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Analysis of the impact of enhanced use of renewable and advanced fossil fuel technologies for power generation in selected ASEAN countries and development of appropriate policies and institutional frameworks.

Final Report

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Executive Summary

In this report the main findings from the project "Analysis of the impact of enhanced use of renewable and advanced fossil fuel technologies for power generation in selected ASEAN countries and development of appropriate policies and institutional frameworks" is presented.

The project has been carried out by Department of Energy and Environment, Chalmers University of Technology, Sweden, in close collaboration with Stockholm Environment Institute, Sweden, Institute of Energy, Vietnam, Agency for the Assessment and Application of Technology (BPPT), Indonesia and Department of Energy, Philippines.

The project has been partly funded by the European Commission (EC) through the EC-ASEAN Energy Facility (EAEF) and the project is referred to as EAEF 91-2004 of the facility.

This project considers possible future energy solutions of the three ASEAN countries Indonesia, Philippines and Vietnam. The countries are among the largest of the South-east Asian countries. Their current per capita energy consumption is still very low compared to most industrialised countries. However, due to strong economic growth, their energy demand potential and, in particular, the electricity demand potential is very high. For example, the electricity demand in Vietnam has in last few years grown at the rate of 13-15% per annum and this strong increase is expected to continue in future.

The countries are also in the process of rapidly developing their energy infrastructure. In spite of different conditions and resource availability a common feature is the possibility for options which might enhance energy security and at the same time contribute to improved environmental sustainability locally as well as globally. Selection of appropriate technologies and resources are one of the key components of such development. Therefore, such a selection of appropriate technologies and resources, design of appropriate policies and strategies, become crucial.

Given the high capital intensity and long life of energy infrastructure, any less well chosen technology may result in economic disadvantages and/or severe environmental impacts for years to come. There is a high risk of so-called lock-in situations since so much capital is bound in energy infrastructures.

In this project, the possible role of appropriate technologies for improved energy security, economic development and reduced environment impact is addressed. Using advanced energy systems modelling, the so-called MARKAL model, the project examines and quantifies, the role of clean and advanced energy technologies in efficient local resource exploitation. Consequences for energy security and environmental conditions are also analysed.

The main focus is on renewable and advanced fossil technologies for power generation. The project aims at developing country specific modelling frameworks in order to identify country specific appropriate technology choices and to quantify their implications in terms of energy savings, fuel substitution, investments needed and pollutions avoided.

Europe is one of the market leaders in some of the new and advanced energy technologies (both fossil and renewable such as coal super critical, gas combined cycle, solar, wind etc.). Over the years, Europe has successfully developed its energy system employing innovative policies and institutional frameworks. This project also identifies the potential ASEAN markets for European energy technologies and financial institutions. Finally, the aim of the project is to contribute to the development of institutional and policy framework needed for enhanced use of advanced

energy technologies in the countries under consideration and techno-economic cooperation between EU and ASEAN regions.

Target groups include country-specific energy policy and decision making institutions, ASEAN, ASEAN energy industries, European Union, European energy industries and donor and lending organisations.

Methodology

Under the Australian-ASEAN Energy Policy System Analysis Project[1], a MARKAL[2] model was developed for each of the ASEAN country's energy systems. In the present project, this existing modelling framework was a starting point without which the present task could not have been accomplished. The existing modelling framework has been used with considerable upgradation and modification according to the need defined by the objectives of the present project.

The entire energy systems, comprising both supply and demand sides, of these countries have been modelled in the MARKAL framework. However, common to all countries, the demand side is not very elaborate primarily due to the shortage of reliable data but also since this was not the focus of the present work. Sometime, demand for a particular energy service may not response with energy price changes. In contrast, the electricity system in all countries has been modelled in greater details.

The modelling framework is used for scenario analysis. At the first step, the model is simulated for a Business-as-Usual (BAU) Scenario that examines the consequences of continuation of the current trends of population, economy, technology and human behaviour. In the next section, a detailed description of the BAU scenario is presented.

The Technology Scenario development is a central part of the project that primarily expands the technology options for power generation in each country model. For the Technology Scenarios, a database is developed that include potential renewable and advanced fossil technologies for power generation those are available, or are likely to be available within the time frame of analysis (2000-2030), from European energy industries.

The Technology database together with a number of local conditions is connected to the country models. Under the Technology Scenarios, the model is simulated to examine the role of technologies (measured in terms of the incremental quantitative effects relative to the Business-as-Usual Scenario), in 1) efficient local resource exploition 2) energy security issues, and 3) environment impact.

Results obtained from each of the scenarios are compared with the BAU Scenario results in order to quantify the impact in terms of fuel savings, fuel substitution, country-specific technology choices, energy supply costs, investment requirement, and emissions. Detailed descriptions of the Technology Scenarios are presented in the following sections.

The scenarios are also used to identify the country specific best technology choices and their diffusion patterns in terms of penetration amount and schedule to meet different policy goals such as energy security, environmental target. At the next step, barriers and deficiencies for the diffusion of these technologies that currently exist in the energy sectors, are identified.

1 http://www.aseanenergy.org/projects/epsap/epsap.htm
2 http://www.etsap.org/markal/main.html

Institutional and policy frameworks at local and regional level necessary for technology diffusion are discussed.

Business-as-Usual (BAU) Scenario

In constructing the BAU Scenario, each country model, has made country-specific assumptions on macro-economic development (like population, GDP etc), energy systems development, resource availability and exploitation, domestic resource potentials and technologies to be used and their characteristics. Assumptions on population and GDP growth rates are presented in Table 1.

Some of the assumptions have been made common to all models. All models have e.g. assumed a common oil price for international trade. The international oil price has been considered as an important parameter for the long-term energy strategies in all three countries. As well known, during the past 30 years, international oil prices have been highly volatile,

Table 1: Compound annual growth rate for population and GDP (%)

	2003-05	2005-10	2010-15	2015-20	2020-25	2025-30
			Population			
Indonesia	1.64	1.42	1.26	1.04	1.00	1.00
Philippines	2.12	2.03	1.85	1.63	1.48	1.28
Vietnam	1.41	1.07	1.16	1.02	0.75	0.75
			GDP			
Indonesia	6.0	6.1	6.5	6.5	6.5	6.5
Philippines	5.0	5.0	5.0	5.0	5.0	5.0
Vietnam	7.5	7.2	7	6.5	6.6	6.5

Source: Agency for the Assessment and Application of Technology (BPPT), Indonesia; Department of Energy, Philippines; Institute of Energy, Vietnam.

Table 2: Future oil price in € (2004) per barrel as assumed in the study

Year	BAU- Low Oil Price Case	BAU- High Oil Price Case
2010	28.16	34.62
2020	29.77	46.23
2030	31.38	57.01

therefore, two oil price cases have been developed for the Business-as-Usual scenario; the BAU-Low oil price case (BAU-L) and the BAU-High oil price case (BAU-H). While the Low oil price case assumes a future oil price as projected by International Energy Agency (IEA), the POLES projections[3] are used for the High Oil Price case (Table 2). 10% discount rate is assumed. All costs are in € (2004). The base year for Philippines and Vietnam is 2000, while for Indonesia it is 2003. The energy system for all countries is modelled till the year 2030.

[3] carried out by Département Energie et Politiques de l'Environnement, LEPII-Grenoble for DG Research) obtained through personal communications with Dr Patrick Criqui.

Technology Scenarios

An assessment on the development of technical and economic performances of technologies suitable for the targeted countries has been carried out based on literature surveys and expert consultations. The technologies considered are currently commercially available in the market or expected to be available within the time frame of the analysis.

Since one of the objective of the project is to explore possible markets for European technologies, focus is on those "European" technologies in a broad sense; technologies which are being manufactured mainly in Europe, technologies being developed in Europe or for which European companies have a dominant market position. The technologies considered are presented in Table 3.

Table 3: Technologies and the abbreviations considered for the analysis

Category	Fuel source	Technology
Fossil	Coal	Supercritical Pulverised Coal Combustion (Coal-SC)
		Circulating Fluidised Bed combustion (CFBC)
		Integrated gasification combined cycle (IGCC)
Fossil	Natural gas	Advanced combined cycle gas turbine (Adv-CCGT)
Nuclear	Uranium	Pressurized Water Reactors (PWRs)
Renewables	Biomass	Co-firing
		Combustion-power only
		Combustion-Heat and power (Biomass-CHP)
		Gasification-power only (BIGCC)
Renewables	Wind	Onshore
Renewables	Solar	Solar PV
		Solar-thermal

In the MARKAL model, each technology is represented by a number of technical (life, capacity factor, input-output ratio), economic (capital cost, fixed operating and maintenance (O&M) cost, variable O&M costs) and environmental parameters (emission factors). Assumptions on these parameters over the modelling horizon are obtained through extensive literature survey, consultations with experts from research institutions and industries. These technologies will be available to the model from the year 2010 onwards. In general, a range of values are available for most of the parameters. A sensitivity analysis on some of these parameters may be useful, however, given time limitations, it has been left for future analyses.

Investment costs in Indonesia and Philippines need special attention. Investment costs of current technologies like sub-critical pulverised coal, CCGT etc. in these two country models are normally significantly higher than that in the global market. These costs are developed based on projects that came up or were proposed during or after the financial crisis when the currencies were volatile and risk was high. Also, the archipelagic nature of these two countries with difficult terrain, makes installation cost higher. Accordingly, some adjustments are made on investment costs for the new technologies when used in these two countries in order to make them compatible. It should be noted that it has some influence on the results.

Some caps are imposed to limit the capacity development. or maximum possible new investment. These limits are country-specific and set for economic, technical, behavioural, or other reasons. In the concerned countries accurate assessment of technically and economically achievable potentials of renewable resources are scarce. Conservative upper limits for the capacity of technologies using resources like wind and solar radiation have been assumed.

The technology scenarios are simulated for both the low and high oil price cases and results are compared with the respective BAU case (i.e for a country, results of technology scenario in low oil price case has been compared with the BAU low oil price case (BAU-L)) to estimate the effects of the additional technologies under different oil price assumptions. At first, technology scenarios are simulated without any policy constraints. At the next step, two types of policy scenarios are constructed by imposing policy constraints, on CO_2 reduction target and country specific policy goals. Table 4 presents the definition and abbreviation used for all scenarios in different countries.

Table 4: Definitions and abbreviations of different scenarios used for three countries in the analysis

	Policy constraints	Technology database	Indonesia		Philippines		Vietnam	
			Low oil price	High oil price	Low oil price	High oil price	Low oil price	High oil price
Business-as-Usual Scenario	No	No	IBAU-L	IBAU-H	PBAU-L	PBAU-H	VBAU-L	VBAU-H
Technology Scenario	No	Yes	ITECH-L	ITECH-H	PTECH-L	PTECH-H	VTECH-L	VTECH-H
	CO2 reduction-low target	Yes	ICO2-L1	ICO2-H1	PCO2-L1	PCO2-H1	VCO2-L1	VCO2-H1
	CO2 reduction-high target	Yes	ICO2-L2	ICO2-H2	PCO2-L2	PCO2-H2	VCO2-L2	VCO2-H2
	CO2 reduction-low target	No	ICO2-L1(WT)	ICO2-H1(WT)	PCO2-L1(WT)	PCO2-H1(WT)	VCO2-L1(WT)	VCO2-H1(WT)
	CO2 reduction-high target	No	ICO2-L2(WT)		PCO2-L2(WT)			
	Import reduction	Yes			PENSEC-L	PENSEC-H		
	Primary energy reduction	Yes	IPERED-L	IPERED-H			VPER-L	VPER-H

CO_2 reduction scenario

Technology scenario when run without any policy constraint on CO_2 (as described in the previous section), additional technologies are being efficient or CO_2 neutral (renewable), some amount of CO_2 is reduced when compared with the respective Base cases (low and high oil price) (please see the results in Chapter 4). CO_2 reduction scenarios are designed in such a way so that CO_2 reduction is higher as compared to the Technology scenario (without any policy constraint on CO_2 reduction). The objective is to identify the maximum potential reduction that can be achieved with the help of additional technologies. An additional constraint on CO_2 reduction is imposed to the model. For each country, two scenarios are constructed targeting low and high CO_2 emissions reduction.

CO_2 reduction scenarios are simulated for both low and high oil price cases. To understand the effects of the advanced fossil and new renewable technologies in a better way, these scenarios are also simulated in absence of additional technologies. For all three countries, when higher reduction targets are attempted with high oil price and without advanced technological options, the model becomes infeasible. In the case of Vietnam, even for the low oil price case, higher reduction target is unachievable without additional technological options.

Country-specific scenario
For the Philippines, with a high import dependence (measured as share of import in total primary energy supply (projected as 67% in 2030 in BAU case)), the role of additional technologies to reduce import dependence is examined.

For the other two countries, given their abundant domestic energy resources, the import share needs not be very high during the modelling horizon (for Vietnam, it has been projected as 20% for 2020 in the BAU case (please see Chapter 4)).

The extent of primary energy demand that can be reduced by employing advanced technologies is analysed. All scenarios are simulated for low and high oil price cases.

Results

Following sections present results and analyses from BAU scenario followed by Technology scenarios for each country. In the analysis, for all scenarios, low oil price case has been presented in details and for high oil price case, only main changes over low oil price case are highlighted.

Indonesia

BAU scenario

Indonesia's GDP is assumed to grow at an average annual rate of 6.4% GDP. With the assumptions given to the model in the BAU scenario this leads to a fivefold growth of energy demand, from 4458 PJ in 2003 to 20392 PJ in 2030. Assumptions of modest improvement in energy efficiency lead to only marginal reduction in energy-GDP intensity. The industrial sector remains the largest energy consuming sector, demanding five times more energy than today. The transport sector, the second largest energy consumer, is growing at the rate of 6.6% annually. Oil continues to be the dominant source of final energy consumption, contributing about 33%-35% of the total energy demand. Biomass, which is the largest source of final energy in 2003, is expected to lose its share over time because of supply limits as well as households' preference for modern fuels. A high oil price assumption leads to some but not significant substitutions of oil by coal and gas, due to the demand side limitations of the model. Despite the high growth rate, per capita final energy consumption in 2030 will be low compared to many developed countries.

Growth in electricity demand is very steep, almost an eleven fold increase between 2000 and 2030. Electricity generation grows from 122 TWh in 2003 to 1318 TWh in 2030. While the present power system is diversified in terms of fuel sources, the model predicts a future with much less diversity (Figure 1). Future power system will have following characteristics:

- Coal, being plentifully available in the country and relatively cheap, is dominating as source for power generation. Coal based generation is expected to increase from 30 TWh in 2000 to about 780 TWh in 2030. Pulverised sub-critical coal technology is used.
- Gas is the second choice as a source for power generation, with a share of 30% in 2030.
- Nuclear will penetrate from 2020 and will contribute about 18 TWh in both 2025 and 2030.

- Among renewables, geothermal power penetrates rapidly and generation increases from 5 TWh at present to 35 TWh by 2030. Generation from large hydro power increases from 12 TWh in 2000 to 49 TWh in 2030. However, the share in the total generation declines. Wind power is not competitive. Biomass (combustion) power and solar PV contributes to a small amount particularly in small islands. The share of renewables falls over time and by 2030 renewables contribute only to about 8% of the total generation compared to 19% today.
- During the time frame of the study, additionally 200 GW is needed, amounting to almost 7 GW new capacity annually.

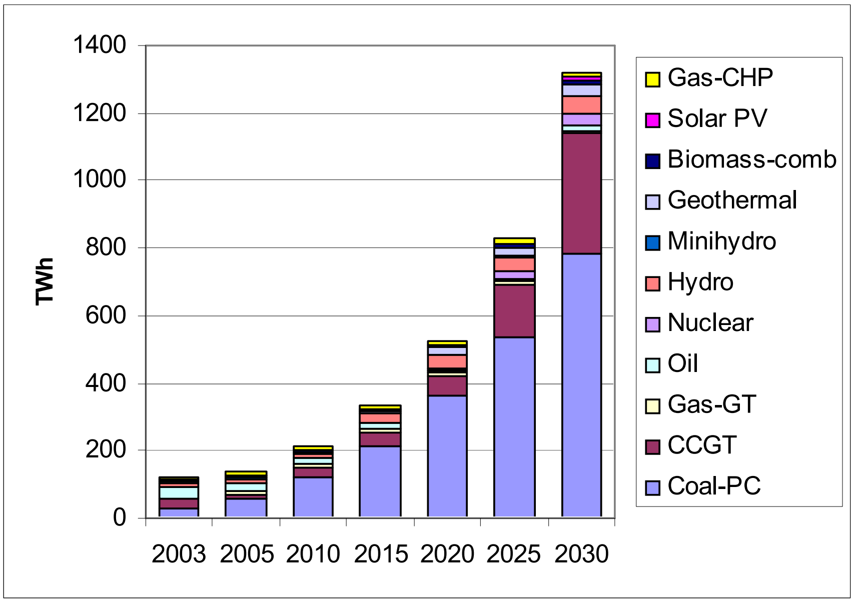

Figure 1: Power generation in Indonesia in IBAU-L case

Oil is only used marginally for power generation in the future. In the high oil price case, some nominal changes are observed in terms of fuels used for power generation.

Primary energy supply is expected to increase from 6292 PJ in 2003 to about 30000 PJ in 2030, at the rate of about 6% annually with significant changes of sources of energy supply. The share of coal in the total primary energy supply will grow from less than 10% at present to nearly 40% in 2030. In absolute terms, supply of coal grows from 562 PJ in 2003 to 12556 PJ by 2030. The share of renewables, on the other hand, will fall from 30% to 15%. Given rapidly depleting oil resource and long-term commitment on large amount LNG export, the shares of oil and natural gas are expected to fall as well, but at a slower rate. Oil remains the second largest source of primary energy.

Despite large growth in domestic energy production, from 2020 and onwards, the country is becoming a net energy importer. While the share of import in total supply will remain more or less same as today (at 25%), Indonesia is importing 90% of its oil demand by 2030 unless a significant discovery in oil reserves takes place. The net energy import bill in 2030 will be about

42 billion €. With a high oil price, although the oil import will fall, import bill will increase further.

CO_2 emissions grow dramatically during the modelling period, from 328 million tonnes in 2003 to 2043 million tonnes in 2030. The CO_2-primary energy intensity, determined as amount of CO_2 emissions per unit of primary energy supply, is increasing due to higher use of fossil fuels (mainly coal), and so is the CO_2-GDP intensity. Per capita CO_2 emissions increase significantly from 1.4 tonne currently to about 7 tonne in 2030. This is comparable to the current emissions of many developed countries. In the high oil price case, CO_2 emissions is marginally higher because of replacement of oil by coal.

Indonesian power sector needs an investment of about 852 billion € (2004) between 2003 and 2030, and the average annual investment requirement in power generation is about 27 billion €. The undiscounted energy system costs in the low and high oil price cases are 3259 billion € and 3623 billion €, respectively.

Technology related scenarios

In order to investigate the consequences on the energy system of Indonesia if these technologies were to be utilised, in the Technology scenarios (with and without policy constraints), the model is allowed to make use of an expanded list of state-of-the-art technologies, in order to quantify their possible impact. The results are briefly presented below.

In ITECH-L Scenario (Technology scenarios without any policy constraints), in power generation, CFBC is the favourable technology compared to pulverised sub-critical coal plants in Java and Sumatra power systems. Some smaller size sub-critical plants are expected to be installed in other islands. Coal based generation increases because of technological advantages (technically as well as economically). Similarly, CCGT is replaced by advanced CCGT. However, while gas based generation increases by almost 81% over IBAU-L case in 2020, it falls in 2030 by 35% since other cheaper technological options are available. Gas based CHP is replaced by biomass CHP.

The share of fossil fuels declines in the Technology scenario when compared to the IBAU-L case. The share of generation from large hydro and geothermal declines compared to IBAU-L case as a number of other renewable options become competitive, including wind, biomass combustion, BIGCC, solar PV and solar thermal power, which contribute significantly particularly in decentralised generation. Biomass (combustion and IGCC) contributes about 100 TWh in 2030. A large part of it is captive generation.

Coal consumption for heating purpose in final use, primarily in the industrial sector, goes down and is replaced by heat from the biomass based captive CHP plants. Part of the coal is also replaced by natural gas as there is now surplus gas due to the efficiency improvement in the power generation. Coal is diverted for power generation.

The primary energy requirement falls by about 5% and 9%, respectively, in 2020 and 2030 compared to IBAU-L case. While the oil supply requirement remains unchanged, the coal requirement will fall by 30% and 16%, respectively, in 2020 and 2030 over IBAU-L.

Import falls marginally compared to IBAU-L case while export increases and annual export earnings in 2030 increase from 3.5 billion € to about 8.5 billion €.

The cumulative CO_2 emissions decline by 3.7 billion tonnes (12%) over the IBAU-L case with zero or negative marginal costs from an energy system point of view since the total energy system costs are reduced by 240 billion € compared to IBAU-L. There is large reduction in SOx and NOx emissions also resulting from replacement of coal sub-critical with CFBC, and CCGT and gas CHP by advanced CCGT and biomass CHP respectively. Advanced technologies brings down the marginal costs of electricity supply.

CO_2 reduction scenarios

Two CO_2 reduction scenarios are examined, low and high reductions. The aim is to investigate at what additional cost the advanced fossil and new renewable technologies may contribute further to reduction of CO_2 emissions.

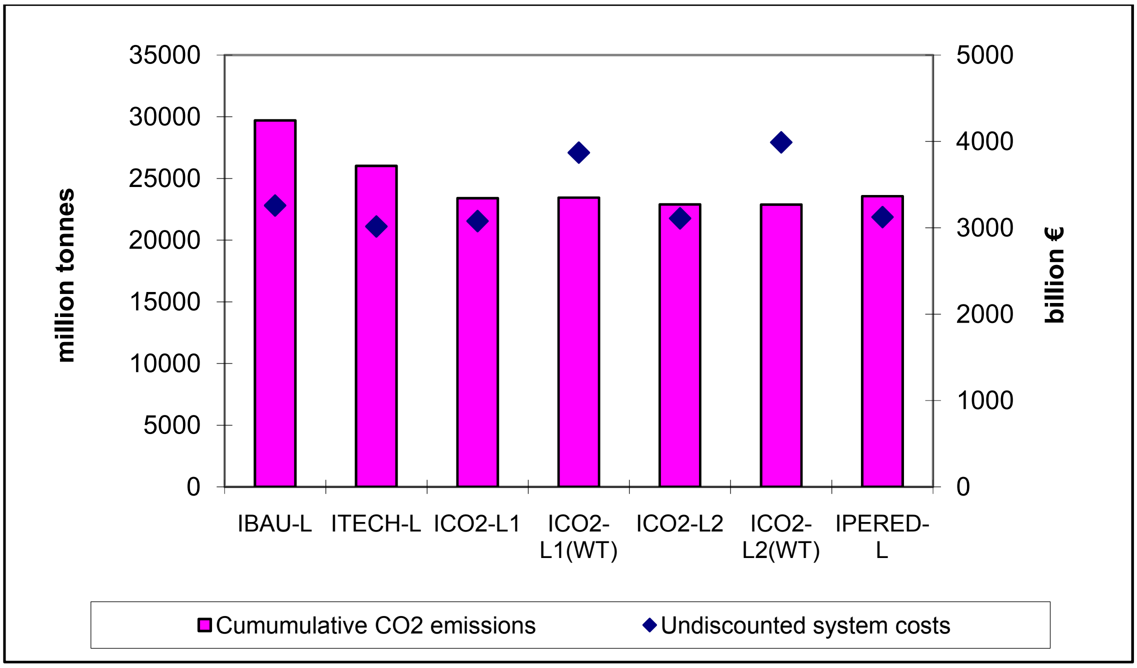

Figure 2: Cumulative CO2 emissions and undiscounted energy system costs in IBAU-L and all Technology related scenarios

At the low reduction target, both in 2020 and 2030, CFBC and advanced CCGT are favourable technologies for power generation. However, when the higher reduction target is applied, in 2030, super critical technology is preferred along with CFBC and advanced CCGT. Generation based on renewables triples. BIGCC and biomass combustion are the most favourable technologies and together contribute about 60 TWh.

The primary energy requirement falls, 5% in 2020 and 10% in 2030 as compared to the BAU. As expected, coal consumption falls substantially. Coal is substituted primarily by renewables and partially by natural gas.

The cumulative emissions reductions will be respectively 6.3 and 6.8 billion tonnes at the low and high reduction targets as compared to 3.7 billion tonnes in the Technology scenario without any reduction target.

When the system is simulated in absence of additional technologies, it is possible to achieve the reduction targets. However, it imposes an additional cost of about 600 to 700 billion € to the total energy system. The marginal reduction cost is then in the range of 62 € to 196 € per tonne depending upon the reduction level.

Energy reduction scenario

In the Technology scenario, about 5% and 9% of the primary energy requirement is reduced in 2020 and 2030 from the IBAU-L level. In the Energy reductions scenario, the possibility of achieving higher reduction, respectively about 12% and 17% in those years (with higher reduction targets, model becomes infeasible) with the help of additional technologies is examined. The model concludes that it is possible to achieve these targets. On the demand side, it makes similar types of adjustments as in the CO2 reduction scenarios. Regarding power generation, the model suggests to

- replace coal subcritical technology by more efficient CFBC, coal super critical and even IGCC technology.
- replace CCGT by advanced CCGT.
- double the contribution from renewables in both years 2020 and 2030.

Large hydro, BIGCC, wind and solar (thermal as well as PV) are favourable renewable technologies. The share of renewables in the total electricity generation increases from 13% and 8%, respectively, in IBAU-L case in 2020 and 2030 to 26% and 18% in the energy reduction case.

Table 5.: Advanced fossil and new renewable technologies as selected in different scenarios in Indonesia

Scenario	Fossil technologies	Renewable technologies	Nuclear
Technology scenario	CFBC Advanced CCGT	Wind Biomass-combustion BIGCC, Solar PV Solar thermal	Nuclear
CO2 reduction scenario			
Target 1	CFBC Advanced CCGT	Wind Biomass-combustion BIGCC, Solar PV Solar thermal	Nuclear

Target 2	Super critical CFBC Advanced CCGT	Wind Biomass-combustion BIGCC , Solar PV Solar thermal	Nuclear
Energy reduction scenario	Super critical, CFBC, IGCC, Advanced CCGT	Wind, Biomass-combustion, BIGCC, Solar PV, Solar thermal	

Savings in coal consumption over IBAU–L is as high as 38%. An added benefit is that CO_2 emissions decline too, and the cumulative reduction is as high as 6 billion tonnes. In addition, all these benefits are achieved along with a total system cost savings amounting to135 billion €.

Table 5 compiles the advanced and new power generation technologies those are favourable under different Technology scenarios. Figure 2 compares the cumulative CO2 emissions and undiscounted energy system costs in different technology related scenarios with IBAU-L Scenario.

Philippines

BAU-Scenario

The future energy scene in Philippines is different compared to Indonesia. Energy demand is expected to grow at the modest rate of 3.7% annually during 2000-30, lower than the assumed GDP growth of 5%. This can be attributed to factors like moderate improvement in energy efficiency and transformation of the economy towards service oriented activities. Energy-GDP intensity in 2030 is expected to be about 28% lower than in 2000, falling at the rate of 1% per annum and will then be lower than in the USA but higher than in many other developed countries like Japan and Germany.

Unlike in most of countries, the transport sector dominates the current energy consumption and continues to do so given the country's archipelagic nature, major dependence on road transport and lack of railway network. Transportation energy demand will triple from 341 PJ in 2000 to 1109 PJ in 2030. Households will remain the second largest energy consuming sector, however, its share will fall from current 27% to 24% in 2030. Service sector shows the highest growth rate of 5.6% although from very low level of 109 PJ in 2000, and is attributed to the country's rapid transition towards service oriented economy.

Oil continues to be the dominant source of final energy consumption, accounting for more than 50% of the total. In absolute terms, oil consumption is expected to grow from 533 PJ in 2000 to 1571 PJ in 2030. Natural gas is expected to play a small role in final energy consumption because of its limited availability. The contribution from biomass doubles from 285 PJ in 2000 to 601 PJ in 2030 while the share falls from 28% to 19%.

The electricity consumption is expected to grow at the rate of 5.9% per annum. In absolute terms, consumption is expected to be 240 TWh in 2030 as against the current level of 43 TWh. Per capita electricity demand, although projected to increase significantly from 569 kWh in 2000 to 1877 kWh, remains low compared not only to many developed countries but also compared to some developing countries. Same is true for per capital final energy consumption, projected to be only 24 GJ per capita by 2030.

Electricity generation grows from 50 TWh in 2000 to 281 TWh in 2030 (Figure 3). Main characteristics of the future power system are as follows:

- Similarly to Indonesia, the model predicts coal, being the cheapest source, as the main fuel for power generation for the next 30 years. Generation from coal is expected to increase from almost 14.5 TWh in 2000 to 202 TWh in 2030, at the rate of 9% per annum, contributing 72% of the total generation in 2030.
- Oil which is currently important for power generation is expected to be almost phased out in future.
- Geothermal power is the second largest source of power generation, contributing about 34 TWh in 2030 as compared to 9 TWh in 2000.
- Gas penetrates rapidly in the beginning but slows down later since the domestic supply is limited and import is expensive.
- The contribution from large hydro remains constant throughout the study period. Renewables (including large hydro) will contribute about 22% of the total generation in 2030, as compared to 49% in 2002.
- Power generation capacity requirement is projected as 52 GW in 2030. The additional capacity requirement is 38 GW for the period 2000-30, on average 1.3 GW of new capacity annually.

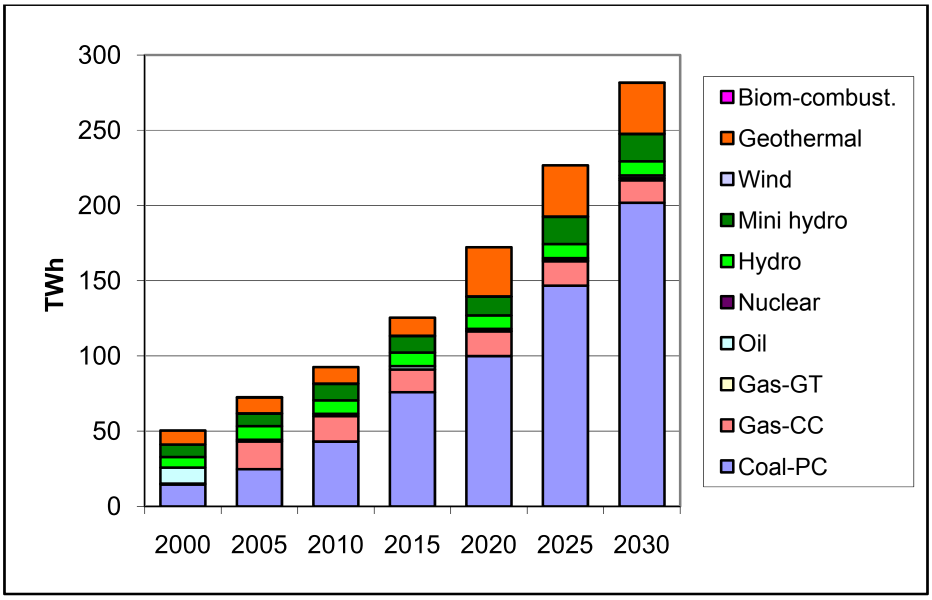

Figure 3: Power generation in Philippines in PBAU-L Case

The primary energy requirement is expected to grow from 1433 PJ in 2000 to 5147 PJ in 2030. Coal, oil and renewables are expected to be the main primary energy sources for future. Gas with limited domestic resources and LNG import being expensive, will make negligible contributions. Coal is expected to penetrate rapidly, replacing primarily both oil and renewables, with its share increasing from 13% in 2000 to 41% in 2030. Oil will continue to be the dominant fuel. However, its share will fall. Renewable's share, too, will decline from 40% to 25% in the same period.

The domestic fossil fuels production is insignificant during the whole modelling horizon, although increase in renewable energy production will improve the situation at some extent. Country will continue to be heavily import dependent. Import dependence will decrease from 70% in 2000 to 58% in 2020 and will go up again, to 67%, by 2030.

CO_2 emissions from energy related activities are increasing from 67 million tonnes in 2000 to 329 million tonnes by 2030 at the low oil price, a growth by almost a factor of five. This is due to both growth in energy consumption and an increase in carbon intensive fuels in the primary energy supply. CO_2-GDP intensity increases over time by about 15%. CO_2 emissions per capita increase rapidly from 0.9 tonne today to 2.6 tonne in 2030.

The power sector needs investment of about 114 billion € over the modelling horizon of 2000-30. Average annual investments requirement are about 3.8 billion €. The model estimates that the undiscounted total energy system costs for the modelling horizon 2000-30 are 1524 billion €.

In high oil price scenario, whereas, sector-wise total final demand changes only marginally, however, within sectors, some fuel substitutions take place. As expected final consumption of oil is reduced and replaced by natural gas. Substitution takes place primarily at the residential and transport sectors. As overall impact, oil and gas requirement declines and compensated by coal. Import of coal goes up marginally. High oil price increases the CO_2 emissions but marginally since more coal is used. It also increases the undiscounted energy system costs by 130 billion compared to the low oil price case.

Technology related scenarios.

The inclusions of advanced technologies have limited impacts on the final energy use as demand side of the model is less flexible. The total energy demand by sectors remains similar as PBAU-L case, however, some fuel substitutions take place.

The model suggests to replace subcritical coal based capacity beyond 2010 mainly by supercritical and partly by CFBC technologies. IGCC and nuclear remains economically inefficient and cannot make its way into the power system. CCGT is replaced by advanced CCGT. Because of the favourable technical and economic performance of new technologies, coal and gas together contributes more to power generation than in the PBAU-L case, at the expense of renewables, particularly geothermal, which loses its competitiveness. Although, wind, biomass combustion technology and solar thermal power enter the system, the total contributions from renewables decline in Technology scenario. The share of renewables in total electricity generation falls from respectively 32% and 22% in PBAU-L case to 24% and 15% in PTECH-L Scenario. Capacity requirements fall by about 2 GW in 2030 because of a higher availability factor offered by advanced technologies. This leads investment requirement in power generation to fall by about 9 billion € over the modelling horizon 2000-30.

The higher efficiency offered by advanced technologies lead to reduction in primary energy requirement respectively by 9% (300 PJ) and 14% (700 PJ) compared to the PBAU-L case in 2020 and 2030. Main contributors in reductions are coal and renewables. Oil products consumption increases slightly in the final use. Import requirement reduces too.

Cumulative CO_2 emissions over the modelling horizon 2000-30 are reduced by 745 million tonnes, almost 9%, over the PBAU-L Scenario. There is large reduction in SOx and NOx emissions too resulting from replacement of coal sub-critical with supercritical and CFBC and a higher amount of generation from advanced CCGT. In Philippines too, energy system costs fall by about 19 billion euro. This implies a negative cost for CO_2 reductions since in the Technology scenario both the total CO_2 emissions and the total energy system cost are lower than in the BAU scenario. Advanced technologies also bring down the marginal costs of electricity supply.

In the high oil price case, technology choices and impacts are more or less similar to the low oil price case.

<u>CO_2 reduction constraint</u>

When CO_2 reduction constraints are imposed, impacts on the demand side again are low for similar reasons as explained earlier. As expected, the power sector shows the major impacts. Also as expected, the model looks for low cost electricity generation technologies that cause less or no CO_2 emissions than standard technologies. The following observations are made based on the model results:

- subcritical pulverised coal technology is replaced by super critical technology and also by CFBC. IGCC remains uncompetitive,
- generation from fossil fuels is lower than the PBAU-L Case,
- advanced CCGT will make large contribution replacing CCGT,
- contribution from renewables, primarily hydro (both large and mini) and geothermal, increases,
- in the low CO_2 reduction case, shares of renewables are respectively 39% and 24% in 2020 and 2030, as against 31% and 22% in PBAU-L Scenario,
- among new renewables, wind, biomass combustion and solar thermal power are the contributors to the additional renewable generation.

A high oil price together with a high CO_2 reduction target makes the model infeasible since it cannot find a solution. It should be noted that coal based generation in PBAU-H Scenario is higher than in the PBAU-L Scenario. Therefore, CO_2 reduction is higher as well. Consequently, when advanced technologies are available, coal super critical plays even larger role here. Otherwise, impacts are more or less same as in the low oil price case.

When the oil price is low and similar CO_2 reduction target is applied, in absence of additional power generation technologies, contribution from subcritical pulverised coal technology falls by 50% in low CO_2 reduction case and by 75% in the high CO_2 reduction case. Gas and renewables play the role to curb emissions. CCGT increases its generation substantially and the remaining generation primarily come from hydro and geothermal. Mini hydro plays an even larger role than in the Technology Scenario without policy constraint.

CO_2 reduction attempts cut down coal use as primary energy source which ranges from 35% to 50% in 2020 depending upon the CO_2 reduction targets, oil prices (low or high) and availability of technological options. When technological options are not available, reduction of coal use is higher. It ranges from 34% to as high as 75% in 2030. CO_2 reduction does not have any effects on oil products consumption since oil is consumed mainly in final energy use, which offers limited flexibility in terms of technology or fuel substitutions. Coal is replaced by combinations of three energy sources; gas, renewables and nuclear. In some cases, the total energy requirement falls as compared to PBAU-L Case. Import requirements fall as well since more renewables are used (and these are domestic resources).

Reductions in cumulative emissions over 2000-30 are in the range of 1.4 to 1.8 billion tonnes depending upon the reduction targets, oil price and availability of technologies, as against 0.75 billion tonnes in Technology scenario without any reduction target. In both oil price cases, it is possible to achieve both the reduction options at lower costs than in respective BAU (PBAU-L/H) if advanced fossil and new renewable technologies are made available.

It is also possible to achieve both the reduction targets without the advanced technological options being available (at low oil price), however, it imposes an addition cost to the energy system, illustrating the benefits of advanced technologies. At high oil price, it is not possible to achieve the higher CO_2 reduction target and the low CO_2 emissions target can be achieved at an additional (undiscounted) cost of about 26 billion €.

While the marginal costs of CO_2 reduction are negative when additional technologies are deployed, it will be in the range of 4€ to 51€ per tonne, depending upon the level of reduction, level of emissions and timing of reduction, when the technologies are not available.

Energy security scenario

Philippines depends heavily on import to meet its energy supply needs. The share of import in primary energy supply is projected to increase in the future if no measures are taken. In the Energy security scenario, a constraint on import has been imposed and simulated for both the low and high oil price case. These scenarios cannot be achieved without advanced technological options since the model then becomes infeasible. However, it is possible to reduce import as defined with advanced technological options in the low as well as in the high oil price cases and also at lower costs than in the BAU. More efficient fossil technologies are used in power generation and the model also employs a combination of measures that include, higher use of renewables and enhancement of domestic mining activities. The country primarily depends on import of fossil fuels. However, there is no impact on oil consumption since oil products are primarily consumed for final use and current modelling framework offers limited scopes for fuel substitutions in the final use. Coal, which is largely used for power generation, can be reduced by employing better technologies or substituted by other sources like renewables.

To reduce the import dependence, radical changes are needed in the power generation in terms of both technologies to be deployed and resources to be used. The following observations are made:

- since the country depends on imported coal, the use of coal is reduced,
- biomass-cofiring makes a large contribution since in this technology, biomass replaces coal consumption up to 20% by energy input,
- super critical and CFBC are other favourable technologies for power generation from coal,
- advanced CCGT becomes a prominent technology,
- nuclear cannot penetrate as nuclear fuel needs to be imported,
- a large number of renewable technologies including biomass combustion, BIGCC, wind, geothermal, hydro (large and mini) and solar thermal will be employed. Additional contributions from renewables (excluding biomass cofiring) are 21 TWh and 18 TWh in 2030 as compared to respective BAU scenario in low and high oil price cases, respectively.

Deployment of efficient technologies brings down the primary energy consumption by about 5% and 9% in 2020 and 2030 compared to the respective BAU scenarios in the low and high oil price cases. The coal consumption falls drastically, up to 50% over the BAU case. In contrast, the renewable energy supply is increased. There is no impact on oil and only a marginal increase in gas use.

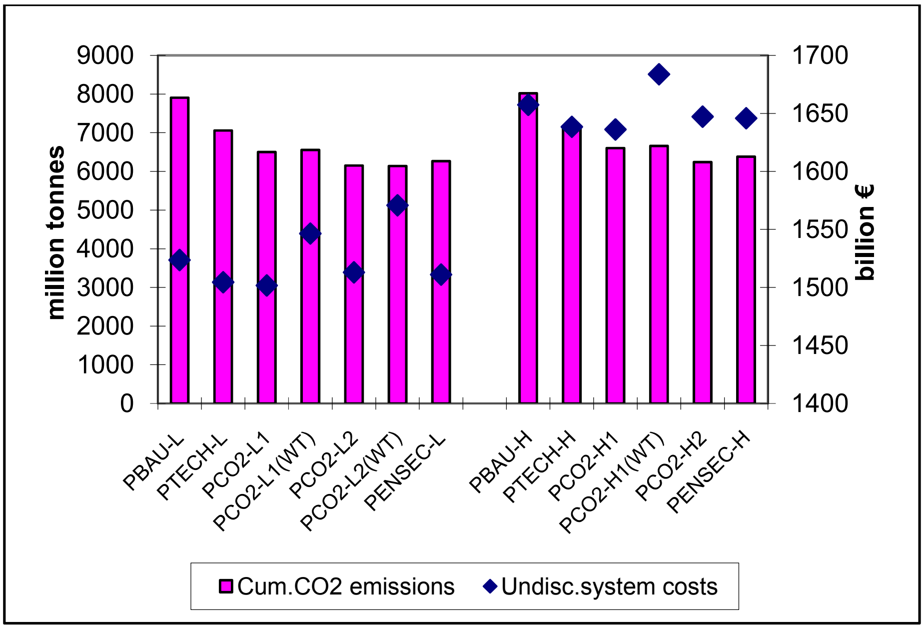

Figure 4: Cumulative CO2 emissions and undiscounted energy system costs in PBAU-L/H and all Technology related scenarios

Table 6. Advanced fossil and new renewable technologies as selected in different scenarios in Philippines

Scenario	Fossil technologies	Renewable technologies	Nuclear
Technology Scenario	Super critical CFBC Advanced CCGT	Wind Solar thermal	
CO_2 reduction scenario			
Target 1	Super critical, Advanced CCGT	Wind, Biomass-combustion, Solar PV, Solar thermal	Nuclear
Target 2	Super critical Advanced CCGT	Wind Biomass-combustion Solar PV, Solar thermal	Nuclear
Import reduction scenario	Super critical, CFBC, Biomass-cofiring, Advanced CCGT	Wind, Biomass-combustion, BIGCC, Solar PV, Solar thermal	

Domestic mining activities become economic and production of fossil fuels increases although not substantially. Import bills fall. Reduction in the average annual import bill ranges from 0.5 billion € to 1.2 billion € in the low oil price case and, therefore, this leads to less pressure on the country's foreign currency reserves. In high oil price case it is slightly lower.

This energy security can be achieved with no additional costs and with the added co-benefit of reduction in CO_2 emissions if advanced fossil and new renewable technologies are available. The cumulative CO_2 reduction potential is 1.6 billion tonnes. Cost savings are about 12 billion €.

Table 6 compiles the advanced and new power generation technologies those are favourable under different Technology scenarios. Figure 4 compares the cumulative CO_2 emissions and undiscounted energy system costs in different technology related scenarios with PBAU-L/H Scenarios.

Vietnam

BAU Scenario

The energy demand is growing at the rate of 6.2% annually during 2000-30 supporting an assumed annual GDP growth of 6.9% during the same period. Energy-GDP intensity is falling from 25 GJ per 1000 € in 2003 to about 16 GJ per 1000€ by 2030, at a rate of 1.3% per annum. Even after 30 years energy-GDP intensity remains higher than the current energy intensity of most of the developed countries.

Concerning sectoral energy consumption, the major growth in energy demand is in the industry and transport sectors. Industries, which will contribute to this growth, include manufacturing industries such as building materials, chemical, metal etc. The transport energy demand during 2000-30 is expected to grow from 212 PJ in 2000 to 1146 PJ in 2030. During this period, while rail transportation will grow marginally, a manifold growth in all other modes, road, air and water is expected. The demand for the residential sector will grow rather slowly, 3.8% per annum during the period 2000-30, therefore losing its dominant share in the total consumption from 39% in 2000 to mere 20% in 2030. This is due to a lower population growth than in the past and transition from use of biomass to more efficient fuels like LPG, natural gas etc. The per capita final energy demand is expected to grow from 12 GJ in 2003 to 56 GJ by 2030, however, it still remains much lower than what a per capita demand in the developed world today.

The contribution from renewables (primarily biomass) in final use (mainly in the residential sector) remains constant throughout the modelling horizon due to limited supply and the preference of households for modern fuels. Use of natural gas is expected to increase rapidly till 2020. The growth slows down thereafter as domestic gas availability is expected to reach a plateau. Oil consumption grows from 279 PJ in 2000 to 1404 PJ in 2030. Electricity demand grows from about 20 TWh in 2000 to 452 TWh in 2030, at an annual rate of 11%. Industry is expected to be the largest consumer of electricity with its share growing from 46% today to 65% in 2030. The residential sector remains the second largest consumer. However, its share falls substantially from 46% in 2000 to 26% in 2030. Per capita electricity consumption grows rapidly from 267 kWh in 2000 to 2232 kWh in 2020 and further to 4288 kWh in 2030. However, it will still remain lower than the current EU-15 average and much lower than the per capita consumption in USA.

Electricity generation increases from 24 TWh in 2000 to 466 TWh in 2030, growing at the rate of 10.4% per annum (Figure 5). Main characteristics of future electricity system include:

- generation from gas combined cycle plants will increase rapidly in the beginning till 2015, thereafter, generation will fall because of limitation in domestic gas availability,
- oil based generation is phased out by 2010,
- generation from pulverised subcritical coal plants is expected to increase rapidly from 0.5 TWh in 2000 to 273 TWh in 2030, an increase of 540 times, making coal as the main fuel source for power generation,
- generation from hydro will rise continuously from 16 TWh in 2000 and reaches its upper limit of 87 TWh by 2025 and thereafter remains constant,
- nuclear is expected to enter the power system in 2020, and by 2030, it will produce 60 TWh,
- other renewables, mini hydro and biomass combustion make contributions of respectively about 8 TWh and 14 TWh in 2025; wind and geothermal contribute insignificantly from 2025 and onwards. The share of renewables (including large hydro) falls from 66% in 2000 to 25% by 2030.
- Vietnam also is expected to import some amount of electricity from neighbouring countries.

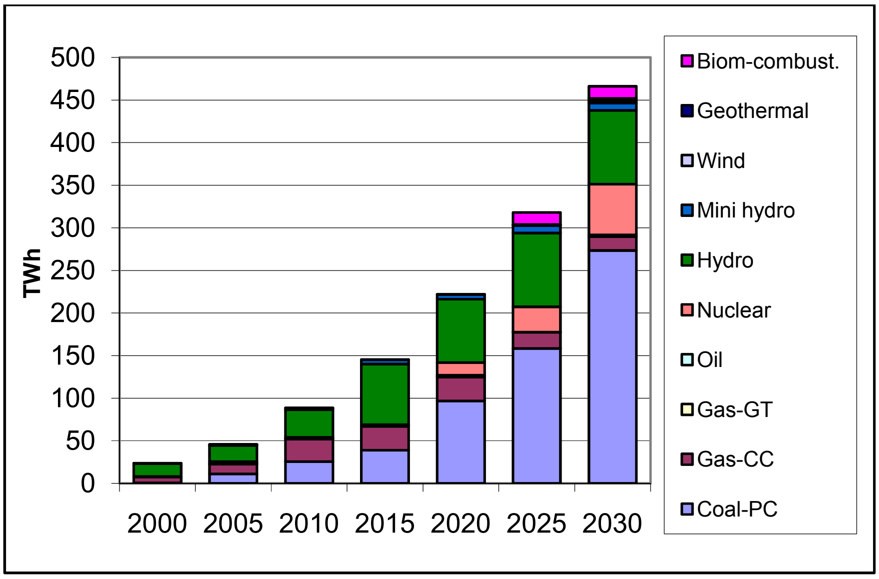

Figure 5: Power generation in Vietnam in VBAU-L Case

During 2000-2030, the primary energy supply in the low oil price case will increase by more than eight times, from 1187 PJ to 9347 PJ. Coal and oil will play the major role, together contributing 50% to 60%. In the earlier periods of the modelling horizon, natural gas will make a rapid penetration but, after that its growth slows down. In absolute terms, supply of renewables (primarily biomass and large hydro) increases from about 491 PJ in 2000 to 1828 PJ in 2030. However, its share in the total supply falls significantly from about 41% in 2000 to about 19% in 2030. Nuclear makes rapid entry at the end of the modelling horizon and by 2030, contributes about 8% of the total supply. When the oil price is high, the oil requirement falls and the reduction in 2030 is about 22% over the low oil price case. Demand of coal and gas on the other hand, goes up.

Although domestic fossil fuel production increases rapidly, it cannot keep pace with the growing demand. From 2025 onwards, the country becomes a net importer of energy. It imports coal and oil (products) which go up rapidly, particularly coal at the end of the modelling horizon. However, it remains large exporter of oil as well. It is expected to import some amount of electricity although not very large quantity. When the oil price is high, oil import falls by 122 PJ and 622 PJ respectively in 2020 and 2030. Gas import is needed from 2020 and onwards. There is minor increase in coal import as well.

Between 2000 and 2030, CO_2 emissions from the energy sector will increase by more than 10 times, from 54 million tonnes to 569 million tonnes suggesting needs for technological and policy measures to curb it. Despite use of renewables, the domination of fossil fuels (primarily coal) leads to the steep rise in CO_2 emissions. The CO_2 intensity of primary energy supply grows from 45 kg per GJ to 60 kg per GJ in 2030. Per capita CO_2 emissions are expected to increase rapidly from 0.7 tonne to 5.4 tonnes in 2030, same as the current per capita figures for many European countries. The CO_2-GDP intensity rises by almost 50% between 2000 and 2030. When the oil price is high, CO_2 emissions remain more or less same as in the low oil price case.

During 2000-30, total investment requirement in the power sector is about 140 billion €. 65% of the investment is needed on the generation side. Therefore, Vietnam faces a challenging task of mobilising investment of approximately 4 billion € every year to the power sector to meets its growing electricity needs. Undiscounted energy system costs over the whole modelling horizon is 1061 billion € and in high oil price case it is about 20 billion € more.

Technology related scenarios

When advanced fossil and new renewable technologies are brought into the Vietnamese energy system, impacts are expected both in demand and supply sides. Some reduction in the final use of coal and gas are seen as these fuels are diverted for power generation. This reduction is 10% for coal and, respectively, 25% and 39% for natural gas for the years 2025 and 2030. Oil demand goes up as it replaces these fuels.

For power generation, the following observations are made:

- favourable technologies are super-critical, CFBC, Advanced-CCGT,
- some amount of generation from large hydro is replaced with some cheaper options,
- among other renewables biomass, primarily biomass-combustion makes large entry and replaces at some extent generation from mini hydro and wind,
- from 2025 and onwards, BIGCC makes some contribution,
- solar thermal or PV remains unattractive,
- because of a high availability factor, the capacity requirement falls by 6 GW in 2030.

The same amount of energy demand services can be met with about 2% and 12% less primary energy than in the VBAU-L case in the years 2020 and 2030 respectively. Higher efficiency in power generation leads to reduction in coal requirement by 356 PJ and 780 PJ respectively in the years 2020 and 2030, about 17% and 18% over VBAU-L case. Despite higher generation, except in 2020, gas requirement falls due to the higher efficiency in power generation. Oil requirement, on the other hand, will increase by 12% and 18% respectively in 2025 and 2030 as it replaces coal and gas for final consumption which are diverted for power generation. Need for nuclear fuel falls since it is replaced by coal and gas for power generation. There is a mixed impact on energy from renewables.

Vietnam is not a large importer of fossil fuels till 2020 but, however, from 2025 import of fossil fuels goes up in BAU Scenario. Use of more efficient fossil and renewable technologies would limit the import. The overall import (primarily coal) falls particularly from 2025 and onwards. The import dependence i.e, share of import in total primary energy supply, falls from 38.5% in BAU-L in 2030 to 35.7%. The annual import bill in 2030, is expected to fall from 9.2 billion € to 8.4 billion €.

Added environmental and economic benefits are :

- large reduction in SOx and NOx emissions from the power sector resulting from replacement of coal sub-critical with supercritical and CFBC and a higher amount of generation from advanced CCGT.
- savings in CO_2 emissions. The cumulative CO_2 emissions over the modelling horizon fall by about 1.1 billion tonnes.
- savings in energy supply costs. Energy system costs decrease (by 30 billion €). Contributed by less capacity requirement and availability of cheaper technologies, investment requirement in power generation declines by about 10 billion €. Marginal costs of electricity supply falls as well.

CO_2 reduction scenarios

When future oil price is expected to be low, there is reduction in final energy demand. Impact is more prominent in 2030 since reduction target is higher in that year. Model replaces CO_2 intensive coal with efficient and less CO_2 intensive liquid fuels. Gas consumption is reduced as final use since it is diverted for power generation. Impacts on demand sector are higher when advanced technologies for power generation are not available (VCO2-L1(WT)). It should be noted that, the model becomes infeasible when the higher reduction target is applied in absence of additional technologies.

The model selects super-critical, CFBC, advanced CCGT, over subcritical and CCGT technologies for power generation. When the reduction target is higher, it is only super critical which is appropriate for coal based power plants. Nuclear as already has reached specified upper limit in the BAU Scenario itself, cannot make any additional contributions. While hydro power makes an additional contribution in 2020 to curb CO_2 emissions, in 2030, since it already hit the maximum potential assumed in VBAU-L case, no additional contribution is allowed. Increased use of other renewables lead to substantial CO_2 emissions reduction. These renewables include wind, biomass combustion and BIGCC. Solar PV or thermal cannot compete even in the higher CO_2 reduction scenario.

In the low and high CO_2 reduction target scenarios, respectively, 24% and 18% reductions of cumulative CO_2 emissions are achieved. Both targets can be achieved at cost savings over BAU-L, making the marginal cost of CO_2 reduction as zero or negative.

When additional technologies are not available, model picks up CCGT, wind, geothermal and biomass combustions to achieve reduction target. However, an additional cost of 40 billion euro is needed to achieve the low reduction target. Marginal cost of CO_2 reduction is in the range of 17 € to 66 € per tonne.

Primary Energy reduction scenario

According to the VBAU-L/H cases, energy demand grows by a factor of 8 in 2030 as compared to the 2000 level. If advanced technologies can help to reduce energy requirement is analysed. A scenario reducing primary energy consumption by, respectively, 10%, 15% and 20% over BAU-L in 2010, 2015 and 2020 and 25% after that is defined. A similar scenario is also defined for the higher oil price. Model simulation shows that it is possible to achieve this amount of reduction in energy requirement with the adoption of technologies and appropriate energy system changes.

However, similar problem as in Indonesia were encountered while constructing this scenario due to the substitution principle applied for estimating primary energy equivalent of renewable energy technologies and, therefore, the scenario is reconstructed not to apply substitution principle while defining the constraint.

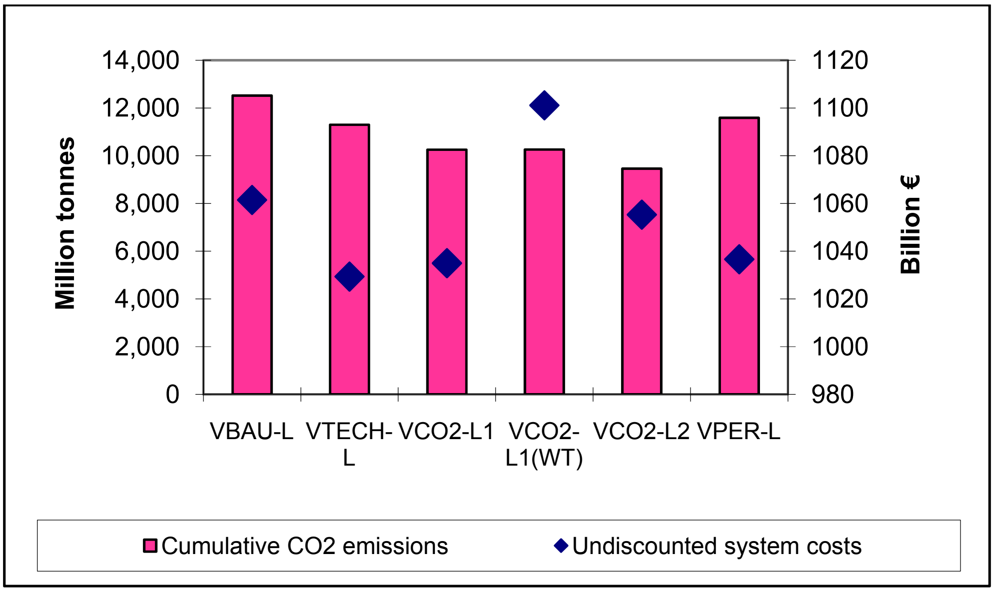

Figure 6: Cumulative CO2 emissions and undiscounted energy system costs in VBAU-L and all Technology related scenarios

Table 7. Advanced fossil and new renewable technologies selected in different scenarios.

Scenario	Fossil technologies	Renewable technologies	Nuclear
Technology Scenario	Super critical CFBC Advanced CCGT	Wind Biomass-combustion BIGCC	Nuclear
CO2 reduction scenario			
Target 1	Super critical CFBC Advanced CCGT	Wind Biomass-combustion BIGCC	Nuclear
Target 2	Super critical Advanced CCGT	Wind Biomass-combustion BIGCC	Nuclear
Energy reduction scenario	Super critical CFBC Advanced CCGT	Biomass-combustion BIGCC Solar PV	

The model does not suggest any significant changes on the demand side when the oil price is low or high. In power generation, the model replaces coal sub-critical, conventional CCGT with, super critical, CFBC, and advanced CCGT technologies. Renewables primarily large hydro, and biomass make larger contribution.

The primary energy supply goes through changes. Coal consumption falls and renewable increases marginally. Reduction in the import amount and import bill is the additional benefit along with reduction in cumulative CO_2 emissions of about 0.9 billion tonnes. Local pollutions reduce too. In addition, the energy system costs decline by about 25 billion € in both oil price cases.

Table 7 compiles the advanced and new power generation technologies those are favourable under different Technology scenarios. Figure 6 compares the cumulative CO_2 emissions and undiscounted energy system costs in different technology related scenarios with VBAU-L case.

Policy and Institutional Framework towards diffusion of clean energy technologies

As the model results suggested, these countries are potentially large market for clean power generation technologies. For the next thirty years, in the Business-as-Usual Scenario, the model projects an additional capacity requirement of 490 GW corresponding to an investment potential of 870 billion €. However, these technologies are often developed and manufactured in industrialised countries, e.g. in Europe. Existing barriers and necessary policy and institutional framework for their diffusion are presented.

Barriers

Given primary concern is to meet the large demand-supply gap of electricity at minimum cost (4 cents per kWh in Indonesia), state of the art fossil and renewable energy technologies which are considered to be expensive, get second priority in investment choices. Inefficient energy pricing is a barrier a too.

Despite international efforts (demonstration projects, capacity building, and information dissemination), the attitude towards renewables is still often negative due to inadequate knowledge and information.

Due to international efforts, renewables has got some place in the policy agenda of the countries concerned, this is not the case for clean fossil technologies. Adequate knowledge on clean fossil technology is missing.

Very often, technology selection is made by a donor country or by available financing (e.g. bilateral export loans or tight aid), leading to sometime inappropriate technology choices. Sometime, financiers come with technology/equipment as package and buyers do not have choice given its weak financial and technical capability.

Policies on pollution control are not tough enough to stimulate demand for cleaner technologies. Given life quality of large part of the population is miserably low, basic amenities like food, health care, shelter are inadequate, in development agenda, environment, particularly global environment, gets back seat.

Ownership matters. Plants own and operated by foreign companies have same technological standards as any of the plant in the developed world.

Universities lack resources as well as interactions with industries resulting into development of human resources or conducting the research activities those are redundant to the industry.

The main focus of the developed world is on India and China when it comes about promotion and transfer of clean coal technologies to developing countries. Countries concerned are ignored perhaps because of gravity of the situation is not well understood. Additional reason may be the under-estimation of the market size.

Companies like ABB and Siemens, the main equipment suppliers of thermal power plants, make efforts to educate decision makers on latest technology development, but perhaps the rigid and traditional thinking of the decisions makers fail to produce results.

Siemens and ABB are concerned that cheap Chinese technologies with cheap development assistance from Chinese government will flood the market, the performances of which are unknown.

Weak contracting procedure and monitoring also may be barriers for diffusion of efficient technologies.

Policy and institutional framework

Foreign Direct Investment (FDI) can be a vehicle to bring capital, technology and management skills which are necessary to these countries to develop its clean technology (CCICED, 2000). However, it needs favourable policies in the recipient countries. For example, while Philippines has total market based approach as far as installation of new power plant is concerned, the master plan restricts foreign investment, such as IPP (Independent Power Producer) and BOT (Built, operate and transfer), to 20% in Vietnam. Similar situation exists in Indonesia as well. 100% ownership of new facilities may be better for technology transfer as foreign company would have more control over the management and operation of the facility as well as higher financial interest in its efficient operation (CCICED, 2000).

CDM can be an effective instrument, however application of CDM in mega size fossil project is still need to be tested.

Regarding renewables, introduction of a quota target is at different stages of discussions in all three countries. Once this is in place, it will give a boost to the renewables. While CDM can be an effective instrument, case-studies have shown that financing schemes for small companies, e.g. soft-loans, subsidies and tax credits, may help to improve the adoption rate (Worrel et al., 2001). Experience of other developing countries may be useful.

Given the capital shortages in these countries, promotion of these technologies through export credits, ODA etc would be beneficial for both donor and recipient countries.

Technology assessments and selections are very important. An important arena for co-operation between the industrialised and developing countries involves the development and strengthening of local technical and policy-making capacity, for example technology assessment capacity.

Technology transfer projects need continued support from the technology supplier. This is all the more true for these countries as given their relatively small market size, unlike India and China, instead of developing manufacturing capacity, they will continue to be the technology buyer. A strong and continued cooperation therefore, is needed between technology supplier and recipient companies.

Transferred technologies seldom reach the designed operational efficiencies, and often deteriorate over their productive life (TERI, 1997) due to several reasons. Improper maintenance, inadequate availability of spare parts and incomplete transfer of &software' are some of the problems. This stresses the need for effective adaptation strategies, including transfer of technical and managerial skills. Technical training is a very important aspect of a technology transfer (Hassan, 1997), and should preferably be done in the local language.

Given the gravity of the two issues, global energy security and climate change, it should be the interests of the developed world to ensure clean technologies to these countries.

Development of industry-educational/research institution partnership is necessary, so that universities consider the industry's need in curriculum development and research activities. A certain percentage of industries profit can be channelled to education, training and research activities.

International R&D collaboration can be an effective means of technology transfer. IEA implementing agreements are at the core of the IEA's International Energy Technology Co-operation Programme. If not directly all countries, engage ASEAN secretariat or ASEAN Centre for Energy (ACE) in these agreements. ACE can play an important role in terms of information dissemination, coordination and as a bridge between developed world and ASEAN members.