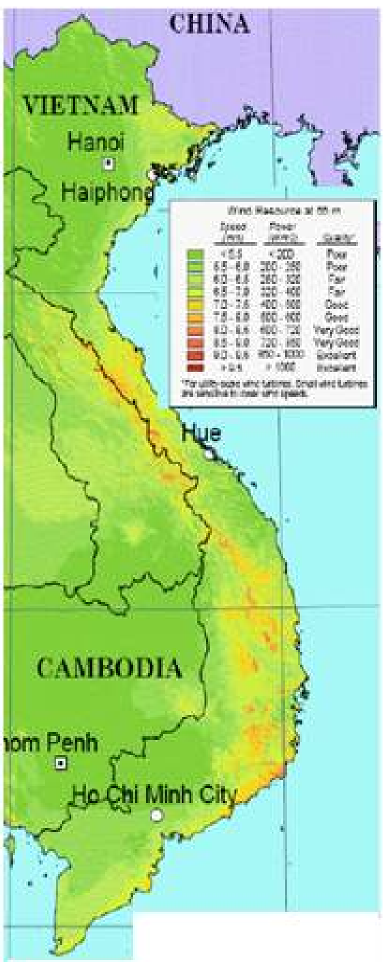
Source: Institute of Energy (2008a).

*Table 3-4: Solar radiation levels at different typical locations in Vietnam.*

| No. | Location | Total radiation level | | No. of sunny hours/year (hrs) | Electricity generation of a 120Wp PV solar panel (kWh/year) |
|---|---|---|---|---|---|
| | | Cal/cm2/day | Wh/m2/day | | |
| 1 | Ha Giang | 301 | 3,496 | 1,437 | 86.22 |
| 2 | Lao cai | 320 | 3,722 | 1,588 | 95.3 |
| 3 | Dien Bien | 383 | 4,456 | 2,015 | 120.89 |
| 4 | Hoa Binh | 325 | 3,780 | 1,621 | 97.25 |
| 5 | Thanh Hoa | 357 | 4,155 | 1,668 | 100.1 |
| 6 | Quang Tri | 353 | 4,105 | 1,887 | 113.2 |
| 7 | Pleiku | 408 | 4,740 | 2,377 | 142.62 |
| 8 | Qui Nhon | 404 | 4,702 | 2,559 | 153.51 |
| 9 | Nha Trang | 456 | 5,305 | 2,554 | 153.22 |
| 10 | Phan Thiet | 511 | 5,937 | 2,911 | 174.66 |
| 11 | Soc Trang | 405 | 4,708 | 2,400 | 143.97 |

Source: MOIT (2009).

*Figure 3-3: Wind map at 65m.*




Source: World Bank (2001).

*Wind energy:* Vietnam locates in the range $8^0$–$23^0$ North latitude within the monsoon tropical climate area with a long coastline of above 3,000 km making it be the richest country of wind power resources in the South East Asia. Some regions, mainly at the coastline areas, are suited exceptionally well for wind power deployment due to abundant resources and high proximity to population centres.

As an evaluation by World Bank (2001), with over 3,000 km of seashore and 70% mountainous land, Vietnam has about 513 GW of theoretical wind power capacity. This figure is 10 times the peak load demand forecast for the year 2020. Figure 3-3 shows a map of wind power resource at 65m in Vietnam and the key findings of this World Bank's study are summarized in Table 3-5.

However, in the World Bank study, no restrictions on technical and/or economical feasibility have been considered. Some arguments, hence, suggested that the estimation by the World Bank (2001) is very optimistic (MOIT, 2009; Fitchner, 2009; Phung Bui, 2009).

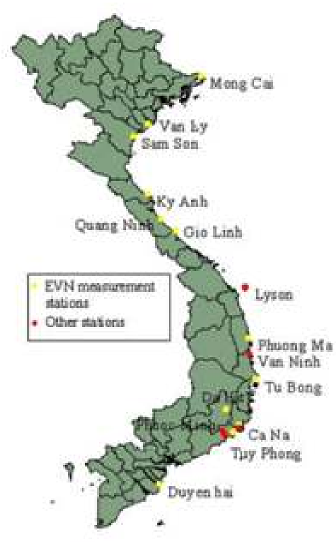
Khanh Nguyen (2007a) further improved the World Bank's findings using a multi-step evaluation process aided by a geographical information system (GIS). It found that 120.5 GW of wind capacity could be potentially deployed for generating electricity, but did not differentiate between wind classes. So far, the EC-ASEAN Energy Facility Program (2007) estimated about 22.4 GW in capacity that could be used for providing electricity in Vietnam under different three levels of wind speed: "relatively high", "high", and "very high".

*Table 3-5: Wind Energy Potential in Vietnam, estimated by World Bank (2001).*

| Classification | Low | Medium | Relative high | High | Very high | Total |
|---|---|---|---|---|---|---|
| Average wind speed | < 6 m/s | 6-7 m/s | 7-8 m/s | 8-9 m/s | > 9 m/s | |
| Area ($km^2$) | 197,242 | 100,367 | 25,679 | 2,178 | 111 | |
| Area (%) | 60.6% | 30.8% | 7.9% | 0.7% | > 0% | 100% |
| Potential (MW) | | 401,444 | 102,716 | 8,748 | 452 | 512,864 |

Source: World Bank (2001).

*Figure 3-4: Measurement stations.*




Source: MOIT (2009).

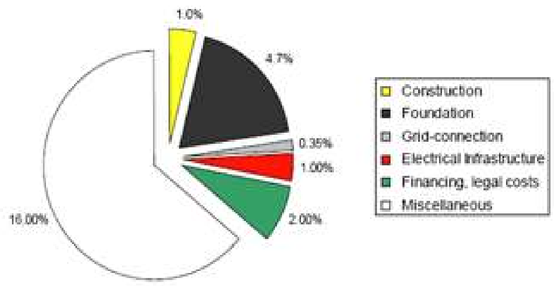
To EVN, it has also implemented an separate assessment within 12 regions including Mong Cai, Quang Lan island (Quang Ninh), Do Son (Hai Phong), Ly Son island (Quang Ngai), Van Linh (Khanh Hoa), Phuong Mai (Binh Dinh) Ninh Phuoc and Ca Na (Ninh Thuan), Tuy Phong and Luong Son (Binh Thuan), Duyen Hai, etc (Figure 3-4).

As a result, a total 1,785 MW is estimated economically for EVN to construct wind power plants, mostly concentrating in the Central region[8] (PECC4, 2007; PECC3, 2007; Institute of Energy, 2007a; MOIT, 2009).

Recently, Fitchner (2009) carried out a more detailed classification of wind power potential in Vietnam in dependence of different economic levels. It used most recent costs related to wind power facilities, including the local costs (Figure 3-5) to calculate cumulative frequency distribution of the levelised electricity costs (LEC) over all the sites differentiated between site quality (Table 3-6 and Figure 3-6). Based on the current situation of the Vietnamese power sector, Fitchner (2009) suggested a total wind power capacity of 629 MW to be economically developed for electricity production up to 2020.

[8] The figure of this technical potential is not fully estimated as the project also focused on the regions next the coastline. Therefore, it would need further investigation/studies in order to build up the overall picture of wind resources in Vietnam (MOIT, 2009).

*Figure 3-5: Local costs for wind power development.*



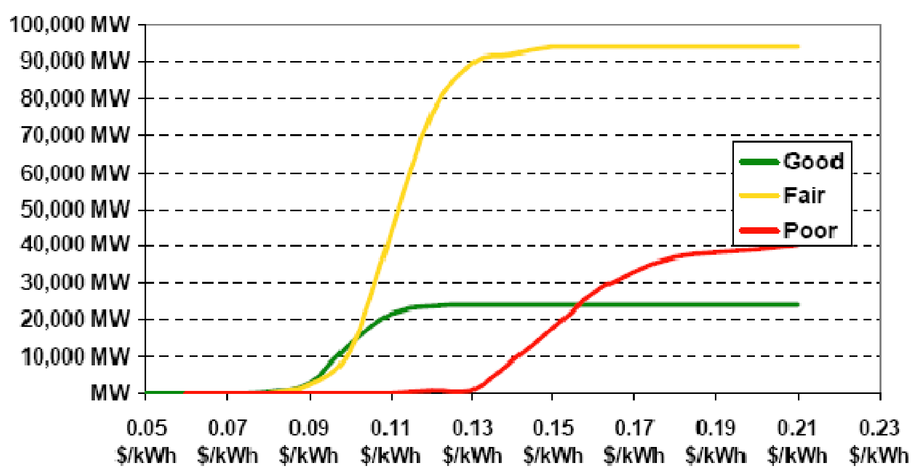

Source: FICHTNER, 2009.

*Table 3-6: Modified wind power potential from World Bank (2001) & Khanh Nguyen (2007a).*

| Wind classification | Fair | Good | High | Very high | Total |
|---|---|---|---|---|---|
| Average wind speed | 6-7 m/s | 7-8 m/s | 8-9 m/s | > 9 m/s | - |
| Area (km$^2$) | 100,367 | 25,679 | 2,178 | 111 | - |
| Area (%) | 30.8% | 7.9% | 0.7% | > 0% | 100% |
| Potential (MW) | 94,230 | 24,110 | 2,053 | 106 | 120,500 |
| Percentage of total | 78.2% | 20% | 1.7% | 0.1% | - |

Source: Fitchner (2009).

*Figure 3-6: Potential new capacity of wind power in dependence of LECs.*




Source: Fitchner (2009).

*Biomass energy:* Vietnam has abundant biomass resources that could be used for electricity generation purpose. They include: biogas to rice husk, paddy straw, bagasse (sugar cane, coffee husk, and coconut shell), wood and other agricultural residues, municipal solid wastes (MSW), and wood plantation. There are a number of studies providing different results on the potential of biomass resources. Nguyen and Tran (2004) estimated about 1,350 MW from rice husk, bagasse, and paddy straw that could be exploited for electricity production, whereas Institute of Energy (2008a) determined only 715 MW being economically used for producing electricity by 2025. Of this potential, bagasse accounts for 43.4%, rice husk 15.4%, wood and other residues 7%, and the rest of 34.2 from MSW.

In this study, basing on the relevant database[9] we further performed an assessment of biomass potential using a broader range of usable factors for electricity production from different types of agricultural residues and production. As results, about 2,085 MW could be economically exploited up to 2040. These include bagasse (accounting for 23%), rice husk (15.5%), wood and other residues (4.8%), MSW (13.6%), and paddy straw (43.1%). Moreover, the country possesses over 4.7 million hectares of unused land by 2008. Supposed that 70% of this unused land (3.5 million hectares) will be used to meet the demand for future agricultural use and other purposes, the remaining 1.05 million hectares (30%) of unused land could be considered for wood plantation to provide material for electricity generation with a total installable capacity of 1,800 MW.

Overall, Vietnam has lots of diverse sources of renewables but they are not yet fully exploited. Table 3-7 further presents how they are fully untapped for electricity generation until now.

*Table 3-7: Summaries that Vietnam has many renewable energy resources yet fully exploited.*

| **Energy resources** | **Economical potential** | **Current development in 2009** | **Development planned up to 2025** | **Development estimated up to 2040** | **Maximum exploitable potential** |
|---|---|---|---|---|---|
| Hydro | 84 TWh/yr | | | | |
| + Large hydro (>30 MW) | 18-20 GW | 9 GW | 17 GW | 17 GW | 17 GW |
| + Small hydro (<30 MW) | 4,045 MW | 500 MW | 3,250 MW | 4,045 MW | 4,045 MW |
| + Mini hydro (<1 MW) | 100 MW | | | | |
| Hydro pump storage | 10.2 GW | Negligible | 10.2 GW | 10.2 GW | 10.2 GW |
| Geothermal | 1.4 GW (1) | Negligible | 340 MW | 472 MW | 472 MW |
| Wind energy | 22 GW | Negligible | 560 MW | 840 MW | 6,000 MW(2) |
| Solar energy | - | Negligible | 3-5 MW | 10 MW | Not defined |
| Rice husk | 323 MW | Negligible | 113 MW | 113 MW | 323 MW (3) |
| Paddy straw | 898 MW | Negligible | - | - | 898 MW (4) |
| Bagasse | 480 MW | 30 MW | 310 MW | 480 MW | 480 MW |

9 (i) literatures and reports (COGEN, 2001; Enerteam, 2001; Nguyen and Tran, 2004; Institute of Energy, 2008a; Nguyen and Ha-Duong, 2009; MOTI, 2009; Enerteam, 2009); (ii) National Statistics Data (Statistics Yearbook 1995-2009; Vietnam General Statistic Office; World Bank Database); (iii) projections of growth rates for population and urbanization prospects, future agricultural productions, and households' and commercial needs for agricultural residues (United Nations, 2009; ADB Projects Database; Le, 2009, Decision 26/2007/QĐ-TTg, MARD); and (iv) development plans and overall studies for renewable energy (World Bank, 2002; Institute of Energy, 2008a; Enerteam, 2009; ISE, 2009; MOIT, 2009),

| Energy resources | Economical potential | Current development in 2009 | Development planned up to 2025 | Development estimated up to 2040 | Maximum exploitable potential |
|---|---|---|---|---|---|
| MSW | 284 MW | Negligible | 245 MW | 284 MW | 284 MW |
| Wood residue | 100 MW | Negligible | 50 MW | 100 MW | 100 MW |
| Wood plantation | 1,800 MW | Negligible | - | - | 1,800 MW ([5]) |

(1) : Total potential that could be exploited for both electricity production and heating purpose.

(2) : Assumed by the author based on the above assessments.

(3), (4), (5): Estimated by the author' own combination and calculation.

Source: the author's own combination from above literature sources.

## 3.3 Economic potential of diverse renewables sources in power sector

### 3.3.1 Integrating renewables into the IRP simulation model

In this study, the economic potential of renewables energy and its implications for the development of electric power generation in Vietnam are analyzed by comparing a model run without renewables against a model run with renewables. The two scenarios will be named "B1" and "B2". The B1 scenario assumes the power sector in Vietnam for a period of 2010-2040 will not develop any renewables sources, except for large hydro and hydro pump storage. The B2 scenario assumes that during the same period, a number of renewables sources will be considered for sustainable development of electric power generation in Vietnam. The B2 scenario applied in the present study coincides exactly with the baseline development used for the whole thesis study (BAU scenario). In this baseline scenario, the quantity of renewables for electricity generation that determined by the official Vietnamese Government agencies, are fewer than the economically feasible potential assessed by our present study.

All the data on energy resources (including renewables and non-renewables), and candidate generation technologies are presented in Table 3-8, Table 3-9, and Table 3-10 respectively. Both scenarios assume that there are no direct climate change policy interventions and demand-side management are not used. In all other respects, the scenarios are identical and all prices are based on 2008. In addition, we also carry out a sensitivity analysis assuming higher levels of energy prices and a restriction of energy supply sources. More details will be presented in the sensitivity analysis.

In the IRP simulation, 2 seasons (rainy and dry) are modelled in a year. The load curve in a day of a season is divided into 24 blocks (1 hour/block). Renewable energy (such as wind, solar, and small hydro) generation is modelled correlatively to its intermittent nature. In the IRP, the dispatch of renewables-based generation plants is modelled depending on their energy source availability, i.e. generation of wind/solar technology depends on the available level of wind, sunlight in each block of a day, and that of small hydro depends on the water level in each season. Moreover, in this study the stand-by capacity requirement is modelled for the whole power electric generation system under the utility's least cost perspective (i.e. there is a reliability system constraint and the peak reserve margin of system capacity is set corresponding to the operation stipulation of the national load dispatching centre), instead of for each individual plant because electricity market is not available yet in Vietnam. And the cost of this stand-by system capacity is modelled identically for all scenarios' analysis.

*Table 3-8: The renewable energy resources are exploited for electricity generation in the B2 scenario (or baseline (BAU) scenario) from 2020-2040.*

| Resource | 2020 | 2025 | 2030 | 2040 |
|---|---|---|---|---|
| Small/mini hydro | 1200 | 3250 | 3500 | 4045 |
| Baggases | 268 | 308 | 310 | 480 |
| Rice husk | 110 | 110 | 113 | 113 |
| Wood and other residues | 23 | 46 | 50 | 100 |
| Municipal solid waste | 57 | 232 | 245 | 284 |
| Wind power | 484 | 556 | 690 | 840 |
| Geothermal | 100 | 250 | 340 | 472 |
| PV Solar | 4 | 6 | 8 | 10 |

Source: the author's own combination from Electricity of Vietnam (2007), Institute of Energy (2008a), Institute of Energy (2009), MOIT (2009).

*Table 3-9: Quantitative estimates and assumptions of fuels and electricity imports to meet electricity demand in Vietnam during 2010-2040.*

| | Estimated quantity of fuels for electricity generation (unit/year), by Vietnamese agencies | | | Assumptions for the baseline and other scenarios in IRP (unit/year) | Assumptions for sensitivity analysis in IRP (unit/year) |
|---|---|---|---|---|---|
| **Energy fuel/electricity** | **Estimated maximum quantity in 2020-2030** | **Estimated maximum quantity in 2030-2040** | **Feasible quantity in 2020-2030-2040** | **Maximum quantity in 2020-2030-2040** | **Maximum quantity in 2020-2030-2040** |
| Dom. coal (million tons) | 60-70 | 75-100 | 65-75-100 | 65-75-100 | 57-70-90 |
| Imp. Coal (million tons) | 45-90 | 90-120 | 45-80-120 | 45-80-120 | 45-70-90 |
| Dom. Gas (billion $m^3$) | 14 | 20-23 | 14-20-23 | 14-20-23 | 14-20-20 |
| Imp. Gas (billion $m^3$) | 4-5 | 8-13 | 4-7-8 | 4-7-8 | 4-7-8 |
| Electricity (MW) | 5,000-5,800 | 8,000-9,000 | 5,000-5,800-5,800 | 5,000-5,800-5,800 | 3,000-4,600-4,600 |
| Nuclear (GW) | 10 | 15-16 | 2-8-16 | 2-5-10 | 2-4-6 |

Source: the author's own combination from different data sources.

*Table 3-10: Cost (based on 2008 price) and performance specifications of selected candidate power generation technologies without CCS considered for the study's analysis, 2010-2040.*

| No. | Candidate plants | Capital cost ($/kW) 2010 | 2020 | 2030 | 2040 | Eff. (%) | Fixed O&M cost ($/kW.yr) | Variable O&M cost ($/MWh) | Life time (year) | Emission factor (kg $CO_2$/MWh) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Subcritical coal | 1300 | 1210 | 1158 | 1100 | 40 | 33.6 | 1.3 | 30 | 880 |
| 2 | Supercritical coal | 1500 | 1355 | 1300 | 1200 | 44 | 33.6 | 1.3 | 30 | 800 |
| 3 | IGCC coal | 1800 | 1643 | 1518 | 1390 | 46 | 30.8 | 1.1 | 30 | 740 |
| 4 | NGCC gas | 750 | 690 | 677 | 671 | 56 | 27 | 1.13 | 25 | 370 |
| 5 | Steam fired Gas | 1050 | 990 | 980 | 970 | 40 | 21.6 | 1.48 | 30 | 616 |
| 6 | Very large hydro | 1120 | - | - | - | 100 | 7.2 | 0 | 40 | 0 |
| 7 | Large and medium hydro | 1200-2000 | 1150-1917 | - | - | 100 | 10.08 | 0 | 40 | 0 |
| 8 | Small hydro | 1300-1450 | 1235-1378 | 1173-1309 | - | 100 | 39-44 | 0 | 40 | 0 |
| 9 | Geothermal < 5MW | 1700 | 1615 | 1480 | 1406 | 100 | 85 | 0 | 30 | 0 |
| 10 | Geothermal 10MW | 1600 | 1520 | 1368 | 1300 | 100 | 80 | 0 | 30 | 0 |
| 11 | Geothermal 15-20MW | 1560 | 1482 | 1334 | 1267 | 100 | 78 | 0 | 30 | 0 |
| 12 | Wind farm (20-60MW) | 2337 | 2123 | 1911 | 1830 | 100 | 82.41 | 0.0000128 | 20 | 0 |
| 13 | Solar PV grid connected | 6000 | 3840 | 2458 | 1573 | 100 | 75 | 0 | 20 | 0 |
| 14 | Bagasse co-firing 5MW | 1200 | 1125 | 1092 | 1092 | 23 | 36 | 0 | 25 | 0 |
| 15 | Bagasse co-firing 10MW | 1150 | 1078 | 1047 | 1047 | 23 | 23 | 0 | 25 | 0 |
| 16 | Bagasse co-firing 30MW | 1067 | 1000 | 971 | 971 | 23 | 21 | 0 | 25 | 0 |
| 17 | Biomass DC < 5MW | 1800 | 1688 | 1638 | 1638 | 16 | 34 | 0 | 25 | 0 |
| 18 | Biomass DC 5-30MW | 1700 | 1594 | 1547 | 1547 | 25 | 33-34 | 0 | 25 | 0 |
| 19 | MSW DC 7-30MW | 2500 | 2466 | 2023 | 2043 | 36 | 125 | 0 | 25 | 0 |
| 20 | Biomass gasified 30-100MW | 2000-2370 | 1907-2260 | 1861-2205 | 1814-2150 | 36-38 | 66 | 0 | 25 | 0 |
| 21 | Nuclear PWR Gen.3 | 4270 | 3725 | 3317 | 3044 | 35 | 70.1 | 5 | 60 | 0 |

Source: the author's own combination from different data sources.

### 3.3.2 Improving energy security while protecting environment

#### *3.3.2.1 Conserving domestic coal and improving energy independence*

By optimizing over a broader panel of generation technologies including conventional and non-conventional sources over the period 2010-2040 in the IRP model, the study permits to give new insights about what it is economic feasible to integrate renewables into the electricity generation portfolio and a better cost-effective comparison among generation technologies. Particularly, the study examines the quantitative differences between the two scenarios, which are summarized in Tables 3-11, Table 3-12 and Table 3-13 in term of electricity energy planning, natural energy resources conservation and energy security, cost expenditures and financing requirement, and environmental benefits.

Overall, the IRP simulates 6 GW being exploited from renewable energy technologies for the production of electricity in Vietnam over the period 2010-2040 for the baseline development. Small hydro and biomass energy (bagasse, rice husk, and wood/other residues, municipal solid wastes) account for 63.8% and 15.4% of this capacity, respectively. The rest comes from geothermal energy (7.4%), wind power and solar energy (13.4%).

*Implications for Electricity Planning:* How could the combination of diversified energy sources, including non-conventional energy sources, enable the expansion of electric power generation in Vietnam? Compared to the B1 scenario, the more effective combination of diverse energy resources in the B2 scenario reduces the total amount of electricity generated by conventional thermal plants, from 10,100 TWh to 9,556 TWh over 2010-2040 (5.4% in reduction). Specifically, the IRP simulation suggests that electricity generation based on domestic coal-fired plants can be reduced by 3.9%, imported coal-fired plants reduced by 14.2%, and oil-fired plants reduced by 3.7%. The country would also avoid 0.2% of the total electricity imported from external supplies during the same period. However, the result also shows that the electricity generation from gas-fired plants would slightly increase by 4.9%.

Moreover, compounding renewables sources with conventional sources could lightly increase the average thermal efficiency, 42.9% in the B1 scenario and 43.1% in the B2 scenario, but distinctly decrease the average capacity factor from 64.2% in the B1 scenario to 63.5% in the B2 scenario. This implies generation units that are more efficient can be effectively utilized already and some generation units that are less efficient can be relied upon less in the B2 scenario. And the grid-integration of renewables plants, which are characteristically simulated in the IRP with low capacity factors, plainly makes the total average capacity factor decreased.

We now look at the national renewable energy development targets: 3% of renewables over the total commercial energy supply by 2010, 5% by 2020 and 11% by 2050. As suggested by the IRP, with the baseline integration of renewables capacity, the sector could exceed by 2.8% the 2020 target of renewables share in energy production. However, the share of energy production from renewables trends to decrease from 7.8% by 2020 to 2.8% by 2040. This provides that in order to achieve the target of 11% by 2050, the extensive exploitation of renewables sources for electricity after 2020 should be already taken into the Government development agenda.

*Table 3-11: Electricity capacity generation in Vietnam, 2010-2040. B1: with no renewables. B2: with renewables. Simulations were carried out using the IRP model.*

| Case | Nuc-lear | Non-fossil fuel sources | | | Fossil fuel sources | | | | Imp. power | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Renew-ables | Large Hydro | Hydro Pump Storage | Dom. Coal | Imp. Coal | Dom. Gas | Oil | | |
| **Capacity installed by 2040 (GW) and percentage (%)** | | | | | | | | | | |
| B1 | 10.0 | 0.4 | 17.0 | 10.2 | 36.2 | 62.1 | 17.2 | 0.6 | 5.8 | 159.5 |
| | 6.3 | 0.3 | 10.7 | 6.4 | 22.7 | 38.9 | 10.8 | 0.4 | 3.6 | 100.0 |
| B2 | 10.0 | 6.3 | 16.8 | 10.2 | 37 | 54.1 | 17.2 | 0.6 | 5.8 | 158 |
| | 6.3 | 4.0 | 10.6 | 6.5 | 23.4 | 34.2 | 10.9 | 0.4 | 3.7 | 100.0 |
| **Electricity generation over 2010-2040 (TWh) and percentage (%)** | | | | | | | | | | |
| B1 | 788 | 51.2 | 2,070 | 389.3 | 3,881 | 3,632 | 2,550 | 37.0 | 744.5 | 14,143 |
| | 5.6 | 0.4 | 14.6 | 2.8 | 27.4 | 25.7 | 18.0 | 0.3 | 5.3 | 100.0 |
| B2 | 788 | 584.6 | 2,045 | 389.6 | 3,729 | 3,117 | 2,674 | 35.6 | 743.1 | 14,106 |
| | 5.6 | 4.1 | 14.50 | 2.8 | 26.4 | 22.1 | 19.0 | 0.3 | 5.3 | 100.0 |

*Table 3-12: Electricity capacity generation by renewables in Vietnam, 2010-2040. B2: with renewables. Simulations were carried out using the IRP.*

| Case | Small hydro | Biomass | | | | | | Geothe-rmal | Wind | Solar | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Baga-sse | Rice husk | Paddy straw | Wood residue | MSW | Sub-total | | | | |
| **Capacity installed by 2040 (MW) and percentage (%)** | | | | | | | | | | | |
| B2 | 4,045 | 480 | 113 | 0 | 100 | 284 | 977 | 472 | 840 | 10 | 6,344 |
| | 63.8 | 7.6 | 1.8 | 0.0 | 1.6 | 4.5 | 15.4 | 7.4 | 13.2 | 0.2 | 100.0 |
| **Electricity generation over 2010-2040 (TWh) and percentage (%)** | | | | | | | | | | | |
| B2 | 400.4 | 55.0 | 14.8 | 0.0 | 12.0 | 38.6 | 120.4 | 46.2 | 17.5 | 0.012 | 584.6 |
| | 68.5 | 9.4 | 2.5 | 0.0 | 2.1 | 6.6 | 20.6 | 7.9 | 3.0 | 0.0 | 100 |

*Implications for Natural Energy Resource Conservation and Energy Security:* How could more efficient use of more diverse energy resources in Vietnam, including more non-conventional sources, help the country conserve domestic energy sources and slow the drain on scarce foreign exchange reserves due to fossil fuel importing?

Table 3-13 suggests that renewable energy sources could substitute to a significant extent for domestic and imported coal. The country could save approximately 68 million tons of indigenous coal but expense an additional amount of 20 billion $m^3$ of gas for producing electricity during the specified period. Furthermore, the country could distinctly change its fuel import policies: the demand for imported resources in the B2 scenario is only 981 million tons of coal, 9.1 million tons of oil, and 743 TWh; compared to the B1 import demand of 1,139 million tons of coal, 9.4 million tons of oil, and 745 TWh. The differences are small in relative terms, but corresponds to savings of 1.9 billion US$ in fuel and variable operation and maintenance (O&M) costs over the planning horizon.

*Table 3-13: Technical, economic, and environmental comparison between the B1 scenario (no renewables) and the B2 scenario (with renewables) for the period 2010-2040. Simulations of the Vietnamese power sector were carried out using the IRP model.*

| **Implications** | **Without renewables** | **With renewables** | **Avoided (absolute)** | **Avoided (%)** |
|---|---|---|---|---|
| 1. Electricity utility implications | | | | |
| Total generation capacity installed up to 2040 (MW) | 159,464 | 157,940 | 1,524 | 0.96 |
| Total electricity generation over 2010-2040 (GWh) | 14,143 | 14,106 | 36.8 | 0.26 |
| Average thermal efficiency (%) | 42.85 | 43.08 | -0.23 | -0.54 |
| Average capacity factor (%) | 64.19 | 63.50 | 0.69 | 1.07 |
| 2. Implications for energy resource conservation and energy security | | | | |
| Domestic fuel consumption over 2010-2040 | | | | |
| Coal (million tons) | 1,567 | 1,499 | 68 | 4.31 |
| Gas (billion m3) | 451 | 471 | -20 | -4.43 |
| Imported fuel consumption over 2010-2040 | | | | |
| Coal (million tons) | 1,139 | 981 | 157.7 | 13.85 |
| Gas (billion m3) | 0 | 0 | 0.00 | 0.00 |
| Oil (million tons) | 9.4 | 9.1 | 0.30 | 3.16 |
| Imported electricity during 2010-2040 (TWh) | 744.5 | 743.1 | 1.4 | 0.18 |
| 3. Economic Implications | | | | |
| Capital cost during 2010-2040 (million $) | 27,633 | 28,838 | -1,205 | -4.36 |
| Fuel and variable O&M costs, 2010-2040 (million $) | 64,478 | 62,539 | 1,940 | 3.01 |
| Fixed O&M costs during 2010-2040 (million $) | 14,862 | 16,142 | -1,280 | -8.61 |
| Total discounted cost, 2010-2040 (million $) | 106,974 | 107,519 | -545 | -0.51 |
| Average incremental cost AIC ($cent/kWh) | 4.57 | 4.59 | -0.02 | -0.44 |
| Long run average cost LRAC ($cent/kWh) | 4.29 | 4.32 | -0.03 | -0.70 |
| Average abatement cost of $CO_2$ ($/t$CO_2$) | | | | 1.05 |
| 4. Environmental Implications | | | | |
| Total emissions during 2010-2040 | | | | |
| $CO_2$ emission (Mton) | 7674 | 7156 | 517 | 6.74 |
| $SO_2$ emission (Kton) | 16880 | 15301 | 1579 | 9.35 |
| $NO_X$ emission (Kton) | 8753 | 8042 | 711 | 8.12 |

#### *3.3.2.2 Reducing the sector's $CO_2$ emissions and local environmental effects*

*Environmental Implications:* To what extent could renewables reduce the health and environmental effects of meeting the nation's increased demand for electricity? The IRP gives analysis of the mitigation potential of renewables with respect to emission of $CO_2$ and other harmful substances in the power sector in Vietnam. Table 3-13 shows that the total cumulative $CO_2$ emissions released in the B2 scenario is reduced significantly, with 517 Mt (6.7%) over

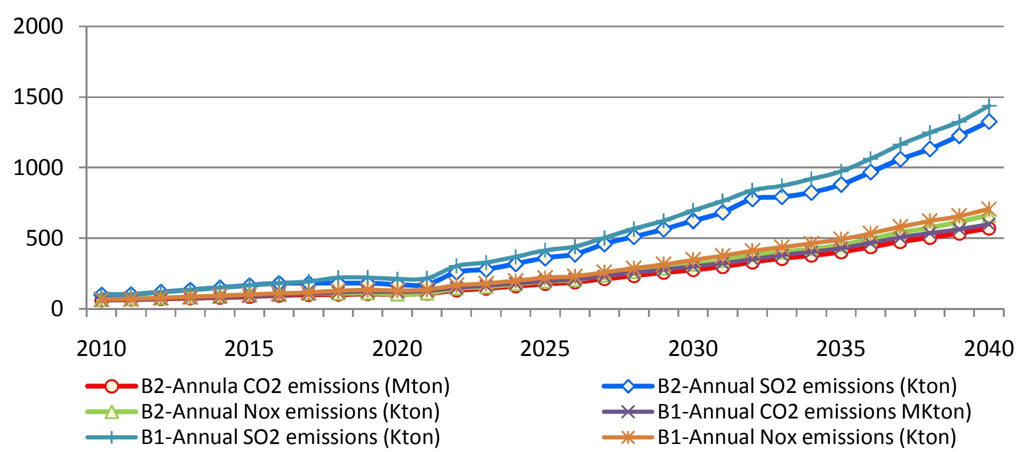
7,674 Mt emitted in the B1 scenario for the period 2010-2040. This is an average reduction of 17 Mt of $CO_2$ per year during 2010-2040, which compares favourably to the estimated 36 Mt of total $CO_2$ emissions emitted from Vietnam's electricity generation industry in 2006 (Nguyen and Tran, 2005).

Typically for this kind of bottom-up model, the average abatement cost is 1.05 US$/t$CO_2$ since the model finds an optimal solution that involves a broader array of generation technologies. Compared to the values of $CO_2$ emission damaged costs, which have been used in the World Bank's recent economic analyses ranging from 15-20US$/t$CO_2$ (MOIT, 2009), this low $CO_2$ abatement cost gives a promising signal that renewables-based electric power generation in Vietnam could offer a large possibility hosting Clean Development Mechanism (CDM) or CDM-like-mechanism-funded projects. More judicious strategy and incentive policies would need to be made in order to seize opportunities of sustainable development, if any, for the Vietnamese power sector when political uncertainty at the global level resolves for the post-2012 climate change policy.

In addition to mitigating global emission, the country could also avoid 1,579 Kt of $SO_2$ and 711 Kt of $NO_X$ emissions during the same period. This is an average reduction of 51 Kt of $SO_2$ and 23 Kt of $NO_X$ per year during 2010-2040, which compares favourably to the estimated 128 Kt of total $SO_2$ and 102 Kt of total $NO_X$ emitted by the electricity-generating industry in Vietnam in 2006 (Nguyen and Tran, 2005). Figure 3-7 illustrates the environmental implications of integrating renewables into the power sector between 2010 and 2040.

It notes here that in the present study, the optimization procedure did not take into account the environmental or health costs of energy sources. Including these costs would reduce the use of conventional thermal power plants, especially coal-fired plants. At the social optimal, emissions of $CO_2$ and other harmful substances by the electricity-generating industry in Vietnam would be reduced accordingly.

*Figure 3-7: Annual emissions of $CO_2$, $SO_2$, and $NO_X$ emitted from electricity generation during 2010-2040 in the B1 and B2 scenarios. Simulations of the IRP model.*



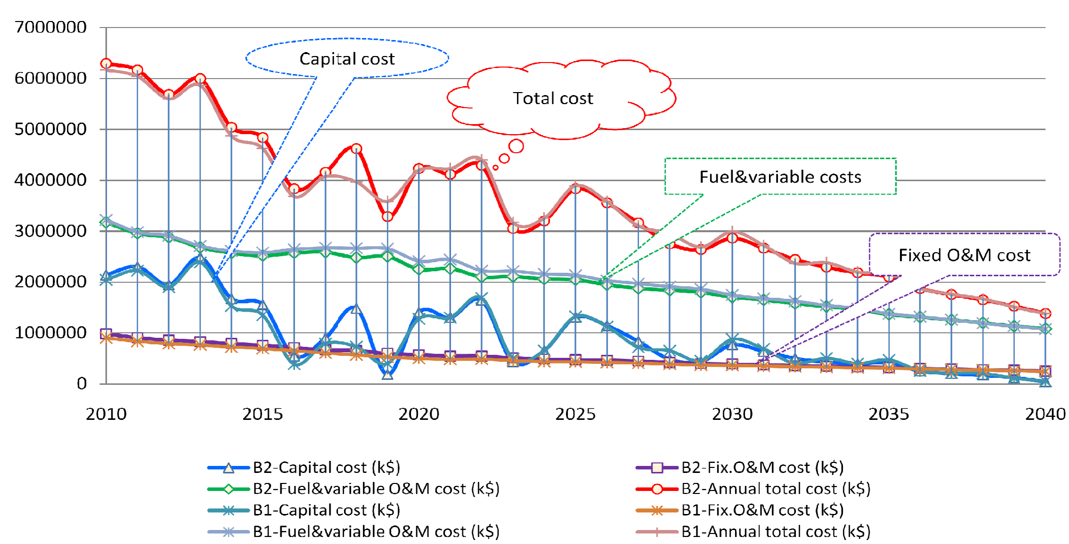
### 3.3.3 Cost and financing issues for deployment of renewables

*Cost and Pricing:* How cost-effective would the combination of diverse energy sources be for producing electricity in Vietnam?

Table 3-13 suggests that an increase of 0.51% (545 million US$) in the total discounted cost of electric power generation plan should be expensed by optimizing the inclusion of renewables in the generation mix. Table 3-13 and Figure 3-8 compare the B1 and B2 scenarios in terms of annual fuel and variable cost. Since fuel and variable cost account for 60-75% of the cost of electricity production, the lower fuel and variable costs in the B2 scenario (1.9 billion US$ lower compared to the B1 scenario) could potentially lead to lower production costs. However, that is not the case in this analysis because some of renewables technologies in Vietnam are still costly compared to conventional technologies. The IRP simulation suggests that higher capital and fixed O&M costs in the B2 scenario implies some renewables technologies could not yet become cost-effective enough to compete against conventional sources. This also leads to a slight increase by 0.03 $cent/kWh (0.7%) in the long run average cost during 2010-2040.

To deploy about 6 GW of new renewables-based power generation plants during this period, the Vietnamese Government needs to mobilize an investment of 279 million US$ per year on average. This would grow the pressure on obtaining the necessary finance for the request of expanding the electricity generation industry.

*Figure 3-8: Annual component costs of electricity generation during 2010-2040 in the B1 and B2 scenarios. Simulations of the IRP model.*




The reasons of falling over time (especially during 2030-2040) in capacity and fuels costs as indicated in Figure 3-8 would be explained as: the average electricity demand is estimated to increase by 17% in the period of 2010-2030, but the increasing rate of  peak load demand in the period of 2030-2040 is much lower, only 7%. In addition, in the IRP simulation the transmission and distribution loss is set to decrease gradually from 10.8% in year 2010 down to 7.0% by 2040. These would be leading to reducing the additional energy capacity installed, i.e. capacity and fuels costs for the additions would be falling accordingly, to meet the peak load demand over the last years of the study time frame. Furthermore, over this period of 2030-2040, some of existing less efficient plants, i.e. higher fuels consumptions, would be retired and replaced by more efficient ones with lower fuels consumptions. This would result in falling fuel prices at the later part of the study period.

*Cost-competitiveness of renewables:* How renewables-based power generation options would be cost-competitive to conventional options for ensuring energy security while enhancing energy independence for Vietnam?

This part of the study focuses on argument for seeking greater energy independence and energy security by integrating diverse energy sources for generating electricity in Vietnam under assumptions of market changes in fuels prices and insufficient fossil fuels/energy supply. Particularly, the study determines what kind of renewables could be cost-effective in some specific sensitivity cases, and how much electricity energy they could generate cost-effectively. The sensitivity cases (referred to as SA1 through SA6) are formed using different parameters: quantities of fuel/electricity imported during the period 2010-2040 (Table 3-9), which are based on the country's policy and availability of fuel/electricity sources (Institute of Energy, 2008a, 2009; Institute of Science and Energy, 2009; Institute of Strategy and Development, 2009), and changes in fossil fuels prices based on market levels observed in recent years and the World Energy Outlook (IEA, 2006b, 2007a) and World Energy Outlook (IEA, 2009e), by which the prices are assumed to increase by 2% to 3% per year. However, the study also made cross-reference check the assumptions of fuels prices with other domestic/international sources: the World Bank (WB), the Asian Development Bank (ADB), (Institute of Energy, 2009; Institute of Strategy and Development, 2009).

Table 3-14 shows among renewable generation options simulated in the baseline development (BAU scenario), small hydro (400 TWh), biomass-bagasse (55 TWh), and geothermal (46 TWh) would be exploited for electricity generation in a completely cost-effective manner, compared to conventional options, and have the largest potential for producing electricity in all sensitivity analysis scenarios. Specific incentive policies from the Vietnamese Government, thus, should be offered to these renewables sources for the next development stage in order to obtain more fully sustainable benefits that could be brought in from them. Moreover, in all cases of sensitivity, the total electricity (TWh) generated by geothermal and biomass-bagasse during the period from 2010 to 2040 would not exceed those in scenario B2. This seems that the maximum potential for these two renewables to generate electricity in a cost-effective manner is significantly achieved in the B2 scenario. Inversely, the total electricity production (TWh) by small hydro energy would lightly increase, compared to that in the B2 scenario (BAU scenario) when placing restrictions in energy supply resources and increased prices of fossil fuels in the IRP simulation.

In contrast to the small hydro, biomass-bagasse, and geothermal energy, other renewables: paddy straw, wood residues, municipal solid wastes, wood plantation, wind power, and solar energy would not be cost-competitive with conventional energy sources to produce electricity at their technology costs assumed. The following part determines the answer to the question of at what conditions would these renewables become cost-effective with fossil options in Vietnam, and how much these could be cost-effectively generated.

The IRP results suggest that all these renewable energy options could become cost-effective in the SA4 scenario where a very restricted level of energy supply resources is introduced. In this case, the renewables sources could contribute to ensure energy security by providing a total of 574 TWh to the grid during the period 2010-2040. Solar energy (70 MW) is found to be cost-effective also in this case but provides a very small amount of electricity energy. This implies that compared to other renewables, power generation technology based on solar energy is still very costly in the Vietnamese power sector.

As modelled in this sensitivity analysis, the increased level of fossil fuels prices (2-3% per year) as assumed in the SA5 case would not be incentive enough to make generation plants using biomass material (paddy straw, wood residues, municipal solid wastes, and plantation), wind power and solar energy enter the electricity generation portfolio. But, the cost-effectiveness of generation plants using rice husk is likely to be very sensitive to the change in fossil fuels prices in this case. This suggests rice husk emerges as a promising source of electricity supply in the context of the rising energy costs in Vietnam. Though our sensitivity scenarios suggest that neither wind power nor biomass energies (paddy straw, wood residues, municipal solid wastes, and plantation) would become cost-effective in the scenario of increased fuels prices, they would become cost-competitive in all other cases related to the scarcity of energy supply sources. Table 3-14 suggests the scarcer in energy supply resources given, the more electricity production provided by these renewables sources.

*Table 3-14: Energy capacity and electricity generation by type of renewable source in Vietnam, 2010-2040. B2: baseline scenario using limited renewables. SA1-SA6: different sensitivity analysis cases. Simulations were carried out using the IRP model.*

| Sensitivity analysis cases | Small hydro | Biomass | | | | | | | Geothe-rmal | Wind | Solar | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bagasse | Rice husk | Paddy straw | Wood residues | MSW | Wood plantation | Sub-total | | | | |
| **Capacity installed by 2040 (MW)** | | | | | | | | | | | | |
| B2 | 4,045 | 480 | 113 | 0 | 100 | 284 | 0 | 977 | 472 | 840 | 10 | 6,344 |
| SA1= all renewables freely integrated | 4,045 | 400 | 0 | 0 | 0 | 0 | 0 | 400 | 472 | 0 | 0 | 4,917 |
| SA2= SA1+ coal supply restricted | 4,045 | 480 | 323 | 900 | 100 | 12 | 1,600 | 3,415 | 472 | 2,060 | 0 | 9,992 |
| SA3= SA2+ gas supply & electricity import restricted | 4,045 | 480 | 323 | 900 | 100 | 12 | 1,800 | 3,615 | 472 | 2,120 | 0 | 10,252 |
| SA4= SA3+ nuclear restriction | 4,045 | 480 | 323 | 900 | 100 | 284 | 1,800 | 3,887 | 472 | 4,160 | 70 | 12,634 |
| SA5= fossil fuel prices changed from 2-3% per year | 4,045 | 480 | 288 | 0 | 0 | 0 | 0 | 768 | 472 | 0 | 0 | 5,285 |
| SA6= SA5+SA1 | 4,045 | 480 | 323 | 900 | 100 | 252 | 1,800 | 3,855 | 472 | 4,160 | 0 | 12,532 |
| **Electricity generation over 2010-2040 (TWh)** | | | | | | | | | | | | |
| B2 | 400.4 | 55.0 | 14.8 | 0.0 | 12.0 | 38.6 | 0.0 | 120.4 | 46.2 | 17.5 | 0.0 | 584.6 |
| SA1: all renewables freely integrated | 401.0 | 43.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 43.3 | 42.1 | 0.0 | 0.0 | 486.4 |
| SA2: SA1+fuel coal supply restricted | 401.0 | 44.6 | 6.5 | 18.3 | 1.0 | 0.05 | 8.8 | 79.2 | 42.1 | 14.8 | 0.0 | 537.1 |
| SA3: SA2+ gas supply & electricity import restricted | 403.0 | 46.6 | 6.5 | 18.9 | 1.5 | 0.05 | 9.9 | 83.5 | 41.1 | 22.2 | 0.0 | 549.7 |
| SA4= SA3+ nuclear restriction | 403.4 | 47.3 | 8.1 | 20.4 | 2.0 | 1.6 | 19.8 | 99.2 | 41.1 | 30.6 | 0.1 | 574.4 |
| SA5= fossil fuel prices changed from 2-3% per year | 416.7 | 49.7 | 21.4 | 0.0 | 0.0 | 0.0 | 0.0 | 71.1 | 42.3 | 0.0 | 0.0 | 530.1 |
| SA6= SA5+SA1 | 416.7 | 49.7 | 22.1 | 18.9 | 2.0 | 1.4 | 9.9 | 104.0 | 42.3 | 20.8 | 0.0 | 583.8 |

### 3.4 Opportunities for renewables deployment with possible new climate regimes

In the above analysis, we assumed that there are no direct climate change policy interventions given to the Vietnamese power sector over the period 2010-2040. The simulation shows that the share of electricity generation using renewables is likely modest. This is due to still-high production costs of renewables, compared to conventional energy supply options. However, these renewables could become cost-effective to enter the electricity generation portfolio if carbon value is internalized in the development of Vietnamese power sector under possible new climate regimes.

#### 3.4.1 Integrating renewables into the IRP with carbon prices and caps

We simulate three different trajectories of carbon prices imposed on the sector's $CO_2$ emissions. They include (i) a low carbon price trajectory (LCV): carbon price gradually increases from 5 US\$/t$CO_2$ in 2010 to 20 US\$/t$CO_2$ by 2040, (ii) a moderate carbon price trajectory (MCV): from 5 US\$/t$CO_2$ in 2010 to 35 US\$/t$CO_2$ by 2040, and (iii) a high carbon price trajectory (HCV): from 5 US\$/t$CO_2$ in 2010 to 50 US\$/t$CO_2$ by 2040. All three trajectories of carbon prices are combined with a full set of renewable energy options (RET scenario) forming three other scenarios: RET-LCV, RET-MCV, and RET-HCV respectively.

Assuming another climate policy of placing caps on $CO_2$ emissions in the same RET scenario, which vary from a low level of $CO_2$ caps (LCC) forming a scenario RET-LCC to a high level of $CO_2$ caps (HCC) forming a scenario RET-HCC as indicated in Table 3-15, the study outputs help examine the effectiveness of various environmental policies for promoting sustainable energy supplies in the sector and further look at a possibility of building up the country's NAMAs[10]. These assumed levels of $CO_2$ reduction were made in a way that would be appropriate to the circumstances of the future economy development in Vietnam.

*Table 3-15: Three scenarios assumed with different levels of carbon emissions reduction targets, 2010-2040.*

| | | | | |
|---|---|---|---|---|
| RET-LCC | **2020 to 2025** | **2026 to 2030** | **2031 to 2035** | **2031 to 2035** |
| | 5% | 5% | 10% | 10% |
| RET-MCC | **2015 to 2025** | **2026 to 2030** | **2031 to 2035** | **2031 to 2035** |
| | 5% | 10% | 20% | 20% |
| RET-HCC | **2015 to 2025** | **2026 to 2030** | **2031 to 2035** | **2031 to 2035** |
| | 5% | 15% | 20% | 25% |

[10] In December 2007, parties to the United Nations Framework Convention on Climate Change adopted the Bali Action Plan (United Nations, 2007) for the enhanced implementation of the Convention, according to which developing countries would consider nationally appropriate mitigation actions (NAMAs) in "the context of sustainable development, supported and enabled by technology, financing and capacity-building".

### 3.4.2 Results of renewables deployment with carbon prices and caps

*Results of renewables deployment with carbon prices*

Overall, placing prices on $CO_2$ emissions could result in broader penetration of non-fossil fuels in the electric power generation industry over the period 2010-2040. Table 3-16 presents the shares of electricity generation from both non-fossil fuel sources and fossil fuel sources in different scenarios simulated with and without carbon prices between 2010 and 2040.

The IRP simulation suggests a response of energy generation mix to a price placed on $CO_2$ emissions in the sector is not only a switch to renewables technologies but also to new carbon control technologies using fossil fuel. This is the case of power generation plants using imported coal fuel, in which their share in electricity generation would only increase when higher carbon prices are placed in the power sector. As a result, low efficient coal-fired generation units are either under-utilized or completely replaced by advanced efficient coal-fired plants typically using imported coal fuel, to form the electricity generation portfolio. These advanced efficient technologies include supercritical and IGCC coal-fired plants.

*Table 3-16: Electricity generation (TWh) by fuel types in Vietnam, 2010-2040. Simulations were carried out using the IRP model.*

| Case | Nuclear | Non-fossil fuel sources | | | Fossil fuel sources | | | | Oil | Imp. power |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Renew-ables | Large Hydro | Hydro Pump Storage | Dom. Coal | Imp. Coal | Dom. Gas | Imp. Gas | | |
| B2 | 788 | 585 | 2,045 | 389 | 3,729 | 3,117 | 2,674 | 0.0 | 35.6 | 743 |
| | 5.6 | 4.1 | 14.5 | 2.8 | 26.4 | 22.1 | 19.0 | 0.0 | 0.3 | 5.3 |
| RET-LCV | 817 | 1,160 | 2,084 | 389 | 1,329 | 3,427 | 3,162 | 710 | 37.8 | 758 |
| | 5.9 | 8.4 | 15.0 | 2.8 | 9.6 | 24.7 | 22.8 | 5.1 | 0.3 | 5.5 |
| RET-MCV | 817 | 1,149 | 2,085 | 389 | 1,185 | 3,428 | 3,284 | 710 | 36.4 | 758 |
| | 5.9 | 8.3 | 15.1 | 2.8 | 8.6 | 24.8 | 23.7 | 5.1 | 0.3 | 5.5 |
| RET-HCV | 817 | 1,161 | 2,085 | 389 | 1,059 | 3,502 | 3,303 | 710 | 38.9 | 758 |
| | 5.9 | 8.4 | 15.1 | 2.8 | 7.7 | 25.3 | 23.9 | 5.1 | 0.3 | 5.5 |

Particularly for renewables, the share of total electricity production from generation plants using renewables in the RET-HCV scenario would be double larger than that in the BAU scenario during the same period when carbon prices are internalized in the sector, increasing from 4.1% to 8.4%. In term of energy capacity, about 14.6 GW of renewables-based power generation plants would be effectively exploited by 2040 in the same scenario, compared to only 6.3 GW of renewables developed in the BAU scenario (Table 3-17).

*Table 3-17: Comparison of energy capacity and electricity generation by type of renewable source in different development scenarios with a positive carbon value scheme, 2010-2040. Simulations were carried out using the IRP model.*

| **Scenarios** | **Small hydro** | **Biomass** | | | | | | | **Geothermal** | **Wind** | **Solar** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Bagasse** | **Rice husk** | **Paddy straw** | **Wood residues** | **MSW** | **Plantation** | **Subtotal** | | | | |
| **Capacity installed by 2040 (MW)** | | | | | | | | | | | | |
| B2 | 4,045 | 480 | 113 | 0 | 100 | 284 | 0 | 977 | 472 | 840 | 10 | 6,344 |
| SA1= all renewables freely integrated | 4,045 | 400 | 0 | 0 | 0 | 0 | 0 | 400 | 472 | 0 | 0 | 4,917 |
| RET-LCV | 4,045 | 480 | 323 | 900 | 100 | 284 | 1,800 | 3,887 | 472 | 6,140 | 10 | 14,554 |
| RET-MCV | 4,045 | 480 | 323 | 900 | 100 | 284 | 1,700 | 3,887 | 472 | 6,140 | 30 | 14,474 |
| RET-HCV | 4,045 | 480 | 323 | 900 | 100 | 284 | 1,800 | 3,887 | 472 | 6,140 | 70 | 14,614 |
| **Electricity generation over 2010-2040 (TWh)** | | | | | | | | | | | | |
| B2 | 400.4 | 55.0 | 14.8 | 0.0 | 12.0 | 38.6 | 0.0 | 120.4 | 46.2 | 17.5 | 0.0 | 584.6 |
| SA1= all renewables freely integrated | 401.0 | 43.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 43.3 | 42.1 | 0.0 | 0.0 | 486.4 |
| RET-LCV | 416.7 | 55.6 | 41.7 | 70.0 | 12.6 | 39.5 | 168.3 | 387.7 | 46.8 | 308.3 | 0.2 | 1,159.7 |
| RET-MCV | 416.7 | 55.6 | 41.7 | 70.0 | 12.6 | 39.7 | 156.8 | 387.9 | 46.8 | 308.3 | 0.3 | 1,148.5 |
| RET-HCV | 416.7 | 55.6 | 41.7 | 70.0 | 12.6 | 39.9 | 168.3 | 388.1 | 46.8 | 308.3 | 0.9 | 1,160.8 |

In term of increase in power sector production cost due to the introduction of carbon prices, the study finds that the long run average cost (LRAC) during the period 2010-2040 would increase by 6.7%, 7.4%, and 8.6% in the RET-LCV, RET-MCV, and RET-HCV scenarios respectively, compared to the baseline LRAC. However, considering sustainable benefits of above 25% of reduction in the sector cumulative $CO_2$ emissions, and over 69% in $SO_2$ and 54% in $NO_X$ emissions potentially avoided during the next 30 years (for example in scenario RET-HCV), such an increase in power sector production cost seems to be modest.

In the view of macroeconomic, the increases in LRAC would result in the increases of 6.7%, 7.4%, and 8.1% in total costs for delivering a kWh of electricity to end-users (costs of transmission and distribution, and administrative management are included) in the respective scenarios. Given an estimation that the GDP would decrease about 0.161% and the Consumer Price Index (CPI) would increase approximate 1.25% if the average electricity tariff increased by 20% in both the household and industrial sectors (Thanh, D. Nguyen et al., 2008), the estimated increases in power sector costs in these scenarios seems to be rather modest.

Remarkably, the Vietnamese power sector could have a great potential for Clean Development Mechanism (CDM) or CDM-like mechanism funding. At relatively low carbon prices, there are several options for CDM projects: biomass (including rice husk, paddy straw, wood residue), and wind power is economical at 4 $/t$CO_2$, while wood plantation and municipal solid wastes is economical at 6 $/t$CO_2$. In terms of marginal abatement costs, many renewable energy projects in the power sector that would be competitive with energy projects in other developing countries would be possible under the CDM system at the promising price of 6 $/t$CO_2$. However, solar energy is not cost-effective for grid-connected in the Vietnamese power sector if the carbon value is lower than 30$/t$CO_2$ to relax the constraint of its high technology cost and diffused scale.

*Results of renewables deployment with carbon caps linkages*

What we find is that placing caps on $CO_2$ emissions in the power sector would also foster the wider deployment of renewables for energy production. In this case, the energy capacity of renewables installed by 2040 would increase from 6.3 GW in our baseline scenario to 12.2 GW (92% in increase) in the RET-LCC scenario and 14.5 GW (128% in increase) in the RET-HCC scenario. Also the share of total electricity generation from renewables during the period from 2010 to 2040 would increase from 4.1% in our baseline to 6.4% in the RET-LCC scenario and 7.5% in the RET-HCC scenario (Table 3-18).

Similarly, the long run average cost (LRAC) during the period would also increase by 1.6% and 5.3% in the RET-LCC and RET-HCC scenarios respectively. Taking into account the sustainable benefit of $CO_2$ emissions reduction by 8.9% and 18.7% in these two scenarios, compared to the baseline $CO_2$ emissions, the average abatement costs vary from 18.7 US$/t$CO_2$ to 35.1 US$/t$CO_2$ respectively. In direct comparison of abatement costs, using caps on $CO_2$ emissions in the power sector seems to be less efficient than the use of prices on $CO_2$.

*Table 3-18: Electricity generation (TWh) by fuel types in Vietnam, 2010-2040. Simulations were carried out using the IRP.*

| Case | Nuc-lear | Non-fossil fuel sources | | | Fossil fuel sources | | | | | Imp. power |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Renew-ables | Large Hydro | Hydro Pump Storage | Dom. Coal | Imp. Coal | Dom. Gas | Imp. Gas | Oil | |
| B2 | 788 | 585 | 2,045 | 390 | 3,729 | 3,117 | 2,674 | 0.0 | 35.6 | 743 |
| | 5.6 | 4.1 | 14.5 | 2.8 | 26.4 | 22.1 | 19.0 | 0.0 | 0.3 | 5.3 |
| RET-LCC | 810 | 896 | 2,070 | 390 | 3,108 | 3,125 | 2,846 | 38.3 | 34.8 | 745 |
| | 5.8 | 6.4 | 14.7 | 2.8 | 22.1 | 22.2 | 20.2 | 0.3 | 0.2 | 5.3 |
| RET-MCC | 802 | 982 | 2,074 | 390 | 2,030 | 3,497 | 3,037 | 406 | 40.7 | 746 |
| | 5.7 | 7.0 | 14.8 | 2.8 | 14.5 | 25.0 | 21.7 | 2.9 | 0.3 | 5.3 |
| RET-HCC | 802 | 1,047 | 2,074 | 390 | 1,852 | 3,620 | 3,062 | 367 | 45.4 | 747 |
| | 5.7 | 7.5 | 14.8 | 2.8 | 13.2 | 25.8 | 21.9 | 2.6 | 0.3 | 5.3 |

With regards to cost-competitiveness of renewables, the IRP results suggest almost renewables (except for solar energy) would become cost-effective for electricity production if the assumed reduction targets are placed as assumed (Table 3-19). Solar only becomes cost-competitive for grid-connected electricity generation when carbon caps imposed are higher than the level assumed in the RET-MCC scenario. However, only a few quantity of electricity production from solar energy would be supplied in both the RET-MCC and RET-HCC scenarios.

Compared to the abatement cost of $CO_2$ emissions in other countries around the developing world (ECN, 2007), the average abatement cost of 18.7 US$/t$CO_2$ in the RET-LCC scenario is rather modest to achieve 9% of the power sector cumulative $CO_2$ emissions (7.2 Gt) during the period from 2010 to 2040. This is also prominent that Vietnamese power sector would offer low-cost opportunities for hosting carbon reduction projects.

Conclusively, deploying renewables in Vietnam's power sector is likely to be a promising opportunity that could lead to sustainability and meet the requirement for being eligible for assistance given under UNFCCC mechanisms in reduction of global GHG emissions. Moreover, renewable energy can hedge against the possibility of fossil fuels prices volatility, improve the generation fuel diversity and the independence of Vietnam's power sector. However, choosing incentive support instruments for promoting renewables-based electricity production is also a question in practice.

*Table 3-19: Comparison of energy capacity and electricity generation by type of renewable source in different development scenarios with a positive carbon value scheme, 2010-2040. Simulations were carried out using the IRP.*

| **Scenarios** | **Small hydro** | **Biomass** | | | | | | | **Geothermal** | **Wind** | **Solar** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Bagasse** | **Rice husk** | **Paddy straw** | **Wood residues** | **MSW** | **Plantation** | **Sub-total** | | | | |
| **Capacity installed by 2040 (MW)** | | | | | | | | | | | | |
| B2 | 4,045 | 480 | 113 | 0 | 100 | 284 | 0 | 977 | 472 | 840 | 10 | 6,344 |
| SA1= all renewables freely integrated | 4,045 | 400 | 0 | 0 | 0 | 0 | 0 | 400 | 472 | 0 | 0 | 4,917 |
| RET-LCC | 4,045 | 480 | 323 | 900 | 100 | 284 | 1,800 | 3,887 | 472 | 3,792 | 10 | 12,206 |
| RET-MCC | 4,045 | 480 | 323 | 900 | 100 | 284 | 1,800 | 3,887 | 472 | 5,760 | 70 | 14,234 |
| RET-HCC | 4,045 | 480 | 323 | 900 | 100 | 284 | 1,800 | 3,887 | 472 | 5,968 | 70 | 14,442 |
| **Electricity generation over 2010-2040 (TWh)** | | | | | | | | | | | | |
| B2 | 400.4 | 55.0 | 14.8 | 0.0 | 12.0 | 38.6 | 0.0 | 120.4 | 46.2 | 17.5 | 0.0 | 584.6 |
| SA1= all renewables freely integrated | 401.0 | 43.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 43.3 | 42.1 | 0.0 | 0.0 | 486.4 |
| RET-LCC | 403.4 | 55.1 | 37.8 | 68.0 | 12.0 | 38.6 | 85.8 | 297.3 | 46.7 | 148.7 | 0.0 | 896.1 |
| RET-MCC | 411.1 | 55.1 | 39.0 | 67.2 | 12.1 | 38.6 | 99.0 | 311.0 | 46.8 | 213.1 | 0.4 | 982.4 |
| RET-HCC | 411.3 | 55.1 | 39.0 | 68.0 | 12.1 | 38.6 | 136.4 | 349.2 | 46.8 | 238.5 | 0.6 | 1,046.5 |

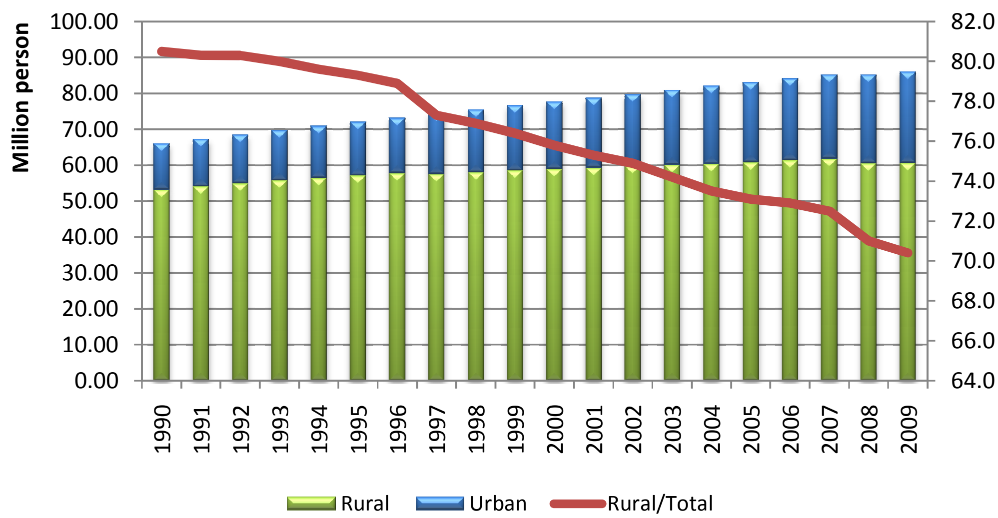
## 3.5 The important role of renewables for sustainable development in rural areas

The above discussions focused on the role of renewables for grid-connected power generation. But, they may play an even larger role in off-grid electrification in very remote areas or islands/mountains where the electricity grid could not be connected to. This part of the study aims to discuss the role of renewables for energy supply in rural communities in Vietnam.

### 3.5.1 The increasing use of electricity for rural development

Vietnam has more than 70% of the population, of which 93% are the poor, living in rural areas, upland areas or small islands (Figure 3-9). The rural people's average income was 762 thousand VND per month (equals to US$ 46) in 2008. This figure equals to 47% of average urban monthly income.

*Figure 3-9: Vietnam's population by region (rural and urban), 1990-2009*




(Source: VGSO, 2010).

A great proportion of rural communities still experience limited access to modern energy services. Instead, they heavily rely on traditional fuels from biomass, i.e. animal dung, crop residues, and wood, for their energy needs in both daily life and other productive activities. Energy from biomass plays an important role and takes the largest share of primary energy supply in rural areas, which accounted for 98%, 95%, and 90% of total rural energy consumption in 1993, 1998, and 2002, respectively. About 70% of rural people are using this type of energy for their cooking purpose. Other renewables, such as mini hydro, wind, solar energy, are not contributing significant share to the rural energy balance, but will take an increasingly important role in fuelling the socio-economic development in these remote regions. Khanh Nguyen (2007c) already proved the economic feasibility for deployment of wind turbine and solar PV in rural villages and remote areas in Vietnam. So far, NCST (2002) suggested mini hydro power could meet several hundred thousand households' energy needs in the more mountainous north and central areas of Viet Nam.

A recent study survey by IOS (2009) provides that a switch in the sources of energy used by rural households has occurred over time, in which electricity energy has been becoming a very popular energy supply source (Table 3-20). The use rates of electricity in surveyed areas were increasing from 44% in 2002, to 89% in 2005 and to 95% in 2008. These shifting rates indicate a tendency towards rural electrification in Vietnam which running fast over the last decade.

*Table 3-20: The five most common sources of energy used by surveyed rural households.*

| Rank | 2002 | 2005 | 2008 |
|---|---|---|---|
| #1 | Fuel wood | Fuel wood | Electricity |
| #2 | Kerosene | Electricity | Fuel wood |
| #3 | Dry cell batteries | Petrol | Petrol |
| #4 | Electricity | Kerosene | Candle |
| #5 | Petrol | Dry cell batteries | Dry cell batteries |

Source: IOS (2009).

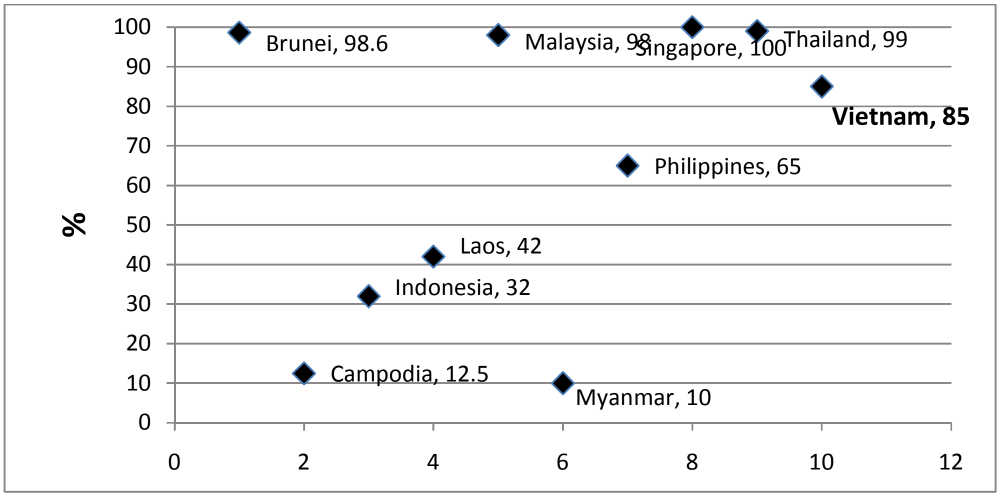
### 3.5.2 Renewable energy: the key option for rural electricity use

Recently, Vietnam achieved a great electrification rate that is at top level in South-east Asian countries (Figure 3-10). In 2008, the Vietnamese rural electrification rate was 94.5% compared to a mere 14% in 1993. But, the mountainous and remote areas, and islands have still no access to electricity network (GTZ, 2009).

The rural electricity system often provides low quality and long overhead lines that are susceptible to weather conditions. Because of the long-distance-grid connecting, energy costs per customer are usually higher than that in urban areas. Although there exist a number of policy for poverty reduction and hunger eradication, and subsidy for rural electricity, the assess to electricity is still limited in many places. This is also due to high poverty rate and low average income in rural areas. Despite electricity tariff for rural areas are regulated by the Government, people often suffer for costly electricity prices, even 1.5 times higher than the regulated one in many places, due to the high power loss rate and poor management locally.

According to the official plan, there will be 98% by 2015 and 100% by 2025 of the communes able to use electricity. To pursue the specified targets, the deployment plan of renewables for remote off-grid electricity generation system is already launched. By 2015, the whole electricity supply system for 338,712 households in these areas will be based on local renewables sources with a total of 87.78 MW in capacity. Furthermore, another system for an extra 216,554 households will be developed for the next period 2016-2025 with a total of 50.42 MW. Technologically, the development focuses on scaling-up the use of micro-hydro, wind turbine, biomass, and solar PV for many of rural households.

*Figure 3-10: The rate of electricity access in 2008 among ASEAN countries.*




Source: Asian Trends Monitoring (2010).

### 3.6 Concluding remarks

Renewable energy sources could have a minor but non negligible part in the national plan to generate electric power in Vietnam. There are a number of candidate grid-connected generation technologies that could be potentially developed for electricity production. These include small hydro, geothermal, wind turbine, biomass (bagasse, rice husk, municipal solid waste, wood residue, paddy straw, plantation), and solar.

The study finding suggests the country's available renewable energy sources could potentially contribute to satisfy the soaring electricity demand, mitigate polluting emissions, and enhance energy independence and energy security over 2010-2040 even though the prices for fossil fuels are assumed in the present study relative modest and their annual inflation rates are rather low, compared to the market levels observed by today (IEO, 2010). However, the rising fossil fuel prices only boost more promising prospects for renewable energy development in the Vietnamese power sector. Moreover, deploying renewables in Vietnam's power sector is likely to be a promising opportunity that could lead to sustainability for the development of Vietnam's power sector development and meet the basic requirement for being eligible for assistance under UNFCCC mechanisms in reduction of global GHG emissions (Climate Change, 2007). Yet, they play an even larger role in off-grid electrification in the context of the increasing use of electricity for remote areas in Vietnam.

However, cost and financing of deploying renewables for Vietnam's power sector could provide a disputed issue and choosing incentive support instruments for promoting wider development of renewables-based electricity production is not always a simple matter.

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## Chapter 4. $CO_2$ capture and storage: a promising climate instrument for $CO_2$ mitigation

### 4.1 Introduction of Chapter 4

To meet rising energy demand in next decades, coal is expected to be a major fuel for power sector. If no $CO_2$ emission control is applied, coal-fired electricity generation will increase global annual $CO_2$ emissions by about 7.6 billion tons by 2030 (TCAP, 2010). For South East Asian (ASEAN) countries, the primary energy demand is projected to increase 76% during the period from 2007 to 2030 and of this demand, coal will dominate the largest proportion (ADB, 2010). If the current development policy is continued, $CO_2$ emissions will double from 7.2 Gt in 2009 to 14.3 Gt by 2030 in both China and five economies of the ASEAN: Indonesia, Malaysia, Philippines, Thailand, and Vietnam (World Bank, 2010e).

Carbon capture and storage (CCS) is the only technology available for large-scale fossil fuel use to mitigate the dangerous threat of climate change (IEA, 2008a; IEA, 2009f). Over the last decade, many researchers have assessed its socio-economic technical feasibility (David and Herzog, 2000; IPCC, 2005; IEA, 2008a,b; Ha-Duong et al., 2009) and sought to integrate knowledge about its economics into economic models (Eckaus, et al., 1996; Dooley, et al., 1999; Kim and Edmonds, 2000; McFarland, J. R., et al., 2003; McFarland, J. R., et al., 2004; Johnson and Keith, 2004; Wise and Dooley, 2004; Stangeland, 2007). All these suggested integrating CCS into electricity generation industry is a necessary answer to the major challenges of energy security associated with the disruptive climate change. However, to date, CCS has not been commercially available at large-scale projects, and mostly are under demonstration stages. Within the seven current projects in Asia, only one CCS project is implemented as a commercial project, the Gorgon CCS project in Australia (CO2CRC, 2010).

ADB (2010) also suggested that in addition to necessary changes in the pattern of primary energy consumption and fuel switching in electricity generation, climate mitigation options for the four ASEAN countries (Indonesia, Philippines, Thailand and Vietnam) in the coming decades could also include CCS. With an expected carbon price of 7 US$/t$CO_2$, geological storage of $CO_2$ is suggested to become economically feasible by 2020 for these countries. If carbon price rises to around 26 US$/t$CO_2$, injection of $CO_2$ into deep saline aquifers is expected to become economically feasible by 2050 and could capture 133 Mt$CO_2$ per year. With carbon price above $80/t$CO_2$ by 2050, CCS is very likely to play an even more important role in $CO_2$ emission reductions in all these countries. In this case, coal beds and deep saline aquifers are projected to store 192 Mt$CO_2$/yr and 310 Mt$CO_2$/yr respectively by 2050 and total $CO_2$ storage capacity using all available storing forms could preserve 506 Mt$CO_2$/yr by 2050.

Using the bottom-up IRP model, this research study provides new insights about the extent to which CCS would be cost-effective deployed in the Vietnamese power sector and play an important role in broader climate change mitigation efforts, and examines its cost-competitiveness to other $CO_2$ emissions mitigation options in the Vietnamese power sector.

## 4.2 CCS in Vietnam's power sector: the economic potential

### 4.2.1 Explore the promising storage capacity

Though there are differences between natural accumulation and engineered storage, injecting emission of $CO_2$ into deep geological formations at well-investigated sites can store it underground for long periods of time, probably 1,000 years. The most promising sites using geological formations comprise deplete oil/gas reservoirs, possibly coal formations and deep saline aquifers (IPCC, 2005). This special scientific report of the IPCC also suggested that the added economic values of incremental oil and methane production could reduce costs of storing emission of $CO_2$, even negative the costs in some areas, where the storages are undertaken in conjunction with enhanced oil/gas recovery (EOR/EGR) and enhanced coal bed methane (ECBM). There are 3 questions typically being considered for a deployment plan for CCS: (i) Where: potential storage basins and $CO_2$ sources (ii) When: as soon as possible or urgent compared to the business-as-usual (BAU) scenario, (iii) How: ensuring security, economic incentives, designed regulation, industrial pilots, low cost, public acceptance, etc.

In Vietnam, several investigations have been recently made by the Research Department of Geology and Mines of TKV, Ministry of Natural Resource and Environment, Vietnam (MONRE), and Bureau de Recherches Géologiques et Minières (BRMG), France to estimate the potential for geological storage of $CO_2$. The estimates are using the following criteria:

- ✓ All formations of sediment whose thickness should be beyond 1,000 meters
- ✓ They should be 10 kilometres away from the major faults
- ✓ Not more than 100 kilometres away from $CO_2$ emitting sources (generation plants)

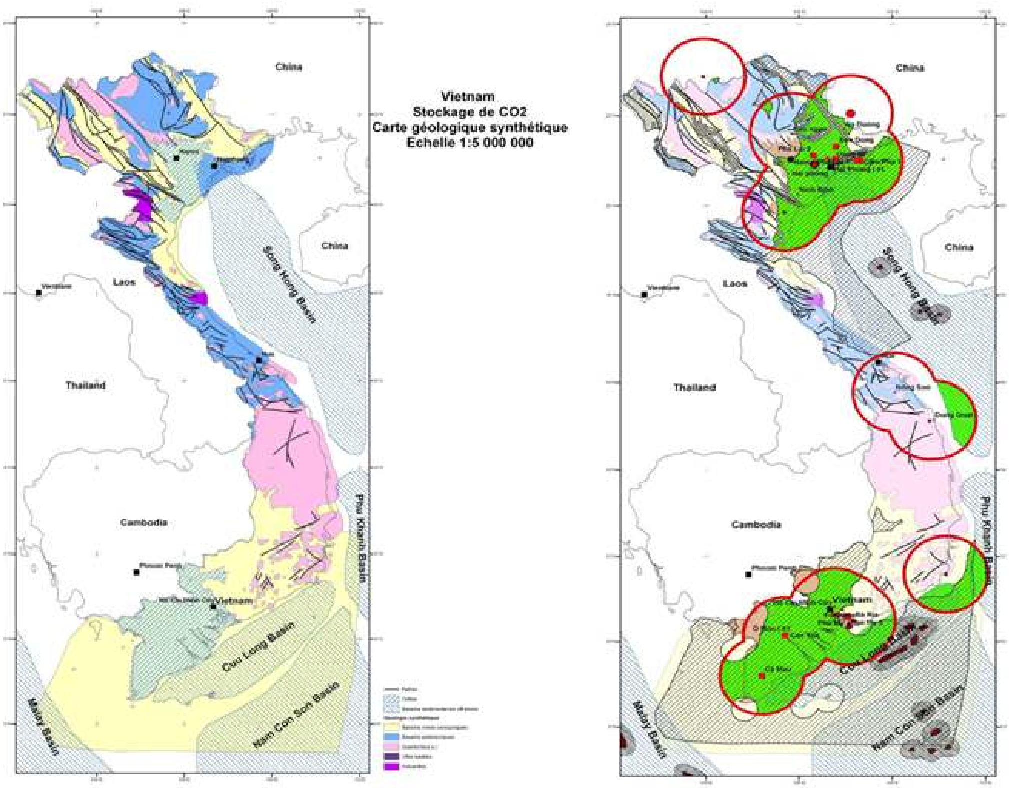
As results, there are promising opportunities for geologically storing the emission of $CO_2$ under various forms:

- ✓ Enhanced Oil Recovery (EOR) in the river basin area of Cuu Long.
- ✓ Injection of $CO_2$ emissions into the oil fields already fully exploited in the river basin areas of Cuu Long and Song Hong, the North end.
- ✓ Enhanced Coal Bed Methane Recovery (ECBM) in Quang Ninh coal basin.
- ✓ The existing of hydrocarbon sources could potentially improve the added economic of $CO_2$ emissions in conjunction with EOR and EGR production.

Specifically, the reservoir of Utsira in the Northern coastal area is estimated to have sufficient capacity to store about 20 to 60 Gt of $CO_2$. This is a significant fraction of total global need for $CO_2$ emission reduction (145 Gt) over the period from 2010 to 2050 (Bonijoly, 2009; TKV, 2009a). Figure 4.1 presents the major basins in Vietnam and promising areas featuring formations of sediment that could be potentially developed for geologically storing emission of $CO_2$. Totally, there are 6 major areas including 5 basins: Red River, Phu Khanh, Cuu Long, Nam Con Son, Malay, and the Northern end.

These storing areas are then optimally estimated based on their near-by locations of $CO_2$ emission sources (electricity generation plants) as well as pre-specified distances and geological features for routing the expected $CO_2$ transportation pipeline system. As an investigation, a list of electricity generation plants with above 2.5 Mt of $CO_2$ emissions emitted per year is identified for possible opportunities of the CCS deployment. They include existing and future candidate coal-fired/natural gas combined cycle power plants (such as Pha Lai, Uong Bi, Hai Phong, Cam Pha, Quang Ninh, TBKHH Mien Trung, Coal Mien Trung, etc.) in the river basin area of Song Hong and the North end, and the existing and future candidate natural gas combined cycle/coal-fired power plants (such as Phu My, Ca Mau, TBKHH Mien Nam, Tra Vinh, Kien Giang, Coal Mien Nam, etc.) in the river basin area of Cuu Long.

*Figure 4-1: The areas including 5 major basins in Vietnam identified for storage opportunities.*




Source: Bonijoly (2009); TKV (2009a).

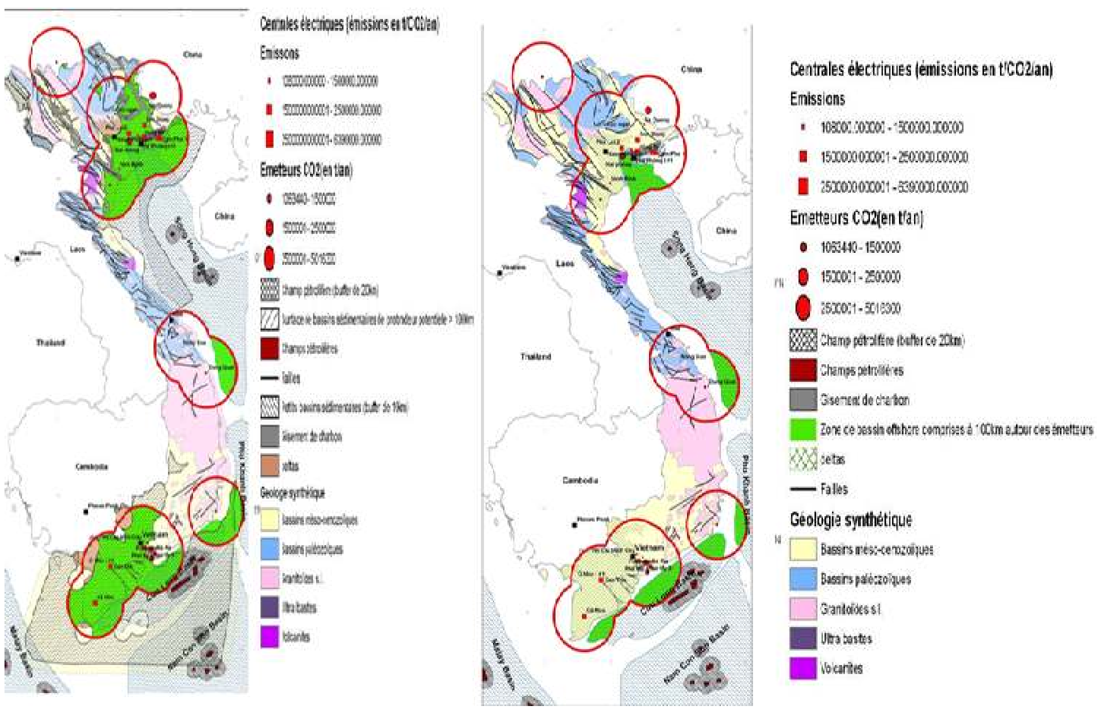
Figure 4-2 illustrates $CO_2$ emission storing opportunities onshore and near-by onshore close to electricity generation sources.

*Earlier proposal for CCS deployment in Vietnam at White Tiger Field: a suitable host for the first carbon capture and storage project registered under the CDM?*

Indeed, the White Tiger (Bach Ho) Field project in Vietnam was an early proposal to include a CCS project under the CDM. It involves $CO_2$ capture from Natural Gas Combined Cycle

(NGCC) plants, pipeline transport, and storage in offshore/onshore oil fields and enhanced oil recovery. As the first commercial CCS project in Asia, it would have a high demonstration value, and could potentially generate emission reductions of approximately 7.7 million $tCO_2$ per year, facilitating the recovery of an average of 50 thousand barrels of crude oil per day (IEA, 2008a). Work to include CCS in the CDM started in 2006, but has not yet been concluded as of December 2009. There are pending methodological issues, given that the technology is still evolving, and the scale is out of proportion relative to the average CDM project: out of 2,236 requested and registered projects in February 2010, only 7 are larger than the White Tiger project in terms of avoided emissions (Figure 4-3).

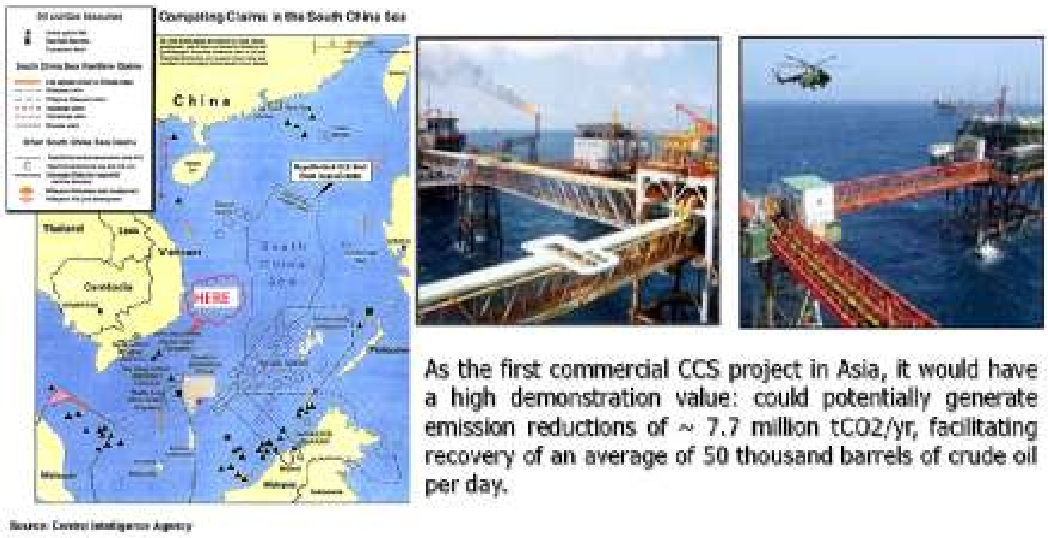
*Figure 4-2: Storage opportunities onshore and near-by onshore identified with $CO_2$ sources in Vietnam.*




Source: Bonijoly (2009); TKV (2009a).

The ability and prospect to capture and sequester emission of $CO_2$ offers a promising technology in a manner that is compatible with the future electric power generation industry while allowing the use of coal to meet the pressing needs for energy. This part of the study attempts to explore economic potential for deploying CCS in Vietnam's power sector. We aim to answer the question: to the extent which the deployment of CCS would become cost-effective in the Vietnamese power sector? and to compare its cost-competitiveness to other $CO_2$ mitigation options in the sector using the IRP simulation.

*Figure 4-3: Earlier proposal for the CCS deployment in Vietnam at White Tiger Field .*




Source: The Central Intelligence Agency & Petro Vietnam (2009).

### 4.2.2 Integrating CCS options into the IRP model

We integrate CCS options into the IRP simulation under different assumptions about the level and timing of carbon prices that might be imposed to the sector. They include (i) a low carbon price trajectory (LCV): carbon price gradually increases from 5 US$/t$CO_2$ in 2010 to 20 US$/t$CO_2$ by 2040, (ii) a moderate carbon price trajectory (MCV): from 5 US$/t$CO_2$ in 2010 to 35 US$/t$CO_2$ by 2040, and (iii) a high carbon price trajectory (HCV): from 5 US$/t$CO_2$ in 2010 to 50 US$/t$CO_2$ by 2040. The sector's response to imposing a price on $CO_2$ emissions would be multiform in both demand-side (less energy is used) and supply-side effects (a switch to lower or non-carbon intensive fuels is occurred, efficiency of new and existing power plants is enhanced, and new cleaner generation technologies are introduced, e.g. renewables, CCS).

All three trajectories of carbon prices are combined with the baseline, RET, and CCS options forming 3 sets of scenarios: (BAU-LCV, BAU-MCV, and BAU-HCV), (CCS-LCV, CCS-MCV, and CCS-HCV), and (RET-CCS-LCV, RET-CCS-MCV, RET-CCS-HCV). It should note that the definition here for the scenarios (RET-CCS-LCV, RET-CCS-MCV, RET-CCS-HCV) is entirely identical to that for the scenarios (RET-LCV, RET-MCV, RET-HCV) used in the Chapter 3, in which a full set of renewable energy options is combined together with all assumed CCS options. More specially, we will also examine the relevance of CCS as a key climate policy instrument in the Vietnamese power sector assuming a action scenario (ACT scenario), in which carbon price gradually increases from 5 US$/t$CO_2$ in 2010 to 40 US$/t$CO_2$ by 2030 and rises to 60 US$/t$CO_2$ by 2040. Table 4-1 designates the conventional and non-conventional technologies, and with/without CCS in different scenarios.

*The CCS options:* There are 10 alternative CCS options assumed to be available since 2025. The detail of cost and performance specifications related to CCS are presented in Table 4-2.

*Table 4-1: The alternative candidate technologies including conventional and non-conventional used in Vietnam's power sector, 2010-2040.*

| No. | Candidate generation technologies | BAU | BAU-LCV | BAU-MCV | BAU-HCV | CCS-LCV | CCS-MCV | CCS-HCV | RET-CCS-LCV | RET-CCS-MCV | RET-CCS-HCV | CCS-ACT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Subcritical coal-fired | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 2 | Supercritical coal-fired | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 3 | IGCC coal-fired | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 4 | NGCC gas-fired | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 5 | Conventional gas-fired | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 6 | Very large hydro | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 7 | Large and medium hydro | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 8 | Small hydro | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 9 | Geothermal < 5MW | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 10 | Geothermal 10MW | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 11 | Geothermal 15-20MW | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 12 | Wind farm (10-60MW) | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 13 | Solar PV grid connected | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 14 | Baggase co-firing 5MW | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 15 | Baggase co-firing 10MW | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 16 | Baggase co-firing 30MW | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 17 | Biomass direct combustion < 5MW | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 18 | Biomass direct combustion 5-30MW | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 19 | MSW direct combustion 7-30MW | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 20 | Biomass gasification 30-100MW | | | | | | | | √ | √ | √ | |
| 21 | Nuclear PWR Gen.3 | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 22 | Subcritical coal-CCS | | | | | √ | √ | √ | √ | √ | √ | √ |

| No. | Candidate generation technologies | BAU | BAU-LCV | BAU-MCV | BAU-HCV | CCS-LCV | CCS-MCV | CCS-HCV | RET-CCS-LCV | RET-CCS-MCV | RET-CCS-HCV | CCS-ACT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | Subcritical coal-CCS-ready | | | | | √ | √ | √ | √ | √ | √ | √ |
| 24 | Supercritical coal-CCS | | | | | √ | √ | √ | √ | √ | √ | √ |
| 25 | Supercritical coal-CCS-ready | | | | | √ | √ | √ | √ | √ | √ | √ |
| 26 | IGCC coal-CCS | | | | | √ | √ | √ | √ | √ | √ | √ |
| 27 | NGCC gas-CCS | | | | | √ | √ | √ | √ | √ | √ | √ |
| 28 | Subcritical coal-CCS retrofit | | | | | √ | √ | √ | √ | √ | √ | √ |
| 29 | NGCC gas-CCS retrofit | | | | | √ | √ | √ | √ | √ | √ | √ |

*Table 4-2: Cost and performance specifications of selected candidate power generation technologies with CCS employed.*

| No. | Candidate plants | Capital cost ($/kW) | | | | Efficiency (%) | | Fixed O&M cost $/kW·year | Variable O&M cost $/MWh | Life time (year) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **2010** | **2020** | **2030** | **2040** | **2025-2035** | **3035-2040** | | | |
| 1 | Subcritical Coal-CCS | 2120 | 1960 | 1920 | 1800 | 30 | 34 | 41.3 | 4.8 | 30 |
| 2 | Subcritical Coal-CCS-ready | 2004 | 1853 | 1815 | 1702 | 30 | 34 | 41.3 | 4.8 | 30 |
| 3 | Supercritical Coal-CCS | 2430 | 2401 | 2185 | 1860 | 35 | 40 | 41.3 | 4.8 | 30 |
| 4 | Supercritical Coal-CCS-ready | 2314 | 2286 | 2081 | 1771 | 35 | 40 | 41.3 | 4.8 | 30 |
| 5 | IGCC Coal-CCS | 2400 | 2100 | 2000 | 1880 | 37 | 41 | 40.2 | 3.9 | 30 |
| 6 | NGCC Gas-CCS | 1210 | 1150 | 1050 | 991 | 46 | 48 | 46.8 | 1.7 | 25 |
| 7 | Retrofit subcritical coal-CCS#1 | 984 | 910 | 891 | 835 | 21 | 26 | 65 | 4.8 | 30 |
| 8 | Retrofit subcritical coal-CCS#2 | 984 | 910 | 891 | 835 | 28 | 33 | 60 | 4.8 | 30 |
| 9 | Retrofit NGCC Gas-CCS#1 | 552 | 525 | 479 | 452 | 36 | 38 | 71 | 1.7 | 25 |
| 10 | Retrofit NGCC Gas-CCS#2 | 552 | 525 | 479 | 452 | 44 | 46 | 66 | 1.7 | 25 |

Source: Electricity of Vietnam, 2007; MOIT, 2009; Institute of Energy and Science, 2009; Institute of Strategy and Development, 2009; WETO (2006); Das and Ahlgren (2008); Broek et al., (2008) and Broek et al., (2009); IEA (2008a); IEA (2008b); IEA (2009f); EIA (2009).

*Given the assumed CCS cost and performance specifications, by how much would the integrating CCS into the electricity generation portfolio increase cost of production and how much would it cost in terms of captured and avoided $CO_2$ emissions?*

The levelised cost of electricity (COE) is an economic assessment for costs of electricity-generating system. They include all costs consumed over the system lifetime: operating expenses, payment of debt and accrued interest on initial project expenses, and payment of an acceptable return to investors. Three main components are commonly used: capital charge, operation and maintenance costs, and fuel costs. In this study, the levelised cost of a kWh electricity for a conventional power plant with no CCS is determined as:

$$COE_{ref} = \frac{CAPEX + \left(OPEX_{ref} + FUEX_{ref}\right) \times \frac{P}{A}(i\%, n)}{AE \times \frac{P}{A}(i\%, n) \times LF \times (1-k)} \tag{4.1}$$

where: "*ref*" as a reference plant without CCS, *COE* is levelised cost of a kWh electricity generated (\$/kWh), *CAPEX* is plant capital cost (\$), *OPEX* is O&M costs (\$/year), *FUEX* is fuel cost (\$/year), *AE* is annual electricity production (kWh/year), *LF* is load factor (%), *k* is auxiliary power consumption factor (%), and *P/A (i%,n)* is levelised factor, *i* is interest rate (%), *n* is lifetime (year), and

$$\frac{P}{A}(i\%, n) = \frac{(1+i)^n - 1}{i \times (1+i)^n} \tag{4.2}$$

$$FUEX_{ref} = AE \times \frac{860}{HR \times \eta_{ref}} \times P_{FUEL} \tag{4.3}$$

where *HR* is heat rate value (kcal/kg or kcal/MBtu), $\eta$ is efficiency (%), $P_{FUEL}$ is fuel price (\$/ton or \$/MBtu).

For power generation plants integrated with carbon capture facilities, in addition to plant-capital cost (*CAPEX*) the expenditure is also involved with costs of $CO_2$ capture and compression facilities, and relevant infrastructure (*CCSFEX*). IEA (2008a) suggested that the expenditures for capital, operation and maintenance, and fuel for a power plant with CCS can vary within wide bounds depending on a number of variables. The cost of capturing $CO_2$ varies from different types of power plants including their overall efficiency and energy need for capturing process. In the present study, the levelised production cost for an electricity unit generated from a power plant integrated with CCS is determined as the following:

$$COE_{withCCS} = \frac{\left(CAPEX + CCSFEX_{withCCS}\right) + \left(OPEX_{withCCS} + FUEX_{withCCS}\right) \times \frac{P}{A}(i\%, n)}{AE \times \frac{P}{A}(i\%, n) \times LF \times (1-k)} \quad (4.4)$$

$$FUEX_{withCCS} = AE \times \frac{860}{HR \times \eta_{withCCS}} \times P_{FUEL} \quad (4.5)$$

where: *"withCCS"* as a reference plant with CCS

The introduction of $CO_2$ capture and compression facilities certainly increases energy use within a plant that leads to its additional emissions generated. This key feature is also essentially taken into account in the study. The measuring cost of $CO_2$ captured/removed reflects economic viability of a $CO_2$ capture system that can be defined as:

$$Cost \quad of\ CO_2\ captured\left(US\$/tCO_2\right) = \left[\left(COE_{withCCS}\right) - \left(COE_{ref}\right)\right] \Big/ \left(CO_{2captured}\ kWh^{-1}\right) \quad (4.6)$$

The measuring cost of $CO_2$ avoided, which is widely used to reflect average cost of reducing one unit of atmosphere $CO_2$ mass emissions, can be defined as:

$$Cost_{avoidedCO2}\left(US\$/tCO_2\right) = \left[\left(COE_{withCCS}\right) - \left(COE_{ref}\right)\right] \Big/ \left(CO_{2ref}\ kWh^{-1} - CO_{2captured}\ kWh^{-1}\right) \quad (4.7)$$

In follows, what is more interesting, perhaps, are the costs of $CO_2$ captured and avoided from various generation technologies using CCS during the period between 2025 (the earliest timing of deployment of CCS) and 2040, which are summarized in Table 4-4.

The use of $CO_2$ capture system would add 30-64% of capital cost to a reference plant if CCS is deployed in earliest timing, and 30-52% if CCS is deployed in latest timing. Similarly, the cost of electricity production would increase 30-60% if CCS is deployed in earliest timing and 27-38% if CCS is deployed in latest timing, while achieving 64% to 88% in reduction of $CO_2$ emissions per net kWh generated. To add CCS to a reference generation plant, much more energy fuel input per unit of electricity production (MWh) as well as operation and maintenance work should be necessarily required. In other words, capturing $CO_2$ emissions reduces significantly the whole plant efficiency while expenditures for operation and maintenance activities increases, compared to a reference plant without CCS.

*Table 4-3: Costs of $CO_2$ captured for different generation technologies in Vietnam's power sector from 2025 to 2040. The cost analysis results.*

| Item | Sub PC-CCS | Sub PC-CCS-ready | Super PC-CCS | Super PC-CCS-ready | IGCC-CCS | NGCC-CCS |
|---|---|---|---|---|---|---|
| Cost year basic (constant dollars) | 2008 | 2008 | 2008 | 2008 | 2008 | 2008 |
| Interest rate (%) | 10 | 10 | 10 | 10 | 10 | 10 |
| Capacity (MW) | 300 | 300 | 600 | 600 | 1,000 | 750 |
| **Year 2025** | | | | | | |
| Reference plant TCR (US$/kW) | 1184 | 1184 | 1328 | 1328 | 1581 | 684 |
| Capture plant TCR (US$/kW) | 1940 | 1834 | 2293 | 2184 | 2050 | 1100 |
| Incremental TCR for capture (US$/kW) | 756 | 650 | 965 | 856 | 470 | 416 |
| Reference plant COE (US$/MWh$^{-1}$) | 54.7 | 54.7 | 54.8 | 54.8 | 61.0 | 61.1 |
| Capture plant COE (US$/MWh$^{-1}$) | 82.0 | 80.2 | 83.3 | 81.3 | 79.2 | 78.3 |
| Incremental COE for capture (US$/MWh$^{-1}$) | 27.3 | 25.5 | 28.5 | 26.5 | 18.2 | 17.2 |
| Cost of $CO_2$ captured (US$/t$CO_2$) | 42.1 | 39.2 | 43.8 | 40.8 | 28.0 | 39.3 |
| Cost of $CO_2$ avoided (US$/t$CO_2$) | 45.4 | 42.5 | 47.1 | 44.1 | 31.3 | 41.9 |
| **Year 2040** | | | | | | |
| Reference plant TCR (US$/kW) | 1100 | 1100 | 1200 | 1200 | 1390 | 671 |
| Capture plant TCR (US$/kW) | 1800 | 1702 | 1860 | 1771 | 1880 | 991 |
| Incremental TCR for capture (US$/kW) | 700 | 602 | 660 | 571 | 490 | 320 |
| Reference plant COE (US$/MWh$^{-1}$) | 64.4 | 64.4 | 62.8 | 62.8 | 57.7 | 60.90 |
| Capture plant COE (US$/MWh$^{-1}$) | 88.7 | 86.9 | 83.1 | 81.5 | 73.1 | 76.63 |
| Incremental COE for capture (US$/MWh$^{-1}$) | 24.3 | 22.5 | 20.3 | 18.7 | 15.4 | 15.7 |
| Cost of $CO_2$ captured (US$/t$CO_2$) | 37.2 | 34.5 | 31.2 | 28.7 | 23.8 | 36.1 |
| Cost of $CO_2$ avoided (US$/t$CO_2$) | 40.0 | 37.3 | 33.9 | 31.5 | 26.5 | 38.6 |

In term of cost per ton of $CO_2$ avoided, which allows it to be compared with other $CO_2$ abatement options, the study provides an economic analysis integrating the costs for transport and storage of captured $CO_2$ into the IRP simulation. These costs can be defined as:

$$Transport\ \ \cos t\ \ (US\$/tCO_2) = Tran\cos t_{tCO2} \times \left[E_{withCCS} \times \left(ECO2_{ref} - ECO2_{withCCS}\right)\right] \tag{4.8}$$

$$Storage\ \ \cos t\ \ (US\$/tCO_2) = Storage\cos t_{tCO2} \times \left[E_{withCCS} \times \left(ECO2_{ref} - ECO2_{withCCS}\right)\right] \tag{4.9}$$

where: $ECO2_{ref}$ (kg/MWh) and $ECO2_{withCCS}$ (kg/MWh) are $CO_2$ emission factors of a reference plant without CCS and with CCS respectively; $E_{withCCS}$ (GWh) is total electricity generated by a plant with CCS; $Trancost_{tCO2}$ (US$/t$CO_2$) and $Storagecost_{tCO2}$ (US$/t$CO_2$) are the costs for transport and storage of one ton of $CO_2$ emission respectively.

GlobalCCSInstitute (2009a) showed that extending the flow of $CO_2$ emissions through a pipeline system can significantly save the cost for transporting $CO_2$. For instance, the cost to transport $CO_2$ emissions by an individual pipeline could be significantly reduced by 50% if the captured $CO_2$ are combined from three or more industrial plants into a common pipeline system, in which the flow of $CO_2$ could be increased to above 10 Mtpa. Using the cost estimation for specific transport modes (onshore and offshore pipelines, ship transport versus diameter and distance) from the IPCC (2005) and recent updated reports (IEAGHG, 2006; IEA, 2006a; Davison, 2007; Broek et al., 2008; GlobalCCSInstitute, 2009a), we assume the transport system for $CO_2$ using common onshore pipeline networks will be available in Vietnam since 2025 to connect 3 major power generation sources in the Northern, Middle, and Southern areas to the identified storing areas. The relevant cost is assumed in Table 4-4.

With respects to $CO_2$ storage, the cost of geological storage depends on type of formation, onshore or offshore location, number of wells for injection, etc. The IPCC (2005) argued the cost for storing, including monitoring works, ranges from 0.6 US$/t$CO_2$ to 8.3 US$/t$CO_2$. If storage is in conjunction to the EOR, the cost could be even negative (benefits gained) between 10 US$/t$CO_2$ and 16 US$/t$CO_2$ (at the oil prices of 15-20 US$ per barrel) and much larger for higher oil prices. Based on this basic cost-estimation and recent updated project database from the just above-mentioned reports we assume the storage cost for $CO_2$ emissions in Vietnam as presented in Table 4-4.

*Table 4-4: Costs (based on 2008) of transport and storage process assumed in the study.*

| No. | Cost (UD$/t$CO_2$) | 2025-2030 | 2030-2035 | 2035-2040 |
|---|---|---|---|---|
| 1 | Cost of $CO_2$ transportation process | 2 | 1.5 | 1.5 |
| 2 | Cost of $CO_2$ storage process | 2 | 1.5 | 1 |

Source: Johnson (2002); IPCC (2005); IEAGHG, 2006; IEA, 2006a; Viebahn et al., (2007); Davison, 2007; MIT (2007); Broek et al., 2008; Broek et al., (2009); GlobalCCSInstitute (2010).

With the assumed costs related to CCS deployment, the study shows that the cost of $CO_2$ avoided for different generation technologies in the Vietnamese power sector could vary from 27-47 US$/t$CO_2$. Though this range of cost for $CO_2$ avoided is not high compared to that examined in many cases for developed countries (IPCC, 2005), it is virtually not cost-competitive to other $CO_2$ mitigation options in the sector, such as energy efficiency or renewable energy (Nguyen and Ha-Duong, 2010; ECN, 2007). Unless, a strict climate policy instrument needs to be favourably employed for promoting deployment of CCS in the sector.

### 4.2.3 Results: CCS enters after 2030 at $CO_2$ values over $25

*How would the introduction of a positive scheme of carbon price favour the deployment of CCS in the Vietnamese power sector? At what carbon price does CCS-based power generation become cost-effective? And how much CCS would be contributing to $CO_2$ reduction?*

As CCS is still expensive as an abatement option in the power sector, there is no surprise that low carbon price in the CCS-LCV scenario would not have enough incentive robustness to impulse the penetration of generation plants with CCS into the electricity generation portfolio. But, higher price on $CO_2$ emissions (25 US$/t$CO_2$ to 35 US$/t$CO_2$) in the CCS-MCV scenario would create an incentive driver for a few units with CCS to enter cost-effective the generation system between 2030 and 2040. In this case, the two units are gas-fired generation plants (2x750 MW). Totally, during the period from 2030 to 2040 these two generation units produce 119,316 GWh to the electricity grid and achieve a significant reduction of about 39 Mt$CO_2$.

Moreover, one subcritical coal-fired generation plant (300 MW) retrofitted with CCS would become cost-effective for electricity production by 2038 when price of carbon rises to 33 US$/t$CO_2$ and another one (300 MW) integrated with CCS-ready would enter the system by 2040 when price of carbon increases to 35 US$/t$CO_2$. Both provide an amount of 1,612 GWh to electricity network during the period from 2038 to 2040 and contribute a great fraction of 78% in total cumulative $CO_2$ (1.35 Mt) that could be potentially emitted to the atmosphere during the same period in the case of without CCS deployment.

Overall, with a moderate trajectory of carbon price increasing from 25 US$/t$CO_2$ by 2030 to 35 US$/t$CO_2$ by 2040 would be incentive to favour the deployment of CCS in the Vietnamese power sector. Though the number of energy capacity with CCS seems to be very modest (2.1 GW) compared to total energy capacity within the system by 2040 (154 GW), they would contribute to a great $CO_2$ reduction of 40 Mt between 2030 and 2040.

When the IRP simulates higher carbon price increasing gradually from 5 US$/t$CO_2$ to 50 US$/t$CO_2$ over 2010-2040 in the CCS-HCV scenario, it gives a result that four candidate gas-fired generation units with CCS (4x750 MW) would become economically generated for electricity. The first two units dispatched by 2030 (at 35 US$/t$CO_2$) producing 11,457 GWh per year. The others would be added to the system by 2031 (at 36.5 US$/t$CO_2$) producing the same amount of electricity energy. Totally, during the period 2030-2040 these four generation units with CCS would produce 240,597 GWh to the electricity network and achieve a $CO_2$ reduction of 78.44 Mt, which is nearly 2 times as much as that in the CCS-MCV scenario.

Also in this CCS-HCV scenario, two subcritical coal-fired generation plant (300 MW) with CCS-ready would become cost-effective by 2030 when carbon price increases to 35 US$/t$CO_2$. Compared to the CCS-MCV scenario, no subcritical coal-fired generation plant (300 MW) with CCS retrofitted selected in this case. As higher price placed on emission of $CO_2$ would favourably impulse earlier dispatch and more utilization of energy generation from these two coal-fired generation units with CCS-ready, the total amount of 22,035 GWh would be generated during the period 2030-2040, which is much larger than those generated from both coal-fired generation units (with CCS retrofitted and CCS-ready) in the scenario CCS-MCV.

Table 4-5 summaries that CCS would enter the Vietnamese power sector after 2030 at $CO_2$ values over $25.

*Table 4-5: Effects of carbon prices favor the cost-effectiveness of CCS-based power generation plants, the IRP simulation.*

| Item | Units selected (unit) | Earliest year dispatched | Capacity (MW) | Energy (GWh) | $CO_2$ savings by CCS (Mt) | Total cost (million US$) | LRAC ($cent/ kWh) | AIC ($cent /kWh) |
|---|---|---|---|---|---|---|---|---|
| **Case with CCS integration: CCS-MCV scenario** | | | | | | | | |
| NGCC-CCS | 2 | 2030 | 1,500 | 119,316 | 39 | - | - | - |
| PC-CCS ready | 1 | 2040 | 300 | 573 | 0.37 | - | - | - |
| PC-CCS retrofit | 1 | 2038 | 300 | 1,039 | 0.68 | - | - | - |
| Total | 4 | - | 2,100 | 120,928 | 40.05 | 111,388 | 4.57 | 5.15 |
| **Item** | **Units selected (unit)** | **Earliest year dispatched** | **Capacity (MW)** | **Energy (GWh)** | **$CO_2$ savings by CCS (Mt)** | **Total cost (million US$)** | **LRAC ($cent/ kWh)** | **AIC ($cent /kWh)** |
| **Case with CCS integration: CCS-HCV scenario** | | | | | | | | |
| NGCC-CCS | 4 | 2030 | 3000 | 240,597 | 78.44 | - | - | - |
| PC-CCS ready | 2 | 2035 | 600 | 22,035 | 14.34 | - | - | - |
| Total | 6 | - | 3600 | 262,632 | 92.78 | 112,106 | 4.61 | 5.16 |

*Sensitivity analysis*:

This part of sensitivity analysis adds a dimension to the previous view of how the choice and dispatch of CCS-based power generation technologies would be affected by assuming higher costs for $CO_2$ capturing process, transport and storage system (Table 4-6), and a slow technological innovation leading to a lower net efficiency of power generation plants integrated with CCS (Table 4-7).

*Table 4-6: Changes in capital cost and net plant efficiency assumed for sensitivity analysis in the IRP.*

| No. | Candidate plants | Capital cost ($/kW) | | Efficiency (%) | | Life time (year) |
|---|---|---|---|---|---|---|
| | | 2010 | 2040 | 2025-2035 | 3035-2040 | |
| 1 | Subcritical Coal-CCS | 2544 | 2160 | 30 | 32 | 30 |
| 2 | Supercritical Coal-CCS | 2916 | 2232 | 34 | 36 | 30 |
| 3 | IGCC Coal-CCS | 2880 | 2256 | 36 | 38 | 30 |
| 4 | NGCC Gas-CCS | 1452 | 1189 | 43 | 45 | 25 |
| 5 | Subcritical Coal-CCS ready | 2405 | 2042 | 30 | 32 | 30 |
| 6 | Supercritical Coal-CCS ready | 2777 | 2125 | 34 | 36 | 30 |
| 7 | Retrofit subcritical coal-CCS#1 | 1181 | 1002 | 20 | 24 | 30 |
| 8 | Retrofit subcritical coal-CCS#2 | 1181 | 1002 | 27 | 31 | 30 |
| 9 | Retrofit NGCC Gas-CCS#1 | 662 | 542 | 34 | 36 | 25 |
| 10 | Retrofit NGCC Gas-CCS#2 | 662 | 542 | 42 | 44 | 25 |

*Table 4-7: Changes in transport and storage cost assumed for sensitivity analysis in the IRP.*

| No. | Cost (US$/tCO2) | 2025-2030 | 2030-2035 | 2035-2040 |
|---|---|---|---|---|
| 1 | Cost of $CO_2$ transportation process | 2.5 | 2 | 1.5 |
| 2 | Cost of $CO_2$ storage process | 2.5 | 2 | 2 |

IRP simulation suggests that in the CCS-MCV scenario the choice and dispatch of CCS-based power generation technologies would be changed lightly when capital cost increases by 20%. In this case, one unit of coal-fired generation with CCS retrofit would be selected, instead of with CCS-ready, in the IRP. However, in the CCS-HCV scenario, the choice and dispatch of CCS-based power generation technologies would be distinctly changed resulting in significant changes in energy production and planning cost, and $CO_2$ emission savings. Table 4-8 summaries how a change in capital cost affected the choice and dispatch of CCS plants.

*Table 4-8: Effects of change in capital cost to the choice and dispatch of generation plants with CCS, the IRP simulation.*

| Item | Units selected (unit) | Earliest year dispatched | Capacity (MW) | Energy (GWh) | $CO_2$ emission savings by CCS (Mt) | Total planning cost (million US$) |
|---|---|---|---|---|---|---|
| **CCS-MCV scenario: case with defined capital cost** | | | | | | |
| NGCC-CCS | 2 | 2030 | 1,500 | 119,316 | 39.00 | - |
| PC-CCS ready | 1 | 2040 | 300 | 573 | 0.37 | - |
| PC-CCS retrofit | 1 | 2038 | 300 | 1,039 | 0.68 | - |
| Total | 4 | - | 2,100 | 120,928 | 40.05 | 111,419 |
| **CCS-MCV scenario: case with 20% increase in capital cost** | | | | | | |
| NGCC-CCS | 2 | 2030 | 1,500 | 119,311 | 39.00 | - |
| PC-CCS ready | 0 | - | - | - | - | - |
| PC-CCS retrofit | 2 | 2039 | 600 | 1,394 | 0.91 | - |
| Total | 4 | - | 2,100 | 120,705 | 40.00 | 111,432 |
| **Item** | **Units selected (unit)** | **Earliest year dispatched** | **Capacity (MW)** | **Energy (GWh)** | **$CO_2$ emission savings by CCS (Mt)** | **Total planning cost (million US$)** |
| **CCS-HCV scenario: case with defined capital cost** | | | | | | |
| NGCC-CCS | 4 | 2030 | 3,000 | 240,597 | 78.44 | - |
| PC-CCS ready | 2 | 2035 | 600 | 22,035 | 14.34 | - |
| Total | 6 | - | 3,600 | 262,632 | 92.78 | 112,106 |
| **CCS-HCV scenario: case with 20% increase in capital cost** | | | | | | |
| NGCC-CCS | 4 | 2030 | 3,000 | 232,615 | 75.84 | - |
| PC-CCS ready | 0 | - | - | - | - | - |
| PC-CCS retrofit | 1 | 2039 | 300 | 867 | 0.56 | - |
| Total | 5 | - | 3,300 | 233,482 | 76.40 | 112,057 |

Further, the IRP result suggests the cost-effectiveness of CCS-based power generation plants is very sensibly interplayed with changes in costs for transporting and storing $CO_2$. By increasing an unit of carbon price (1 US$/t$CO_2$) in total costs for both transporting and storing $CO_2$, the choice and dispatch of CCS-based power generation plants in the sector would be clearly changed that leads to reduction in energy production and $CO_2$ emission savings (Table 4-9).

*Table 4-9: Effects of change in transport and storage to the choice and dispatch of generation plants with CCS, the IRP simulation.*

| Item | Units selected (unit) | Earliest year dispatched | Capacity (MW) | Energy (GWh) | $CO_2$ emission savings by CCS (Mt) | Total planning cost (million US$) |
|---|---|---|---|---|---|---|
| **CCS-MCV scenario: case with defined transport and storage cost** | | | | | | |
| NGCC-CCS | 2 | 2030 | 1,500 | 119,316 | 39.00 | - |
| PC-CCS ready | 1 | 2040 | 300 | 573 | 0.37 | - |
| PC-CCS retrofit | 1 | 2038 | 300 | 1,039 | 0.68 | - |
| Total | 4 | - | 2,100 | 120,928 | 40.05 | 111,419 |
| **CCS-MCV scenario: case with an increase in transport and storage cost** | | | | | | |
| NGCC-CCS | 1 | 2030 | 750 | 54,610 | 17.80 | - |
| PC-CCS ready | 0 | - | - | - | - | - |
| PC-CCS retrofit | 0 | - | - | - | - | - |
| Total | 1 | - | 750 | 54,610 | 17.80 | 111,394 |
| **Item** | **Units selected (unit)** | **Earliest year dispatched** | **Capacity (MW)** | **Energy (GWh)** | **$CO_2$ emission savings by CCS (Mt)** | **Total planning cost (million US$)** |
| **CCS-HCV scenario: case with defined transport and storage cost** | | | | | | |
| NGCC-CCS | 4 | 2030 | 3,000 | 240,597 | 78.44 | - |
| PC-CCS ready | 2 | 2035 | 600 | 22,035 | 14.34 | - |
| Total | 6 | - | 3,600 | 262,632 | 92.78 | 112,106 |
| **CCS-HCV scenario: case with an increase in transport and storage cost** | | | | | | |
| NGCC-CCS | 2 | 2030 | 3,000 | 228,394 | 74.46 | - |
| PC-CCS ready | 0 | - | - | - | - | - |
| PC-CCS retrofit | 0 | - | - | - | - | - |
| Total | 2 | - | 3,000 | 228,394 | 74.46 | 112,077 |

In the view of slow technological innovation, the IRP simulation shows that if net efficiency of generation plants with CCS decreased as assumed in Table 4-6, there is no change in the choice and dispatch of CCS-based power generation technologies except for a minor change in energy production that leads to a small reduction in $CO_2$ emission savings.

*Table 4-10: Effects of change in net plant efficiency to the choice and dispatch of generation plants with CCS, the IRP simulation.*

| Item | Units selected (unit) | Earliest year dispatched | Capacity (MW) | Energy (GWh) | CO2 emission savings by CCS (Mt) | Total planning cost (million US$) |
|---|---|---|---|---|---|---|
| **CCS-MCV scenario: case with defined efficiency of plants** | | | | | | |
| NGCC-CCS | 2 | 2030 | 1,500 | 119,316 | 39.00 | - |
| PC-CCS ready | 1 | 2040 | 300 | 573 | 0.37 | - |
| PC-CCS retrofit | 1 | 2038 | 300 | 1,039 | 0.68 | - |
| Total | 4 | - | 2,100 | 120,928 | 40.05 | 111,419 |
| **CCS-MCV scenario: case with a decrease in efficiency of plants** | | | | | | |
| NGCC-CCS | 2 | 2030 | 1,500 | 112,153 | 36.56 | - |
| PC-CCS ready | 1 | 2040 | 300 | 573 | 0.37 | - |
| PC-CCS retrofit | 1 | 2038 | 300 | 1,039 | 0.68 | - |
| Total | 4 | - | 2,100 | 113,766 | 37.61 | 111,427 |
| **Item** | **Units selected (unit)** | **Earliest year dispatched** | **Capacity (MW)** | **Energy (GWh)** | **CO2 emission savings by CCS (Mt)** | **Total planning cost (million US$)** |
| **CCS-HCV scenario: case with defined efficiency of plants** | | | | | | |
| NGCC-CCS | 4 | 2030 | 3,000 | 240,597 | 78.44 | - |
| PC-CCS ready | 2 | 2035 | 600 | 22,035 | 14.34 | - |
| Total | 6 | - | 3,600 | 262,632 | 92.78 | 112,106 |
| **CCS-HCV scenario: case with a decrease in efficiency of plants** | | | | | | |
| NGCC-CCS | 4 | 2030 | 3,000 | 232,615 | 75.83 | - |
| PC-CCS ready | 2 | 2035 | 600 | 23,732 | 15.45 | - |
| Total | 6 | - | 3,600 | 256,347 | 91.30 | 112,195 |

## 4.3 The relevance of CCS as a climate policy instrument

### 4.3.1 A potential 20% abatement in the power sector at $60 t/CO_2$

*What is the relevance of CCS as a climate policy instrument in the Vietnamese power sector?*

This part examines in greater detail the question that in what context CCS could play as climate policy instrument in the Vietnamese power sector and how it would play. To find the answer, we simulate a direct action of strict climate policy (ACT) by placing price on $CO_2$ emissions in the power sector: increasing gradually from 5 US$/t$CO_2$ in 2010 to 40 US$/t$CO_2$ by 2030, and to 60 US$/t$CO_2$ by 2040. This assumed action of climate policy is combined with CCS options to form a major climate mitigation scenario in Vietnam: CCS-ACT.

The simulation finds that a strong switch from coal- and gas-fired generation plants with no CCS to coal- and gas-fired generation plants with CCS is definitely occurred when a strict climate policy is in place. In the CCS-ACT scenario, 5.9 GW in energy capacity using CCS would be installed by 2030, accounting for 5.4% of the system energy capacity in the same year. It then increases to 52.6 GW by 2040 that accounts for 24.4% of the system energy capacity in the same year. In term of energy production, electricity-generating plants using CCS provide 7.3% of total electricity production (588.4 TWh) by 2030 and increase to 24.6% (1212 TWh) by 2040. Among technologies using CCS, supercritical PC-CCS and supercritical PC-CCS-ready, IGCC Coal-CCS, and NGCC-CCS are optimally suggested by the IRP model.

In term of $CO_2$ savings, the penetration of 68 power generation units using CCS could help cut down about 1.3 Gt of $CO_2$ during the period from 2030 to 2040. This figure takes a significant fraction of 18% over 7.2 Gt in total cumulative $CO_2$ emissions that the power sector could discharge into the atmosphere between 2010 and 2040. Table 4-11 summaries the key findings for the prospects of CCS deployment in Vietnam's power sector as a climate policy instrument.

*Table 4-11: The relevance of CCS as a climate policy instrument in Vietnam's power sector, the IRP simulation.*

| Item | Units selected (unit) | Earliest year dispatched | Capacity (MW) | Energy (GWh) | CO2 emission savings by CCS (Mt) | Total planning cost (million US$) |
|---|---|---|---|---|---|---|
| **Case with CCS integration: CCS-ACT scenario** | | | | | | |
| NGCC-CCS | 4 | 2030 | 3,000 | 240,597 | 78.4 | - |
| Super PC-CCS | 22 | 2030 | 13,200 | 529,005 | 344.4 | - |
| Super PC-CCS ready | 14 | 2030 | 8,400 | 361,735 | 235.5 | - |
| IGCC Coal-CCS | 28 | 2030 | 28,000 | 930,551 | 605.8 | - |
| Total | 68 | - | 52,600 | 2,061,888 | 1,264 | 114,564 |

To date, there are mostly absent of specific studies on economic potential for the deployment of CCS-based power generation plants in Vietnam yet. However, a study by ADB (2009, 2010) suggested that under a scenario of 450ppm with an expected carbon price above 80 US$/t$CO_2$ by 2050, CCS could play a key role in reduction of $CO_2$ in Vietnam in the forms of coal beds and deep saline aquifers. Given promising potential for $CO_2$ storage in Vietnam and the above analysis results, the present study suggests dozens of CCS-based power generation projects could be economic feasibly deployed in the Vietnamese power sector by 2030 if carbon price increases from 40 US$/t$CO_2$ by 2030 to 60 US$/t$CO_2$ by 2040.

### 4.3.2 Renewables cheaper than CCS without EOR/ECBM

*How would deployment of CCS-based power generation plants become cost-competitive compared to other mitigation options as renewable energy in the Vietnamese power sector?*

We further examine the prospects of CCS options by comparing their cost-competitiveness to that of renewables as a key climate abatement option in the Vietnamese power sector. In this case, we combine the assumed action of climate policy with both CCS options and RETs to form another major climate mitigation scenario in Vietnam: RET-CCS-ACT.

Results from IRP simulation suggest that integrating CCS (without EOR/ECBM) into the electric power generation industry in Vietnam would not be cost-competitive to renewables for mitigating $CO_2$ emissions under such a context assumed in the present study. As modelled here, in the RET-CCS-ACT scenario there are no power generation plants using CCS would enter cost-competitive to produce electricity energy during the period 2025-2040. This result also interprets that for the decades to come, i.e. before 2040, CCS-based power generation plants would not be cheaper than renewables-based power plants for mitigating $CO_2$ emissions in the Vietnamese power sector. However, although our climate mitigation scenario suggests CCS options (without EOR/ECBM) are not yet cost-effective generation sources compared to renewables, the possibility that they will become so as a result of future changes in the market and in the technologies themselves should not be ignored.

Specially, due to unavailability of relevant data we did not take into account in this study the added economic values of incremental oil and methane production (i.e. EOR and ECBM), which should exist greatly within Vietnam. If these values are internalized, they could reduce costs of storing emission of $CO_2$, even negative the costs that could lead to enhancing cost-competitiveness of CCS-based power generation plants in Vietnam. The IPCC (2005) provided that enhanced oil production (EOR) for onshore integrated with CCS could generate net benefits of 10-16 US$/t$CO_2$ (based on oil prices before 2003). Compared to the changes in fuel prices based on market levels observed in recent years and its future possibly increasing trend, benefits of added economic values from CCS deployment in Vietnam in conjunction with EOR and ECBM would be even possibly higher than what the IPCC (2005) already proved.

Overall, the study results favourably provide a promising prospect for CCS deployment associated with EOR in the Vietnamese power sector as structures of $CO_2$ storage in depleted oil reservoirs are already well known and some are already significant in place (IPCC, 2005).

### 4.3.3 Domestic requirements for CCS initiatives

Though CCS deployment was early proposed as the first commercial CCS in Asia involving the EOR production at the White Tiger Field, CCS seems still to be a quite new concept in Vietnam. Specially, Vietnamese Government seems not to be sufficiently ready to the exploitation of CCS opportunities in Vietnam to date. Particularly, Vietnam does not have any policy or legislation typically addressing the deployment of CCS technology. However, Vietnam has already implemented a certain number of policy and strategy related to climate change and energy development. These could be feasibly linked to a significant framework for supporting CCS initiatives from domestic side.

*Cooperation:* Vietnam should have more necessary cooperation and collaboration by participating in regional and international forums/projects relating to CCS around the globe. This could help overcome barriers relating to lack of awareness/information and provide access to possible financing mechanisms for deployment of CCS projects. More international conferences/workshops/trainings and research development activities should be actively hosted and strategically implemented with participations from all relevant sectors (economic, political and technical, environmental, etc.) in order to enhance local capacity sources. International cooperation could include foreign expert visits to Vietnam or Vietnamese delegations travelling elsewhere. Necessary actions such as joining the International Energy Agency, the Global Carbon Capture and Storage Institute, etc., which could enable more international attentions to the country and receive supports for capacity development.

*Incentives:* This could vary from Government funding for research development and technology demonstration to considerably using incentive instrument, as taxation incentives.

Currently, there are no research centres at both regional or national level with necessary basic research facilities and infrastructures for CCS development. Thus, a special budget is necessarily considered. Some research centers, which are undertaking R&D activities in relation to energy, environment and climate change are inventively encouraged to be involved in extensive research for CCS deployment. In this regard, the country could learn international experiences and practices from other Asian countries such as China, India, Indonesia. For example, in Indonesia, the national R&S centre for oil and gas technology has been pointed as the focal point in performing specific research and development of CCS. In China, they have already initiated publicly-available incentives and policies regarding demonstration and early deployment for CCS by which there are various CCS-related projects being undertaken in the form of Government-business joint ventures and mostly based on Government involvement and intergovernmental cooperation (GlobalCCSInstitute, 2009b).

In Vietnam, there are currently no specific regulations typically grating tax incentives to the development of clean energy technologies including CCS. Recent years, Vietnamese Government has been undertaking technical assistance programs from international organizations such as European Commission to assess the possibility of enhancing the use of environmental protection taxes and levies. This is really a good opportunity and due time for the country to think about the integration of CCS for the future development stages.

*Regulation and power sector reform:* The present regulatory framework, in which sufficient supporting measures are entirely absent for the use of clean energy whereas electricity price is mostly administered by the Government. These reasons would virtually make EVN, the state-established leader in the sector, lean toward less costly generation options and pay no interest to more expensive energy supply options related to $CO_2$ reduction in the sector. For deployment of CCS, financial issues are extremely important while technical advances are also a crucial driver. Moreover, appropriate regulation in place have to be essentially developed to provide attention to both developers and the public. Though public awareness and objection against CCS might not be a problem in Vietnam but this would not be ignored in the CCS development agenda. Furthermore, there clearly exist a need of reforming power sector to improve its capacity and performance so that it could be not only run in a more effective manner but also provide a wider access to possible future of CCS in the sector, when the potential of CCS-based power generation projects are proven and accepted.

## 4.4 Concluding remarks

Developing countries like Vietnam with greater use of coal for future electricity production could potentially benefit from funding opportunities through the CDM or CDM-like mechanism by deployment of CCS projects. To date, none of CDM projects is for a coal-fired power generation plant with CCS but there have been several proposals to include CCS projects under the CDM. One of these, the White Tiger Field project in Vietnam has a high sustainable development value since it is likely to become the first commercial CCS project in Asia (IEA, 2008a). It involves collection of $CO_2$ emissions from combined cycle natural gas power plants in the Phu My power complex, a transport system with 144 km pipeline to the injection site at While Tiger Oil Field, which is in conjunction with EOR. It is expected to generate a reduction of approximately 7.7 $MtCO_2$ per year and recover 50 thousand barrels of crude oil per day on average (UNFCCC, 2009c), as well as offer employment opportunities.

The ability and prospects to capture and sequester $CO_2$ emissions (CCS) offers a promising technology of significant $CO_2$ reduction in a way that is compatible with the future fossil-fuel power generation industry whereas allowing coal to meet the pressing needs for energy. Vietnam is expected to be heavily dependent on coal use to fuel the power sector development within next 30 years. Moreover, Vietnam is estimated to have significant potential for geological storage of $CO_2$, a part in conjunction with Enhanced Oil Recovery (EOR) and Enhanced Coal Bed Methane (ECBM). All these provide that climate mitigation options for the Vietnamese power sector in the coming decades could also include CCS.

The present study showed that deployment of CCS-based power generation technologies is not economically feasible if carbon price is below 25 US$/$tCO_2$ by 2030. However, dozens of CCS projects would be economically proliferated in the power sector during the period from 2030 to 2040 if carbon price increases to 40 US$/$tCO_2$ by 2030 (by 2030, domestic and imported coal costs 64 and 76 US$/ton respectively, and domestic gas costs 7.3 US$/MBtu as assumed by the study), and to 60 US$/$tCO_2$ by 2040 (by 2040, domestic and imported coal costs 81 and 84 US$/ton respectively, and domestic gas costs 8.9 US$/MBtu as assumed by the study). Compared to renewables in mitigating $CO_2$ emissions for the Vietnamese power sector, deployment of CCS options would not be cost-competitive before 2040. However, the added economic values of incremental oil (EOR), which should exist greatly within the country could potentially favour its cost-competitiveness and earlier adoption. Finally, the option of carbon capture ready plants for the future development stages of the power sector is recommended if the CCS is included as a key climate mitigation option in the Vietnamese Government agenda.

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# Chapter 5. Systhesis outline of the potential for $CO_2$ mitigation with climate policies

## 5.1 Introduction of Chapter 5

At the Copenhagen 2009, parties to the UNFCCC failed to achieve the details of a new global climate regime for the post-2012 period. Most developing countries are still viewing binding of carbon emissions on their economic growth as a potential cap and hardly to accept binding targets in a post-2012 climate agreement. However, they would involve an commitment on emissions reductions and implement necessary mitigation actions to the extent that developed countries comply with their promises of financial resources for mitigation, adaptation, technology transfer and capacity building. The Climate Dialogue at Pocantico[11] also suggested that one key to engage developing countries in stronger international efforts is a flexible framework in which countries assume different types of commitments being best suited to their circumstances (Lewis and Diringer, 2007).

At the moment before the COP 16 in Cancun, there are no evidences that the CDM should be abolished. Instead, its overall effectiveness and efficiency are essentially discussed on roundtable of the international climate agenda (Cames et al., 2007; Michealowa and Purohit, 2007; Schneider, 2007; Wara and Victor, 2008; Wara, 2008; Streck, 2007; Sterk and Wittneben, 2006; Schneider, 2009; Bakker et al., 2009). However, the continuation of the CDM is still uncertain to date. The structure of new climate policy post-2012 may involve new approaches or reform the CDM or form new mechanisms linked to CDM such as: the sectoral approach or the Nationally Appropriate Mitigation Actions-NAMAs (Cosbey, et al., 2007; Bodansky, 2007; Schmidt, et al., 2008; Cames, et al., 2007; Schneider, 2009; Michealowa and Muller, 2009).

However, a national strategy for sustainable energy development today must be linked with environmental sustainability, in which people have to consider urgently the climate change-related challenges and look for opportunities of increased sustainable development in conjunction with international carbon emission mitigation.

Before entering the part B of the study thesis discussing how to practically promote sustainable development for Vietnam's power sector, this bridging chapter provides a synthesis discussion of the technical potential for $CO_2$ emissions mitigation in the Vietnamese power sector considering the above-examined energy options including: demand-side management (DSM), renewables (RET), and carbon capture and storage (CCS) under the context of relevant climate policies (carbon prices and carbon caps). Technically, it permits to give the insights that how efficient climate policies would favour the potential mitigation of $CO_2$ emissions in the Vietnamese power sector by using the IRP simulation.

[11] The Climate Dialogue at Pocantico was convened by the Pew Center on Global Climate Change to provide an opportunity for informal discussion among senior policymakers and stakeholders from 15 countries on options for advancing the international climate change effort.

## 5.2 The technical potential for mitigation of $CO_2$ emissions in the power sector

*$CO_2$ emissions can be reduced by 19% for the baseline development*

Without a price or a cap on carbon emissions, fossil fuels dominate the energy generation mix in the baseline power sector development (BAU scenario) in Vietnam. If the current development policy scenario is continued, coal share of the overall energy generation is set at 48.5%, while renewable energy would account for only 4.1%. The power sector $CO_2$ emissions grow at an annual growth rate of 26% over 2010-2040, reaching approximately 570 Mt by 2040 and a total of 7.2 Gt.

Placing, in 2010, a 5 US$/t$CO_2$ price in the power sector and it is increasing gradually to 20 US$/t$CO_2$ by 2040 (in BAU-LCV scenario), to 35 US$/t$CO_2$ by 2040 (in BAU-MCV scenario), and to 50 US$/t$CO_2$ by 2040 (in BAU-HCV scenario) reveals a technical mitigation cumulative potential set at 17%, 18.6%, and 19.2% respectively from the BAU scenario over the period from 2010 to 2040. This reduction comes both from (i) demand-side effect: where energy-consumers would use less energy due to an increase in electricity price caused by imposing carbon price in the sector, and (ii) substitution (supply side) effect: where a strong switch to cleaner and more efficient generation technologies such as NGCC gas-fired, supercritical, and IGCC coal-fired technologies, as well as renewables generation sources would be deployed. However, placing such carbon prices in the sector would also increase the LRAC by 4.9%, 5.8%, and 6.5% respectively.

### 5.2.1 Renewable energy option: a potential 25% of $CO_2$ emission abatement

To exploit a broader mix of renewable energy sources in a scenario which fully includes energy supply options available (renewables, CCS), the sector cumulative $CO_2$ emissions in the baseline scenario could potentially be reduced by 23.4% (in RET-CCS-LCV scenario) to 25.2% (in RET-CCS-HCV scenario) when placing the same assumed prices on $CO_2$ emissions in the sector. It notes that no CCS options would be cost-effective selected in the IRP model when such a full set of renewables is integrated in all scenarios. Similarly, the LRAC would increase by 6.7% to 8.1% respectively. As CCS options are not cost-competitive to renewables in all these combined scenarios integrating full energy supply technologies, the extra reduction of 6% in total cumulative $CO_2$ emissions, compared to baseline abatement (19%), is mainly contributed by more fully integrated diverse renewables sources.

Similarly, the long run average cost (LRAC) for one kWh electricity energy production would be also increased by 6.7 to by 8.1% respectively, compared to the baseline cost, when carbon prices are used as environmental policies in this context.

### 5.2.2 Energy efficiency and renewables: most significant 34% $CO_2$ abatement

The IRP results suggest that DSM options in the Vietnamese household sector alone offers a significant technical reduction of 9.7% in the baseline cumulative $CO_2$ emissions (over 7,156 Mt) during the 2010-2040 period. This reduction implies an average reduction of

22.4 Mt per year during the same period, which is a large fraction compared to the 36 Mt of $CO_2$ emissions emitted from the Vietnamese electricity sector in 2006. Thus, more effectively in improving the environment performance, fully combining both energy supply options (renewables) and demand-side options (DSM) even better suggests a 34% $CO_2$ abatement could be potentially achieved if carbon price varies from 5 US$/t$CO_2$ in 2010 to 50 US$/t$CO_2$ by 2040. In this case, the reduction implies an average reduction of 78.5 Mt per year during the same period, which is even double larger than the 36 Mt of $CO_2$ emissions emitted from the Vietnamese electricity sector in 2006.

What more interesting is that such a fully combined scenario would not increase the long run average cost of electricity production (LRAC), even potentially decrease it by about 0.2%. This is because DSM programs offer the "free lunch" option for mitigating $CO_2$ emissions in the IRP simulation.

### 5.2.3 Opportunities for $CO_2$ mitigation projects with competitive abatement cost

As a simulation result given in the chapter 3, Vietnam's power sector could offer a large opportunity for hosting $CO_2$ mitigation projects under the CDM or CDM-like mechanism at relatively low carbon prices: biomass (including rice husk, paddy straw, wood residues), and wind power become competitive at 4 $/t$CO_2$, while wood plantation and municipal solid wastes become competitive at 6 $/t$CO_2$.

Looking at the CDM activities in Vietnam, we found that as of February, 2009, the Vietnamese Designated National Authority (DNA) had approved 78 CDM Project Design Documents (PDDs), of which only 44 projects have made it all the way through the domestic approval cycle since 1 August 2008. As estimated initially, these 44 projects would offer a total reduction of 31.6 Mt $CO_{2eq}$ ($CO_2$ equivalent) over a 10-year period, and the country would gain 63 million $/year between 2008 and 2012 by selling certified emission reductions (CERs) from these projects.

According to local CDM consultants, Vietnamese CDM projects have been fetching approximately 12€ (equal to 17 $ at exchange rate of 0.705 $/€) in the emissions reduction purchasing agreements during the period from 2008 to 2010. In this part of the study, we include all the transaction costs associated with a CDM project cycle and its commercial viability so that carbon prices should be below 12€/ton $CO_2$. Next, we simulate the technical potential for $CO_2$ emissions reduction projects in the sector that could be technically produced at a plausible price of 6 $/t$CO_2$.

The IRP simulation results showed that at this carbon price, about 1 Gt of $CO_2$ could potentially be saved under a scenario of widespread renewables projects deployment in the sector over the period from 2010 to 2040. This represents an average savings of 30 Mt of $CO_2$/year, representing 186 million $/year in estimated selling carbon value. Compared to the CDM potential estimated in the current pipeline for the 44 approved projects mentioned above, the IRP results suggest that the technical economic potential of $CO_2$ emissions reductions in the power sector alone could offer a high potential for sustainable development and could even achieve a 30-fold increase in emissions reduction under this system.

More specifically, compared to the indentified GHG emissions mitigation alternatives for the electricity sector in selected developing countries studied by ECN (2007), the study finding suggests that the Vietnamese power sector could offer a range of GHG emissions reduction options, which are significantly competitive with energy options in other developing countries.

### 5.3 How efficient climate policies affect the power sector's carbon emission reduction?

In the IRP model, a cap on $CO_2$ emissions seems to be less effective in achieving high level of $CO_2$ emissions reduction in the Vietnamese power sector. In other words, it seems to give less incentive to improve the environmental performance, compared to a price instrument. Specifically for modelling exercise, though using the same parameters and scenarios the level of $CO_2$ reduction in all investigated simulation cases with carbon caps could not be cost-optimally achieved as the same significant level, which could be achievable in the cases using carbon prices. For example, placing carbon prices (varying from 5 US\$/t$CO_2$ in 2010 to 50 US\$/t$CO_2$ by 2040) could potentially achieve a significant 25% $CO_2$ abatement in a scenario RET-CCS-HCV (the RET-CCS scenario uses both a broader set of renewables (RET) and CCS options), whereas placing high level (HCC) of caps on $CO_2$ emissions in the same RET-CCS scenario could only achieve a 19% $CO_2$ abatement as the most significant in the RET-CCS-HCC scenario. Introducing higher levels beyond the HCC level in caps on $CO_2$ emissions would always lead to infeasible cost-optimized solutions. This finding may give an implication that placing a cap on $CO_2$ emissions would give limited incentives, in the lowest-system-cost optimization manner, to optimally achieve the desired objective of significant environmental performance in the Vietnamese power sector, compared to a price instrument.

We can now further look at the analysis issue on the angle of abatement costs among these two environmental policies. The IRP results provide that the sector cumulative $CO_2$ emissions would be already reduced by 23% in the RET-CCS-LCV scenario, even at relative low carbon price (LCV), varying from 5 \$/t$CO_2$ in 2010 to 20 \$/t$CO_2$ by 2040, while a high average abatement cost of 35 \$/t$CO_2$ should be laid out if using carbon caps, but for achieving only 19% of $CO_2$ cumulative emissions as in the RET-CCS-HCC scenario during the same period.

However, using carbon caps within the IRP simulation is likely to be more stringent than the use of carbon prices in fostering the wider penetration of CCS options to balance the expansion and environmental protection. As simulated here, integrating CCS into the Vietnamese power sector would not be cost-competitive to renewables option if carbon prices are employed, even in the case with high carbon price trajectory. However, with a high level of carbon caps (HCC) imposed as in the RET-CCS-HCC scenario, 38 GW in energy capacity of CCS options would be already cost-effective entering the electricity generation portfolio by 2040. It notes here all parameters and mitigation options including renewables and CCS are identically used in these simulations.

Overall, adding to the theoretical analysis on the impact of different environmental policy instruments, the study finding would be likely to be in line with the argument that regulatory mechanisms are generally less efficient than economic instruments or economic incentives has more innovation effects than command-and-control regulation (Jaffe et al., 2001; Menanteau et al., 2003; Lanoie, 2008; Rodi, 2008; Couture and Yves, 2010).

Particularly, the IRP simulation results represent a practical angle of the use direct regulation (quantity-based instrument) that under a lowest-cost-optimisation perspective direct regulation would offer an incentive to improve the environmental performance up to only a certain level of carbon emissions reduction. Beyond that, it could not give an incentive to improve the performance, whereas price-based instrument would give an incentive to reach higher environmental performance with higher carbon prices even though its cost-effectiveness would not be always linearly increasing with higher prices. In practice, the dynamic environmental performance (or environmental effectiveness) of direct regulation is easily criticised as its limited external flexibility, i.e. its ability to react to changes in external circumstances, such as technological progress or an increase in the number of polluters (Kalle Mäler, 2008). With this aspect, Menanteau et al., (2003) already proven that while technical progress enables companies to reduce the cost of complying with regulations, no incentive is given, by these regulations, to companies to improve environmental performance beyond what is formally required. Instead, taxes and permits are regarded as more effective in promoting technical change. They enable companies to reduce the costs of pollution control and save on taxes or on the purchase of permits.

Furthermore, there exists a relationship between cost-effectiveness and environmental-effectiveness that the more cost-effective an instrument is, the more ambitious may be the environmental policy goal (Kalle Mäler, 2008). From this point of view, the study suggests that carbon caps are likely cost-ineffective in the Vietnamese power sector, the environmental policy goals may be more ambitious in the sector with the use of cost-effective carbon prices.

In practice, direct regulation is often supported as it is able to achieve the desired environmental goal within a given timeframe. In addition, with regards to incentive policy cost control, it would be more effective, because there usually exists uncertainty regarding cost curves and future market prices of carbon emissions.

## 5.4 Concluding remarks

Atmospheric releases of $CO_2$ emissions by Vietnam's power sector are not inevitable, but rather are a consequence of choosing fossil fuel-based electric power generation. There are many cleaner technological solutions available which could help to overcome the challenging global problem of climate change and its detrimental local consequences as well as bring sustainability to the sector.

The study showed that more aggressively pursuing policies and measures to improve the efficiency of energy use combined with greater exploitation of renewable energy sources for electricity production could offer a significant 34% abatement of the baseline $CO_2$ emissions in the Vietnamese power sector during the period from 2010 to 2040. The study also proved that Vietnam could be well qualified to deal carbon certificates on the international market by expansion of grid-connected electricity generation from renewables. This could earn an extra income, at the same time improve the country's currency account balance.

Moreover, Vietnamese policy-makers should not ignore the ability and prospects to capture and sequester $CO_2$ emissions (CCS) that could also potentially provide a possible future for sustainable development of fossil-fuel power generation industry in Vietnam whereas allowing coal to meet the pressing needs for energy in the country.

Technically, within the IRP simulation, the study finding is likely to be in line with the argument that regulatory mechanisms are generally less efficient than economic instruments or economic incentives has more innovation effects than command-and-control regulation in serving as environmental policy for sustainable energy options. However, it would need more empirical studies on practical environmental policies including economic instruments, which are suitable to the country specific boundary conditions, towards sustainable opportunities for the sector.

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# Part B: How to practically promote sustainable development for Vietnam's power sector?

# Chapter 6. Strategies for promoting the wider deployment of sustainable energy options

## 6.1 Introduction of Chapter 6

In Vietnam's power sector, a large number of coal-fired generating plants that have already been committed to and those planned in the years leading up to 2015 are based on conventional pulverized and circulating fluidized bed technologies. Advanced and cleaner coal-fired technologies such as IGCC and PFBC are not yet included in the long-term generation capacity expansion development master plan. Vietnam is also endowed with a variety of renewable energy resources distributed throughout the country. These resources can be used for electricity generation. Their ultimate potentials are poorly known, but current estimates suggest that a very small portion of available renewable energy flows is being tapped at present (Nguyen and Ha-Duong, 2009).

In this thesis chapter, we analyse the social barriers to the adoption of renewables and higher efficient coal-based generation technologies that could contribute to the issues of sustainable development in the Vietnamese power sector for the next thirty years, based on a domestic expert survey. Then, we use an empirical analysis approach to examine different appropriate policy means including incentive instruments/schemes and sector reform for such sustainability of the power sector.

Particularly, we consider small hydro and geothermal energy generation technologies (collectively called RETs hereafter) and cleaner coal generation technologies, including pressurized fluidized-bed combustion (PFBC) and integrated gasification combined cycle (IGCC) coal-fired technologies (hereafter collectively called CCTs) as potentially sustainably profitable technologies for the Vietnamese electricity generation industry given the current conditions regarding energy development policy in Vietnam. If barriers to the adoption of these technologies can be overcome, it would definitely not only improve Vietnam's energy security but also help the Vietnamese power sector move towards a more sustainable energy path.

The next section describes the survey that was used to gather experts' opinions about barriers to implementing efficient energy technologies. It also discusses the characteristics of the sample and outlines the mathematical principles of the Analytical Hierarchy Process (AHP), which has been widely applied for multi-objectives analysis and decision making issues (Weiss et al., 1987; Saaty, 1990; Bryson et al., 1997; Saaty, 2006; Wijayatunga et al., 2006).

## 6.2 Barriers and policies to the adoption of sustainable development options

### 6.2.1 The study approach

#### *6.2.1.1 Identification and ranking of major barriers: A survey*

Generally, barriers are defined as factors that inhibit technology transfer. In this study, three electricity generation technologies were considered: small hydro, geothermal, and high-efficiency coal. As discussed above, there seem to be major barriers to the diffusion of these technologies in Vietnam. The study was organized according to the following steps:

Step 1: An overall review of the academic literature and technical reports was carried out to list all of the barriers that have been noted as hindering the widespread adoption of clean and energy-efficient technologies in the power sector. The lists were further refined through discussions with the country's key experts. The full list of relevant barriers was then narrowed down to a short list of five major barriers for each of the three selected technologies.

Step 2: Five criteria were developed to evaluate and rank the barriers: monetary cost to remove the barriers, level of effort required to create awareness, level of political or bureaucratic effort needed to remove barriers, impact of barriers on the adoption of a technology and lifespan of the barriers.

Step 3: Each expert provided weights for each pair of technologies or criteria.

Step 4: These weights were aggregated within each expert group.

Finally, the barriers were ranked by aggregating the data across criteria and groups using weighted averages. The weights used for the five criteria are presented in Table 6-2, and those for the expert groups are presented in Table 6-1. These weights are based on experts' judgments.

Mathematically, AHP estimates priority weights for a set of criteria or alternatives from a square matrix of pair-wise comparisons, $A = [a_{ij}]$, which is positive. Should the paired comparison judgment be perfectly consistent, the matrix is reciprocal, i.e., $a_{ij} = 1/a_{ji}$ for all $i,j = 1, 2, 3... n$. The final normalized weight $w_i$ for the $i^{th}$ element is given as:

$$w_i = a_{ij} / \left( \sum_{k=1}^{n} a_{kj} \right) \forall_k = 1,2...n \tag{6.1}$$

The individual pair-wise matrices provided by the group members for the alternative options in each criterion are used to obtain the aggregated pair-wise matrix for each criterion. In this study, the geometric mean method is used, with the formula:

$$\overline{W_i} = \left( \prod_{j=1}^{n} a_{ij} \right) \frac{1}{n} \tag{6.2}$$

where n is number of members and $a_{ij}$ is the preference of member a for elements '$i$' through '$j$'.

*Table 6-1: Numbers of respondents and priority weights of the six expert groups.*

| Priority ranked | Key Actor groups | Numbers of respondents | Priority weight calculated by AHP |
|---|---|---|---|
| 1 | Energy experts | 10 | 0.213 |
| 2 | Policy-makers | 7 | 0.199 |
| 3 | Environmental experts | 6 | 0.196 |
| 4 | Project developers and power facility owners | 6 | 0.155 |
| 5 | Equipment manufacturers and suppliers | 4 | 0.131 |
| 6 | Users of electricity | 4 | 0.106 |
| Total | | *n*=37 | 1 |

*Table 6-2: Priorities of evaluation criteria for ranking barriers calculated by AHP, based on expert opinions.*

| Criteria for ranking barriers | Weighted by AHP | Definition of criteria (*) |
|---|---|---|
| Monetary cost of removing a barrier | 0.307 | The cost of removing barriers varies with the type and nature of the barriers. Subsidies can be used to remove barriers related to high initial investment. While it is difficult to assess the exact cost of removing a barrier, one can give a qualitative judgment about the cost. |
| Impact of a barrier on the adoption of a technology | 0.209 | Different barriers have different degrees of impact on the adoption of efficient options. Removing barriers is more or less likely to result in the introduction of efficient options, depending on the specific barrier. This feature implicitly recognizes the importance of barriers. A barrier that is easy to overcome may have a low impact on the adoption of options. On the other hand, a barrier that is difficult to remove may have a larger impact on the adoption of options. |
| Lifespan of a barrier | 0.221 | Each barrier has its own lifespan, i.e., the time it takes to cease to be a barrier. Without any external intervention, some barriers tend to last longer than others.. Normally, barriers with shorter life are preferable to those with longer ones. |
| Level of effort required to create awareness | 0.138 | Awareness about efficient technologies plays a major role in overcoming barriers. Adopting a technology is easier for users who know something about the technology. Therefore, it is very important to create awareness among users. However, the level of effort required to create awareness depends on the type of barriers. Some barriers require less effort to create awareness, while others require much effort. |
| Level of political effort required to remove barriers | 0.125 | Political and bureaucratic efforts play major roles in removing barriers. Such efforts may include lobbying, introducing bureaucratic initiatives, and providing clear instructions to policy makers. However, barriers can be complex in nature. Barriers are often intertwined with other social and political considerations. The barrier may be linked to various government policies. The more complex a barrier is, the more difficult it is to overcome. Therefore, the level of political and bureaucratic effort required to remove the barriers depends upon the type of barrier considered. |

(*) Source: IPCC (1996), Shrestha and Abeygunawardana (2003).

#### *6.2.1.2 The interviewed survey and its questionnaire samples*

We conducted the questionnaire-based research survey. Opinions and judgments were collected from domestic experts and stakeholders. All respondents were knowledgeable about the power sector and familiar with clean and efficient energy generation technologies and the barriers hindering their widespread adoption in Vietnam. The experts were from the Ministry of Industry and Trade (MOIT), the Ministry of Natural Resources and Environment (MONRE), the Ministry of Planning and Investment (MPI), The Electricity Corporation of Vietnam (EVN), the Institute of Energy of Vietnam (IE), Electric Utility, Ha Noi Polytechnic Institute, and private companies, manufacturers and suppliers.

For consistent ranking and evaluation, we classified these experts into six groups, as shown in Table 6-1: energy experts (A1), environmental experts (A2), policy-makers (A3), project developers and power facility owners (A4), equipment manufacturers and suppliers (A5) and electricity users (A6). To maintain a diversity of points of view, we aimed at a balanced distribution of the number of respondents across groups. The list of interviewed respondents is presented in the Annex.

Excluding non-replies and inconsistent replies12, we collected 37 completed questionnaires from the total of 62 expert questionnaires distributed (Table 6-1). Expert Choice software (2000) was used to compute the final weight for each barrier and to check the consistency of the analysis.

### 6.2.2 Barriers to geothermal and small hydroelectric power generation

Table 6-3 shows the study results. For each technology, it lists the five barriers that emerged from the literature review and ranks them according to the aggregation of the experts' judgments. This section discusses barriers to the adoption of geothermal and small hydro technologies only. Barriers to cleaner coal technologies (lower third of the table) are discussed in the section that follows.

This section addresses barriers that fall into the categories of economic/financial (high initial investment and production cost, lack of capital investment and scarcity of financial resources), awareness/information, institutional, and political/regulatory. In addition, for small hydropower technology, it assesses the lack of domestic equipment suppliers and technical services. For geothermal technology, the remote location of renewable resources is examined.

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[12] The pair-wise comparison matrix should have a consistency level within 10% (Saaty, 2006). Inconsistent replies are those in which the pair-wise comparisons are inconsistent by over 10%. The required level of consistency was maintained through a re-examination process when necessary. Thus, we did not consider any questionnaire response with an inconsistency level of over 10% in the analysis.

*Table 6-3: Selected technologies: barrier weights calculated by AHP, based on expert opinions.*

| Barriers to selected technologies | Actor groups unequally prioritized | |
|---|---|---|
| | **Weight** | **Ranking** |
| **Small hydro** | | |
| Lack of capital investment and scarcity of financial resources | 0.214 | 1 |
| Low capability of technological development and lack of domestic equipment suppliers/services | 0.210 | 2 |
| Weak government policy and regulatory frameworks for clean energy development | 0.205 | 3 |
| Multiplicity of authorities and insufficient local capability to develop and operate networks | 0.205 | 4 |
| Lack of information on national energy resource potential | 0.166 | 5 |
| **Geothermal** | | |
| Lack of information and awareness about technical know-how, technological development and national resource potential | 0.213 | 1 |
| Weak level of scientific, technological and industrial capability | 0.204 | 2 |
| Insufficiency of incentive measures, promotion policies and regulatory framework | 0.200 | 3 |
| Geothermal energy sources are located in remote areas | 0.198 | 4 |
| High electricity production cost of geothermal technology | 0.185 | 5 |
| **CCTs** | | |
| Weak level of science and technology, insufficient industrial capability, and difficulty in technology transfer | 0.235 | 1 |
| High initial investment cost and high production price | 0.221 | 2 |
| Lack of technical know-how and technological development information | 0.197 | 3 |
| Scarcity of financial resources | 0.174 | 4 |
| Inadequate current electricity pricing system | 0.173 | 5 |

#### *6.2.2.1 Economic/financial barriers*

As in other developing countries, economic and financial issues are considered to be crucial for the development of RETs in Vietnam. The experts and stakeholders interviewed argued that small hydropower in Vietnam could not be widely implemented mainly due to a lack of capital. High electricity production cost is considered to be a major barrier preventing the utilization of geothermal power. AHP rankings (Table 6-3) show that in the case of small hydropower, among the five major barriers, the financial hurdle is the most important barrier, and the economic issue of high production cost is the least important barrier.

The extra costs preventing the widespread adoption of renewables in the Vietnamese power sector arise as a result of difficult geography, the weak financial and managerial capabilities of investors and project developers, the poor qualifications of commercial banks, an inadequate electricity pricing system, and a deficiency in the Government's policies and incentives.

Moreover, renewable resource sites are located primarily in remote areas of Vietnam, away from load centers and difficult to access. The people living in these areas are poor and under-educated. Inadequate infrastructure makes it difficult to develop renewable resources for generating electricity. Capital investments and financial resources are difficult to attract to these areas because of a lack of incentives.

In light of this difficulty, the Vietnamese Government has recently appealed to sources of financial capital to help implement a series of investment plans that call for the creation of small hydropower plants. These plants are intended to spur economic development as well as to serve remote areas. State-owned companies or subsidiaries of state enterprises are often appointed as the owners of these hydroelectric projects, which are to be realized in the form of small joint-stock hydroelectric companies. Most owners cannot acquire enough capital to finance the projects, and 80–90% or more of the capital for these projects takes the form of bank loans, especially from domestic commercial banks. Therefore, these joint-stock companies often have a tendency to expect interventions or sponsorships from the Government, rather than to be active in negotiating and seeking adequate financing agreements (local, national, and international) for the projects through power purchasing agreements before beginning work on the projects. Some owners even fail to estimate the financial requirements of the projects, which can result in delays or postponements.

Domestic commercial banks play an increasingly important role in financing renewable resource projects, including those using small hydropower technologies. However, insufficient capacity of some of the banks to appraise projects has been problematic. This has sometimes led to ineligible projects receiving loans while qualified projects are denied funding.

Another economic barrier is the manipulation of the prices of fossil fuels and electricity, which can make renewable resources less attractive to investors and independent power producers in Vietnam. As a result of subsidized prices for fossil fuels and electricity, and without a nation-wide production cost sharing system, the investment rates for renewable resource projects are generally still much higher than fossil fuel prices and electricity costs.

#### *6.2.2.2 Awareness and information barriers*

The potential positive side benefits of renewables, including small hydropower and geothermal energy, have not yet been systematically estimated with any precision. Information on local markets and physical potentials is crucial to project developers, but this information is often unavailable. Vietnam's databases on the potential of renewable energy resources are limited, scattered, dispersed, and infrequently updated, creating difficulties for developers in analyzing and evaluating the feasibility of their projects.

The AHP analysis (Table 6-3) shows that a lack of information and awareness about technical know-how, technological development and national renewable resource potential is the number one barrier to the deployment of geothermal energy for electricity generation in Vietnam. In the case of small hydropower technologies, the information barrier was not ranked as the biggest obstacle to development, but it was nonetheless considered to be a predominant barrier that must not be ignored (Table 6-3). A majority of respondents argued that a lack of reliable data on small hydroelectric resources has posed many difficulties for making development plans. Even when the data are available, they are often dispersed in various sectors and may not be detailed enough to help project developers and investors make good decisions.

#### *6.2.2.3 Institutional barriers*

Many of the experts and stakeholders interviewed considered both insufficient coordination, due to a multiplicity of Government bodies with energy authority, and institutional capacity limitations (R&D, demonstration and implementation) as critical institutional hindrances to the proliferation of renewable technologies in Vietnam. According to the AHP rankings, the barrier of insufficient coordination among authorized Government bodies and insufficient local capability to develop and operate the networks is the fourth most important hindrance to greater adoption of small hydropower, while institutional capacity limitations in R&D and technological and industrial capability form the second most important major barrier to the penetration of geothermal energy technology.

In practice, the management missions of small hydroelectric sources in Vietnam are inadequate and irrational. There are various functional Government bodies from the central to the local levels that are authorized to exploit renewable resources. In some cases, these responsibilities have been managed in a way that prolonged the investment decision-making process or obstructed the execution of renewables projects. For instance, (PREGA, 2005) provided that EVN once had a plan to purchase electricity from 49 small hydropower projects, but many local organizations were unprepared or unwilling to cooperate with the plan, which caused long delays in the execution of those projects.

Our interviews also revealed that there is no clear division of authority between units functioning at the state level, such as EVN, and provincial and local authorities when it comes to exploiting and developing renewable resources for electricity production. For example, some renewable resource power stations were constructed and put into service by the Government, but the operation and maintenance responsibilities of the relevant parties remained unclear. Provincial and local units did not have the capacity or the human resources to manage and maintain the long-term operations of the plants. While EVN is capable of helping, local-level actors are unlikely to request this help because there are no adequate incentives for their staff to work in these remote locations for long periods of time. No one wants responsibility for the operation of the plants due to insufficient human resources, and projects continue to be delayed as a result.

There is a lack of adequate guidance and technical support for operators that prevents efficient exploitation of renewable resources. In reality, many small hydropower stations are local investments managed by independent individuals, with no involvement from utilities and modern control system. Without timely access to technical and maintenance services, small operational failures are more likely to escalate to long-term halts or permanent standstills.

As Table 6-3 shows, a "weak level of scientific, technological and industrial capability" is the number two barrier to geothermal power. Interviewees argued that this barrier exists not only because Vietnam is still a low-income country, but also due to inadequate Government attention to R&D and the Government's failure to facilitate science activities and improve human resources. There are no regional or national research centers with the necessary basic research facilities and infrastructures for renewables development. The current renewables research projects have usually been spontaneous, with limited budgets, and have been undertaken in the form of demonstrations, pilot projects or for reporting purposes only.

#### *6.2.2.4 Political and regulatory barriers*

To date, the Government of Vietnam has not set up clear or specific policy and regulatory frameworks for clean energy development. The country is still taking its first steps toward drafting an overall development plan for renewables usage. Through the survey, we learned that a deficiency in the policy and regulatory framework and weak policy implementation at both the central and local levels are considered to be chronic constraints to the wider adoption of small hydropower and geothermal energy for Vietnam's power sector. The importance of this barrier is confirmed by the analytical results (Table 6-3), which rank political and regulatory constraints as barrier number three. Moreover, political and regulatory barriers are considered by most of the experts and stakeholders interviewed to be "must-be-overcome" barriers that prevent other barriers from being overcome.

There is a lack of national funding or other appropriate incentive mechanisms to promote cleaner electricity usage through R&D, demonstration, implementation, and utilization. Supportive policy measures related to small power purchasing agreements (SPPAs), Feed-in Tariffs, pricing reflective of clean energy's extra benefits, production cost sharing systems, etc., need to be strategically included in the national regulatory framework to meet the needs of financiers and developers of on-grid renewables projects.

Moreover, legislation to reform the electricity market progresses sluggishly. The historical electricity market operator, EVN, provides very limited grid-connected access to renewables. On one hand, developers argue that they will go bankrupt investing in renewable energy projects if EVN insists on purchasing their electricity production at the same pricing level as that for fossil fuel projects. On the other hand, EVN faces the difficult situation that their selling prices are already at the ceiling level (which is controlled by the Government) and that they are in a critical financial situation and therefore cannot buy electricity at a higher production cost.

Vietnamese Government is aware of these issues but does not seem dedicated to making effective changes in the short term. Conflicting objectives and interests among policy-makers have the effect of causing power to shift to lobbyists, hindering the formulation of policies and creating incoherent strategies.

The lack of clear legislation and bureaucratic issues are cited as additional roadblocks to renewables projects for investors and developers, and particularly for private and foreign investors. Investing money in renewables development in Vietnam is presently fraught with doubts and uncertainties.

#### *6.2.2.5 Technical and geographical barriers*

As Table 6-3 shows, the lack of domestic equipment suppliers and technical services hinders the development of small hydropower, and the remote locations of the necessary resources are problematic for geothermal power.

Survey respondents stated that technical issues have been a major threat to many small hydropower plants in Vietnam over the last decade. This is because most existing and planned small hydropower stations utilize poor-quality equipment and technologies. Technical problems usually arise after just a few years of operation, and interruption of service occurs frequently. At the moment, there are no domestic commercial enterprises manufacturing or supplying small hydropower technologies/equipment and services. Cheap, but often insufficient, equipment is mostly imported from China.

### 6.2.3 Barriers to cleaner energy-efficient coal-fired power generation

#### *6.2.3.1 Institutional barriers*

Although cleaner coal technologies are more efficient than conventional technologies, their adoption using technology transfer is barely promoted in Vietnam, where there continue to be low levels of science and technology and insufficient industrial capabilities. The usage of cleaner coal technologies such as PFBC and IGCC, which allow for the expansion of carbon capture and storage, require more advanced scientific and technological capacities.

Experts were asked why Vietnam still prefers to use conventional technologies (e.g., pulverized and sub-critical pulverized coal) over high-efficiency technologies such as supercritical or ultra-supercritical coal. The answer, which is weighted in Table 6-3 presents that these technologies are still perceived to be costly, unproven and unsuitable for usage with local coal types. Among countries in the region, only China has succeeded in building several supercritical and ultra-supercritical coal-fired power plants, and there tends to be little experience with the implementation and operation of cleaner high efficient coal-combustion systems like IGCC and PFBC. In most developing economies in the region, and especially in Vietnam, any focus on circulating fluidized bed systems occurs only because these systems allow for the use of low-grade coal in the combustion process. A lack of previous exposure is another reason why Vietnamese industrial organizations and technical business stakeholders do not seem to be ready to endorse these advanced technologies.

Furthermore, since the usage of cleaner coal technologies is currently limited to non-anthracite coal, the experts and stakeholders interviewed suggested Vietnam should promote the adoption of cleaner coal technologies with imported bitumen coal that will be available as soon as 2015.

#### *6.2.3.2 Economic/financial barriers*

Results in Table 6-3 shows that economic/financial barriers are predominant among the major barriers to the adoption of cleaner coal technologies. In reality, the cost of cleaner electricity production in Vietnam is still more expensive than that of conventional technologies that creates major barriers to the widespread promotion of these technologies. Currently, low electricity pricing in Vietnam does not account for environmental effects. The existing average electricity cost of 5.4 cents (US$/kWh) in Vietnam is hardly adequate to make up for the high costs of advanced cleaner coal-fired generation technologies. The benefits of cleanliness are not fully accounted for, which prevents investors from laying out capital resources for advanced low-carbon-coal-fired power. Even as innovation drives down the cost of low-carbon-coal-fired technologies, it is likely that these technologies will remain uncompetitive relative to conventional technologies.

Furthermore, a scarcity of financial resources[13] for the expansion of the power generating system has been blamed as a key cause of electricity shortages over several years. Thus, the deployment of expensive technologies hardly seems financially justifiable and viable at this stage. Policy makers lean toward less costly generation options that maintain electricity prices at levels moderate enough to enable the country's products to remain competitive in the global market. In order to secure funds to finance such a massive expansion of power generation system, the Government of Vietnam has drawn out a roadmap, which was approved by the Prime Minister in 2007, to reform the Vietnamese electricity market. With this reform, the Government plans to increase the price of electricity to the long run marginal cost of 7.5 cents (US$/kWh) by year 2012. In the context of $CO_2$ emission reductions, this reform could provide an opportunity to reconsider the deployment of advanced coal-fired generation technologies for producing electricity in Vietnam.

### 6.3 Regulatory mechanisms for promoting sustainable development options

Though deployment of renewables for electricity production (RES-E) is not yet set up as a top priority for long-term energy development strategy in Vietnam, the issues of sustainable development related to renewables have moved higher in the development agenda of decision makers, in which the Vietnamese Government encourages and supports the promotion of renewables for electricity energy supply industry. However, there still remain a number of typical barriers slowing down the RES-E as above-identified. Thus, it needs to have a suitable supportive scheme to help overcome the barriers and foster the RES-E in Vietnam.

In this part of the study, we use an empirical analysis approach to examine different appropriate policy means including incentive instruments/schemes by comparing differences among most common supportive instruments in terms of advantages and disadvantages. Principally, we focus on the price-based (Feed-in Tariffs) and quantity-based (Quota

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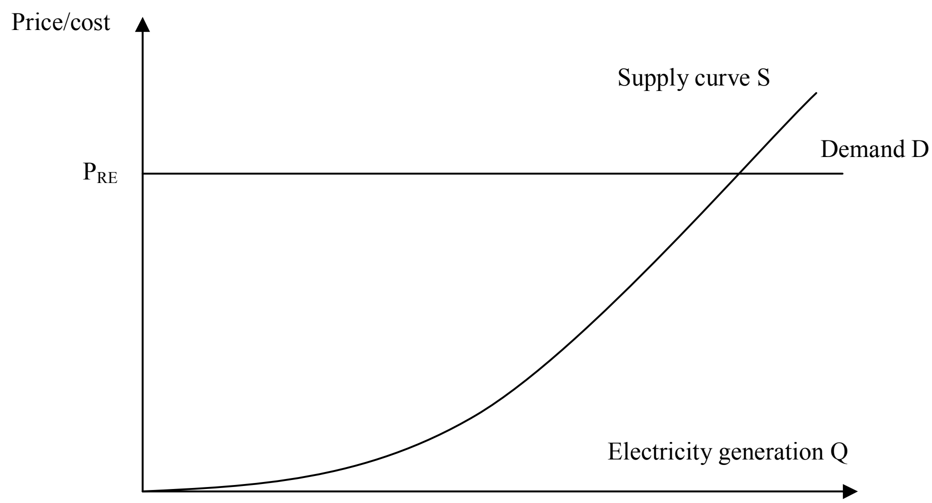
[13] The development of power generation source and power network would require an estimated fund of 4.5 billions USD per annum, while the EVN's revenue of electricity sales reached only 2.4 billions USD in year 2005 (Institute of Energy, 2007).

obligations and Tendering schemes) mechanisms that could be well transferred to the Vietnamese power sector.

### 6.3.1 Price-based mechanism

The core of a price-based mechanism is that the price of electricity generated from renewables is fixed and the quantity is flexible. This principle is presented by Figure 6-1. The obligated entity will purchase electricity-based renewables at a pre-specified fixed price. This fixed price is kept unchanged independently from the quantity, which can be adjusted by electricity suppliers/producers. Within this incentive scheme, generators using renewables technologies will be able themselves to economically enter the electricity generation portfolio until their marginal costs that equal to the level of the electricity tariff pre-specified. The advantages is that suppliers/producers could only take on advanced technical progress or exploit the economies of scale to produce as much as possible electricity energy within the range of fixed price.

*Figure 6-1: Price-based mechanism.*




*Feed-in Tariff (FIT)*

FIT is considered to be the most efficient price-based instrument for supporting the RES-E widely. The FIT is currently used in most of the European Union member states as the principal supportive instrument for the RES-E, particularly in Denmark, Germany, Spain, Italy, etc. Generally, the FIT is a simple and transparent mechanism, and established with three major obligation components: obligation to connect, obligation to purchase, and obligation to pay a certain price for RES-E (Menanteau et al., 2003; Lauber, 2004; Ragwitz et al., 2005; Lauber and Mez, 2006; Held et al., 2007; Langniss et al., 2009; Fitchner, 2009). Within the Feed-in Tariff, the price is fixed and the quantitative supply of electricity is adjusted (Langniss, 2003). As it involves an obligation on the part of electricity utilities to purchase RES-E at a tariff determined by public authorities and guaranteed for a certain period of time, it could provide the highest guarantee and long-term planning stability to investors/producers (Menanteau et al., 2003; Finon and Menanteau, 2004; Ragwitz et al., 2005). With respects to the guaranteed period for the specified tariff levels, adjustment of tariffs might be linked to different reference indicators such as inflation, electricity price, and energy prices or to electricity generation costs. In theory, the possibility to adjust tariffs might result in uncertainty among investors/producers, but the empirical studies for the cases in Germany, Spain and Slovenia have showed that there is no investment uncertainty caused by possible tariff adjustments (Held et al., 2007).

Fitchner (2009) presented two major methods of setting the overall return in practice to investors/producers for this incentive mechanism. In the first, payment level is based on the levelised cost of RES-E, plus a prescribed return, called hereafter as "cost-based" approach. The FIT payment can be designed to ensure a reasonable rate of return to RES-E investors/producers while forming conditions more conductive to the growth of market. In the second, the payment can be set using the estimated value of renewables, i.e. either according to utilities' avoided costs, or by internalizing external costs of conventional generation. This method, which is also called as "value-based" approach, requests to quantify benefits (to utility, society, and environment) for a determination of total compensation that could potentially result in a high degree of administrative complexity. Because of this feature, this "value-based" approach may not harmonize actual costs of renewables generation.

Generally, the Feed-in Tariff is established using a stepped tariff design. Within the design, the flat (basic) tariff can be adjusted with several complementary elements in order to lower the producer windfall profits. The stepped design gives opportunity to reimburse RES-E producers in different bands of marginal cost potential curve according to actual generation costs. The actual level of remuneration that a plant receives depends on its plant size, location and fuel type (Ragwitz et al., 2005; Held et al., 2007; Fitchner, 2009).

*Premium tariff design*

The Premium tariff represents a modification of the fixed tariff. Premium regulations do not provide RES-E producers an overall guaranteed remuneration, but a fix premium that is paid on top of the market price of electricity (Fitchner, 2009). One of the main benefits of implementing a Premium tariff as experienced in Spanish or Slovenian system is that the RES-E generators shows higher compatibility with principles of liberalised electricity markets (Held et al., 2007). Currently, fixed tariff models are widely used in most of the European countries while the Premium tariffs are only applied in Spain, the Czech Republic, Slovenia, the Netherlands and Denmark, but only for onshore wind (Fitchner, 2009).

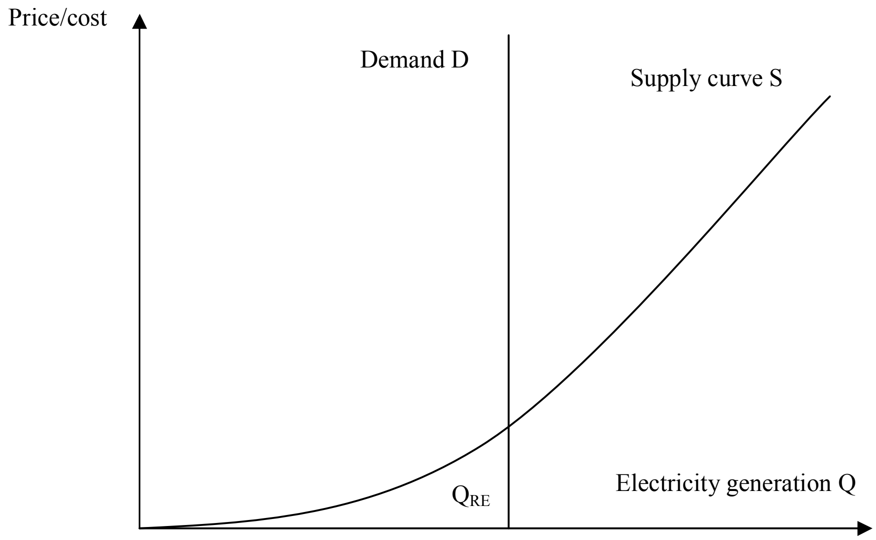
In Asia, China has applied a new regulatory framework promoting a Feed-in Tariff as main supportive instrument for onshore wind power since 2009 while other technologies are fostered on a quasi case-by- case basis. Moreover, the Chinese Government also offers preferential loans for RES-E developers and grants tax benefits to projects listed in the "Renewable Energy

Industrial Development Guidance Catalogue" (Fitchner, 2009; NDRC, 2009; WindChina, 2009). Like China, India has also announced a deployment of a FIT in 2009 fostering all forms of RES-E technologies. The tariff level is technology-specific as determined by the Central Electricity Regulatory Commission (CERC), which is based on actual generation costs of each technology plus adequate producer profit (REF, 2009). Furthermore, the FIT proposal offers tariff payment for a sufficient time period. For instance, technologies with a modest investment like wind power will receive a fixed tariff for 13 years, other technologies requesting a higher capital investment like PV solar will have a guaranteed payment period of 25 years, while small hydro plants (< 3MW) are qualified for receiving tariff for 35 years (Gipe, 2009).

### 6.3.2 Quantity-based mechanism

The core of a quantity-based mechanism (Quota Obligations, Tendering Schemes) is that the quantity of RES-E is fixed and the price is flexible as described by Figure 6-2.

*Figure 6-2: Quantity-based mechanism.*




Within this mechanism, the quantity (quota) is often targeted in form of a specified mandatory proportion of annual electricity energy generation. To promote renewables deployment, the authority sets the demand (D) fixed at $Q_{RE}$ thereby the demand will be fulfilled by RES-E producers/suppliers according to their marginal costs. Thus, higher quota set could lead to the fact that more cost-intensive renewables sources can be exploited. As there exist penalties for a lack of demand meeting, the set quota is expected to be precisely fulfilled. However, limited comparability between RES-E and conventional plants, in terms of capacity factor and mostly non-deterministic dispatch, is likely the problem for capacity-based quotas (Fitchner, 2009).

*Quota Model*

A Quota Model (also referred to as Renewable Set-aside or Renewable Portfolio Standard) provides certain energy suppliers an obligation of supplying a specified minimum share of

RES-E. The minimum share of RES-E is usually set as a long-term target. The obligated parties comply with the obligation by presenting Tradable Green Certificates (TGC) certifying their electricity generation. But, a quota model does not have to include TGC in any case (Menanteau et al., 2003; Held et al., 2006; Mendonça, 2007; Fouquet and Johansson, 2008; Fitchner, 2009).

In Europe, besides the price ceiling and taxation systems, the European Union relies on the quotas as one of the major direct interventional measures. The authority, in general, sets a quota or cap to be respected and fines are attached in case the quota scheme is binding and if the quota-obligated bodies or industries are not fulfilling the obligation (Fouquet and Johansson, 2008). As a conjunction to TGC, a second market for certificates will emerge with a Quota Model. However, the Quota models differ considerably from country to country, especially in a situation with monopolists or quasi- monopolists the system will work only inefficiently (Menanteau et al., 2003; Mendonça, 2007; Fouquet and Johansson, 2008; Fitchner, 2009).

*Tendering scheme*

Tendering schemes are a specific form of a quota obligation. This kind of scheme is based on a fixed amount of renewable energy to be generated. The suppliers of RES-E compete in individual call for tenders against the backing of a previously set amount-allocation. The proposals are classified in increasing order of cost until the amount to be contracted is reached. The winners of the bidding procedures receive a long-term contract to supply electricity at the pay-as-bid-price. The tendering is repeated periodically. Today only France applies tendering for large projects over 12 MW capacity, Ireland swapped to FIT and the UK to a Quota System (Menanteau et al., 2003; Menanteau and Finon, 2004; Fitchner, 2009). Specifically, a tendering scheme only provides support for large projects, the development of small/medium scale projects is usually not fostered by this support instrument (Mendonça, 2007; Fitchner, 2009).

### 6.3.3 The choice of suitable central supportive instrument for Vietnam

Vietnam experiences very low administered electricity prices and the EVN, a (quasi-) monopolist, is still subsidized by regulated fuel-costs, which are lower than the market prices. To date 2010, EVN is mostly running the entire electricity sector that creates difficulties for new IPPs to enter the market (market participations). Therefore, a reliable national policy framework for RES-E projects needs to be set up to arrange investments through long-term coordination and reduction of investment risks for investors/developers.

Structurally, the Vietnamese power sector is in the process of reform and the sector is expected to be opened fully to retailed household sales after 2022. As socioeconomic, national defence and energy security reasons, the state company will remain its monopoly over electricity transmission, and manage regulation of the national electricity system, and construction/operation of large power generation plants (ERAV, 2008). Moreover, the rising issues of energy supply security while protecting environment and scarcity on domestic energy resources (i.e. increasing reliance on imports) for increased electricity production. Yet, the right moment has come for Vietnamese policy decision-makers to have stronger policies and incentive schemes to support sustainable energy issues associated with RES-E in Vietnam.

In order to select a suitable supportive instrument for fostering the deployment of RES-E in Vietnam, we perform an overall comparison among different policy instruments available in the existing international policy dialogue. This comparison takes into account a number of elements such as: the adoption conditions and the maturity of generation technology to be promoted, market features, and other relevant factors. Table 6-4 presents the advantages and disadvantages of selected different supportive instruments. Specially, this comparative analysis also permits to provide the insights about a possible mix of policy instruments by combining advantageous properties of different instruments so that it could even trigger the evolution of RES-E from niche to mass market in Vietnam.

As above-mentioned, ensuring investments through long-term coordination and reduction of investment risks for investors/developers is a crucial policy objective for promoting the RES-E in a developing country like Vietnam. Thus, this objective should be tailored as a top priority in any incentive scheme in order to secure a reliable supporting level for a sufficient period of time. With this essential request, a Tendering scheme seems not to be suitable as it is mostly in line with liberalisation of energy markets and does not guarantee long-term planning security (Voogt et al., 2000; Menanteau et al., 2003; Mendonça, 2007; Fitchner, 2009). In contrast, Feed-in Tariffs could meet this request by providing an obligation on the part of utilities to purchase RES-E from producers within a guaranteed period of time, generally about 15 years (Menanteau et al., 2003; Mendonça, 2007; Cory et al., 2009; Couture and Yves, 2010).

If the electricity industry is featured with only a limited number of incumbent utilities/suppliers, competition is very restricted and typical benefits of governance by markets would not occur in this case. Under such circumstances, quota systems are quite likely unsuccessful to deliver the targeted amount of RES-E (Haasa et al., 2004; Fitchner, 2009). Particularly, Quota systems do not work efficiently without an already strongly competitive market, in which the prerequisites of fulfilling the quota and paying potential penalties shall be fully satisfied by market participants. Moreover, within Quota systems market for usually-coupled green certificates cannot come forth without participation of independent operators (Voogt et al., 2000; Berry and Jacard, 2001; Espey, 2001; Menanteau et al., 2003; Mendonça, 2007; Fouquet and Johansson, 2008; Mendonça et al., 2010). With these aspects, the current structure of Vietnamese power sector, with a single (quasi-) monopolist seems to favour the use of Feed-in Tariffs rather than Quota systems.

More specially, Feed-in Tariffs featured with stepped design for energy capacity could offer remuneration prospects to small and medium scale of RES-E projects, which are mainly charactered with the renewable energy sources in Vietnam. Moreover, Tendering schemes or Quota systems have proven to be only effective in the deployment of large-scale capacity of RES-E with mature technologies (Menanteau et al., 2003; Mendonça, 2007; Fouquet and

Johansson, 2008; Fitchner, 2009), whereas Vietnam has strategically focused on the well-proven and reliable technologies for the deployment of RES-E (Institute of Energy, 2008a). Furthermore, as prices with Feed-in Tariffs are offered in a non-discriminatory manner for each kWh of electricity generated, and can be differentiated according to the type of technology, the size of project, the quality of energy source, specific location of projects (Mendonça, 2007; Fouquet and Johansson, 2008; Langniss et al., 2009), they could attract a broader variety of investors/developers to participate with different technology classes (Lipp, 2007; Klein et al., 2008; REN21, 2009; Cory et al., 2009; Couture and Yves, 2010; Mendonça et al., 2010).

In term of cost-effectiveness, Feed-in Tariffs have consistently accelerated additional supply of RES-E more effectively than alternative policy instruments and at lower cost (Stern, 2006; Ragwitz et al., 2007; Lipp, 2007; Butler and Neuhoff, 2008; Fouquet and Johansson, 2008; de Jagerand Rathmann, 2008; IEA, 2008d; European Commission, 2008; Mendonça et al., 2010).

Internationally, Feed-in Tariffs have been proven and most effectively used for fostering the rapid development of renewables sources with large additional capacity. Some countries even swapped their support instrument to Feed-in Tariff. The superiority of the FIT instrument has been determined through experiences predominantly in Europe and it is currently implemented in 63 jurisdictions worldwide (Mendonça, 2007; IEA, 2008d; European Commission, 2008; Fitchner, 2009; Couture and Yves, 2010; Mendonça et al., 2010).

In addition, the national program for power sector reform aims to include a regulation framework for standardized Power Purchase Agreements (ERAV, 2008; Fitchner, 2009). This also virtually favours the application of the Feed-in Tariff system because standardized Power Purchase Agreements are one crucial element of the Feed-in Tariff (Fitchner, 2009).

Overall, many major empirical studies, on which this study is based, have shown that FITs have proven to be the most effective at overcoming barriers and rapidly creating the benefits of renewables for socio-economic development. Then, we place Vietnam in a context with its specific boundary conditions; our analysis suggests that Feed-in Tariffs are likely the most effective central supportive instrument for forstering the RES-E in Vietnam. However, to get an effective incentive scheme for Vietnam, it requests not only the choice of suitable supportive instruments that makes them efficient, but also its proper design that makes them be well-transferred to the circumstances in Vietnam. Moreover, there is no single and universally applicable ‘best’ supportive instrument or policy for a bundle of different generation technologies using renewables. International examples have already proved that the FIT can be effectively amended with designing features of a quota obligation or with investment grants (Haasa et al., 2004; Fitchner, 2009; OFGEM, 2009). Therefore, a major central support instrument using the FIT supplemented by a series of other support means should be further carefully considered by policy decision-makers in order to achieve the most effective and appropriate incentive schemes for the RES-E in Vietnam.

*Table 6-4: Advantages and disadvantages of incentive schemes. A comparative analysis.*

| Schemes | Advantages | Disadvantages |
|---|---|---|
| **Feed-in Tariff** | + Long-term contract agreements for developers/investors and guaranteed sufficient period of time<br>+ Simple and transparency<br>+ Internationally proven as very effective instrument favouring high capacity additions<br>+ It can be flexibily designed according to changes in technology and market<br>+ It can be designed with capacity stepped that favours the growth of small- and medium scale projects<br>+ Fosters diverse portfolio of technologies<br>+ Low capital due to low risk<br>+ Low transaction costs, thus low costs for society<br>+ Ease of financing and entry | + Though tariff can be amended but consumers may have to pay dispensably high prices for renewable electricity if tariffs are not adjusted overtime.<br>+ Can involve restraints on renewables trade due to domestic production requirements<br>+ Payments must ensure revenues. If payments are too low, little new renewable energy development will result. Too high payments may provide unwarranted profits to developers.<br>+ To be amended with elements from other instruments in order to support "new" renewable energy technology<br>+ Nations RES-E goals might not be reached fully as a (fixed) FIT creates a market independent from the "real" market<br>+ Needs frequent updates to the FIT program structure may lead to policy uncertainty |
| **Quota Mode** | + Competition between technologies, among investors/developers<br>+ Promote least-cost projects (cheapest resources are used first which brings down costs early on)<br>+ Cost-efficient in the case of large amounts of RES-E generation<br>+ To support mature RES-E technologies<br>+ Government RES-E development target will be fully reached by setting quota | + Lack flexibility (difficult to adjust in short-term if situations change), and restriction of market size.<br>+ Complex in design, administration and enforcement leading to a lack of transparency<br>+ Restriction of variety and innovation, and risk of supporting only least-cost options and concentrating best resources<br>+ To favour large, centralized plants and not suited for small investors due to greater investment risk.<br>+ Long-term purchases are not competitive that leads to uncertainty among investors<br>+ No reduction of suppliers' profits feasible<br>+ High transaction costs |
| **Tendering Scheme** | + Competitive element<br>+ Draws out great attention to the development of RES-E in public<br>+ Best suited for supporting mature RES-E technologies and large projects<br>+ Competition among investors | + Does not promote a variety of technologies, while focusing only the most cost-effective options<br>+ Missing many of benefits associated with renewables (jobs, economic development in rural areas, reductions in local pollution, ect)<br>+ Remarkable success must be confirmed through practice (as the last European country Ireland switched from tendering to FIT in 2005)<br>+ Tends to create cycles of stop-and-go development<br>+ Competition may drive costs too low<br>+ Does only favour large, merchant projects |

## 6.4 Structural, regulatory and market reforms for the sustainable power sector

### 6.4.1 The needs for restructuring and competition of power sector

*Why to reform?*

The electricity industries were traditionally characterized with vertically integrated monopolies in almost countries around the globe, and either state-owned or privately-owned and subject to price and entry regulations as natural monopolies (Joskow, 2003). Since 1990s, the reform of electricity sectors is widely embarked in many parts of the world. There is an extensive literature dialogue to discuss the question why one needs to reform the electricity sectors (Besant-Jones et al., 1993; World Bank, 1994; Bacon and Besant-Jones, 2001; Joskow, 2003; Kessides, 2005; Besant-Jones, 2006). As monopolies, the performances of electricity industries in many countries are specified with poor quality of service, low labour productivity. The systems are frequently suffered from supply shortages and deteriorating equipment, low efficiency but high losses, chronically undercapitalized and inadequate investment, too low price and insufficient revenues to cover production costs and support new investment, high pollution, and so on. Therefore, many developed and developing countries have started to restructure their electricity sectors to improve their performance. Particularly for developing countries, Besant-Jones (2006) argued that the main drivers for reforming electricity sectors are based on three major outcomes: (i) better service quality for electricity consumers to support economic growth and welfare, (ii) improvement in government fiscal position, and (iii) more affordable access to electricity for the poor. The means of restructuring power utilities and markets, regulation, competition, and the roles of public and private participants are all the essential elements of the reforms.

The second question is that how far the reforms of electricity sectors in developing world already reached the best objective? Yet, many developing countries have executed far reaching institutional reforms: restructuring, privatizing, and establishing new approaches to regulation over the past decades (United Nations, 2003; Joskow, 2003; Wamukonya, 2003; Kessides, 2005; Besant-Jones, 2006). There is an expansive portfolio of reforming options but at present insufficient evidence is available as to which path will deliver best the desired objective (Weisser, 2004). This is because reforms of electricity sectors have not always improved performance, even been performance problems (Joskow, 2003; Besant-Jones, 2006; World Bank, 2009a).

On the ground of the current circumstances of the Vietnamese power sector, it is clearly that a reform for the Vietnamese power sector is now an imperative but lessons learned from international and experiences from other countries should not be ignored.

*The reform: promising but very slow progress*

Since 1990s, Vietnamese Government has recognized the need for restructuring the electricity industry because of its poor performance while enlarging business scale on the need. Just 2006, the Government launched the first legislation with a decision No. 26/2006/QD-TTg providing the guidelines for development of a competitive electricity market in order to attract financial capital/investment from foreign and private investors. Under this legislation, the power market will be established through three sequential development stages: competitive generation power market, competitive wholesale power market, and competitive retail power market targeted by 2009, 2017, and 2024, respectively. The roadmap for the reform seems to be promising to investors but until today then end of 2010, Vietnam is still listed within the group of 36 developing countries that have the power sector characterized with vertically integrated monopolies plus a few Independent Power Producers (IPPs). In practice, there are a number of major factors affected the reform progress including (i) institutional/organizational instability: arrangement is in place but lack of efficient coordination and clear obligation among involved bodies; (ii) less-effective rule-makers; (iii) inconsistency in policy: (iv) weak-enforcement of policy: relatively strong support but not really committed; (v) slow adaptation and less-efficient management-based old thoughts.

As a part of reform, the first establishment of power market is planned to attract investments from different economy sectors at both national and international levels in order to reduce investment burden on the state. By this way, about 40-50% of new generation capacities is to be developed by private capital through IPP or Built Operate and Transfer (BOT) scheme. However, the first step seems to be ineffective, even very little as expected. This is because, in practice, the major new domestic investors participating as the IPPs are mostly state-owned companies or commercial groups such as: VinaComin, PetroVietnam, Power Construction companies. Moreover, though they all belong to the Government there exist the absence of cross-sector management among themselves that often arise many reasons for delays in power generation projects. More specifically, a barrier of policy deficiency is a very critical factor preventing against the speed-up of reform (Pham D. Hien, 2009b, 2010). Particularly, Vu Q. Viet, (2009) debated that the follies of current policy in building-up the state-owned enterprises as the largest decisive economic conglomerates within the economy while public/private enterprises are subject to competition without similar conditions have negatively affected the whole economy and slow down the reform and competition for relevant economic sectors. Furthermore, the slow adaptation to new tendency in business towards a competitive environment has been also recognized in almost state-owned enterprises due to less-efficient management policy. Also the increased level of benefit-conflicts and frictions among stakeholders for sector management further aggravated halting the reform as well.

### 6.4.2 Lessons learned from international power sector reform

On the ground of empirical studies in many countries around the world including developing countries, Joskow (2003) argued that reforming electricity sectors have been often achieved in countries where the performance of state-owned monopolies were very poor. However, after reviewing the reforms' diverse pathways and problems in different countries: Bolivia, Ghana, India, Poland, and Thailand, Williams and Ghanadan (2006) suggested that reforms will require an emphasis on a broader set of objectives, including service provision, public benefits, effective regulation, and social/political legitimacy. More importantly, the reforms must be based on realistic assessments of national needs and capabilities. Further investigating the reforms of power sector in five South Asian countries, Bhattacharyya (2007) provided an analysis to identify factors forming the problems in these countries. They are instability of rule-makers, poor overall acceptance, slow adaptation, and poor transition management.

Generally, a review of lessons learned about reforming power markets in developing countries stressed the need to adapt the reform to starting conditions then to assess how the different conditions could influence the design of reform programs (Joskow, 2003; Wordl Bank, 2004; Besant-Jones 2006, World Bank, 2009a). Particularly, Besant-Jones (2006) suggested that reforming power sectors is a long-term process that requires patience to achieve the desired objectives. Improving quality of energy service, strengthening government fiscal situation, and providing affordable access to electricity for the poor would take time to accomplish. The suggestion is specifically given to countries starting with weak governance systems and poor investment climates.

To address the specific problems of developing countries like Vietnam where electricity industries grow rapidly and irregularly, Finon (2006) argued that the power sector should be primarily structured according to the need of new capacities installed to meet the fast but uncertain increase in demand for energy. To resolve the problems of insufficient investment, it pointed out two major factors: (i) the coordination of investment decisions and (ii) the limitation of risks for investors through long-term contracts to attract necessary finance. Particular for a country like Vietnam, where the (quasi-) monopolists will remain the central role in the energy sector, it suggested that the single buyer model or some variants of it could be a good alternative if the Government wishes to avoid the twists and turns of the competition paradigm, but in order for it to provide an disputed solution, the institutional environment must be stabilized and the macroeconomic environment predictable, neither of which is the case. Thus, the industrial structure must be carefully established, being less concentrated than the old public monopolies and keeping public authorities at a distance in order to introduce incentives to efficiency. Last, the need for investment through long-term coordination and reduction of investment risks must be kept as the most important objective. In addition, World Bank (2010c) addressed the two issues for the reform in Vietnam: level of tariffs and price negotiation process between utilities and the government. First, the level of tariffs must be maintained at realistic levels or cost recovery levels. Second, a protracted and untransparent process of negotiation on tariff between utilities and the Government should be replaced with one that reflects actual agreed costs and provides predictability for investors.

So far, the study argued that electricity industry features differ from the conditions of an effective competitive market, and there often exist only a limited number of incumbent utilities so that the competition is rather restricted. Thus, the operating principles of the sector reform in Vietnam should be carefully established and well designed in a manner towards the specified desired objectives. These includes (i) attracting investments in response to rapid but uncertain demand. In this regard, whatever solutions that could be adapted to suit each case, in one way or another, should be necessarily considered in order to create possibilities for long-term contractual agreements that permit the outlet and limit the risks for investors; (ii) aligning the demand for energy services towards reducing production costs. In this regard, electricity spot pricing could be practically applied for peak-consumption period; (iii) integrating climate mitigation policy into the sector development strategy in order to gradually advance the energy efficiency of the energy supply infrastructure; (iv) paying more attention and interest to low-income consumers.

Considering the boundary conditions for Vietnam, the study further suggested that the single buyer model or some variants of it could only work worse in Vietnam as the institutional environment is not stabilized and the macroeconomic environment is not easily predictable. Thus, reforming the Vietnamese electricity is clearly needed. However, theory and practical experiences have also showed that opening a competition for an electricity market has not always ensured for good performance of the market. If the country wishes to remove successfully the state monopoly in the electricity sector, Vietnam should balance between the market and the intervention of state management.

Needless to say, regulations are one of the most cost-effective means and indispensable for improving energy efficiency and supporting low-carbon technologies in Vietnam. Lessons learned have proved that weak enforcement of regulations is a main concern in many Asian developing countries (Nguyen and Tran, 2005; World Bank, 2009b, 2010d). Thus, the sector reform in Vietnam needs to be combined with regulations to remove the abovementioned barriers, correct market failures, and foster clean technology development. Regulations also need to be supplemented with the above-discussed financial incentive schemes for both consumers and producers. Especially, regulatory measures are one of the most cost-effective tools to improve energy efficiency. For example, regulatory measures can attract necessary attention to consumers/industrial enterprises but help implement money-making (-saving) energy-efficiency projects (activities) in line with market forces (World Bank, 2010a). Or regulations such as efficiency standards and codes, combined with institutional reforms and financing mechanisms are effectively used to correct market failures and barriers. However, a suite of support policy instruments tailored to the country's specific institutional and political context is also required to remove barriers to energy efficiency (World Bank, 2010d).

Moreover, in a separate study based on formal surveys among national experts (Nguyen et al., 2010), we also argued that enhancing local R&D and establishing joint ventures with foreign companies are the most desirable policy measures for promoting the adoption of renewable and energy-efficient technologies in the Vietnamese power sector. The experts and stakeholders interviewed stressed the view that improving R&D could help Vietnamese authorities to gather reliable data on national renewables for making development plans. This measure would mitigate the barriers of information and awareness of technical know-how and technological development stages and assist in building indigenous scientific/industrial capacities, human resources, and relevant regulatory frameworks. Establishing joint ventures with foreign companies with advanced experience would help to overcome the lack of domestic renewable electricity technology/equipment and services and would facilitate technology transfer progress. Moreover, establishing joint ventures could help to correct the system of codes and standards in the Vietnamese industry and energy sectors, which are a mixture of various systems, including those of America, Germany, Japan, and Russia. Furthermore, our study also pointed out that funding for R&D activities is limited in Vietnam. It was therefore suggested that the country should follow the approaches of "taking a shortcut" and "waiting in front" by enhancing the process of transfer and adaptation of advanced technologies while attempting to lower manufacturing costs, rather than concentrating on costly basic research that focuses on achieving high conversion efficiencies.

Last, the sustainable energy path requires paradigm shifts to not only a new low-carbon development manner but also changes in lifestyle. In this regard, education and awareness campaigns can help increase sustainable lifestyles for energy consumers and provide more informed choices. Specially, consumer awareness campaigns are most effective in conjunction with regulations and financial incentives (World Bank, 2010d).

## 6.5 Concluding remarks

After the modelling simulation, we take a more social approach to identify barriers to the wider deployment of sustainable energy options in the Vietnamese power sector then analyse how to promote the deployment in practice.

Particularly in this chapter 6, the research developed a formal survey among 37 national experts to analyze the major barriers to a wider adoption of geothermal, small hydro, and cleaner coal electricity generation technologies in Vietnam based on the framework of analytical hierarchy process (AHP). The analysis results of the expert survey provided that the dominant barriers to wider adoption of small hydropower are financial hurdles, institutional constraints, and deficiencies in government policy, while the main obstacles to the use of geothermal energy are a lack of information and technical know-how, weak R&D and industrial capability and poor policy framework. The top barriers preventing the adoption of cleaner and more energy-efficient coal-fired generation technologies are related to institutional, economic/financial and awareness/information issues. Although institutional and policy barriers were not ranked as the most significant barriers, they are both considered to be "must-be-overcome" barriers because they prevent other barriers from being overcome.

In follows what, perhaps, is more interesting is that the study performed an empirical analysis approach to examine different appropriate instruments for promoting cleaner electricity generation options, mainly for renewable energy, in the Vietnamese power sector. In order to choose a major incentive support instrument as the best suited for the Vietnamese situation, this present study compared the differences among the most common supportive instruments.

Then, it analysed the international experiences in order to determine the most suitable supportive schemes that could be transferred to the Vietnamese power sector. The determination is necessarily based on the structure of Vietnamese energy sector including the level of regulated electricity prices, market participants and potential (quasi-) monopolists. In addition, the projected electricity demand and the level of grid development as well as the Vietnamese Government's long-term targets for renewables deployment were also indispensably considered. As an analysis result, the study suggested that the Feed-in Tariff appears as the best suited major support instrument for Vietnam. This is because the Feed-in Tariff is already successfully employed around the globe and suits well to the boundary conditions in Vietnam. However, the favourable adoption of an incentive scheme for Vietnam requests not only the choice of a supportive instrument that makes it efficient, but also the proper design. Specifically, the study suggested that in order to promote renewables deployment from niche to mass markets, a mix of policy instruments by combining the beneficial properties of different supportive schemes/instruments, needs to be tailored to the particular electricity generation from renewables and to the country specific situation.

To improve performance of Vietnamese power sector towards sustainability in long-term, the Vietnamese government has decided to transform power sector towards competitive and market-based arrangements. However, experiences of liberalized industries, around the world, also showed that restructuring and competition has not always improved the performance, and performance problems have gone on. Reform should be recognized as a long-term process that requires patience to achieve the desired objectives and must be based on realistic assessments of the national needs and capabilities. Moreover, international experiences on developing country comparable to like Vietnam, where the demand for electricity has grown fast and irregularly, also suggest the electric power industry Vietnam should be structured primarily corresponding to the need of new energy capacity to respond to the rapid but uncertain increase in demand. The financial shortage problem for new investments requires the coordination of investment decisions and the limitation of risks for investors through long-term contracts aimed at attracting necessary investment. Therefore, the reform must be designed in view of the importance of the need for investment through long-term coordination and reduction of investment risks. However, theory and practical experiences have also showed that opening a competition for an electricity market has not always ensured for good performance of the market. If the country wishes to remove the state monopoly in the electricity sector, Vietnam should balance between the market and the intervention of state management.

Last, the sustainable energy development path for Vietnam requires not only major effective policies and financial incentive schemes, institutional reforms and technological innovations but also local R&D improvement and changes in the current unstainable pattern of energy use (consumer behaviour), which could be increased by education and awareness campaigns.

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# Chapter 7. Access to feasible finance sources and the Clean Development Mechanism

## 7.1 Introduction of Chapter 7

The Government can apply a wide range of support policy instruments available to promote RES-E in the Vietnam's electricity generation industry. As discussed above, the choice of support instruments mainly depends on its policy objectives and the country's boundary conditions. However, to implement a support instrument always requires key decisions related to financing issues. In this case, the use of FIT will inevitably cause additional costs, which can increase over time when deployment of RES-E is extensively grown. Therefore, feasible financing schemes need to be considered to cover the additional costs.

Within this chapter 7, we discuss the possible access to feasible financing sources that could help cover the extra costs causing from the use of FIT in particular and foster sustainable energy development typically related to RES-E in the Vietnamese power sector.

## 7.2 Fiscal measures and funding facilities

### 7.2.1 Fiscal instruments and surcharges

To favour the deployment of RES-E, a number of different forms of financial incentives can be used practically. Many Governments provide a variety of fiscal instruments-primarily tax subsidies to promote investments for RES-E. They are typically tax credits, income tax deductions, sales or excise tax reductions, VAT reductions, exemptions, property tax incentives, accelerated depreciation, and lower tax rates, etc (Lewis and Wiser, 2007; Fitchner, 2009). For example, renewable energy market in India is largely driven by various tax incentives since the 1990s. These include 100% depreciation of wind equipment in the first year of project installation, and a 5-year tax holiday (Rajsekhar et al., 1999). Like India, Chinese Government also offers grants tax benefits to projects listed in the "Renewable Energy Industrial Development Guidance Catalogue", and VAT reductions and income tax exemptions on electricity energy, particularly for wind power projects (WindChina, 2009).

Surcharges are also considered as a practical way to support various policy instruments for renewable energy development programs. But, because surcharges are effectively a tax on electricity service, they may be particularly vulnerable to political attack and repeal (Wiser and Pickle, 1997). However, in the boundary circumstances in Vietnam, Fitchner (2009) suggested that surcharges can be imposed for private households and/or commercial businesses purchasing grid power in Vietnam in order to refinance the costs associated with the promotion of wind power projects. Particularly, on the ground of the Master Development Plan for Renewable Energy in Vietnam, Fitchner (2009) already designed a development framework of surcharges on power consumptions due to additional costs from wind power projects remuneration over the period till 2025.

### 7.2.2 Vietnam environmental protection fund

For supporting environmental protection activities in Vietnam, the Vietnam Environmental Protection Fund (VEPF) was established via the Prime Minister Decision No.82/2002/QD-TTg dated 26 June 2002 and the Decision No.35/2008/QD-TTg dated 3 March 2008. This organization is a governmental financial entity, which is linked to the Ministry of Natural Resources and Environment and financially managed by the Ministry of Finance. It runs the business on the non-profit basis, but must ensure the retrieval of its chartered capital, and the coverage of managerial expenses. In addition to the given budget, the extra capital is mobilized from other sources: environmental protection fees (wastewater, solid wastes, gas emission, exploitation of natural resources, etc.); penalty fees for environmental damages, administrative fines for violating environmental protection law; fees for selling/exchanging CERs; sponsors, supports/contributions, and entrust investment from individuals or organizations locally and internationally; supplementary capitals as legally stipulated (VEPF, 2010).

The objects that the VEPF fund could provide financial supports are projects and programs/activities relevant to natural resources and biodiversity conservation and prevention measures, combating and remedying the national or inter-regional environmental pollution, deterioration and incidents of local environmental issues. With these specified objects, the following supports could be provided: loans with preferable interest rates; guarantees for environmental projects loan from credit organization; lending interest rate support when capital is borrowed; financial support for a number of environmental protection agencies and tasks as prescribed in the fund regulation; organizing the registration; monitoring management and fee collection of selling/exchanging CREs.

With regard to the CDM, the responsibility of VEPF includes most of related activities. These vary from register to manage and monitor the implementation of CDM project including other CDM concerned purposes in compliance with the law. Moreover, the VEPF now provides significant assistance with soft loans for environmental projects in Vietnam. It offers subsidies for products from CDM projects (e.g. subsidies for power generated from wind energy projects; see Decision 58/2008/TTLT-BTC-BTN&MT and discussion further below). Thus, it currently takes an essential role in managing the CERs from CDM projects in Vietnam and provides subsidies on products from renewables projects based on the collection fees of CER and available budget given by Vietnamese Government. According to VEPF (2010), the authorities are considering possibilities to set up annual award system for environmental projects and an appropriate mechanism favouring renewable energy projects using premium tariffs (Fitchner, 2009).

### 7.2.3 The global environment facility

The Global Environment Facility (GEF), established in 1991, is a global partnership including 182 member governments with international institutions, nongovernmental organizations, and private sector. It addresses the global environmental issues while supporting national sustainable development initiatives. The GEF provides grants to developing countries and countries with economies in transition for the projects related to six major areas: biodiversity, climate change, international waters, land degradation, the ozone layer, and persistent organic pollutants (GEF, 2010).

The GEF is also the designated financial mechanism for a number of multilateral environmental agreements (MEAs) or conventions. For example, the GEF assists countries in meeting their obligations under the conventions that they have committed. In particular, GEF projects in climate change help developing countries and economies in transition to contribute to the overall objective of the United Nations Framework Convention on Climate Change (UNFCCC). Today, the GEF is the largest funder for projects related to global environment improvement. The GEF has allocated $9.2 billion, supplemented by more than $40 billion in co-financing, for more than 2,700 projects in over 165 developing countries and countries with economies in transition (GEF, 2010). Particularly, as financial mechanism of the UNFCCC, GEF allocates and disburses about USD 250 million dollars per year in projects related to energy efficiency, renewable energies, and sustainable transportation. Moreover, it manages two special funds under the UNFCCC, the Least Developed Countries Fund and the Special Climate Change Fund (Fitchner, 2009).

The largest part of GEF support for the national communications is delivered through an umbrella and support program administered by the United Nations Development Program and United Nations Environment Program. With this umbrella program, countries can also receive supports for overall assessment on vulnerability and adaptation, capacity building, and technology needs. By today, Vietnam has benefited from GEF supports for climate change related activities with a total of 11 projects funded (Fitchner, 2009).

In December 2007, parties to the UNFCCC adopted the Bali Action Plan for the enhanced implementation of the Convention, according to which developing countries would consider nationally appropriate mitigation actions in "the context of sustainable development, supported and enabled by technology, financing and capacity-building." While a new financing architecture is being developed, Vietnam should take advantage of the existing instruments, as much as possible such as: the GEF, the Carbon Partnership Facility for emission purchase agreements beyond 2012, the Climate Investment Funds (CIF), and various carbon funds associated with the Clean Development Mechanism. The largest fund under the CIF umbrella is the Clean Technology Fund (CTF), which will finance demonstration, deployment, and transfer of low-carbon technologies (World Bank, 2009a).

## 7.3 The Clean Development Mechanism (CDM)

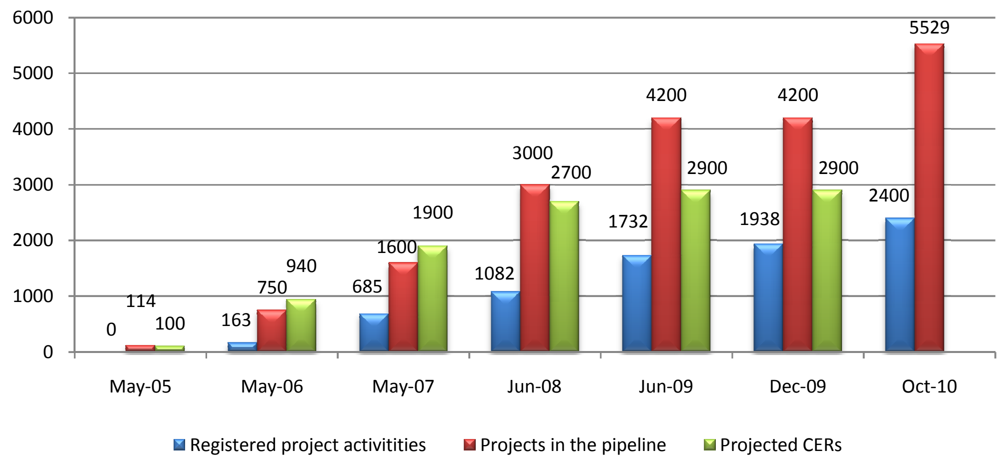
The world has still missed a new agreement on climate change post-2012 at the last open important talks in Copenhagen (2009) and Cancun (2010). Developing countries have opposed to their legal obligations of $CO_2$ emissions reductions though they agreed to implement mitigation actions. However, they have also stressed that the extent to which they meet their obligations to take climate change actions depends on the extent to which developed countries meet their commitments to them on providing finance and technology. In this regard, they expect to continue their contributions to the global effort by hosting $CO_2$ emissions reduction projects and benefiting from these projects as specified in the Clean Development Mechanism (CDM), a financing mechanism arranged in the Kyoto Protocol (1998).

The current functioning of the CDM has been concerned and widely questioned about (i) the environmental effectiveness that relates to whether the CDM contributes to global greenhouse gas emission reductions (Cames et al., 2007; Michealowa and Purohit, 2007; Schneider, 2007; Chung, 2007; Wara and Victor, 2008; Wara, 2008; Schatz, 2008; Haya, 2009; Schneider, 2009), (ii) its contribution to the sustainable development goal in host countries as it's originally framed in the Article 12 of the Kyoto Protocol (Olsen, 2007; Matschoss, 2007; Schneider, 2007; Sutter and Parreño, 2007; Wara, 2008; UNEP/Risø, 2009), (iii) the need to promote equitable geographic distribution of the CDM project activities at regional and subregional levels (Cosbey et al, 2006; UNEP/Risø, 2009; Bakker et all, 2009), (iv) the institutional structure of the CDM and associated difficulties implementing CDM project activities (Michealowa et al., 2003; Michealowa and Jotzo, 2005; Sterk and Witteneben, 2006; Streck, 2007; Streck and Lin, 2008; Castro and Michealowa, 2008; Cames, et al., 2008; Boyle et al., 2009; Castro and Michealowa, 2009), (v) sectoral distribution and windfall profits of projects that relates to the disparity of GHG reduction by CDM projects among sectoral emissions reductions potential (Zegras, 2007; Schneider, 2009; Sterk, 2008; UNEP/Risø, 2009) and high windfall profits/producer surplus of some project proponents and host countries as the costs of achieving some emission reduction have been very low (Wara and Victor, 2008; Schatz, 2008; Bakker et al., 2009), etc. But it has experienced a strong success and steady growth since 2005: globally the trend in number of CDM projects in the pipeline has been almost exponential as at 1 October 2010 (see Figure 7-1), and an offsetting mechanism with global reach of over 2.9 billions certified emission reductions (CERs) expected to the end of 2012 (UNFCCC, 2009a).

Today, after Copenhagen and Cancun, uncertainty on climate policies and market-based finance mechanism post-2012 still remains on the future of the CDM. A variety of options have been proposed to reform the CDM aiming to carry on its momentum (Bodansky, 2007; Cosbey, et al., 2007; Bakker, et al., 2007 and 2009; Cames, et al., 2008; UNFCCC, 2008; Larry and Jinhua, 2008; Olsen and Fenhann, 2008; CAN, 2008 and 2009; Asselt and Gupta, 2009; Schneider, 2009; Michealowa and Muller, 2009; UNFCCC, 2009b).

This part of the study, based on a review of key documents as well as interviews carried out with a number of experts and stakeholders inside and outside the country, is presented as follows. First, we review the present CDM development in Vietnam. We argue that the number of successful projects in the country is disproportionately small compared to the potential. Second, we analyze the barriers explaining why. Third, based on the lessons learnt also in comparable countries and considering possible post-Kyoto contexts, we offer a few suggestions to benefit more from the mechanism or its successor

*Figure 7-1: The CDM continuously grows strongly and steadily since 2005 even we are now getting closer to 2012.*




Source: UNEP Risø Centre, 10.2010.

### 7.3.1 Vietnam and the CDM, a late start

#### *7.3.1.1 A significant potential*

*Large potential for implementation of CDM projects*

Due to growing energy needs, highly inefficient energy use and an ample potential for renewables, Viet Nam is a promising country with enormous opportunities for developing projects under the CDM system. The most potential sectors for developing CDM projects are renewables (dominated by hydropower, wind energy), biomass and biogas (residues from sugar, rice, agriculture, wood production), waste (landfills, animal farms, tapioca starch) and waste water treatment, fossil fuel switching (food, beverage, steel, iron, paper, pulp, rubber, wood), and finally energy efficiency in both industry and buildings.

Greater CDM potential should exist within Vietnam as demand for energy has been soaring. Over the last decade, demand for electricity increased by 14.9% per year for 1996-2000, 15.3% for 2001-2005, and 14.1% for 2006-2007. It is predicted to grow about twice the growth rate of the GDP, by 15% in a low scenario and 18% in a high scenario over 2010-2030. In addition, heavy industry is on the rise to satisfy the country's rapid economic growth. The Vietnamese power system capacity needs to double, basically based on the additions of thermal coal-fired energy generation sources, in just five years to meet the demand. The Vietnam's carbon emissions will more than double in the period 2000 to 2020, increasing from 102.6 million tons in 2000 to an estimated 233.3 million tons in 2020. The sole biggest contributor to this increase is the energy sector, anticipated to rocket from only 45.9 million tons of carbon emissions in 2000 to 197 millions in 2020 (Climate Focus, 2008, 2009). Moreover, in Nguyen and Ha-Duong, (2009), we examined that as a result of huge expansion of coal-fired generation capacities to meet the increasing demand for electricity over 2010-2030, $CO_2$ emissions in the power sector are expected to rocket up and reaching about 352 million tons of $CO_2$ in 2030, which is several times the 45.9 million tons of carbon emissions emitted by the energy sector in year 2000. Therefore, the potential for greenhouse gas (GHG) reduction projects in Vietnam' s energy sector is very high, in which plenty of cleaner technological electricity supply and demand side options are available that could be effectively exploited under the climate protection activities. The country's natural conditions for these kinds of activities such as the CDM are exceptionally good with large hydropower resources, 3 000 km of windswept coast for wind turbine development, over 300 hot-stream sources ranging from 30 °C to 148 °C which can be used for geothermal power generating, 2 400 hours of sunshine per year for solar energy development, plentiful agriculture residues for energy usage, etc. More particularly, we find renewables could be developed for electricity generation at low carbon prices even cost-effectively competitive in some good conditions for small hydropower, biomass (bagasse) and geothermal. Biomass (including rice husk, paddy straw, wood residues), and wind power suggested as cost-effective generation sources at 4 $/t $CO_2$, while wood plantation and municipal solid wastes become competitive at 6 $/t $CO_2$. Energy efficiency in both industry and buildings offer ample potentiality for the CDM development in Vietnam. Energy efficiency of lighting usage on the household and service sectors could offer a free lunch reduction in $CO_2$ emissions, i.e. the abatement cost is negative (Nguyen and Ha-Duong, 2010; Wetzelaer et al., 2007). Furthermore, Vietnam as a developing country has been experiencing an inefficient heavy industry with backward techniques and technology systems that could be a fertile field to exploit the CDM projects potential (PREGA, 2005; Nguyen and Ha-Duong, 2010). It is estimated that beyond 20% of energy in the whole energy sector could be saved by adoption of specific programmes. For example, most of the existing thermal coal/oil-fired power plants operate with very low efficiency, reaching about only 28-32% that is 10% lower than in developed countries. The average efficiency of industrial boilers reached approximately only 60% that is 20% lower than the world level (Nguyen et al., 2010). More practically, the on-going project of Small and Medium Enterprise (SME), which comprises an integrated set of activities designed to address the barriers to widespread utilization of energy efficient management practices, operations and technologies in the 5 selected Vietnamese sectors of brick, ceramics, textiles, paper and food processing estimates to save an amount of 189.5 Ktoe in energy consumption and about 1 Mt of $CO_2$ emissions reduction per annum during the period 2005-2015 (PECSME, 2008).

There is room for other greenhouse gas emissions reduction measures, which could potentially be implemented under the CDM system, in energy sector, industry and mining, waste management and other sectors such as CH4 recovery and utilization from waste disposal sites, coal mining and waste water treatment; associated gas recovery and utilization by oil production activities; agriculture; afforestation and reforestation; chemical, manufacturing, building, and transportation…, etc.

*The country has no shortage of CDM buyers/project developers.*

Like most CDM countries in the region of Asia, Vietnam is not short of CDM buyers. Except for a handful of buyers with established offices in Vietnam, most buyers are from abroad. They undertake frequent visits and regular contacts with local CDM consultants and the Designated National Authorities (DNA). Japanese companies, who often act as investors in the projects, are the first buyers and most dominant group in the country. Buyers or prospective purchasers so far have been large energy companies such as RWE, Tohoku Electric Power, Tokyo Electric Power, Kyushu Electric Power, Essent Energy Trading BV, Shell International, etc, and some of the well-known carbon funds that are acquiring carbon credits as a service to participants or for speculative trading such as KfW Carbon Fund, Tricorona AB, or EDF Trading. Also, project entities have signed deals with European compliance buyers that are large energy utilities (Climate Focus, 2009; Germany Trade & Invest, 2009; UNEP Risø Center CDM pipeline). Table 7-1 presents CDM project developers and consultancy companies in Vietnam.

*Table 7-1: Project developers and consultancy companies in Vietnam, as 2 December 2009.*

| Name | Number of CDM projects | Number of registered projects | Country |
|---|---|---|---|
| AES | 5 | | America |
| Asia Carbon | 6 | | Singapore |
| CAMCO | 3 | | England |
| Carbon Resource Management | 3 | | England |
| Ecoeye | 4 | 2 | South Korea |
| Energy and Environment Consultancy/Joint Stock Company (VNEEC) | 21 | 1 | Vietnam |
| INTRACO | 13 | | Vietnam |
| KYOTOenergy | 12 | 4 | Singapore |
| Mitsubishi UFJ Securities | 3 | | Japan |
| RCEE | 3 | 1 | Vietnam |
| Toshiba | 2 | 2 | Japan |
| Others | 18 | 4 | |
| Total | 93 | 14 | |

Source: UNEP Risø Centre CDM pipeline: http://www.cdmpipeline.org/

*Available supports from CDM partnership agreements*

Vietnam cooperates with many partners from Austria, Japan, Germany, Denmark, and other countries on climate change issues. For example, Vietnam has signed a new cooperation agreement with Denmark since December 2008 with a financial framework of EUR 40 million (Germany Trade & Invest, 2009) and cooperated with the Japan International Cooperation Agency to implement a development program for the afforestation and reforestation Clean Development Mechanism (AR-CDM).

In terms of local capacity building initiatives, Vietnam has received support from many international organizations such as Australian government, Dutch government, World Bank, Japan Bank for International Cooperation (JBIC), the United Nations Environment Programme (UNEP), the Asian Institute of Technology (AIT) and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), etc. Table 7-2 summaries capacity building activities in Vietnam under different supportive programmes.

*Table 7-2: Capacity building initiatives in Vietnam under various programmes, as 2 December 2009.*

| Programmes | Donor, implementing agency | Number of registered projects |
|---|---|---|
| National CDM Strategy Study | Australian government, World Bank | Early assessment of GHG reduction opportunities and abatement costs. |
| Capacity Development for the CDM in Vietnam (CD4CDM) | Dutch government, UNEP Risø | Improve awareness, capacity development for policy makers and the DNA through a series of workshops, among others. |
| EU-Asia institutional cooperation and multinational dialogues on enabling the meaningful participation of Vietnam, Laos, Cambodia in CDM | EU Asia ProEco Programme, HWWA, Germany, JIN, Netherland | Questions and answers on the Kyoto Protocol and the CDM, workshop and brochure. |
| | GTA, Germany | Opportunities for biogas projects under a Programme of Activities. |
| | DANIDA | Identify CDM project opportunities in cement sector. |

Source: Climate Focus (2009).

#### *7.3.1.2 Opportunities exploited so far*

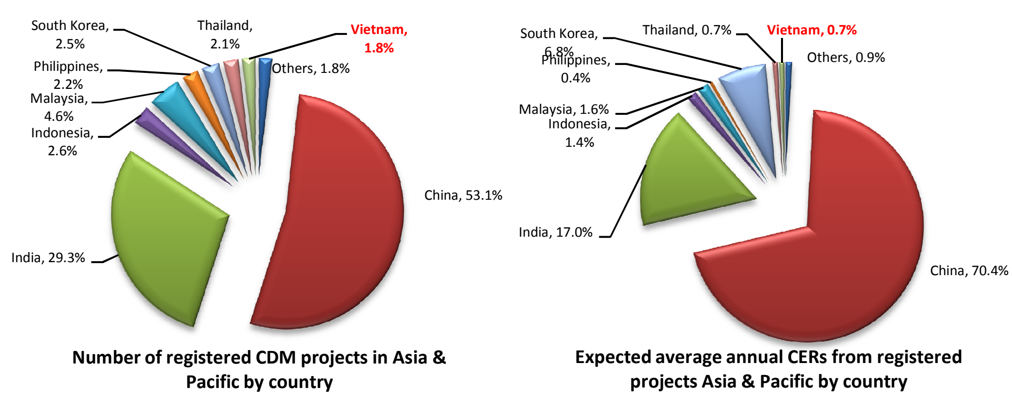
Vietnam soon ratified the Kyoto Protocol on 25 September 2002 and is considered as possessing great opportunities for CDM climate protection activities. However, the CDM development has risen very slowly until now. Though 2008 and 2009 have shown increased activity and many new projects are undertaken, the Vietnamese CDM market has experienced a late start compared to other developing countries with similar climate opportunities.

*Early starting but very slow development progress:* the carbon offsetting market is gathering pace at a frenzied rate, notably in Asia since 2005. Like other countries in the region, Vietnam was ready early to start the implementation of CDM projects with 2 projects being approved in 2004 by the country DNA. But more than 3 years later, only 23 projects were additionally approved by the host country DNA reaching about 25 projects cumulatively in year 2007. Among these, two projects had been registered at the CDM Executive Board (CDM-EB) by this time: the large-scale Rang Dong gas flaring reduction project and the small-scale 2 MW Song Muc hydropower project.

*Fast growth in the pipeline over 2008-2009 but low to be registered compared to other developing country in Southeast Asia:* the recent 17 months have witnessed the increased activity of CDM implementation in the country. By August 2008, there were 44 CDM projects being received host country DNA approval, 27 projects had been submitted to the United Nations Framework Convention on Climate Change (UNFCCC), and only two registered projects. Today, as at 1 October 2010, 135 projects have been approved by Vietnamese DNA, 127 projects submitted to UNFCCC, and 33 registered. However, in direct comparison, Vietnam currently shares 1.8% in the region's CDM projects both in number of registered projects and volume of credits expected by 2012 (Figure 7-2). Table 7-3 also shows that the country is lagging behind other South East Asian countries such as Malaysia, Philippines, and Indonesia, and still ranks at the lower end of countries in the region, just higher than other countries such as Cambodia, Lao PDR, and Myanmar, in term of numbers of registered projects. While Vietnam is endowed with ample hydropower resources, about 30 GW, of which less than a quarter have been developed by 2005 (Nguyen and Ha-Duong, 2009), as of 1 October 2010 the country has only registered 20 small-scale hydropower projects (< 30MW) whilst 249 around the region were registered by the same time (UNEP Risø Centre, 10.2010). Apart from hydropower, additionally, the scope for CDM activities in renewables has been mostly left untapped while greater potential should exist within the country, by which only one renewable energy project, the Binh Thuan wind power farm (30MW), has been registered in early 2009.

The Kyoto Protocol's first commitment period expires at the end of 2012 so that the window of opportunity for registering projects will close because long-time required for building a project to generate any meaningful emission reductions before the end of 2012 whilst the current demand for post 2012 is very limited, the momentum of the CDM may not be easy to remain until 2012 (Lecocq and Philippe, 2007; Climate Focus, 2009).

*Figure 7-2: Share of CDM projects in Asia, 1 October 2010.*




Source: UNEP Risø Capacity Development for CDM, www.cd4cdm.org.

*Table 7-3: Status of CDM projects under development in Southeast Asia, as 2 December 2009.*

| Country | submitted to UNFCCC | Registered CDM projects | Under validation | * Others | Rejected | Approved by DNA |
|---|---|---|---|---|---|---|
| Cambodia | 5 | 4 | 1 | 0 | 0 | 45 |
| China | 2,048 | 652 | 1,057 | 310 | 29 | 2279 |
| India | 1,476 | 463 | 697 | 275 | 41 | 1455 |
| Indonesia | 117 | 33 | 50 | 33 | 1 | 104 |
| Lao PDR | 2 | 1 | 1 | 0 | 0 | No data published |
| Malaysia | 167 | 66 | 46 | 51 | 4 | No data published |
| Myanmar | 0 | 0 | 0 | 0 | 0 | 0 |
| Philippines | 89 | 3 | 33 | 14 | 2 | 64 |
| Thailand | 119 | 26 | 78 | 14 | 1 | 91 |
| Vietnam | 122 | 14 | 101 | 0 | 1 | 104 |

* Projects that are requesting registration, under review, under request for review or under request for correction.

Source: own compilation from UNFCCC project search: http://cdm.unfccc.int/Projects/projsearch.html; UNEP Risø Centre CDM pipeline: http://www.cd4cdm.org; IGES CDM fact sheets of Asian countries: http://www.iges.or.jp/en/cdm/report_country.html, CDM approval updates from NDRC website: http://cdm.ccchina.gov.cn/web/index.asp; CDM approval updates from Department of Methodology, Hydrology and Climate Change, Vietnam: http://www.noccop.org.vn; UNFCCC CDM Statistics: http://cdm.unfccc.int/Statistics/index.html; Monthly newsletter of the GTZ Climate Protection Programme; CDM approval updates from Department of Methodology, Hydrology and Climate Change, Vietnam: http://www.noccop.org.vn.

### 7.3.2 Why has CDM in Vietnam not been more intense? A barrier analysis

On the ground of the country's key studies/documents and experts/stakeholders' options based on face-to-face interviews, the major barriers were identified and analyzed including regulatory barriers for approval process, bureaucracy and corruption, and tariff uncertainty barriers for project developers, barriers of access to information and local capacity, and barriers due to type of projects.

#### *7.3.2.1 Regulatory barriers*

*The institutional structure and regulatory framework for CDM activities*

The Ministry of Natural Resources and Environment of Vietnam (MONRE) was assigned by Vietnamese government as a national focal agency for implementing the Kyoto Protocol in Vietnam. Within its Ministry, the Department of Meteorology, Hydrology and Climate Change is designated since May 2008 to act as CDM Designated National Authority (DNA). This department is responsible for executing CDM projects approval process, and managing all other climate change related activities in Vietnam. The National Steering Committee for

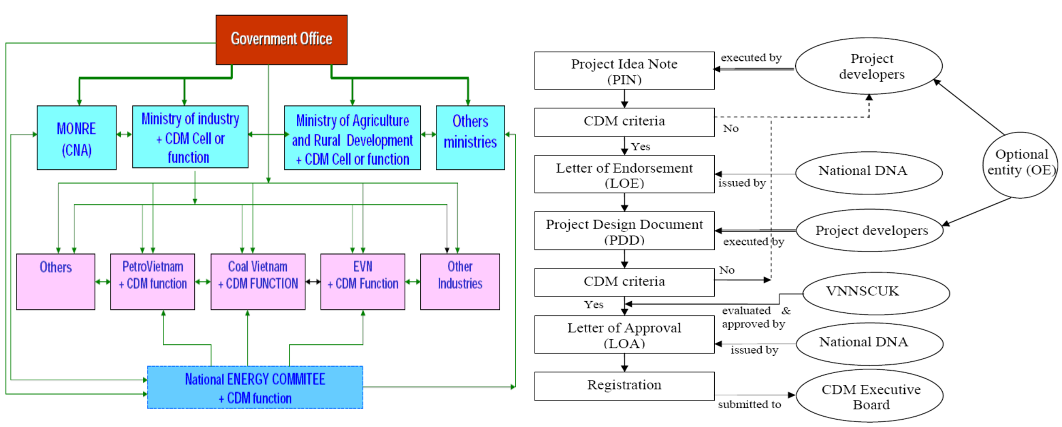
UNFCCC and Kyoto Protocol (VNNSCUK), which consists of 16 representatives from 14 different ministries and one science association and chaired by Vice Minister of MONRE, is the supreme entity of approving CDM projects in Vietnam. Table 7-4 presents an overview of the regulatory framework for CDM projects in Vietnam. Figure 7-3 describes the organizational structure and host country approval procedure for CDM projects. The current administrative system and approval procedure in Vietnam, however, causes a number of critical hindrances for developers, CDM consultants and buyers involved in CDM activities.

*Table 7-4: The current national regulatory framework for CDM development in Vietnam.*

| Date | Regulation | Issued by | Subject |
|---|---|---|---|
| 17 Oct 2005 | Directive No.35/2005/CT-TTg | Prime Minister | Instructions given to ministries, government entities/bodies, provincial/municipal People's Committee to implement the CDM. |
| 12 Dec 2006 | Circular No.10/2006/TT-BTNMT | MONRE | Guidelines for developing CDM projects in Vietnam. |
| 6 April 2007 | Decision No.47/2007/QD-TTg | Prime Minister | National Action Plan to implement the Kyoto Protocol in the period 2007-2010. |
| 2 August 2007 | Decision No.130/2007/QD-TTg | Prime Minister | Financial mechanisms and policies for CDM projects implementation in Vietnam. |
| 4 July 2008 | Circular No.58/2008/TTLT-BTC-BTN&MT | MOF/MONRE | Guiding the implementation of some articles given in Decision No.130/2007/QD-TTg. |

Source: Hoa M. Hoang (2008), Climate Focus (2009).

*Figure 7-3: The CDM institutional structure and host country approval procedures for CDM projects in Vietnam.*




Source: Hieu Nguyen (2007); Hoa M. Hoang (2008).

*Delays in approval process:* as the DNA's own stipulation, time requirement for approving a Project Idea Note (PIN) is 25 days and 50 days for a Project Designed Document (PDD). But project developers experience approval times of about 6 months for a PIN and up to 1 year for a PDD in reality. The periods are quite longer than that in China and India (60 days for both PIN and PDD), which together own 62% of registered CDM projects worldwide. This is due to an inappropriate organizational system for running the CDM approval activities and lack of standing specialized experts-in-charge. According to the DNA's standards, it requires at least 75% of total VNNSCUK members to be present during the CDM project approval meeting. However, a majority of these members are government delegates/experts invited from various ministries and they have own different important tasks/business, which must be executed at their ministries at the same period so that it is a very difficult task to coordinate their agenda and gather full participations for such project approval meetings.

*Document submission system:* the submission process for CDM project documents is recognized inadequate and very underdeveloped by which project developers are required to hand-deliver hard copies of the PDDs personally to all VNNSCUK members. To contact these members for such a hand-submission, developers got to involve a number of phone calls ahead to ask for VNNSCUK members/receivers' appointments whilst electronic email and postal delivery as business standards globally are not preferable by receivers. This peculiar submission procedure takes a plenty of waste time, increases project transaction costs, intensifies opportunities for bureaucratic harassment, and creates motive and environment for the proliferation of corruption.

*Lack of approval criteria:* the evaluation and approval system for PDDs of CDM projects in Vietnam has the absence of clear sound approval criteria on which the members of VNNSCUK could basically rely when there is confusion about the mandate and on which grounds the DNA should comment. The VNNSCUK members, who are assigned from various Ministries, have tendency to evaluate projects on the basic of PDD and their own experiences, backgrounds and reference points on what constitutes sustainable development. They cannot revert to a clear set of guidance criteria but have to form a viewpoint on case by case basis. This is a very work intensive approach for all parties involved. As VNNSCUK members hold a diverse set of backgrounds, this leads them to provide comments on PPDs from their own perspectives. This can create excessive works for project developers and in extreme cases even conflict with CDM guidance (Climate Focus, 2009).

*Lack of a consultative process:* CDM guidelines and regulations have effects on CDM project entities and developers but there is no process in place to consult them. An example is: the Prime Minister issued a Decision No. 130/2007/QD-TTg in August 2007 stipulating a number of financial mechanisms and policies for CDM projects in Vietnam but a year later, MONRE and MOF have jointly issued the Circular No. 58/2008/TTLT-BTC-BTN&MT in July 2008which further explains some articles of the above Decision. Particularly in the circular, a tax on CDM revenues was introduced, which should be channeled back to CDM projects and used to subsidise project development. This messages that experienced CDM consultants and project entities were not invited to participate to the drafting national CDM legislation at the beginning stage. Moreover, the guidance document only became known to CDM project developers once it had already been issued.

*The DNA experts' capacity and provincial approvals:* the Vietnamese DNA consists of only 6 standing experts/staffs and dominantly occasional VNNSCUK members for the whole current CDM activities. Such staffing levels may not be able to manage the CDM activities with the expected increasing PDD submissions. The most concerned cumbersome regulation is due to the provincial approval required by the Vietnamese CDM standard, which is considered as a peculiarity of the Vietnamese administrative system (Climate Focus, 2009). As stipulated, project developers should necessarily demonstrate support from the provincial government for implementation of CDM projects at local territories through endorsement letters from provincial governors. However, provincial governors do not have necessary tools and methods to analyze, to evaluate the feasibility of proposed CDM projects even they have not been well-trained about the CDM either. Project developers therefore face a mass of unpredictable difficulties to obtain the endorsements, especially when they have no "close-relationship" with the government.

#### *7.3.2.2 Barriers due to business climate*

*Corruption and bureaucracy?*

Vietnam is in a transition phase from a "centrally planned" economy to a "market-driven economy with socialist orientation". The recent country's efforts of attracting foreign/private investments have led the central government to seek to improve the country's business and investment climate for foreign/domestic investors. Unfortunately, the evil of corruption and inefficient bureaucracy remain as one of the most problematic factors (including poor law enforcement and poor infrastructure) for doing business generally and executing CDM projects particularly.

Germany Trade & Invest (2009) provided a CDM market brief that evaluates the CDM investment climate among Asian countries through the CDM investment climate index (CDM ICI). The CDM ICI index ranges from 100 points (highest) to 0 point (lowest). As its evaluation, the Vietnamese CDM investment climate is ranked as "average climate" with the CDM ICI of 54.4 points only. The parameters that go into the current assessment are the general investment conditions, in-transparent administration, the taxation of CDM projects, and the small number of registered projects to date. The detailed expression in Table 7-5 shows a regrettable backward step far behind, in term of CDM investment climate, compared to other countries in the region such as Malaysia (91.7 points), South Korea (90.2 points), Thailand (83.7 points), China (83.3 points), India (80.7 points), Indonesia (80.1 points), Philippines (79.5 points)…, etc. Practically, the major barriers for CDM investment climate in Vietnam could be recognized by looking at the country's systematic problem of corruption and intransparent regulation, CDM investment conditions with lack of supporting measures, cumbersome administrative system.

*Table 7-5: CDM investment climate index (CDM ICI) in the Asian region by April 2009.*

| Rank | Country | CDM ICI (max 100 points) | Regional classification |
|---|---|---|---|
| 1 | Malaysia | 91.7 | Very good climate |
| 2 | Korea (Rep) | 90.2 | Very good climate |
| 3 | Thailand | 83.7 | Good climate |
| 4 | China | 83.3 | Good climate |
| 5 | India | 80.7 | Good climate |
| 6 | Indonesia | 80.1 | Good climate |
| 7 | Philippines | 79.5 | Good climate |
| … | … | … | … |
| 25 | Vietnam | 54.4 | Average climate |
| … | ... | ... | |

Source: DEG- Deutsche Investtions and Entwicklungsgesellschaft mbH cited by Germany Trade & Invest, 2009.

In term of competitive climate at global scale, the "Global Competitiveness Report, 2008-2009" published by the World Economic Forum assesses the country's current overall business climate is eroded by weaknesses in the quality of infrastructure and institutions, as well as in higher education and training. Specially, the country's business climate heavily suffers from burdensome government regulation and weak auditing and reporting standards.

Point Carbon (2009) found that institutional conditions have little improved and the DNA was still relatively slow in approving projects due to its inadequate organization. The CDM investment climate has deteriorated by cumbersome regulation and high corruption.

The current organizational structure of the VNNSCUK appears explicitly cumbersome and inefficient. This could lead to conflict objectives and interests among the examiners/evaluators then causes power shifts to lobbyist, and hinders approval progress. In addition, the existing submission and approval system often puts investors/developers into a struggling position so as to obtain necessary endorsements should they are not well-connected with the government (Climate Focus, 2009). Because of endorsement requirement in due time, lobbying governmental officials/authorities in one common "business trading way" in the country with "fostering envelopes" seems to be hardly avoidable. On the other hand, because the low wage standard and insufficient law-abiding spirit, government officials/authorities could easily engage in corruption activities in such a given context. Given the country's current corruption evil, the situation that investors/developers' one blind-eye must be turned to them should they demand extra commissions or bribes in one way or another is not implausible. The unhurried or delayed approval progress for CDM projects, thus, could be foreseeable accordingly.

*Tariff uncertainty and less attractive?*

Compared to other economic sectors in Vietnam, the government is very present in the energy sector. Most of energy products are closely regulated: fixing prices for electricity, setting ceiling prices for gasoline, oil and petroleum products, controlling prices of coal for producing electricity, cement, and fertilize, etc. That leads to decreasing the business attractiveness to investors in the sector and wasting energy resources. The electricity market has been in the process of deregulation since 2005. As per the government's roadmap, the electricity sector will be opened fully to retail/household sales only after 2022. The government now still interferes with the market by limiting the average electricity price at rather low level, at 5.8 cents (US$/kWh), to enable the country's products to remain competitive around the globe. Beyond, the Electricity Corporation of Vietnam (EVN) is subsidized by regulated fuel-costs lower than the market price. By now almost the whole power sector is run by EVN. Currently, the average electricity pricing is governmentally moderated rather low compared to those of other countries in the region. These market distortions detract domestic/foreign developers from investing in generating capacity. Therefore, a scarcity of financial resources for the expansion of the power generating system has been blamed as a key reason of electricity shortages over several years. And this is also putting EVN into a difficult position that to add and deliver a kilowatt-hour of electricity to users is more costly than that they are now allowed to charge for (Nguyen et al., 2010). They attempts to run, hence, the business by minimizing power purchase of external sources at their charges. As a result, many CDM project investors/developers claimed for a bankrupt if they lay out their capital resources for the energy projects whilst EVN continues to purchase electricity production at their expenses only. On the contrary, EVN debates their selling price is already considered at ceiling level and purchasing electricity from external generators at long-term cost of production is beyond what they can charge for.

Furthermore, electricity price is often one way used to help the government control the inflation. When a power supply shortage comes out, as practically-adopted solution the government allows EVN to increase the purchasing price until additional power generators exist sufficiently. However, to investors/developers this solution contains many potential risks of electricity prices and they can not commit to build their electricity generators without long-term contracts or without power purchasing agreements (PPAs) that cover actual costs. Often, EVN declines to commit for long-term contracts and many negotiations for PPAs have gone to dead-end alley already. Another factor limiting investment in CDM projects is that there are no government-incentives for pricing reflective of clean energy's extra benefits and it is not strategically integrated yet into the national regulatory framework. There are no supportive schemes as national cost-sharing system, feed-in tariff mechanism, power purchasing agreement, etc, to create incentives for investment business under the CDM system.

#### *7.3.2.3 Access to information and local capacity*

*Awareness and information of national physical potentials and local markets*

The information on national CDM potential and development strategy are very important to project developers, but they are often hardly accessible in Vietnam. Nguyen, et al., (2010) pointed out that the national potential of renewable resources has not yet been systematically estimated with precision and is often unavailable. That results in many difficulties to project investors/developers in Vietnam. The country's databases are limited, scattered, dispersed, and infrequently updated and mostly centered with a few major state groups/companies such as Electricity Corporation of Vietnam (EVN), and PetroVietnam (PVN). However, the door to these sources is barely accessible if investors/developers have no good relationship with the authorities. Because of this barrier, the awareness/knowledge on CDM potential among enterprises, private sectors, public entities, and NGOs is limited.

Moreover, information on local markets for small-scale renewables technologies is not publicly available in Vietnam. Nguyen, et al., (2010) showed that technology recipients/developers are lacking information and awareness of available domestic and international renewables technologies, which often causes them difficult to make proper investment decision. Some prospective developers even are not aware about potential emissions reductions opportunities offered by these technologies that could be implemented for their projects.

*Access to the electricity sector data*

Climate Focus (2009) found that one of the key barriers for projects seeking CDM registration in Vietnam lies in limited access to the electricity sector data for calculation of the carbon dioxide emission factor of the Vietnamese grid, called Baseline Emission Factor (BEF). CDM consultants and project entities often find it difficult to come by the data for their calculations of the baseline emission factor according to CDM methodologies. So, CDM consultants and project entities often use their personal contacts and relationships for obtaining data but lacking official feature. As a result, projects are often held up in validation stage because of failures in proving transparent and sufficient official data underlying their calculations.

On the same observation, Climate Focus (2009 ) and Germany Trade & Invest (2009) argued that the lack of reliable official data on the Vietnamese power grid generating a leading impediment to calculation of crucial emission factors and baselines for ascertaining carbon emissions savings. Different CDM projects entities use different BEFs for their project calculation design in spite of referencing the same data source and feeding into the same national grid. Table 7-6 shows examples of the BEF calculated for some Vietnamese CDM projects. Most CDM consultants calculated the BEFs for CDM projects in the Vietnamese electricity sector based on the EVN Masterplan covering the period 2001-2010 (Climate Focus, 2009). However, this document is considered a not good source of information for CDM purposes due to the following reasons: (i) there are a number of different versions of the Masterplan but none of which can be clearly identified as the final or official version, (ii) actual generation data is only available for years 2001-2005, which is not current enough to meet validators' requests, (iii) the Masterplan constitutes a plan, which does not fully reflect reality and can deviate from actual power generation in the country. Some of listed plants are not operational yet but are included to meet demand targets.

*Table 7-6: BEFs applied by some Vietnamese CDM projects.*

| Projects | PDD date | OM EF ($tCO_2$/MWh) | BM EF ($tCO_2$/MWh) | CM EF ($tCO_2$/MWh) | Data source |
|---|---|---|---|---|---|
| Song Muc Hydro Power Project | registered | 0.788 | 0.407 | 0.598 | Masterplan-EVN 2001-2010 |
| Song Giang 2 Hydro Power Project | 11/2006 | 0.658 | 0.503 | 0.58 | Masterplan-EVN 2001-2010 |
| Za Hung hydro Power Porject | 06/2006 | 0.658 | 0.503 | 0.58 | Masterplan-EVN 2001-2010 |
| Nam Chim Hydro Power Project | 06/2006 | 0.658 | 0.503 | 0.58 | Masterplan-EVN 2001-2010 |
| Dasiat Hydro Power Project | 09/2007 | 0.744 | 0.469 | 0.62 | Masterplan-EVN 2001-2010 |
| Nam Pia Hydro Power Project | 09/2007 | 0.692 | 0.495 | 0.591 | Masterplan-EVN 2001-2010 |
| Su Pan 2 Hydro Power Project | 01/2008 | 0.698 | 0.681 | 0.690 | Masterplan-EVN 2001-2010 |
| Wind Power Plant No.1 Binh Thuan, 30MW | 02/2008 | 0.701 | 0.475 | 0.644 | Masterplan-EVN 2001-2010 |
| Ngoi But 1 Hydro Power Project | 04/2008 | 0.84 | 0.4 | 0.62 | Masterplan-EVN 2001-2010 |
| Dak Drung 1 Hydro Power Project | 04/2008 | 0.84 | 0.4 | 0.62 | Masterplan-EVN 2001-2010 |
| Song Con 2 Hydro Power Project | 06/2008 | 0.676 | 0.597 | 0.637 | Masterplan-EVN 2001-2010 |
| Ngoi Duong Hydro Power Project | 06/2008 | 0.676 | 0.597 | 0.637 | Masterplan-EVN 2001-2010 |

Note: according to the "tool to calculate the emission factor for an electricity system" adopted by the CDM-EB the BEF is to be calculated as the combined margin (CM), the weight average between the operating margin (OM ) and the build margin (BM). Source: Climate Focus (2009).

*Local capacity*

Overall local capacity is definitely constrained that often creates frustration to project development in Vietnam as: experience is still lacking with the set of CDM instruments at all levels, inadequate technical skills, difficulty in communication because of the language barrier, insufficient knowledge of the mechanism among local CDM participants, poor quality PDDs and methodological groundwork establishing. Particularly, the country's domestic capacity resources for CDM development is at slow growth rate, and vital stakeholders are still lacking awareness and understanding of the CDM and its eligibility criteria in general as a prerequisite for the implementation of CDM projects. Knowledge is supposed to be strongest among a handful of established CDM consultants and government institutions, notably the DNA. Whilst the biggest impediment is the lack of knowledge among projects entities, local banks and engineering consulting firms (Climate Focus, 2009; Germany Trade & Invest, 2009).

Local CDM consultants are at different levels of knowledge about the CDM and its associated requirements and generally well-connected to external carbon market and national institutions as evaluated by Climate Focus (2009). Leading local CDM consultants in the country are VNEEC, INTRACO, and RCEE which have together undertaken 40% of submitted projects and are suffering from under-capacity. Other typical local consultants include Vietnam Institute of Energy, Electricity of Vietnam, Investment and Trade Consultancy Co. Ltd. However, hardly any local consultants are able to design viable project models or support a project from the beginning to registration stage, especially for new projects that require new methodologies and baselines without foreign partners.

Project entities in the country have insufficient knowledge and capacity to develop projects alone and cannot connect with the carbon market without incorporation with a few foreign investors. Therefore, they are fully depending on CDM consultants to help them navigate the CDM flows. Domestic banks appear relatively unfamiliar with the CDM and its requirements that leads to problems for project entities.

Among stakeholders, engineering consulting firms take an important role in the CDM by preparing feasibility studies of projects. They should be trained to look for CDM opportunities and to factor in carbon revenues at an early stage of project development.

Government institutions in Vietnam are still learning about the CDM, therefore lack of awareness exists among themselves that could create a number of barriers: (i) investment guidelines defined by the government may not be suitable to support CDM transactions and hamper demonstration of additionality; (ii) increasing complication from host country approval should members of the National Steering Committee are not fully turning into the mechanism's requirements; (iii) provincial governors, who have to extend their support to projects under the Vietnamese CDM regulation, find it difficult to sign endorsement letters should they are not fully familiar with the mechanism.

#### *7.3.2.4 Structure of the projects portfolio*

*The country's CDM potential lines with small-scale renewables:* greatest CDM potential within the country exist in renewable energy sector, which is dominated by small-scale hydropower and wind energy. At the end of September 2010, about 73% of the CDM projects of Vietnam in the pipeline involve small-scale hydropower. At the same time, hydropower-based CDM projects accounted for 60% of the total registered CDM projects of Vietnam. The scope for more measure of this type, however, is limited (Germany Trade &Invest, 2009). Through international CDM practice, project type, character, size and the host country's specific situation are recognized as the variables most likely to affect CDM project, especially it causes an important influence on CER issuance rates, lead times, and validation and registration success (Castro and Michealowa, 2008). Compared to other types, small-scale renewables in the country face more technological and financial barriers than larger ones. Though these are proven technologies that are implemented successfully and dominant CDM category in many countries, barriers clearly exist that prevent small-scale renewables technologies from being more widely implemented in the country especially when projects developed without intervention or investment from an Annex I party. Nguyen, et al., (2010) identified the following typical barriers: a lack of sufficient technological skill, information, and domestic suppliers, difficulties gathering the financial means and capital, and unsatisfactory government policy. Moreover these projects often require raised levels of funding beyond the CER revenues while the current energy pricing system is less incentive, thus they consume longer time for planning stage and experience longer delays.

*EVN has no interest in small-scale renewables projects:* today the independent power producers (IPPs) are recognized as the sole active enabler for promoting small-scale renewables projects in Vietnam instead the EVN. Legally, EVN is assigned as a state CDM function unit to undertake a principal responsibility for CDM projects in the sector. However, EVN basically operates all for the benefit of their business by which EVN has no interest in small-scale renewables projects. An example is: the wind power project of Phuong Mai could not be implemented under the mechanism even it provides a qualified PDD that was approved by the DNA for carbon financing. The reason is simply that EVN did not agree with the purchasing price of electricity proposed by the project developer, which is supposed not lucrative compared to the current average electricity pricing (USAID, 2007). Many experts argued that the implementation of small-scale power projects under the CDM does not attract much interest to EVN because these projects are often small and generate less profit but consume more timing, human resources. To EVN, compared to larger fossil-fuel fired power projects it seems likely that implementing CDM projects does not bring in expected business benefits but faces more difficult and risky. The reasons could not only be a part from the EVN's business strategy, but also the present national regulatory framework in which sufficient support measures are entirely absent and the electricity prices are government administered.

#### *7.3.2.5 Strategic recommendations*

Overall, the study's barrier analysis gives an answer to the research question that why Vietnam has not been more successful for CDM development during the high movement period of the mechanism around the globe as well as provides signals of necessary changes and improvements for Vietnam's CDM development in the context of the window of opportunity getting closed. These necessary changes and improvements today could be late on the global CDM rise but will be never a waste, the changes we should do today, instead, for the country's future sustainable opportunities. By establishing the country's regulatory and institutional system in a methodical and standardized manner, and building up sufficient essential infrastructures and human resources/capacities, the country is ready position for new international climate change agreements. Climate change challenges could be possibly turned into greater opportunities for sustainable development to the country if the mechanism continues to be a major or a part source of emissions credits for Kyoto signatories. With the objectives in mind, the next discussion provides strategic suggestions.

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First, the Vietnamese approval system for CDM projects should be strongly revised and significantly streamlined so as to ensure a smooth and righteous application process for the letters of approvals, without consuming too much timing, energy, and capacity of all involved parties. More specially, a clearer set of criteria and guidelines built up so that VNNSCUK members could use to evaluate projects in a common manner in stead of keeping the assessment of projects up to the discretionary judgment of each member. Moreover, the current method of project-by-project assessment could be no longer suitable in the way of processing larger volumes of projects[14]. To simplify the approval procedure, it is recommended to cut down the cumbersome capacity existing within the DNA by reducing the required number of participations to 50%. The number of representatives involved by combining only-related ministries in groups, which are controlled by elected group leaders, should be limited. Only in this way, Vietnam can operate as single window clearance to speed up the projects approval[15]. Alternatively, consult the ministries connected to the letter of approval on a project specific base only and do not involve ministries that have no clear connection to the project (Climate Focus, 2009).

Vietnam can infer lessons from other neighbouring countries such as China, India, and Indonesia in providing favourable conditions for involved parties. The business standards as postal-mail, electronic-email should be legally obligated for the submission of PDDs. The CDM consultants and projects entities, somehow, should be publicly invited to give comments on the country's draft CDM legislation.

Next, as local capacity is slowly growing there is a need for enhancing the awareness/ knowledge of climate change and CDM issues among involved bodies. Vietnam, in the past, has been quite successful in attracting international and bilateral donors for capacity building (Dang Hang, 2006). However, there is a further demand to intensify partnerships with foreign counterparts to disseminate deep knowledge on CDM more broadly as well as to improve foreign language. Important here is increasing local experience in preparing and implementing CDM projects. Climate Focus (2009) further suggested when receiving technical support from donors, the government should forge more partnerships between local and international carbon market consultants and necessitate that capacity building extends to all private sector

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[14] A good example is the Indonesian approval procedure that has approval times of only 1 month. The host DNA has applied several approval criteria translating into a questionnaire. Project developers got to provide information, for example, on what measures are foreseen to mitigate any negative social impacts of the projects. Rather than evaluate projects on their PDDs, which has a distinctly different purpose. Projects then are evaluated based on their responses to the questionnaire (IGES; UNEP Risø,).

[15] Another good example is the Indian DNA that runs as single door unit for approving CDM projects. The country's DNA has established an elaborate and effective institutional structure that make the approval process remain straight-forward. On the other hand, India has CDM promotion cells being set up at state level to favor CDM activities such as information dissemination, strengthening coordination between local and central government (IGES; UNEP Risø,).

participants with a stake in carbon transactions (in particular project entities, banks, engineering consulting firms). Alternatively, the country could extend international cooperation to establish consultative or training centers for DNA and provincial authorities, and involved ministries bodies. More on-the-job/sectoral trainings or workshops to transfer skills should be periodically held. Education programmes, campaigns, and R&D activity could also play as a considerable panacea.

Third, for more specific on large small-scale projects potential, e.g. projects of renewables, demand-side energy efficiency, etc, the government of Vietnam should support developers' calculating grid emission factors in order to facilitate validation of these huge potential projects in Vietnam. The proper calculation and periodic updating of the baseline emission factor (BEF)[16]and necessary information should be organized and disseminated to relevant stakeholders. In this aspect, Climate Focus (2009) suggested a structural process as follows:

(i) The Ministry in charge of promoting investments and regulating the energy sector, Ministry of Industry and Trade (MOIT), takes the lead in organizing the process and provides necessary funding.

(ii) MOIT commissions a local consultant to gather the data, perform the calculation progress and undertake yearly updates of the BEF.

(iii) A local consultant should be selected who has access to information on the Vietnamese grid and knowledge of the CDM methodologies. The local organization best positioned for the task is the Institute of Energy (IE), which is in charge of producing the Power Sector Master Plan. One of the specialized local CDM consultancies could be co-commissioned to ensure that the calculation of BEF fully meets developers' needs.

(iv) The DNA publishes the factor and supporting calculations/datasheets on its website.

Beyond most necessities for achieving more benefit from the CDM until the window of opportunity for registering projects closed then reaching more fully benefit from any other climate mechanisms that could appear from a new deal for post-2012 is a clear national strategy and comprehensively bright policies with incentive schemes towards climate mitigation goals[17]. Essentially, there is a vital demand to improve the CDM investment climate

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[16] China is considered as the country having very effective supports in this regard. The government publishes the grid emission factors for all Chinese regional grids on the DNA homepage: http://cdm.ccchina.gov.cn/english/NewsInfo.asp?newsId=2871.

[17] In this regard, Vietnam can learn from Chinese effective policy. To support for the DNA's operation, national CDM policy and its regulatory framework constitutes remarkable features towards CDM such as participation requirements, allocation ratio of CERs, etc so that the approval process could be undertaken within 30 days and effectively operated with 50 CDM projects submitted every month. On the institutional side, China establishes incentive schemes and service providers towards CDM information dissemination and supportive CDM activities (IGES; UNEP Risø,).

by eliminating the cumbersome bureaucracy, and wipe out the existing corruption evil, otherwise the country could continue to wrestle with itself at the lower end of countries in the region in term of climate change mitigation activities under the CDM mechanism.

More specifically on how to move from state monopoly to renewable portfolio in the Vietnamese electricity sector, learn lessons from international practices and the reform progress of different countries having similar electricity industry development should be taken into account at different future sector development stages.

#### *7.3.2.6 Summary*

We have shown that Vietnam is a late-starter on the global rise of CDM. The country lags behind its regional neighbours in term of registered CDM projects activities. By October 1st, 2010, there were only 33 registered CDM projects in Vietnam. This is a small fraction of the potential for successful CDM projects in the country. Opportunities abound in the energy sector, as the country is richly endowed in renewable resources, especially hydropower, wind and biomass.

The barrier analysis outlined the ways in which that facilitating the CDM in Vietnam has not been methodical and efficient enough to complete successful projects. Climate mitigation is not yet considered a strategic priority in the long-term economic development plan. Policy measures are available for a stronger strategy of climate change investment business, fully consistent with the general goal of improving country's investment climate by reducing red tape (bureaucracy, cumbersome regulation) and fighting corruption. Some could be effective even before the window of opportunities for projects under the up-to-2012 rules entirely closes. These measures would be necessary to benefit from a post-2012 CDM-like mechanism. And in any case, they would also facilitate future climate protection activities within the country, could be used as a foundation to improve Vietnam's position in future international climate discussions, and more generally contribute to *turn the climate challenges into sustainable development opportunities for Vietnam* (Vo Van Kiet, 2008).

### 7.3.3 Improving the CDM post-2012: a developing country perspective

#### *7.3.3.1 Copenhagen and the Future of the CDM*

When parties to the UNFCCC met in Copenhagen in December 2009 for the 15th Session of the Conference of the Parties (COP15), they failed to define the details of a new global climate regime. Developing countries, notably large emerging countries, refused to enter legally binding commitment on emissions reductions for the short to medium-term, although they agreed to implement necessary mitigation actions. Additionally, they insisted that climate mitigation actions only be measured, reported, and verified to the extent that developed countries comply with their promises of financial resources for mitigation, adaptation, technology transfer and capacity building.

Many developing countries attended COP15 with expectations for an extensive reform of the CDM or adoption of new, complementary mechanisms to better support implementation of their mitigation and adaptation efforts. And indeed, considerable progress was made with a number of technical documents, including a decision on various improvements to the CDM titled "Further Guidance Relating to the Clean Development Mechanism".[18] Under this decision, the CDM Executive Board will have the ability to streamline the procedures governing registration and CER issuance for CDM projects, and provide new funding to accelerate the development of CDM projects in countries with fewer than 10 approved CDM projects in operation. Lex de Jonge, chairman of the CDM Executive Board, predicted that the reforms would serve to "enhance the efficiency of the mechanism, expand its reach, and maintain its environmental integrity."[19]

But for a variety of environmental and political reasons, negotiations on future commitment periods of the Kyoto Protocol stalled at the Copenhagen climate summit, an impasse that also affects the further role of the Kyoto flexible mechanisms. Currently, the future of the Kyoto Protocol remains unclear beyond 2012, leaving the global carbon markets, including the CDM offsetting market, in a state of uncertainty.

#### *7.3.3.2 Carbon Markets in a Post-2012 Climate Regime*

At the moment, demand and supply dynamics for CERs post-2012 depend on various factors. On the supply side, these are: the fate of CERs issued if Kyoto is or is not extended; constraints on the development of new projects due to an issuance bottleneck; and new projects entering the pipeline. On the demand side, they include: the demand for CERs from the European Union beyond 2012; the introduction of mandatory cap-and-trade systems in other developed countries, including Japan and the United States, and the extent to which these allow for compliance through use of CERs or similar credits; the introduction of new project categories, such as carbon capture and storage (CCS) or reduced emissions from deforestation and forest degradation (REDD); the further development of the CDM in terms of governance and eligibility rules post-2012.

The market for CERs beyond 2012 is vitally linked to the future architecture of the broader carbon market. It is unclear whether and how the CDM or a CDM-like mechanism will be included in the post-2012 regime, and, if it is, what the demand for and supply of credits will be. Despite significant uncertainties at the international level, regional and domestic initiatives continue unfolding in a number of jurisdictions. In many cases, these will continue to operate

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[18] Draft Decision -/CMP.5, Further Guidance Relating to the Clean Development Mechanism, December 2009, available on the Internet at <unfccc.int/files/meetings/cop_15/application/pdf/cmp5_cdm_auv.pdf> (last accessed on 1 March 2010).

[19] Draft Decision -/CMP.5, Further Guidance Relating to the Clean Development Mechanism, December 2009, available on the Internet at <unfccc.int/files/meetings/cop_15/application/pdf/cmp5_cdm_auv.pdf> (last accessed on 1 March 2010).

independently of the progress – or lack thereof – with negotiations for a post-2012 climate agreement.

Currently, the biggest driver for the global carbon market is the European Emission Trading Scheme (EU ETS), which caps emissions of the largest point sources in Europe. It is followed in size by the CDM market, consisting of the primary, secondary, and options market for CERs (Capoor and Philippe, 2009). The latter is closely interlinked with the EU ETS: prices for CERs are highly correlated with the prices of European Union Allowances (EUA), given that CERs are a fungible compliance unit for EU ETS participants. Given the current uncertainties at the international level and excess supply in the market for Assigned Amount Units (AAUs) in the international emissions trading system created by the Kyoto Protocol, this fungibility of CERs under the EU ETS has been considered strategic for the CDM. Importantly, the EU ETS has already been extended beyond 2012 with a 3rd Phase (2013-2020), regardless of the fate of the international climate regime post-2012. This provides an important message to the developing world that the EU ETS, a key carbon market in the first Kyoto commitment period, will continue serving as the main driver for emission reductions within Europe.

Carbon markets are also emerging in the United States at the regional level, and may eventually also be introduced at the federal level. Under the rules framing these markets, international credits, such as EUAs and CERs, might be eligible for compliance purposes under specified conditions. Other countries, such as Japan, Australia and New Zealand, are also actively interested in carbon markets. Over time, such national and regional markets may converge to form a global carbon market from the bottom-up, through linkages across carbon markets, both North-North and North-South (Mehling and Erik, 2009; Tuerk et al., 2009).

Carbon markets are and will remain politically driven, as supply and demand for credits are determined to a substantial degree by political decisions. However, economic forces are a strong underlying driver of policy decisions. Current trends in the growth of increasingly integrated carbon markets may lead to a global reference price for $CO_2$ emissions by 2020 (Point Carbon, 2008).[20] Observers have argued that a global price for $CO_2$ would benefit low-income countries (Ackerman, 2008); they would profit from a wider range of carbon-reducing technologies, and have opportunities for “leapfrogging” beyond the technologies already installed in high-income countries.

#### *7.3.3.3 Vietnam: A Case Study*

*Vietnam as a CDM Project Host: A Large and Untapped Potential*

Vietnam has significant potential for the implementation of CDM projects (German Trade & Invest). Most of this potential lies in the energy sector: between 1996 and 2007, the demand for electricity increased by more than 14% each year. It is expected to continue growing at a

[20] In this study, Point Carbon forecasts a global carbon market worth €2 trillion by 2020 and assumes a market volume of 38 Gt and a carbon price of €50 by 2020 .

faster pace than GDP from 2010 to 2030, rising between 15% and 18% per year. In order to satisfy this rapid growth in demand, the Vietnamese Government is expanding generation capacity mainly through construction of coal-fired plants. Yet many cleaner development options exist:

Vietnam is endowed with an abundance of natural resources and geophysical conditions that can be leveraged to generate significant amounts of renewable energy, including hydropower, wind, geothermal, sun, biogas and biomass,[21] and various forms of waste.[22]

Fuel switching in a number of sectors[23] and improved energy-efficiency in both industry and buildings could offer great opportunities for hosting CDM projects.

Vietnam has large onshore and offshore sedimentary basins that could provide significant potential for storing $CO_2$. The country is expected to have sufficient capacity to store approximately 20 to 60 Gt of $CO_2$ emissions (Bonijoly, 2009). This is a significant fraction of the total global need for CO2 emission reductions (145 Gt) over 2010-2050. Box 1 presents the possibility for carbon capture and storage in Vietnam under the CDM.

Inclusion of reduced emissions from deforestation and degradation (REDD) in the CDM is now considered under the UNFCCC negotiations. Vietnam is one of the nine countries that has promising potential and is supported by the UN-REDD Programme for development of REDD readiness. The country has 48% forest and forestland area (equal to 16.2 million hectares). It grew an average of 236 thousand hectares of forest per year between 1990 and 2000, equivalent to a 2.5% annual increase. The growth rate remained at 2.1% annually from 2000 to 2005.[24]This potential is currently mostly untapped.

In a separate study above, we have examined barriers preventing fuller implementation of CDM projects in Vietnam. We have found that regulatory barriers, barriers arising from an unfavorable business environment, difficulties in access to information, weak local capacity, and the structure of the projects portfolio constitute the main barriers to greater success of the CDM in Vietnam. We conclude that proper Government policies and actions are necessary for Vietnam to benefit more fully from the CDM or any future mechanism similar to the CDM.

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[21] Mainly in the form of residues from sugar, rice, agriculture, and wood.

[22] Mainly waste from landfills, animal farms, tapioca starch.

[23] Notably electricity generation, beverage, iron, steel, cement, pulp, paper, and rubber.

[24] Gesellschaft für Technische Zusammenarbeit (GTZ), "Designing a REDD compliant benefit distribution system for Vietnam: Executive summary. UN-REDD Programme, November 30, 2009.

*Box 1: Vietnam: A Suitable Host for the First Carbon Capture and Storage Project Registered under the CDM?*

Domestic coal reserves, geological potential, rapid expansion of coal-fired electricity generation and pronounced climate change vulnerability all make carbon capture and storage technology (CCS) highly interesting mitigation options for Vietnam. Indeed, the White Tiger (Bach Ho) Field project in Vietnam was an early proposal to include a CCS project under the CDM. It involves $CO_2$ capture from Natural Gas Combined Cycle (NGCC) plants, pipeline transport, storage in offshore/onshore oil fields and enhanced oil recovery. As the first commercial CCS project in Asia, it would have a high demonstration value, and could potentially generate emission reductions of approximately 7.7 million tCO2 per year, facilitating the recovery of an average of 50 thousand barrels of crude oil per day. Work to include CCS in the CDM started in 2006, but has not yet been concluded as of December 2009. There are pending methodological issues, given that the technology is still evolving, and the scale is out of proportion relative to the average CDM project: out of 2236 requested and registered projects in February 2010, only 7 are larger than the White Tiger project in terms of avoided emissions.

#### *7.3.3.4 Vietnam's Role in a Post-2012 Climate Regime*

As a developing country with significant potential for hosting CDM projects, Vietnam could bear risks if it continues pursuing this investment vehicle in the context of an uncertain post-2012 climate regime. In the event that future rules restrict developing country access to the carbon market or revoke the mechanism, Vietnam could fail to receive benefits from the implementation of CDM projects, exposing the Government and investors to significant investment risks. Moreover, given current uncertainties over market prices beyond 2012, it cannot be ruled out that investors will be forced to sell emission reductions credits from CDM projects at very low prices or even prove unable to sell them altogether. Such risks are borne both by the host country Government and the project investors.

As the year 2012 approaches, the window of opportunity created by the first commitment period under the Kyoto Protocol will narrow and eventually close. Project developers launching CDM projects at this point in time will run into the 2012 deadline and may hence suffer investment risks, both due to the time required for implementing a project and the increasing shortage of CER buyers. At present, most commercial CER buyers – such as EU ETS compliance buyers, Japanese buyers, and speculative funds – are not committing to a purchase of post-2012 CERs, except for a minority of buyers willing to commit to forward purchases of post-2012 CERs as part of an offer to purchase pre-2012 CERs. Currently, the most concrete opportunity for sales of post-2012 credits arises from a number of post-2012 carbon funds set up by multilateral institutions. Most of these funds assume the continued existence of a project-based GHG market, and focus on development objectives. In Vietnam, such funds have been set up by the World Bank, the Asian Development Bank, the European Investment Bank, and the Nordic Environment Finance Corporation (NEFCO), among others (Climate Focus, 2009).

One of the most controversial issues addressed during the climate negotiations in Copenhagen was the adoption of emission reduction targets, both directly or indirectly, by developing countries and especially by emerging economies. While many of these countries show hesitation or openly refuse any engagement in this debate, scientific evidence suggests that meaningful participation by all parties to the UNFCCC will be needed to meet the climate challenge, even if the future policy framework remains based on the principle of common but differentiated responsibilities. Under such a framework, developing countries would take on commitments in line with their different levels of economic development. Over time, domestic policies and practices can evolve into low-carbon growth plans, with financial and technical assistance where needed.

In Vietnam, the opportunities and challenges raised by more ambitious climate policies are necessarily featured in the national development agenda, not only because Vietnam is one of the countries most vulnerable to the dangerous impacts of climate change, but also because effective climate action offers prospects for sustainable development: aided by financial support for adaptation and mitigation from developed countries, it can drive investment and clean growth, incentivize job creation, provide opportunities for poverty eradication, and help elevate the standard of living. A discussion of the potential benefits for Vietnam of a reformed CDM follows below.

A number of sectors in the Vietnamese economy offer substantial opportunities for the implementation of mitigation projects, with the energy sector accounting for the largest overall potential. This potential largely rests in the field of renewable energy, an area dominated by small-scale hydropower and wind energy, as well as in energy-efficiency improvements both for industry and buildings (Nguyen and Ha-Duong, 2010). In Vietnam, however, small-scale projects may face greater technical and financial barriers than large projects, suggesting that the CDM process and modalities for small-scale energy projects would need to be simplified and streamlined before the potential for such projects can be fully exploited: small-scale projects implemented under similar environmental conditions and socio-economic settings, using the same technology, methodology, and so on, should be cleared through a fast-track procedure rather than being required to go through all stages of the regular project cycle. In order to harness the potential for such projects most effectively, this process should be as standardized as possible, including establishment of emission reduction baselines for different sectors, systematic definition of positive lists for technologies, simplification of project description formats, and other measures to facilitate participation in the mechanism.

Additionally, Vietnam offers significant potential for small industrial projects and scattered mitigation actions, such as demand-side energy-efficiency improvements, measures for increased boiler efficiency in small industries, biomass-fired cooking stoves, biogas digesters, solar water heating, geothermal energy, small hydropower, and wind energy. CDM Programmes of Activities (PoAs) would appear the most effective mechanism to support such actions in Vietnam, given that PoAs have already proven successful for small-scale projects to include on-grid/off-grid applications using renewable energy. More specifically, registration of renewables as PoAs would result in large benefits for electrification and poverty reduction in remote areas, where more than 70% of the Vietnamese population currently lives.

Further, the adoption of carbon capture and sequestration (CCS) technology in the Vietnamese power sector, which has high CO2 emissions due to the large share of coal-fired generation, could offer significant potential for financial investment and technology transfer to Vietnam if large-scale CCS projects are included as eligible projects in a post-2012 climate regime. Likewise, the inclusion of REDD in the CDM, a proposition currently under discussion, might also create new opportunities for climate finance based on program funding from developed countries or through new climate mechanisms. Specifically, implementation of REDD activities offers one of the most effective ways to alleviate rural poverty and improve biodiversity conservation in Vietnam.

#### *7.3.3.5 National Climate Policy for the Post-2012 Period*

In 2008, Vietnam approved the National Target Programme to Respond to Climate Change (NTP). With the NTP, the Government plots a set of specific policies and action plans for climate mitigation activities over both the short and the long term, focusing on a number of sectors that may be eligible for crediting under a climate regime beyond 2012: energy generation and industry (enhancing energy-efficiency, fossil fuel switching, promoting use of renewables, nuclear energy, early application of CCS for cement and electricity generation, and others), agriculture, forestry and waste (a 5 million hectares reforestation program, restoration of cultivated peaty soils and degraded lands, landfill CH4 recovery, and others), and so on. Nonetheless, the Government has acknowledged the need for financial and technological support from developed countries as well as other international funding sources.[25]

Coming to the Copenhagen summit, the Vietnamese Government expressed its firm adherence to the principle of common but differentiated responsibilities as a premise for participation by all nations around the globe in the international efforts to mitigate climate change:

(i) Developed countries should take the lead in making strong midterm and long term commitments on GHG emissions reductions, although developing countries could make a more active contribution to the global GHG abatement efforts by elaborating and implementing measures such as National Appropriate Mitigation Actions (NAMAs) with adequate support from developed countries and the international community through flexible mechanisms enabling financial and technology transfer.

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[25] Vietnam, National Target Program to Respond to Climate Change, Decision No. 158/QĐ-TTg, 2 December 2008; Institute of Strategy and Policy on Natural Resources and Environment, *Vietnam Assessment Report on Climate Change* (Ha Noi: ISPNRE, 2009).

(ii) The Kyoto Protocol should be retained and expanded beyond 2012 to incorporate new provisions for large GHG emitting countries. Similar to many other developing countries, Vietnam also supports extending the CDM or creating improved CDM-like mechanism to encourage more meaningful participation from developing countries in climate activities. With regard to the CDM,[26] the Vietnamese Government will issue new legal documents this year in order to favor investment in mitigation projects from both domestic and foreign investors and project developers.

(iii) A future international climate regime should be revised to afford greater priority to the specific needs of developing countries like Vietnam, which are most vulnerable to the threat of climate change, and assist them in strengthening capacity to respond to climate change effectively.[27]

#### *7.3.3.6 Improving the CDM: Eight Proposals*

In spite of ongoing concerns about the mechanism's effectiveness and uncertainties about the climate regime beyond 2012, many observers believe that the CDM will prove versatile enough to survive and evolve so as to play a key function in a future international climate regime, whatever shape this may take (Keeler and Thompson, 2008; Fujiwara, 2009). In view of this developing country perspective, we propose eight options for reforming the CDM below.

First, the CDM should be extensively improved to reduce perceived administrative and organizational constraints: (i) at the CDM EB: actions proposed during the Copenhagen climate change summit to improve the CDM[28] should be implemented promptly, including actions to reduce delays in project registration and certification (by streamlining and simplifying administrative procedures for projects and further improving methodologies and additionality criteria), as well as actions to improve the performance of Designated Operational Entities (DOEs) (by providing regional workshops to train and empower DOEs), to the point where the EB can delegate most project reviewing work to DOEs and focus on managing the vetting process rather than projects review. (ii) at host parties: implementing necessary corrective actions by looking at international practices and lessons learnt from more advanced developing countries to alleviate major barriers and administrative constraints in host countries, as well as provision of additional support measures (for instance in the shape of guidelines, workshops and training sessions, local capacity building initiatives, and so on) by developed countries.

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[26] Information provided by the Ministry of Natural Resources and Environment at Side-event on the climate change in Vietnam, which was held at the Copenhagen (2009).

[27] The speech of H.E. Mr. Nguyen Tan Dung, Prime Minister of the Socialist Republic of Vietnam at COP15.

[28] UNFCCC, "Prospects of the CDM and CDM Executive Board", Question and Answer Session at UNFCCC COP15/CMP5, Copenhagen, 10 December 2009.

Second, the CDM can be reasonably extended as a major source of emissions credits for Kyoto signatories. Moreover, if developed countries are allowed to make use of offset credits, this may create an incentive for developing countries to join a new international climate agreement. For the next phase of the EU ETS and other emerging domestic carbon markets in the United States, Japan, New Zealand and Australia, restrictions on the import of CERs or similar credits from developing countries should therefore be adopted cautiously. A more specific option would be, for instance, to allow companies within developed countries to satisfy at least 10% of their national emissions commitment through CDM credits (Keeler and Thompson, 2008).

Third, wider implementation of PoAs (programmatic CDM) should be facilitated both by the CDM EB and potential host countries, as this option potentially enhances the efficiency of the CDM and offers more opportunities for small and low-income developing countries to access the CDM.

Fourth, positive lists of projects and technologies that are deemed additional by default should be adopted, helping streamline the operational process and reducing barriers both at the CDM EB and at the Designated National Authority (DNA) of host countries. Such a positive list could be based on the usage of certain technologies and both small and large scale projects.

Fifth, new project categories – such as CCS – should be included in the CDM in order to enrich the CDM project portfolio and increase the overall volume of credits. Specifically, the motivation to include CCS projects is that the developing world contributes a rapidly increasing share of global CO2 emissions, with growing energy demand largely satisfied through coal-fired power plants; in industrialized countries, CCS technology is already being explored as an important option for deep cuts in $CO_2$ emissions (IEA, 2008b).

Sixth, differentiated approaches should be considered, affording disadvantaged and vulnerable developing countries preferential treatment under the CDM (Schneider, 2008; Bakker et al., 2009). Such treatment could include: (i) giving preferential treatment to certain project categories, sectors, or regions, or allowing for preferential treatment in procedures and methodology (for instance a simplified additionality test or its omission altogether) and preferential access to resources (for instance specific funds for project financing); (ii) differentiating eligibility of potential sellers to host projects or of potential buyers to use CERs for compliance; (iii) introducing a premium rate to incentivize investment and development of certain projects.

Seventh, the criteria for CDM approval could be expanded to allow for a "policy CDM", allowing the focus to shift from "real, verified, and permanent reductions" to climate mitigation and adaptation actions in developing countries (Keeler and Thompson, 2008; Michealowa and Purohit, 2007). CDM resources could then benefit a wider set of policies and activities, such as energy-efficiency standards, renewable energy portfolio standards, and reductions of energy subsidies, that are not eligible within the current framework of the CDM.

Eight, and finally, the CDM should be used to encourage developing country engagement under a new proposed financing framework for nationally appropriate mitigation actions (NAMAs) that is called for by the Bali Action Plan. However, it is necessary to clearly determine how NAMAs can interact with the CDM, and what types of projects may qualify as a NAMA. This is likely easier to negotiate in tandem with an expanded CDM than by merely requesting developing countries to take on explicit emissions caps for the short and medium term.

#### *7.3.3.7 Summary*

In this part, we assessed the evolving framework of the CDM and identified possible reform proposals beyond 2012 from a developing country perspective. Acknowledging the mechanism's performance over time, the incomplete outcome of negotiations at COP-15, and the reluctance of developing countries to enter legally binding mitigation commitments in the near term, we argue that continuation of the mechanism remains an effective way to reduce greenhouse gases emissions.

An analysis of Vietnam's current climate policy and its position regarding the shape of a future international climate regime both suggest that the CDM should be retained and improved for more flexible mitigation options post-2012. Ideally, a reformed CDM would allow for more active and meaningful participation by developing countries in the global efforts to mitigate climate change, while still upholding the principle of differentiated responsibilities. Also, it can be reasonably assumed that developing countries will exert pressure in upcoming negotiations to extend the CDM and enhance its operation.

Finally, the article provides eight proposals to reform the CDM and increase its usefulness in a future international climate change framework. These range from streamlining and simplifying the CDM project cycle and extending it to include additional project categories over improving accessibility for developing countries through differentiation and capacity building to exploring completely new approaches, such as crediting of mitigation policies in addition to projects. As negotiations on the future climate regime resume in 2010, decision makers must carefully these options and also ensure that any project-based mechanism emerging from the CDM find an appropriate role alongside other market instruments and nationally appropriate mitigation actions.

## 7.4 Concluding remarks

In the chapter 7, the thesis analysed the access to feasible finance sources for sustainable power sector development based on previous identified sustainable energy development options, including the Clean Development Mechanism (CDM). In fact, the analysis issues related to the CDM is based on the two papers written before the Copenhagen meeting and published in 2010.

Today, a financing architecture should be necessarily involved to address climate change mitigation and adaptation issues in almost new investments for development of the energy supply infrastructure. With this respect, the study suggested that while the degree of future international agreements on mitigation and adaptation, and its related financing mechanisms to help developing countries pursue a lower-carbon path are currently developed, developing countries like Vietnam should take advantage the statement of the Bali Action through the existing climate policy instruments such as the Global Environment Facility (GEF), the Climate Investment Funds (CIF), the Carbon Partnership Facility for emission purchase agreements beyond 2012, and various carbon funds available.

More specifically for the CDM, the study finds that the Clean Development Mechanism (CDM) in Vietnam is used below its full potential. In spite of efforts to further CDM projects in the recent years, Vietnam still lags behind the comparable neighbouring countries in term of registered CDM projects. Although, although 2008 and 2009 have seen a fast growth in new project only 33 projects were registered up to 1 October 2010. This is much lower than the potential and makes it as a late starter on the global CDM rise when the window of opportunity created by the first Kyoto Protocol period is almost closed. This chapter also analyzed the barriers explaining this late start and slow catch-up. It suggested strategic policy recommendations which could increase the attractiveness of investment business in the context of climate change protection in Vietnam.

Next, the study chapter assessed the future prospects of the Clean Development Mechanism (CDM) from the perspective of a developing country, drawing on Vietnam as a case study. First, the study reviewed the performance of the CDM and describe the evolution of carbon markets on the path towards a post-2012 climate regime. Next, it placed Vietnam in a post-2012 context, and assess potential project resources, challenges, and opportunities that could arise for the country from a future climate policy framework. The analysis suggested that the CDM should remain in place and be improved to facilitate more meaningful participation by developing countries in climate mitigation efforts beyond 2012. Finally, the chapter set out eight proposals that could help improve the CDM as the world progresses towards a new international climate policy framework.

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## Chapter 8. General Conclusions

Since early 1990s, Vietnam has been pursuing economic growth as the top priority for the development and also achieved the desired significant outcomes. However, such a high economic development has already caused an inevitable degradation of environment and natural resources. Now we look forward to the next three decades, sustaining economic growth while protecting the environment will be the greatest energy challenge facing Vietnam. A further double of electricity demand over the next decades, however, would be intensively adding to the challenge of ensuring energy security for the country. Because the indigenous energy supply resources will become scarce after 2015, Vietnam cannot sustain the expected magnitude of electricity demand growth without greater dependence on imports, including imports of steam coal, net oil, and electricity. In the point of a macro-view, the expected increasing reliance on imports for the future development of Vietnam's power sector would be extended to increased risks of price volatility and exposure to disruptions in energy supplies, and virtually certain large increases in power sector costs for Vietnam. Such volatile energy costs could even further contribute to increased poverty, political pressures, and instability.

Moreover, climate change now becomes a major global threat to sustainable human development and Vietnam must take part in the effects and causes. Thus, the right moment has come for Vietnamese Government to review the past progress of the energy development path and have concrete strategy with stronger policies towards a future of sustainable energy for the power sector: improving energy supply for maintaining economic growth while protecting local environment and mitigating climate change. The sustainability also aims to strengthen opportunities for reliability, accessibility, and affordability of energy supply to both rural and urban populations, as well as for reduction of poverty and increase of social equity.

The Part A of this study has shown that both large-scale deployment of energy efficiency and low-carbon technologies are strategic elements of a better policy for a future of sustainable energy development in Vietnam's power sector.

First, the study simulation suggested large-scale improvement for the efficiency of energy use, which brings the power intensity of Vietnam by 2040 at par with that of Malaysia by 2030, could significantly enhance energy security for Vietnam. In this scenario, about 30% of the baseline cumulative electricity production (the business-as-usual demand) could be potentially saved over the period 2010-2040. Of this energy production avoided, the energy generation from imported sources accounts for a very large proportion of 90%. Thus, it greatly reduces the drain on scarce foreign exchange reserves for fuels importing and eases the pressure on the financing request for the expansion of energy supply infrastructure. For example, the figure of a bill for coal importation in the baseline development scenario, which accounts for 2.1% of the GDP (at imported coal price is 110 US$/ton by 2040) could be significantly cut down to 0.4%. In the view of domestic energy resource conservation, more aggressively improving the efficiency of energy use could potentially save 374 million tons of domestic coal for electricity generation during the period from 2010 to 2040. This saving is tripling larger than the estimated total coal production in Vietnam by 2030. In addition, such a large-scale deployment of efficiency in energy use could also mitigate enormous atmospheric releases of polluting emissions by Vietnam's power sector. As an estimated result, the power sector's baseline cumulative $CO_2$ emissions (7.2 Gt) over the period from 2010 to 2040 could be worthily decreased by 37% (2.67 Gt). Besides, it could also bring other sustainable co-benefits of avoiding local environmental vulnerability: 47% of total cumulative 15 Mt $SO_2$ and 41% of total cumulative 8 Mt $NO_X$ emissions could be avoided during the same period. Specifically, the IRP simulation suggested improvement in appliance efficiency in the household sector in Vietnam is a "no-regret" energy option. With this "free lunch" effect, the cost of $CO_2$ abatement is negative and the cost of energy is reduced as well.

The point of most interest is that the study provided the answer to the increasing arguments/doubts given by Vietnamese experts that improving environmental sustainability and enhancing energy security also has trade-offs in Vietnam. For example, the baseline energy development in Vietnam shows a larger share of nuclear energy capacity in the baseline electricity generation portfolio from 2020 to 2040. Hence, an increased role of nuclear energy generators could also increase risks of radioactive wastes and raise the issues of nuclear reactor safety, especially for Vietnam a developing country with the limitations in human/specialsits resources, essential technological and regulatory infrastructures, technical skill and management capability, public acceptance, etc. Instead, the study suggested that widespread deployment of higher energy efficiency together with the use of available diverse energy supply sources (other than nuclear) could be already significantly lowest-cost-optimal to fulfil the baseline demand for electricity during the period from 2010 to 2040. The very ambitious nuclear energy development plan (15-16 GW) for electricity use during the period 2020-2040, in fact, may simply mean an inefficient energy capacity for electricity use, even possible overcapacity. In other words, the current national energy development policy based on large-scale capacity of nuclear energy for meeting the rapid but uncertain increase in demand for electricity over the next three decades may not be the cost-effective way to ensure energy supply security as compared to the cheapest and simpler, safer and more cost-effective measures of higher energy efficiency improvements.

Second, the study argued that to achieve the desired sustainable energy outcomes also requires Vietnamese Government to implement immediate actions to transform its energy sector towards not only much higher energy efficiency but also greater use of low-carbon renewable energy generation technologies. Using the IRP simulation, the study showed that renewable energy can hedge against the possibility of future fossil fuel price volatility and the increasing reliance on the imports, which will be facing by the Vietnamese power sector for the decades to come. As simulated here, about 6 GW of renewable energy capacity could now substitute fossil fuels for producing electricity in Vietnam for the period from 2010 to 2040. These non-conventional energy supply sources include small hydro energy (accounts for 63.8% of total renewables energy capacity), biomass energy including bagasse, rice husk, wood residues, and municipal solid wastes (15.4%), wind power (13.2%), and geothermal (7.4%). Even with a modest integrated level of renewables sources into the electricity system, the share of total cumulative electricity generation provided by coal fuels could be remarkably reduced by 18%, compared to the baseline development scenario. The country, thus, could save 68 million tons of indigenous coal and reduce its fuel/electricity imports: 158 million tons of coal and 2 TWh during the same period. These savings contribute to a reduction of 1.9 billion US$ in fuel and O&M costs for the entire generation system over the planning horizon from 2010 to 2040.

For environmental sustainability, the study found that renewables can help stabilize the Vietnamese power sector' cumulative $CO_2$ emissions over the period between 2010 and 2040 and improve the local environment without compromising economic growth. Particularly, they could reduce 517 Mt of $CO_2$, 1,579 Kt of $SO_2$ and 711 Kt of $NO_X$ cumulative emissions during the period 2010-2040, compared to the scenario with no integration of renewables. The average $CO_2$ abatement cost, in this case, is only 1.05 US$/t$CO_2$. This figure gives a promising signal that renewables-based power generation plants in Vietnam could offer a large possibility of hosting Clean Development Mechanism (CDM) or CDM like mechanism-funded projects. As the share of renewables in the generation mix grows, the total costs in the whole electricity generation system will increase by 545 million US$ (0.51%) over the period 2010-2040, compared to the scenario with no integration of renewables. And to exploit 6 GW of new renewables for producing electricity during this period, the Vietnamese Government needs to arrange an additional budget of 279 million US$ per year on average.

Moreover, the study proved that a large-scale deployment of renewables sources for future electricity production in Vietnam is technically and economically feasible to produce sustainable values for energy development path, better public health, and $CO_2$ emissions stabilization by 2040, given that there are political will, institutional capacity, international support policy related to climate change, and transfer of financing and technologies from developed countries. As modelled here, the share of total electricity generation from a broader use of available diverse renewables sources could be greatly increased double (from 4.1% to 8.4%) larger than that in the baseline development scenario during the same period, if a price on $CO_2$ emissions is in place in the sector. This price is increasing gradually from 5 US$/t$CO_2$ in 2010 to 50 US$/t$CO_2$ by 2040. In term of energy capacity, about 14.6 GW of renewables-based power generation plants could be economically exploited by 2040, compared to only 6 GW of renewables developed in the baseline. Specifically, Vietnam's power sector offers a number of sustainable energy options for hosting $CO_2$ mitigation projects under the CDM or CDM-like mechanism at relatively low carbon prices: biomass (including rice husk, paddy straw, wood residues), and wind power are cost-competitive at 4 $/t$CO_2$, while wood plantation and municipal solid wastes become cost-competitive at 6 $/t$CO_2$. Overall, the study findings suggested renewable energy sources could contribute to release the soaring demand for electricity, mitigate polluting emissions, and enhance energy independence over 2010-2040 although the prices for fossil fuels are assumed relative modest in the present study and their annual inflation rates are rather low, compared to the market levels observed by today. Given that the costs of renewable energy have dramatically decreased with technological innovation progress over the past two decades and rapidly decline in the future, the rising fossil-fuel prices only favour scaling-up the deployment of renewables in the Vietnamese power sector.

Third, given that atmospheric releases of polluting emissions by Vietnam's power sector are not inevitable, but rather are a consequence of choosing fossil fuel-based electric power generation. In this context, the ability and prospects to capture and sequester $CO_2$ emissions (CCS) offers a promising technology of significant $CO_2$ reduction in a way that is compatible with the expected fossil-fuel power generation industry whereas allowing coal to meet the pressing needs for electricity energy in Vietnam.

As abovementioned, besides the energy efficiency, renewable energy option is the second largest source of $CO_2$ reductions for the electric power generation industry in Vietnam. However, over the long-term period that is beyond 2030, CCS could become a critical climate instrument to lower the $CO_2$ emission curve in Vietnam's power sector. The IRP simulation suggested that dozens of CCS projects could be economically developed in the Vietnamese power sector by early 2030 if the carbon price rises to 40 US$/t$CO_2$ by 2030 and reaching 60 US$/t$CO_2$ by 2040. In this study, by the time of 2030 the fuel prices for domestic and imported coal are estimated about 64 and 76 US$/ton respectively, and 7.3 US$/MBtu for domestic gas. And the prices for domestic and imported coal are estimated about 81 and 84 US$/ton respectively, and 8.9 US$/MBtu for domestic gas by 2040. As 24% of total energy capacity in the system integrated with CCS options by 2040, they alone could offer a significant potential 20% $CO_2$ abatement for the sector at a carbon price of $60 t/$CO_2$ while allowing large-scale coal burning for electricity generation. So far, in direct comparison with renewables, we found that CCS options (with no EOR or ECBM) would not be cheaper than renewables for electricity generation in Vietnam in the context of climate mitigation before 2040. However, the economic value-added of the CCS deployment in conjunction to EOR or ECBM could potentially favor its cost-competitiveness and earlier implementation in Vietnam.

Last, before coming to the Part B, the question of how large is the technical potential of $CO_2$ emission reduction in Vietnam's power sector is also answered by the present study as: 25% (1.8 Gt) of the sector's cumulative $CO_2$ emissions in the baseline development could significantly be reduced with a large-scale deployment of diverse renewables sources if the carbon price is gradually increasing from 5 US$/t$CO_2$ in 2010 to 50 US$/t$CO_2$ by 2040. More environmentally effective, a full combination of large-scale deployment of diverse renewables sources and demand-side options (DSM) in the household sector even better offers 34% (2.4 Gt) $CO_2$ abatement with the same trajectory of carbon price assumed.

In the Part B, we took a more holistic stance to address three pragmatic issues. We firstly identified barriers to wider deployment of some typical sustainable energy options in the Vietnamese power sector. Then we analyzed the necessary major incentive policy instruments and institutional reforms that should be necessarily implemented to overcome the abovementioned barriers and transform the electricity sector towards sustainability.

Energy efficiency alone could contribute to a significant reduction of 40% over the baseline $CO_2$ emissions, and is fully justified by benefit values of sustainability for the Vietnamese power sector. To effectively exploit this large potential of energy efficiency in Vietnam, it requires necessary actions from the Vietnamese Government as the key to remove fossil-fuel subsidies and build up energy pricing reflective of clean energy's extra benefits. Moreover, the Government needs to make stronger policies and measures be in place to correct market failures and barriers with effective regulations and financing mechanisms for motivating greater energy efficiency deployment.

The widespread deployment of renewable energy in Vietnam's power sector virtually requires putting a price on carbon emissions and providing financial incentive schemes. In this regard, the study stressed that Vietnam alone cannot get onto a sustainable energy path. The country virtually needs necessary supports, in terms of financing, technology transfer, and capacity building through cooperation and collaboration both at regional and international levels and should be more active to look for increased development opportunities related to international climate change mitigation and adaptation.  The study further suggested that while the degree of international climate change policy and its relevant financing mechanisms to support developing countries to pursue a lower-carbon energy development path are currently negotiated, Vietnam should seize advantages of the Bali Action statement through the current climate policy instruments such as the Global Environment Facility (GEF), the Climate Investment Funds (CIF), the Carbon Partnership Facility for carbon emission purchase agreements beyond 2012, and various carbon funds associated with the CDM.

More importantly, the Feed-in Tariffs are suggested by the study as the central incentive support instrument to mandate and scale up the RES-E in Vietnam. Based on this central support instrument, financial incentive schemes supplemented by a series of other support means are suggested to be further carefully tailored by policy decision-makers. Yet, the study stressed that the practical success of the suggested policy instruments should request not only the best suited choice of support instruments that make them efficient, but also the proper design in accordance with the current circumstances thereby a mix of policy instruments could be appropriately tailored to the maturity and costs of technologies and national context.

For the CCS, it would require more accelerated research, development, and demonstration. However, given its future changes in technology innovation, the promising prospects of CCS deployment in Vietnam estimated by IEA (2008a), ADB (2009, 2010), and the present study itself, we suggested that Vietnamese authorities should pay more attention to an expected clean energy revolution that is compatible with a future coal-fired power generation industry. The delay in necessary action today to promote such a low-carbon technology will fasten up the country's energy sector to a high-carbon infrastructure thus requires more costly retrofitting in the future. More practically, Vietnamese authorities could now consider the possibility for integrating prospective carbon-capture-ready option in new plants for the future development stages. The pre-planned retrofit of existing coal or gas-fired generation plants with CCS integration could make possible its deployment in the near future under a yet not existing international climate change policy. The White Tiger (Bach Ho) Field project that includes the deployment of CCS within the Phu My natural gas-fired generation plants, illustrates this aim to provide a good chance to reduce the sectoral $CO_2$ emissions.

To improve the performance of Vietnamese power sector towards sustainability necessarily requires a paradigm shift to competitive and market-based arrangement mode (World Bank, 2009a; World Bank, 2010c). But, international experiences also suggested that the power sector reform must be based on realistic assessments of the circumstances and designed in view of the importance of the need for investment through long-term coordination and reduction of investment risks and giving accessibility and affordability to low-income populations. If the country wishes to remove the state monopoly in the sector, Vietnam should balance between the market and the intervention of state management.

Finally, a sustainable energy development path for a developing country always requires major effective policies and institutional reforms, adjustments in economic structure, technological innovations, and consumer behavior changes (World Bank, 2010d). Therefore, the major suggestion consulted in this research thesis views changes in government actions (political will and serious commitment with strong enforcement) as the key to overcoming the abovementioned barriers and most essential to open the window of sustainable energy opportunities for the Vietnamese power sector.

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## Annex

### A. The Integrated Resource Planning (IRP) model

This present study develops a bottom-up optimization model using the principles of the integrated resource planning, namely as IRP model. The IRP model package is built with Visual Basic 6.0 and solved with CPLEX, high-performance optimization software for mathematical programming (Shrestha and Nguyen, 2003).

The IRP model uses mixed-integer linear programming (MILP) to compute a lowest-cost electricity generation capacity expansion plan. The integer decision variables represent the number of generation units to be installed in each year of the planning horizon. The other decision variables of the model are the generation of each power plant at each block[29], the number of DSM appliances to be introduced to the system in each year, and the expected supply from external suppliers in each block. The expressions of the extended IRP model's objective cost function and a set of constraints extended to the inclusion of CCS are as follows:

*The objective function of system cost*: The lowest cost combination of different generation sources including coal-fired plants with CCS, the level of end-use electrical appliances to be added (i.e., demand-side), and the levels of electricity generated by different plants are subject to the following constraints calculated as follows:

*(i) Demand constraint:* The total power generation by all power plants (existing and future) and generation avoided by demand-side management options should not be less than the total projected power demand in all periods (blocks), seasons, and years of the planning horizon.

*(ii) Plant availability constraint:* The power generation of each plant is limited to the capacity and availability of the plant during each period of the day.

*(iii) Reliability constraint:* The total power generation capacity of all the plants and the generation capacity avoided by demand-side management options must not be less than the sum of the peak power demand and the reserve margin in each year of the planning horizon.

*(iv) Annual energy constraint:* A maximum limit is set on the energy generation at each plant based on its existing capacity, availability, and maintenance schedule.

A maximum limit is set on the energy generation at each thermal plant based on its existing capacity, availability, and maintenance schedule.

*(v) Hydro energy availability constraint:* The total energy output of each hydro plant in each season should not exceed the plant's maximum available quantity of hydro energy.

[29] The daily chronological load curve in the model is divided into several blocks (time intervals) in order to adequately reflect the effects of variation in power demand over various periods of a day.

*(vi) Maximum potential capacity constraint:* The total installed capacity of each type of power plant must not exceed the maximum allowable capacity of that plant type.

*(vii) Minimum operation capacity constraint:* All selected thermal generating units, depending on their characteristics (off-peak, intermediate, peak plants, etc.) must be operated and dispatched to generate electricity at certain minimum business running capacities.

*(viii) Fuel or resource availability constraint:* Energy generation from a plant cannot exceed the maximum available quantity of fuel supply resources.

*(ix) External power availability constraint:* Imported energy cannot exceed the maximum available quantity of external power generation resources.

*(x) Demand-side management constraint:* The level of adoption of energy efficient devices in a year must not exceed the maximum feasible number of such devices in the year.

*(xi) Emission constraint:* The emissions levels of each kind of pollutant from the total generation system should not exceed the pre-specified value in any year.

*(xii) Guarantee condition for energy supply for mixed hydro thermal system:* These conditions ensure that the total possible electricity generation by thermal and hydro plants should be at least equal to the seasonal energy demand under the defined critical hydro conditions.

*(xiii) Total installed plant capacities (new and retrofit capacities) with integrated CCS systems constraint:* The total installed capacities of power plants with integrated CCS systems are limited to the maximum $CO_2$ emissions absorbing (transporting and storing) capacity available during each period.

*(xiv) Retrofitted plant capacities with integrated CCS systems constraint:* The total retrofitted capacities of coal-fired power plants with CCS are limited to the existing capacities installed.

*(xv) Dispatching a power plant with integrated CCS system constraint:* Cannot dispatch more plant capacity with integrated CCS system than its capacity installed during each period.

*(xvi) Additional energy use with integrated CCS system constraint:* The electricity energy for self-service usage of a plant with integrated CCS system should be more than that of the same plant without integrated CCS system.

*(xvii) $CO_2$ emissions reduction by integrated CCS systems constraint:* The total $CO_2$ emissions reduction from power plants with integrated CCS systems should be less than the maximum $CO_2$ emissions absorbing (transporting and storing) capacity available during each period.

To internalize a carbon value in the total cost objective function, we model the IRP as follows:

$$TC = SC + CV * \left\{ \sum_{t=1}^{T} (E_t - E_t^{REF}) / (1+r)^t \right\} \qquad \text{(A-1)}$$

Where $TC$ is the current value of the total planning cost; $SC$ is the present value of total system costs including capital, fuel, operation, and maintenance, demand-side management, and electricity import costs; $CV$ is the carbon value; $E_t^{REF}$ is the baseline value of $CO_2$ emissions (computed assuming $CV = 0$) in year $t$; $E_t$ is the quantity of $CO_2$ emissions in year $t$ in cases in which the carbon value $CV \neq 0$; $r$ is the discount rate; and $T$ is the planning horizon.

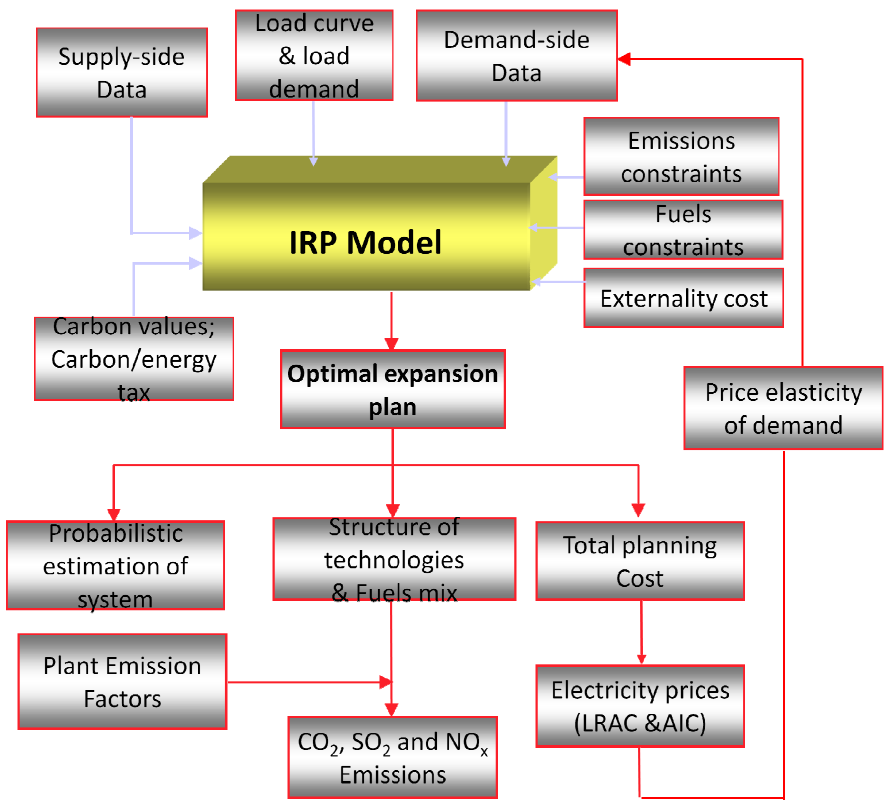
In the IRP model, $CO_2$, $SO_2$, and $NO_X$ emissions from generation sources in year $t$ can be mathematically expressed as:

$$E_t^i = \sum_i (EG_{abc}^i * EF_{abc}^i) \quad \text{(A-2)}$$

Where $i$ is the index of greenhouse gas (GHG) emissions type, $a$ is the index of the fuel type, $b$ is the index of the power plant type, $c$ is the index of the generation technology, $T$ is the planning period, $E_t^i$ is the total GHG emissions of type $i$ emitted in year $t$, $EG^i_{abc}$ is the electricity generation by each generating plant with GHG emissions of type $i$, $EF^i_{abc}$ is the factor of GHG emissions $i$ of each power plant per unit of electricity generation.

Through IRP simulations, two seasons (rainy and dry) are modelled each year. The load curve in each day of a season is divided into 24 blocks (1 h/block). The load shapes, based on load demand forecast data, are also modelled differently for the two seasons in each year and for certain time of a day in the study. Energy generation from renewable sources (such as wind, solar, and small hydro) is modelled in accordance with its intermittent nature. In the IRP, plant dispatch is modelled under the merit order method, and the ability to generate electricity from renewable plants depends on the availability of energy sources (i.e., the generation of wind/solar technology depends on the quantity of available wind or sunlight in each block of a day, and the quantity of small hydro technology depends on the water level in each season). Furthermore, renewable energy technologies are considered to have a quicker lead time than conventional plants (gas and coal), which can take three to five years to construct. Quicker lead times for construction of renewable energy plants enable a more accurate response to growth in demand. For large and small hydro technology plants, the lead time ranges from two to five years for construction, depending on the site. Lead times for different technologies are modelled by inputting the "earliest available year of the candidate plant's operation" and the "annual allowable maximum candidate plant units" that could be feasibly put into service. Figure A-1 presents the analytical flowchart of the IRP model and the details of the model are described in the appendix.

*Figure A-1: The analytical flowchart of the IRP model.*




Source: Shrestha and Nguyen, 2003.

In the IRP model, the electricity price in terms of the average incremental cost (*AIC*) and the long run average cost (*LRAC*) are calculated based on the optimal solution computed for the electricity generation capacity expansion plan using the following formulas:

$$AIC = \left( TC - C_1 - \sum_{i=1}^{T} VC_1 / (1+r)^i \right) / \left( \sum_{i=2}^{T} (E_i - E_1) / (1+r)^i \right) \qquad \text{(A-3)}$$

$$LRAC = TC / \left( \sum_{i=1}^{T} E_i / (1+r)^i \right) \qquad \text{(A-4)}$$

Where $TC$ is the present value of total costs, including capital, fuel, operation and maintenance costs; $C_1$ is the present value of capital costs in year $1$; $VC_1$ is the total fuel, operations and maintenance, and demand-side management costs in year $1$; $E_1$ and $E_i$ are the electricity generation in year $1$ and year $I$, respectively; $r$ is the discount rate; and $T$ is the planning horizon.

Major steps involved in finding the equilibrium levels of electricity price and energy demand in the IRP simulation with the introduction of carbon price are given below.

Step 1: First, run the IRP model to find electricity price ($P_0$) at the level of forecasted demand ($Q_0$) without imposition of any carbon price.

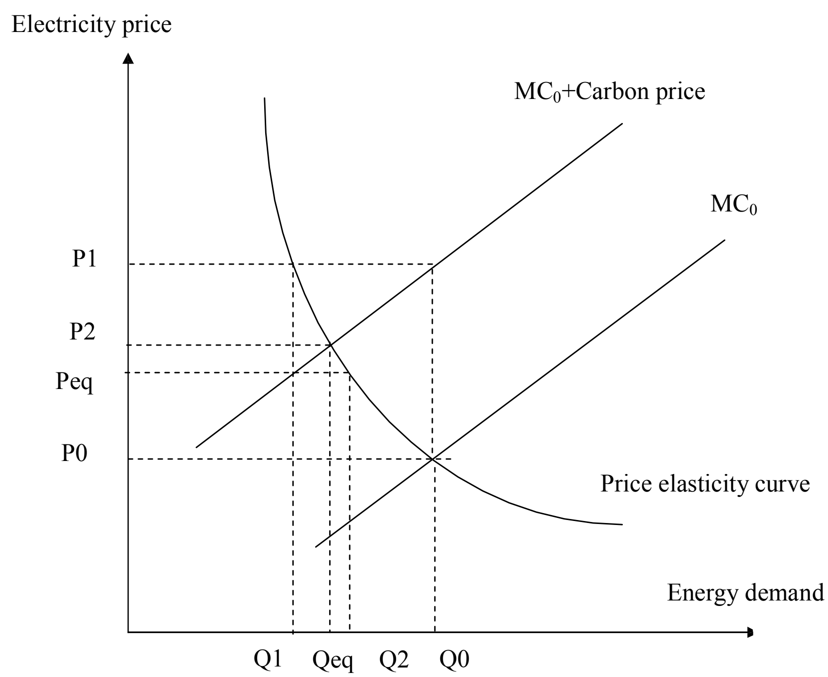
Step 2: Rerun the IRP model with a carbon price. The price will cause electricity price to increase up to a new price ($P_1$).

Step 3: Find the new level of demand ($Q_1$) at the new electricity price ($P_1$) through price elasticity curve.

Step 4: At this level of demand ($Q_1$), rerun IRP model to find again the electricity price ($P_2$).

Step 5: Find the new level of demand ($Q_2$) at the new electricity price ($P_2$) through price elasticity curve.

Step 6: The above iterative process is repeated till; the demand and electricity price converges to a single equilibrium point ($P_{eq}$, $Q_{eq}$).




In the present study, we use the curve for price elasticity of electricity demand in Vietnam that is derived from our separate study (Nguyen, 2002). The details of the IRP model are presented in Shrestha and Nguyen (2003), which is freely accessible at <http://my.opera.com/thanhnhan.nguyen/about/>.

**B. Scenarios: Baseline, Efficiency, Renewables, and CCS**

To meet the increasing needs for electricity in different scenarios of economic development over 2010-2040, the Vietnamese Government is considering policy alternatives for the electric generation industry development such as (i) focusing on energy efficiency improving and energy saving, (ii) utilizing domestic diverse energy resources economically effectively, (iii) importing fuels (coal, gas) and electricity for producing electricity, (iv) promoting research and development of renewables and other cleaner technological options, (v) developing nuclear power for electricity usage. In this study, we consider a baseline development case and four key policy options: nuclear, DSM, renewables and CCS.

*The baseline scenario or business-as-usual (BAU) scenario* was defined in accordance with today's national development plan was enacted as the Power Development Master Plan VI (MP-VI)[30]. This scenario coincides with the low-demand forecast for electricity from official Vietnamese government agencies within the MP-VI. Moreover, in this scenario, fuels (coal, natural gas) and electricity will be imported for generating electricity, modest renewable energy sources (compared to the available sources of renewables within the country) and nuclear option are integrated. All electric home appliances in this scenario are conventional.

*The nuclear option* considers 10 GW in capacity that could be developed by the country over 2010-2040 in this study. In fact, Vietnamese government has a very ambitious plan to develop nuclear energy for supply electricity in Vietnam since 2020 with an expected total capacity of 10-16 GW during the period 2020-2030 (Electricity of Vietnam, 2007 and the Decision QĐ-TTg No.960, dated 2010[31]). However, in consideration of negative public perceptions, an increase in nuclear technology cost during recent years, the country's still-low technological infrastructures, technical and scientific capability, the still-weak industrial and regulatory system, and the lack of human resources and professional specialists, only 10 GW in nuclear power capacity are considered for electricity generation from 2020 to 2040 in the baseline.

*The DSM option* examined in the study involves the replacement of incandescent light bulbs (IL) and fluorescent light bulbs (IL) with compact fluorescent and high efficiency fluorescent light bulbs plus two energy efficiency options of replacing current air-conditioners with high efficiency air conditioners in residential sector. These are high efficient home appliances.

*The renewables option* considers fully available renewables sources that could be economic feasibly deployed up to 2040. The details of renewables sources and their related capacity estimated in different scenarios are presented in the Chapter 3.

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[30] The development of the electric power sector in Vietnam is managed using the MP-VI, which estimates the need for electricity and plans the overall development of the power sector during a 10-year period, taking into account the subsequent 10-year period. The current Sixth MP-VI was approved by the Prime Minister in July 2007. The method used for projecting electricity demand, within the MP-VI, is a combination of econometric and techno-economic approaches including multi-regression, elasticity and intensity aspects, in which GDP and population growth rates are the main driving variables for the projection process.

[31] The Decision No. 906/QĐ-TTg dated 17 June 2010: Approval for the orientation of nuclear development plan in Vietnam up to 2030.

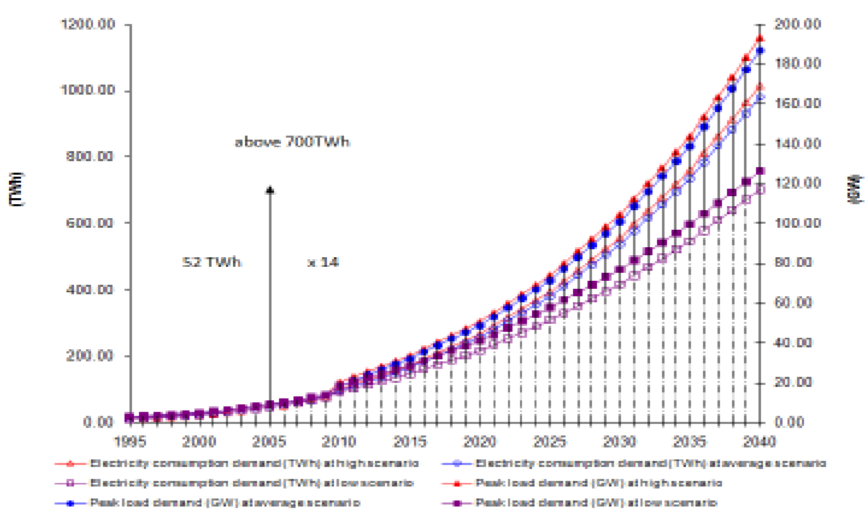
*The CCS option* examined in the study integrates deployment of CCS-based power generation plants. There are 10 alternative CCS options assumed to be available since 2025. The details of cost and performance specifications related to CCS options presented in the Chapter 4.

## C. Parameters and assumptions

*Electricity demand and network data*

The data for electricity demand and network is principally obtained from the Power Development Master Plan (MP-VI) (Electricity of Vietnam, 2007) and the database of operation from National Load Dispatching Centre (A0, 2010). Figure C-1 presents the historical and forecasted need for electricity energy in Vietnam since 1990, when the Vietnamese government launched a comprehensive reform. This reform has helped to improve people's living conditions and has driven the development of the national economy. Gross domestic production (GDP) in Vietnam has experienced a rapid growth rate of 8.2% per annum during 1991-1995. The strong economic growth is the main reason that electricity demand has increased by 13.5% over the same period. Demand then grew faster, by 14%, over the period 1995-2005, together with economic development. According to the MP-VI, the electricity demand is expected to increase by about 16.8% per annum in low scenario and around 21% in high scenario from 2010 to 2030. The demand for electricity over the period 2030-2040 is derived from an additional report for electricity demand projections provided in the investment report on the Nuclear Power development project in Vietnam (Institute of Energy, 2009), in which the demand for electricity during this period is expected to increase 6.9% per annum in a low scenario and 8.2% in high scenario. As argued above, the Vietnamese agencies' projections for electricity demand in both base and high scenarios are likely optimistic. Thus, this study uses the low-demand forecast scenario for electricity consumption (as presented in Table C-1) as the baseline electricity demand for the whole study analysis.

*Figure C-1: Electricity energy and peak load demand in Vietnam, 1995- 2040.*




Source: Electricity of Vietnam (2007), Institute of Energy (2009)

In this study, the same average predicted load demand, transmission and distribution (T&D) losses, and system capacity reserve margin during certain periods (see Table C-1) are applied to all considered scenarios.

*Table C-1: The same average predicted load demand, transmission and distribution loss (%) and capacity reserve margin (%) are applied in all three scenarios.*

| Items | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|
| Peak demand (MW) | 18,513 | 28,671 | 40,922 | 57,804 | 76,914 | 99,604 | 126,289 |
| T&D losses (%) | 10.8 | 9.6 | 8.5 | 7.5 | 7.5 | 7.0 | 7.0 |
| Reserve margin (%) | 0 | 5 | 10 | 15 | 15 | 15 | 15 |

Source: Electricity of Vietnam (2007).

*Energy resource data*

To fuel the electricity generation expansion plan from 2010 to 2040, fuels considered economically include indigenous energy supply resources (fossil fuels and renewables), nuclear energy and fuels imports, including electricity.

The availability of domestic fossil fuels and nuclear energy and the possibilities for importing fuels and electricity sources have been estimated depending on their availability time to time and the country's financial resources. All these data are derived from a set of development plans for different sectors and a number of specific reports (TKV, 2006; Vinacomin, 2007; Vinacomin, 2008; PetroVietnam, 2008; TKV, 2008; Institute of Energy, 2008a; MOIT-JICA, 2008; PetroVietnam, 2009; TKV, 2009b; Institute of Energy, 2009; MOIT, 2009; Institute of Energy and Science, 2009; Institute of Strategy and Development, 2009; BP, 2010; Khanh Toan et al., 2010).

*Technology and fuel data*

In this study, we consider 29 alternative candidate generation technologies (including 24 thermal energy, 3 hydro energy, wind farm and solar PV grid-connected generation technologies). The cost and performance specifications of candidate generation technologies, with and without CCS are techno-economically summarized in the Chapter 3 and Chapter 4.

Mostly, the cost and performance data for candidate power generation plant technologies in Vietnam are derived from Vietnamese agencies (Electricity of Vietnam, 2007; Electricity of Vietnam, 2008; MOIT, 2009; Institute of Energy and Science, 2009; Institute of Strategy and Development, 2009). However, the data for new and advanced gas-and coal-fired power generation technologies (with and without CCS), and renewables (geothermal, wind farm, solar PV grid-connected plants, integrated gasification combined cycle, etc) is also further referred to various international literature sources.

Particularly, the assumptions of overnight investment cost for power generation technologies is relied on: TECHPOL database used by WETO (2006); Das and Ahlgren (2008); Broek et al., (2008) and Broek et al., (2009). The cost and performance specifications for renewable energy-based power generation technologies are comparatively derived from IEA (2003); WETO, (2006);

Bove (2006); Algren and Anjana (2007); Khanh Nguyen (2007b, 2008b); Nguyen and Ha-Duong (2010); Bergqvist et al., (2008); IEA (2008a); IEA (2008b); EIA (2009); Broek et al., (2009); Fitchner (2009), Institute of Energy (2008a).

Specifically for the data related to carbon capture, transport and storage, the author basically derives the assumptions from a set of reference sources: Johnson (2002); IPCC (2005); IEAGHG, 2006; IEA, 2006; Viebahn et al., (2007); Davison, 2007; MIT (2007); Broek et al., 2008; Broek et al., (2009); GlobalCCSInstitute (2010).

In regards to nuclear plants, we take the costs (including decommissioning cost) and performance specifications from Institute of Energy (2009), WNA (2010), WEC (2007).

In fuelling the development plan, there have totally 17 kinds of energy fuels with specific prices projected time to time as presented in Table  C-2. All energy prices and their escalation rates, used in this study, are based on 2008 price and the estimations of Vietnamese Government agencies (Institute of Energy, 2008a; Institute of Energy, 2009; MOIT, 2009; Institute of Energy and Science, 2009; Institute of Strategy and Development, 2009).

As discount rate depends on many factors: inflations, interests, risks and opportunity costs, which are impossible to forecast in a long-term planning period. This is why in common practice most feasibility studies should assume an equal value for discount rate over the whole planning horizon. Since the value may be quite arbitrary, one may conduct a sensitivity analysis with a range of values for the discount factor to see if the conclusion (final assessment of the project feasibility study) would stay robust. In any case, all cash flow models should be seen as an approximation, relying on many assumptions (cash flow estimates, the length of planning horizon, etc), and sensitivity analysis (or simulations) could be done to check their robustness. In this study, the equal discount rate of 10% is employed to perform the cost analysis process for all selected candidate generation technologies, as commonly recommended by the World Bank (Institute of Energy, 2008, 2009a) when making cost analysis for energy projects in Vietnam.

The option of electricity imports (mainly hydro sources from neighbor countries such as China, Lao, and Cambodia) is also included. The price for electricity imported varies from 4.5-5 US$ cent/kWh depending on different supply sources and an average price increase of 2% per annum is assumed to the electricity purchasing price (Institute of Energy, 2009; NLDC, 2010a,b).

*Table C-2: The 17 kinds of energy fuels and their prices (based on 2008 price) assumed in scenarios in the study.*

| No. | Price / Year | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|
| 1 | **Dom.Coal ($/ton)** | | | | | | | |
| | Price | 40 | 45 | 51 | 57 | 64 | 72 | 81 |
| | Escalation rate | | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 |
| 2 | **Imp.Coal ($/ton)** | | | | | | | |
| | Price | 75 | 62 | 71 | 73 | 76 | 80 | 84 |
| | Escalation rate | | -0.035 | 0.029 | 0.006 | 0.01 | 0.01 | 0.01 |
| 3 | Imp.FO ($/barrel) | | | | | | | |
| | Price | 70 | 65 | 74 | 82 | 86 | 90 | 95 |
| | Escalation rate | | -0.015 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 |
| 4 | **Imp.DO ($/barrel)** | | | | | | | |
| | Price | 97 | 90 | 103 | 113 | 119 | 125 | 131 |
| | Escalation rate | | -0.015 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 |
| 5 | **Dom.Gas1 ($/MBtu)** | | | | | | | |
| | Price | 4.6 | 5.1 | 5.6 | 6.1 | 6.7 | 7.4 | 8.1 |
| | Escalation rate | | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 6 | **Dom.Gas2 ($/MBtu)** | | | | | | | |
| | Price | 5 | 5.5 | 6.1 | 6.7 | 7.3 | 8.1 | 8.9 |
| | Escalation rate | | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 7 | **Imp.Gas ($/MBtu)** | | | | | | | |
| | Price | 7 | 6.7 | 7.7 | 8.4 | 9.2 | 10.1 | 11.1 |
| | Escalation rate | | -0.008 | 0.031 | 0.016 | 0.02 | 0.02 | 0.02 |
| 8 | **Nuclear-Ur ($/ton)** | | | | | | | |
| | Price | 2.486 | 2.73 | 3.01 | 3.31 | 3.64 | 4.00 | 4.40 |
| | Escalation rate | | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 9 | **Baggases ($/ton) [co-generation]** | | | | | | | |
| | Price | 2.9 | 3.2 | 3.4 | 3.7 | 3.9 | 4.2 | 4.5 |
| | Escalation rate | | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| 10 | **Rice husk#1 ($/ton) [plants constructed nearby rice husk collecting sites]** | | | | | | | |
| | Price | 4.8 | 5.1 | 5.5 | 6.0 | 6.4 | 6.9 | 7.4 |
| | Escalation rate | | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| 11 | **Rice husk#2 ($/ton) [plants constructed within a diameter of 15km from rice husk collecting sites]** | | | | | | | |

| No. | Price / Year | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|
| | Price | 7.8 | 8.4 | 9.0 | 9.7 | 10.4 | 11.2 | 12.0 |
| | Escalation rate | | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| 12 | **Rice husk#3 ($/ton)** **[plants constructed within a diameter of 30km from rice husk collecting sites]** | | | | | | | |
| | Price | 10.8 | 11.6 | 12.5 | 13.4 | 14.4 | 15.5 | 16.6 |
| | Escalation rate | | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| 13 | **Rice straw#1 ($/ton)** **[plants constructed near by rice straw collecting sites]** | | | | | | | |
| | Price | 12.0 | 12.9 | 13.8 | 14.9 | 16.0 | 17.2 | 18.5 |
| | Escalation rate | | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| 14 | **Rice straw#2 ($/ton)** **[plants constructed within a diameter of 15km from rice straw collecting sites]** | | | | | | | |
| | Price | 13.2 | 14.2 | 15.2 | 16.4 | 17.6 | 18.9 | 20.3 |
| | Escalation rate | | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| 15 | **Rice straw#3 ($/ton)** **[plants constructed within a diameter of 30km from rice straw collecting sites]** | | | | | | | |
| | Price | 14.4 | 15.5 | 16.6 | 17.9 | 19.2 | 20.6 | 22.2 |
| | Escalation rate | | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| 16 | **Wood/other residues ($/ton)** **[plants constructed within a diameter of 50km from fuel collecting sites]** | | | | | | | |
| | Price | 8.0 | 8.6 | 9.2 | 9.9 | 10.7 | 11.5 | 12.3 |
| | Escalation rate | | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| 17 | **Wood plantation ($/ton)** **[price is taken as market price including transportation cost]** | | | | | | | |
| | Price | 25.0 | 26.9 | 28.9 | 31.1 | 33.4 | 35.9 | 38.6 |
| | Escalation rate | | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |

Note: local transportation costs from collecting sites of fuel resources to future constructed power plants are estimated as: 0.1996$/ton.km for rice husk, and 0.08$/ton.km for paddy straw and wood residues.

Source: Institute of Energy (2008a); Institute of Energy (2009); MOIT (2009); Institute of Energy and Science (2009); Institute of Strategy and Development (2009).

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