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RENEWABLE ELECTRICITY IN THE APEC REGION

INTERNALISING EXTERNALITIES IN THE COST OF POWER GENERATION

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FOREWORD

Numerous studies have shown the growing competitiveness of new and renewable energy (NRE) with conventional fossil fuels, particularly in addressing concerns on energy supply security, rural electrification and environment. Its competitiveness however is undermined by a host of barriers and constraints including technological limitations and costs.

It is for the latter that this study had been prepared: first to determine the real costs of electricity generation by accounting the cost of externalities; and second to study the benefits of internalising the cost of externalities in power generation to the economy as a whole. Externality, which has been constantly negated or ignored in most electricity cost estimations, which when taken into account would actually leverage NRE; thereby increasing its share in future power generation structures of most developing economies in the APEC region.

The report is published as the third in the series of studies undertaken by APERC on NRE since 1999, the most recent of which is the "New and Renewable Energy in the APEC Region: Prospects for Electricity Generation" published in 2004. The report has been prepared as an independent study and does not necessarily reflect the views of the APEC Energy Working Group (EWG) or of the individual APEC member economies.

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List of Abbreviations

AAGR	Average Annual Growth Rate
APEC	Asia-Pacific Economic Co-operation
APERC	Asia Pacific Energy Research Centre
CCGT	Combined Cycle Gas Turbine
EIA	Energy Information Administration (USA)
EU	European Union
EWG	Energy Working Group (of APEC)
GDP	Gross Domestic Product
GW	Gigawatt (10^9 Watts)
GWh	Gigawatt hour (one million kilowatt hours)
IEA	International Energy Agency
kW	Kilowatt (= 1,000 watts)
kWh	Kilowatt hour (= 1,000 watts hour)
KP	Kyoto Protocol
LP	Linear Programming
MOED	Ministry of Economic Development
MOIE	Ministry of Industry and Energy
MW	Megawatts (= 1,000 kilowatts)
MWh	Megawatt hour (one thousand kilowatt hours)
NGO	Non Government Organisation
NRE	New and Renewable Energy
OECD	Organisation for Economic Cooperation and Development
O&M	Operation and Maintenance
PV	Photovoltaic
R&D	Research and Development
RE	Renewable Energy
TW	Terawatt (10^{12} Watts)
TWh	Terawatt hour (one billion kilowatt hours)
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

Power generation in the APEC region is projected to increase from 10,128 TWh in 2005 to 15,722 TWh in 2020, at an average annual growth rate (AAGR) of 3.0 percent.[1] The choice of technology selected to meet this burgeoning demand will depend largely on the costs of power generation technologies and fuels, concerns on energy security, as well as environmental considerations.

Comprehensive environmental policies and obligations under international environmental agreements, like the Trans-boundary Air Pollution Convention for Europe and Kyoto Protocol, in developed economies make environmental considerations a priority in selecting future technology options for electricity supply. For developing economies, however, this may not be a critical concern and could eventually lead to significant environmental and human health implications.

Fossil-fuel combustion is often blamed for direct and indirect impact on public health, air, water, and soil ecosystems that lead to overall environmental degradation. These impacts, either positive or negative, are often defined as externalities and are not included in the cost of power generation in most APEC economies.

While external cost is very site sensitive and technology specific, almost all studies and considerations on externality issues in the past three decades have been implemented in developed economies, mainly in the EU and North America. There is an essential shortage of studies similar to the European research network *ExternE*[2] in developing economies within APEC region.

One approach to address environmental problems caused by burning conventional fuels for power generation is to internalise externalities in electricity costs. This approach would not only reap substantial savings to the economies, but would also create a fairly competitive institutional framework to promote renewable electricity.

A modelling approach was adopted and implemented to assess the impact of internalising the cost of externality in power generation to the share of new and renewable energy (NRE) in electricity production within the APEC region. The main idea was to compare the share of renewable energy in the power generation mix (for all 21 APEC member economies), against that of conventional fossil fuels, under a least-cost optimisation function. The later account total cost for power generation with and without externality cost. A commonly recognisable definition of "externality cost" and its valuation among APEC member economies would however be a critical issue. Still a number of uncertainties might arise, such as projections for future electricity demand, national power grids extensions and development of regional interconnections, not to mention the depreciation of investment cost for NRE caused by technological progress.

KEY FINDINGS AND IMPLICATIONS

Internalising externality costs in electricity production within the APEC region would:

- Increase the share of renewable electricity in total electricity production of the APEC region by about 3 or 4 percent (or between 430 and 600 TWh).
- Increase the average annual growth of renewable electricity production by about 3 to 4 percent from the business-as-usual case.
- Increase the average generation cost of electricity, twice that of its current level.

[1] APERC (2002)

[2] See Box 1 on page 9

Further analyses have shown that:

- Varying degrees of avoided externality cost per KWh or "externality yield" among member economies exist.
- An average of 2 to 3 yield of externality cost per renewable electricity investment cost could be expected.
- Additional investments for renewable electricity will reach about US$200 billion in the next 15 years.
- Externality costs based on *ExternE* assessments are considered to be close to optimal for the purpose of renewable electricity promotion.

Infrastructure constraints and cost of access to renewable energy resources are additional critical issues for renewable energy economics and development.

Regardless of externality, solar technologies have to be subsidised by up to 80 percent of investment cost to compete with traditional power generation technologies; hydro will remain as one of the cheapest option among power generation technologies; while externality accounting would make almost any type of renewable electricity (except solar) competitive with coal generation in any APEC member economy.

Some least sensitive to externality internalisation economies as US, Japan, Korea and Chinese Taipei could have economic and social benefits as a result of the consequential increase in equipment orders for renewable electricity generation.

The study confirms the importance of institutional framework and background studies for assessments of government's subsidies for NRE. However to further promote renewable electricity within the APEC region, studies should be based on a fair market competition approach for different power generation technologies, comprehensive renewable energy resource data, power interconnection and grid development evaluations, research and development (R&D) efforts to decrease the per unit cost of renewable electricity.

INTRODUCTION

INTERNALISING EXTERNALITY COSTS IN POWER GENERATION

Combustion of fossil fuels for electricity generation has been considered to have contributed to human health and environmental degradation. Despite this perceived ill effect, the extent of fossil fuel use has continued to expand because of the apparent low price economies have to pay per kilowatt hour, not realizing the much larger price of mitigating its impacts to people and environment. Numerous studies have been made which attempted to determine the actual costs of these mitigation measures, which have lead to further research using life cycle costs analysis and externality cost accounting.

What is an externality? Why is there a need to determine the cost of externalities in power generation? What is the impact of internalising externality costs to mass deployment of renewables for power generation? How will economies and society as a whole benefit from this? How are these benefits achieved? These are but some of the questions that this study will attempt to answer in the context of rising future electricity demand within APEC member economies.

A recently published report by APERC, entitled: "New and Renewable Energy in the APEC Region: Prospects for Electricity Generation", described the areas where electricity generation could benefit from renewable energy. APEC economies could gain substantial environmental and economic benefits if the share of renewable energy in electricity generation were increased by 42 percent in the next 45 years. This would result in total fuel savings of US$4.4 trillion to US$5.8 trillion, not to mention the avoided CO_2 emissions of 206 billion to 254 billion tons of carbon dioxide equivalent, during the same period.

To achieve these reductions, renewable energy (RE) technologies need to overcome various barriers and constraints either through the application of one or a combination of the following instruments: a) removal of fossil fuel subsidies; b) use of life cycle costs; c) removal of investment and import restrictions for NRE technologies; d) introduction of pollution taxes; e) technology incentives; and f) inclusion of externality costs, among others.

By internalising externality costs in power generation, economies would actually be paying less than the full real cost of mitigating the ill effects of burning fossil fuels.

SCOPE OF THE STUDY

The study extends the previous APERC NRE study's initial findings by attempting to make a comparative cost analysis between renewable energy and conventional fossil fuels by internalising the costs of externalities. It is believed that internalising externality costs would leverage renewable energy technologies against the more popular conventional fuels.

Externalities as considered in this report include the costs and benefits associated with the effects on the physical-biological environment generated from the production and use of electricity which are not reflected on the price. Likewise, all other economic activity which results in a liability or benefit to a third party and which are not reflected on the price is considered externality. Examples of these are: environmental degradation, impact on public health, water and land pollution, concerns on global warming resulting from fossil fuel combustion.

On the other hand, externalities could be transmitted to power generation due to a phenomenon known as "fuel substitution", when consumers are shifted to a rival mode of energy service. One example is in the residential sector where fossil fuel combustion is replaced by electric appliances.

Basic externality assumptions used in this study were taken from estimations made in the *ExternE* project, carried out by the European Union.

CHAPTER I

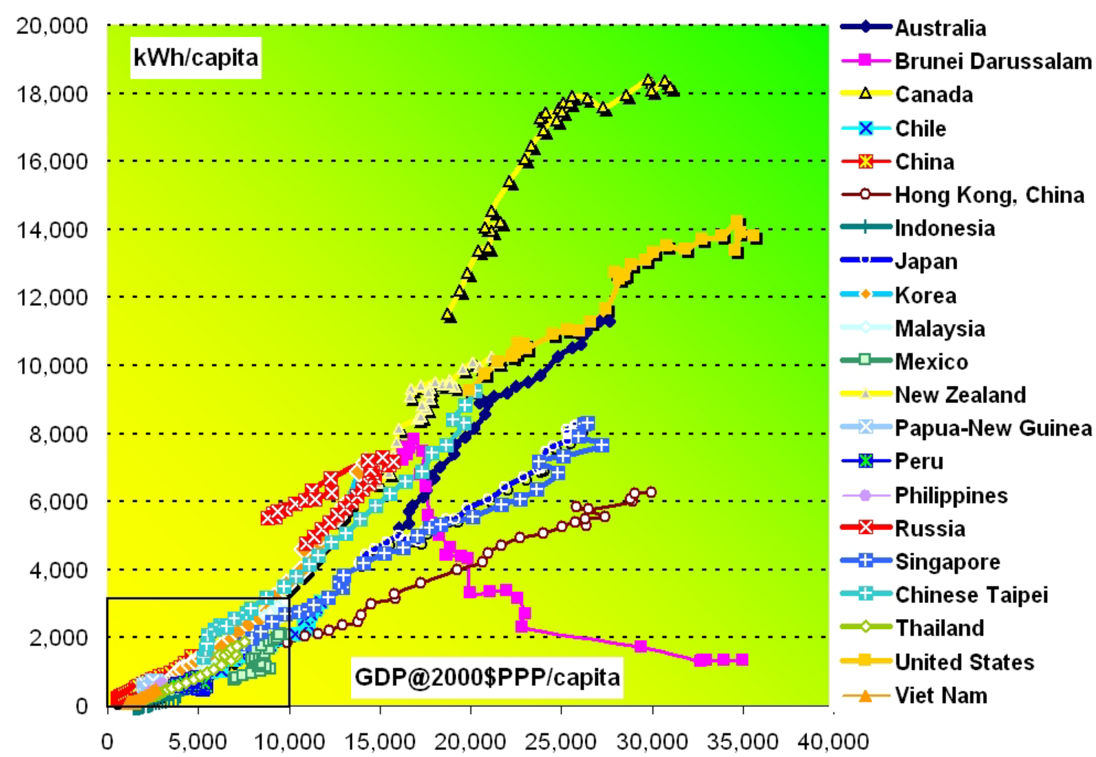
RENEWABLE ELECTRICITY DEPLOYMENT IN THE APEC REGION

ELECTRICITY CONSUMPTION PATTERN IN THE APEC REGION

The demand for electricity in APEC has increased very rapidly over the last two decades and is projected to increase further by 82 percent at an average annual growth rate (AAGR) of 2.9 percent between 1999 and 2020[3]. Electricity consumption from final energy demand in the APEC region accounted for 17 percent in 1999 and is expected to reach 21 percent by the year 2020. Growth in the annual average demand for electricity is expected to be lower than final energy demand at 3.2 percent for the same period, as transmission and distribution losses are projected to fall. Developing economies are expected to have a higher annual growth rate of 5.2 to 5.3 percent for the same period[4]. This is attributable to their current under-developed energy infrastructures as well as their potential economic growth that would, in turn, increase the demand for electricity.

The historical electricity consumption pattern for APEC economies is shown in Figure 1a. Current per capita electricity consumption for most developing economies is still below 2,000 kWh but is expected to increase with their rise in affluence (see Figure 1b).

Figure 1a APEC electricity consumption pattern (1975-2003)

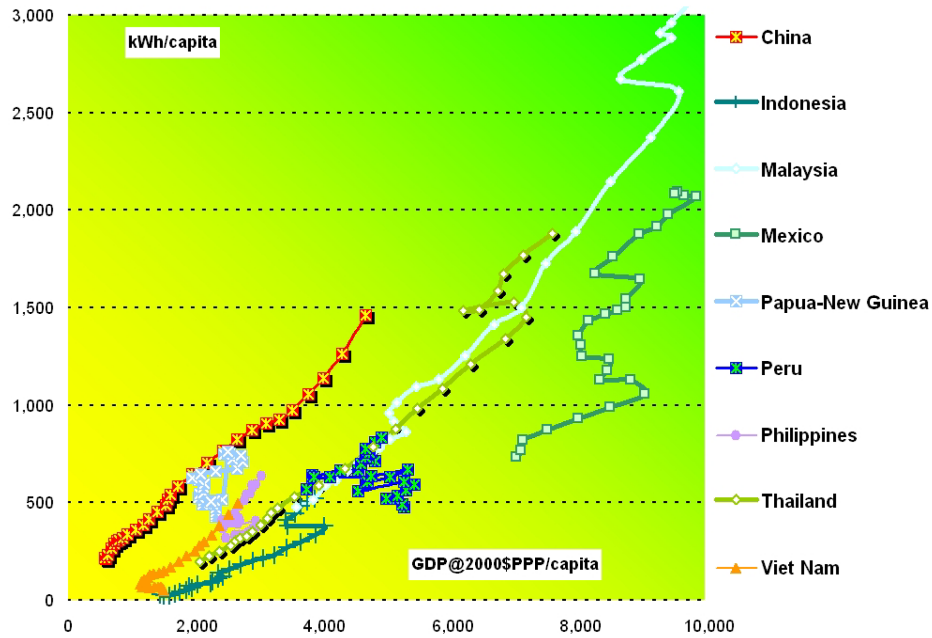


Source: IEA (2005), APERC (2002a), GI (2005)

[3] APERC (2002) APEC Energy Demand and Supply Outlook 2002

[4] *Ibid*

Figure 1b APEC electricity consumption pattern for developing economies (1975-2003)



Source: IEA (2005), APERC (2002a), GI (2005)

The choice of technology to meet this burgeoning electricity demand will depend largely on the cost of technology, fuel costs, construction period, operation and maintenance (O&M) costs, as well as environmental considerations. Comprehensive environmental policies and obligations under international environmental agreement, such as the Kyoto Protocol, in developed economies makes environmental considerations a priority in selecting future technology options for electricity supply. However, for developing economies, this may not be a critical concern and could lead to significant environmental and human health damage.

GROWING ENVIRONMENTAL AWARENESS

The growing awareness of environmental issues and climate change are perhaps the two main motivations to increase the deployment of renewable energy.

There is a general understanding[5] about the unsustainability of fossil fuel and its harmful effect to the environment. Anthropogenic impacts to the environment caused mainly by emissions from power generation facilities became the subject of abatement in regional and international treaties, such as Trans-boundary Air Pollution Convention for Europe (Geneva, 1979), United Nations Framework Convention on Climate Change (UNFCCC, New York, 1992) and Kyoto Protocol to UNFCCC (Kyoto, 1997). Commitments to undertake reduction of polluting substances and air emissions have paved the way for the implementation of less environmentally destructive energy sources, i.e. renewable energy, thus leading to more innovative mechanisms for its extended use.

Environmental movements worldwide have also helped in 'greening' policies. Governments as policy actors have been in active pursuit of promoting "environment friendly" technologies as opposed to conventional fuel technologies.

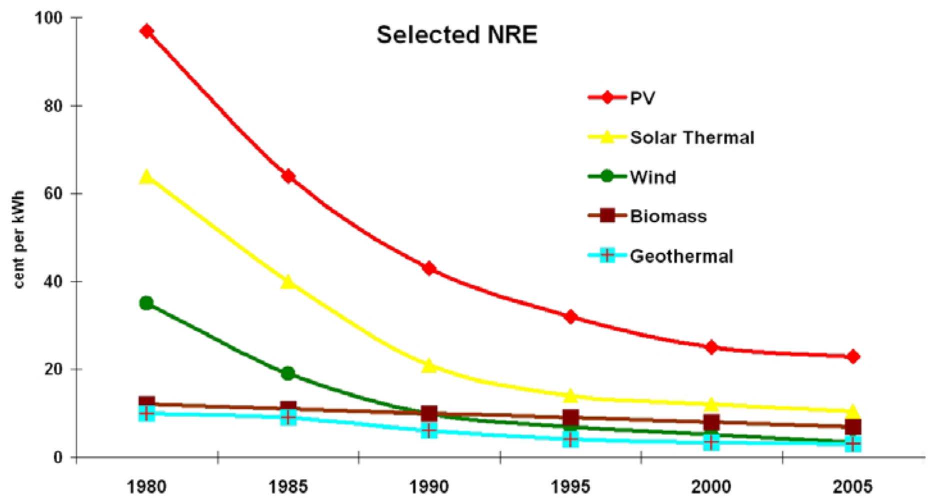
Production of electricity using renewable energy technologies are widely accepted although some of the technologies may not be competitive with conventional fuels. The main reason for its non-

[5] Rio-de-Janeiro (1992)

competitiveness is the high investment cost. However, studies have shown that despite the high capital costs, electricity production cost using selected renewable energy technologies have been declining as techniques to manufacture NRE technologies improve with time and the level of installed capacity increases.

Figure 2 illustrates the steeper learning curves for photovoltaic (PV), solar thermal, and wind than biomass and geothermal as an indication of cost reduction in the development of renewable energy.

Figure 2 Cost reduction for renewable electricity (1980-2005)



Source: Data NREL (2005) and reconstructed by APERC.

Despite the high investment costs, renewable energy technologies worldwide have recorded gradual growth for more than two decades. Taking into account a very small base, the share of NRE, nevertheless, is negligible in terms of total electricity production. The growth relied mostly on various policy interventions in developed economies. The competitiveness of some renewable energy like wind, biomass and geothermal relied heavily on subsidies and other financial incentives it received from government funding. A fact that is often taken for granted is that traditional fuels also received massive amounts of incentives in the form of subsidies and other indirect benefits that were not included in the final cost analysis.

RENEWABLE ENERGY POLICY BASICS

While some renewable energy technologies may not be competitive commercially, as a result of government's responsibility to establish adequate and reliable supply of energy that is environment friendly, efforts have been initiated towards the removal of barriers that impede greater deployment of NRE technologies, including the issuance of subsidies. After NRE technologies became mature and competitive, preferences are usually then eliminated to remove distortions of market signals. Government's policy and system of economic instruments, including taxation and budget subsidies, at the end are aimed at ensuring fair competition among producers of commodities and services for better consumer's satisfaction, also taking into consideration public health and environment improvements.

Sufficient government intervention therefore is absolutely necessary in the early stages of research and development (R&D) to the point where technologies can be commercially viable in the electricity market. Assessment of NRE competitiveness with subsidies is essential for renewable energy policy fundamentals. While there are numerous instruments for renewable energy promotion, such as Renewable Portfolio Standards, Feed In Laws, and various tax incentives and subsidies, the underling basis is the "real cost" of technology, the total unsubsidised cost of renewable electricity production.

CHAPTER II

ASSESSING THE IMPACT OF EXTERNALITY COST ON RENEWABLE ELECTRICITY

WHAT IS ENVIRONMENTAL EXTERNALITY?

The combustion of coal in industry and by power plants throughout South East Asia and parts of North East Asia without or very limited flue gas pollution control technologies has led to the gradual degradation of air quality. Emissions of sulphur and nitrogen oxides – as a result of limited desulphurization capacity – have also led to a higher incidence of acid rains that posed significant detrimental impacts on both human health and agricultural productivity, especially food security.[6,7] Added to these are the large volumes of water used in power plants – especially nuclear power plants – for cooling off boilers/reactors. This water is typically collected from either riparian or marine sources and after the water has been used, it is usually discharged to this same source; at higher temperature than when it was originally obtained thus causing the rise in temperature of the receiving body of water. This phenomenon is referred to as thermal pollution and causes both thermal shock and thermal enrichment of the receiving water body; both of which reduce the amount of dissolved oxygen. In extreme cases, thermal pollution can put stress on temperature sensitive species causing death, which in turn could have a negative effect on the food chain that may cause some adverse effects on the ecosystem in question.

The above are examples of environmental externalities in the power sector; in that the costs/liability associated with this pollution of the "greater environment" are not completely reflected in the price that consumers pay for the electricity they consume. Likewise it follows that any economic activity that results in a liability (or benefit) to a third party, but is not reflected in its price, can be considered as an externality. Environmental degradation, impact on public health (that is, loss of work days, health care costs), water and land pollution, in addition to the concerns surrounding global warming from fossil-fuel combustion are currently not included in power generation cost for the majority of APEC economies.

Evaluating the costs of environmental externalities is however very difficult and centered on assumptions that can be subject to wide and varied interpretation. These costs are also very site sensitive and technology specific, with almost all studies and considerations on this externality issue in the past three decades having been implemented in developed economies, mainly in the EU (please see Box 1 "European experience") and North America. As there is a shortage of studies similar to the European research network *ExternE* for the developing economies of the APEC region the externality costs for each fuel type from the European study have been used in this report. It should be noted that NRE also have some environmental burdens other than life cycle emissions, which can include visual impacts, noise and some ecological impacts. For example in the case of wind technologies birds can be killed when colliding with turbine blades, and with some ocean technologies the ability of marine species to move freely is impaired by the construction of weirs and permanent structures within the harbours/estuaries. However, the externality costs associated with these environmental impacts are very site specific and usually reversible; therefore, for all intents and purposes tend to be lower than that of conventional fossil fuel power plants[8].

[6] UK (2005)

[7] WSJ (2006)

[8] It is important to note that for conventional technologies initiatives such as scrubbers and desulphurization units can also be installed to minimise air pollutions.

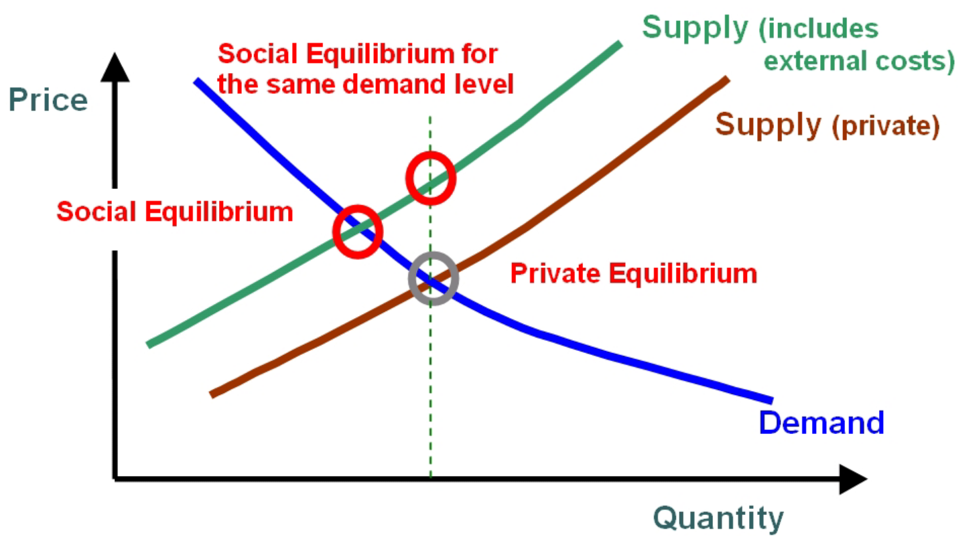
EXTERNALITY THEORY

For environmental economics, one of the most important market failures is caused by negative externalities. A negative externality occurs where a transaction imposes costs on a third party (not the buyer or seller) who is not compensated. Environmental externalities generally arise for three reasons:

- Common resources (not privately owned - e.g. ocean fisheries)
- Public goods (indivisible common resources - e.g. the air)
- Future generations (sources of externality include ecosystems and infrastructure degradation)

In these cases, **private equilibrium** of supply and demand is not the same as the **social equilibrium** which includes all costs[9], Figure 3.

Figure 3 Optimal private and social costs for electricity demand



Source: *UOS (2005)*

Externality arises when "private costs or benefits to the producers or purchasers of a good or service differs from the total social costs or benefits entailed in its production and consumption"[10]. An "external cost" or "negative externality" results when part of the cost of producing a good is born by a subject other than the producer or purchaser. Externalities of either the "positive" or the "negative" sort create a problem for the effective functioning of the market to maximize the total utility of the society. The "external" portions of the costs and benefits of producing goods are not factored into its supply and demand functions because rational profit-maximizing buyers and sellers do not take into account costs and benefits they do not have to bear. Hence a portion of the costs or benefits will not be reflected in determining the market equilibrium prices and quantities of the good involved.

[9] UOS (2005)

[10] Glossary (2005)

Box 1 The European experience

Determination of the external costs … is the monetary quantification of socio-environmental damage.

An external cost, also known as an externality, arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group. The consideration of external costs is one way of re-balancing social and environmental dimensions with purely economic ones.

There are several ways of taking account of the cost to the environment and health, i.e. for "internalising" external costs. One possibility would be environmental regulations (e.g. limit values for emission of pollutants), eco-taxation or tradable permits. Another solution would be to encourage or subsidise cleaner technologies thus avoiding socio-environmental costs.

External costs have to be quantified before they can be taken into account and internalised.

This is precisely the goal of the ***ExternE* (External costs of Energy) European Research Network** active from the beginning of the Nineties last century. These multidisciplinary teams of researchers adopted a common methodology, conducted case studies throughout Europe and succeeded in presenting robust and validated conclusions. Within this coherent framework, the *ExternE* results allowed different fuels and technologies for electricity and transport sectors to be compared. ***Policy actions could therefore be taken to tax the most damaging fuels and technologies*** (like oil and coal) ***or to encourage those with lower socio-environmental cost*** (such as renewables or nuclear). The internalisation of external costs will also give an impetus to the emergence of clean technologies and new sectors of activity for research-intensive and high added value enterprises.

… in … widely accepted evaluation methods such as green accounting, life-cycle analysis and technology comparison, the quantitative results of external costs are an important contribution to the overall results.

External cost data gained from *ExternE* are useful for a quantitative comparison of magnitude with each other as well as with other data expressed in monetary values …. Such a comparison represents a trade-off ratio between marketed and non-marketed goods that is based on a consistent … approach of individual preferences and willingness-to-pay.

[Externality] Numbers have … already been used in several policy areas, such as economic evaluations of the draft directive on non-hazardous waste incineration, the Large Combustion Plant Directive, the EU strategy to combat acidification, the National Air Quality Strategy, the Emission Ceilings Directive, proposals under the UNECE multi-pollutant, multi-effect protocol and many more policies, green accounting research projects, and air quality objectives.

External Costs: ***Research results on socio-environmental damages due to electricity and transport***

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The price of the commodity producing the externality will tend toward equality with the marginal **personal** cost to the producer and the marginal **personal** utility to the purchaser, rather than toward equality with the marginal **social** cost of production and the marginal **social** utility of consumption. Thus, normal market incentives for the buyer and seller to maximize their personal utilities will lead to the over- or under-production of the commodity in question from the point of view of society as a whole, not the socially optimal level of production. Commodities involving a negative externality will be "overproduced" from the point of view of society as a whole. For electricity production it means that conventional technology for power generation (i.e. coal burning) with high external costs would be overproduced at the expense of more environmentally friendly renewable electricity.

APPLICATIONS OF EXTERNALITY

Government regulations or tax policies are often justified to the public as a means of "correcting" the outcome of the market for goods involving especially sizable negative externalities. The government special charges would force the sellers (or the buyers) of the good or service to begin to start taking into account these external costs along with their own and would effectively shift the supply curve (or the demand curve) to the left, resulting in somewhat smaller quantities of the good being sold at a somewhat higher price in the new equilibrium after inauguration of the tax – and thus, somewhat fewer costs will be imposed on third parties.

Internalisation of external costs into the full energy production cost could be an efficient policy instrument to reduce these negative impacts and move towards more sustainable energy supply and use. The convenience of merging production cost with external cost into a total specific cost is in the fact that this approach can serve as a comparative indicator for evaluation of economic and environmental performance of energy technologies. Consideration of externalities is useful for providing an indication of damages/benefits associated with different energy options, for assessing trade-offs between different energy options, for ranking energy options and for introducing economic instruments that reflect the social as well as economic costs of energy[11].

Although such an instrument omits other important aspects of the policy- and decision-making processes, for instance the political and social acceptance of certain energy systems, it is important to know, what the possible effects are of internalisation of externalities in the energy system, as it might affect greatly the cost of electricity production and structure of the power generation industry.

External cost values used in this study have been derived from the outcomes of the European Commission *ExternE* Project. The methodology used for this project attempts to apply the impact pathway approach, i.e. the pathways of polluting substances are followed from the release source to the point of damage occurrence. The consecutive negative impacts (damage) are quantified using a damage function. Economic valuation of the damage is obtained by the "willingness to pay" of the affected individual to avoid a negative impact resulting from energy production from an actual power plant. This 'bottom-up' approach emphasizes detailed site-specific characterization of technologies, enabling consideration of every important stage in different energy chains and comparison between different fuel-cycles and different types of burden and impact within a fuel-cycle[12].

There is also a direct approach to reducing environmental externalities costs; that is, **reducing the emissions of pollutants** which adversely affect the environment, see Box 2 "Direct approach to control damaging pollutions".

In comparison to the direct approach, externality cost considers many more negative external factors other than just pollution, and is, thus more comprehensive. Other advantage for this policy is possible collection of additional cash flow to special funds for subsidizing research and development (R&D) and the renewable electricity industry as a whole.

Nevertheless, *ExternE* methodology is sometimes criticized by pointing at the [large] uncertainties involved[13]. Individual sources of uncertainty have to be identified and quantified. It is appropriate to group them into different categories, even though there may be some overlap. These categories include, data uncertainty, model uncertainty, uncertainty about policy and ethical choices, uncertainty about the future, and idiosyncrasies of the analyst.

Box 2 Direct approach to control damaging pollutions

This approach reduces emissions implying institutional measures as maximal permissible emission of specific pollutants, prohibition to operation (or construction) under specific conditions, *etc.* This direct approach can easily be combined with a market-based approach to cost minimization, through the application of a single output-based emissions standard for each of the pollutants of concern combined with an emissions allowance trading system which permits more efficient and less emitting producers to sell allowances to less efficient and producers with higher emissions.

This approach would provide non-government-funded incentives for the construction of new, high efficiency, low emissions generators of all types (the market value of the allowances available to be sold), and economic incentives to the owners of existing, low efficient and polluting power generators to close down such facilities.

[11] IIASA (2003)

[12] EU (2003)

[13] Ibid.

Despite these uncertainties, according to *ExternE*, the use of the methods described here are seen to be useful, as the knowledge of a possible range of the external costs is obviously a better aid for policy decisions than the alternative – having no quantitative information at all:

- The relative importance of different impact pathways is identified
- The important parameters or key drivers, that cause high external costs, are identified
- The decision making process will become more transparent and comprehensible; a rational discussion of the underlying assumptions and political aims is facilitated

"It is however remarkable that despite these uncertainties, certain conclusions or choices are robust, *i.e.* do not change over the whole range of possible external costs values. Furthermore, it can be shown that the ranking of electricity production technologies with respect to external costs does not change if assumptions are varied.

Thus, the effect of the uncertainty of externalities depends on the application. The key question is: what is the increase in total life cycle cost to society if one makes the wrong choice? A detailed analysis of this question in a specific situation involves the probability distribution of the total social cost for each of the options under consideration, to estimate the expectation value of the social cost or the probability of making the wrong choice"[14].

In the absence of a comprehensive definition and assessment of externality cost within the APEC region, the study attempts to apply identical externality costs to all APEC member economies. However, it is limited to assessing the impact of externality accounting to the competitiveness of renewable electricity against other conventional technologies to produce electricity in APEC region.

Table 1 shows the estimations of average European externality values for aggregated technologies of electricity production. Some externality cost assessments are non-zero for geothermal technology, but considering hot springs or dry rock technologies it is assumed that the absence of any external cost has occurred. Authors make non-zero externality values for ocean power generation technologies as well as for solar thermal power to reflect some health and environmental damage currently not estimated within the *ExternE* methodology.

Table 1 Basic externality cost for electricity production.

Technology	Externality value range[1]	Adopted for this study	Number of EU-15 economies with externality values
	¢ per kWh	*¢ per kWh*	
Coal steam turbine	2.0-15.0	**8.5**	12
Petroleum turbine	3.0-11.0	**2.5**	5
Combine cycle natural gas turbine	1.0-4.0	**2.5**	21
Nuclear electricity (including fuel chain)	0.2-0.7	**0.45**	5
Biomass steam turbine	0-3.0	**2.5**	11
Hydropower	0-1.0	**0.5**	7
Geothermal power[2]	0.2-0.5	**0**	
Wind turbines	0.05-0.25	**0.25**	6
Ocean power generation technologies[3]	n.a.	**2.0**	-
Solar thermal power[3]	n.a.	**2.0**	-
Photovoltaic power generation	0.6	**0.6**	1

Note: [1] *Estimations based on EU (2003);* [2] *IIASA (2003);* [3] *Authors estimations*

[14] EC (2003), p.17

ASSESSMENT METHODOLOGY

This section will describe the methodology in assessing the consequences for renewable energy in case of externality internalisation for electricity production within APEC region. Impact assessment of externality internalisation could be made by comparison of future rational structure of power generation with and without externality cost accounting in total electricity production cost for all 21 APEC member economies.

Two important issues are addressed by this methodology, through total electricity production cost calculation, and determination of the future structure of power generation. Common rule for cost calculations in power generation is to split total cost of electricity production to investment cost (for new generation capacities), operation and management cost, and fuel cost. Externality cost will make another addendum to this formula. A common approach to determine future rational structure of power generation is to find out least-cost solution under circumstances for existing generation capacities, assumptions for electricity production costs and compulsory projected targets. Usually, an optimisation economic model is applied to get this solution.

When applying the formal methods, a lot of assumptions should be made in order to make compromise between quality of the solution and ability to fit requirements for these formal methods used. The first compromise would be the number of power generation technologies under consideration and electricity production projections for each APEC economy. In total, eleven aggregated technologies for electricity generation are considered; four are fuel based and seven related to renewable energy technologies. The structure of electricity production for the base year 2005 and electricity production targets for year 2020 are similar to the latest APERC Outlook for Energy Demand and Supply[15].

A formal optimisation method called "linear programming" (LP) was implemented to determine the future generation mix for each APEC economy in the year 2020. The only two compulsory conditions are to meet projected electricity demand and provide least-cost electricity supply. In order to implement the formal optimisation method the LP model for each APEC economy has to be described and then "solved". The solution is the structure for electricity production for a given economy in the year 2010 and 2020, under the same constraints but for different objective functions. Generation mix for two cases has to be compared: 1) the "Business-As-Usual" (BAU case), and 2) policy implementation for monetising externalities and internalising them in total electricity production cost, hereinafter referred to as the "Externality" case.

This model requires some important data sets to be determined and quantified:

- Leveraged cost of electricity produced by each technology under consideration
- Limitations on new power generation capacity construction
- Current structure of electricity production and future production targets

LEVERAGED COST OF ELECTRICITY PRODUCTION

Leveraged cost of electricity production (LeveragedCost) is the sum of four components – investment cost, operation and management cost (O&M), fuel cost and externality cost, all referred to one kWh production cost:

$$\textbf{LeveragedCost} = \textbf{InvestmentCost} + \textbf{O\&MCost} + \textbf{FuelCost} + \textbf{ExternalityCost}$$

Investment cost refers to the construction of new generation and does not include the cost of electricity grid enhancement. It is important to note that in the case of remote locations of renewable energy utilities, such information could be obtained only on an individual project basis, and could not be used as an average indicator. Specific capital costs for technologies are used as default values if economy-specific data is not available (for default values please refer to Box 3 "Default values for leveraged cost"). The cost of capital is incorporated into the technology's capital cost as a loan coefficient, calculated on

[15] APERC (2002)

the basis of lead time for each technology, interest rate and profile of total investments spent during construction period.

$$\textbf{InvestmentCost}\ [\$/\text{kWh}] = \frac{\text{Specific\_cost}[\$/\text{kW}] \times \text{Loan\_coefficient}[]}{\text{Lifetime[year]} \times \text{Capacity\_factor[hours/year]}}$$

$$\textbf{Capacity\_factor}\ [\text{hours/year}] = \frac{\text{Electricity\_Sales\_to\_Grid}\,[\text{kWh/year}]}{\text{Installed\_Capacity}\,[\text{kW}]}$$

$$\textbf{Loan\_coefficient}\ [] = \sum_{t=1}^{Tlead} \alpha_t \times (1+ir)^{Tlead-t}$$

where *Tlead* – lead-time for facility construction;

α_t – share of total investment spend in year *t* of construction;

ir – interest rate for loan;

For α_t values and interest rate for loan implemented please see Box 4 "Loan coefficients and investment spending profile".

Box 3 Default values for leveraged cost

Technology	Overnight cost	Fixed O&M cost	Capacity factor	Efficiency	Lead time	Life time
	$/kW	*$/kW*	*%*	*%*	*years*	*years*
Coal based	1100	30	80	37	4	30
Gas based	560	12	65	51	3	20
Petroleum based	400	13	20	32	3	20
Nuclear	2000	70	85	not appl.	6	30
Biomass	2000	20	50	– " –	4	20
Hydro[1]	1500/2500	15	45	– " –	4	50
Geothermal[2]	3100/5000	110	45/90	– " –	4	20
Solar thermal	3000	40	20	– " –	3	20
Solar PV	5000	12	15	– " –	2	20
Wind	1200	20	25	– " –	3	20
Ocean[3]	2000/5000	40	20/35	– " –	4	50

[1] large/small size
[2] hot springs/dry rock
[3] tidal/OTEC, current or wave
Sources: IIASA (2003), EIA (2005), ICRE (2004)

Box 4 Loan coefficients and investment spending profile

		% Shares of total investments during lead time					
Loan Coefficients	**Year**	**1**	**2**	**3**	**4**	**5**	**6**
1.05	1	100					
1.071	2	60	40				
1.087275	3	50	30	20			
1.112101	4	35	30	20	15		
1.126454	5	30	30	20	10	10	
1.154262	6	24	23	20	15	10	8

Operation and management costs refer to the cost of all operating expenses for power generation except for capital assets, expansion investments and fuel cost. The cost of dispatching was also not considered, since it is rather complicated to include it in the assumptions adopted for this study. This means that the cost of reserve capacity, maintenance, economic losses due to excess (or deficit) of generation capacity, reliability, static and dynamic stability, transmission lines restrictions and losses, *etc*, are not included into O&M cost for electricity production.

$$\textbf{O\&MCost}\ [\$/\text{kWh}] = \frac{\text{O\&MCost\_per\_kW}[\$/\text{kW}\cdot\text{year}]}{\text{Availability\_factor[hours/year]}}$$

Fuel cost is what is paid for fuel consumed for production of electricity available for on-grid wholesales or on-site consumption.

$$\textbf{FuelCost}\ [\$/\text{kWh}] = \frac{\text{Fuel\_price}[\$/\text{toe}]}{11630\,[\text{kWh/toe}] \times \text{Thermal\_efficiency}[\,]}$$

In case of nuclear technology:

FuelCost [$/kWh] = **Fuel_cost_nuclear** [$/kWh]

The default values for nuclear fuel costs were assumed at 1.6 cents per kWh, as reported by TEPCO for fuel cycle costs,[16] however, there are very differing indications of these costs among APEC economies, being dependent on confidentiality, energy policy and security issues.

Subsidies, fees and taxes are the mainstay of renewable energy policy and thus should be identified **after** assessing the impact of externality cost internalisation. These economic instruments have to be treated "as is" in case of fuel prices gathered on individual economy basis.

The externality cost for each of the eleven technologies considered was defined earlier in this report as constant for the specific technology of electricity production, and applied uniformly for each of the 21 APEC member economies.

ExternalityCost [$/kWh] = **Constant**, for each aggregated power generation technology considered.

All components of the production cost should be leveraged and relate to 1 kWh of electricity sent to the power grid from the production site. Table 2 indicate the structure of leveraged cost depending on cost interpretation for objective functions coefficients in the model.

Table 2 Components of leveraged cost

	InvestmentCost	O&MCost	FuelCost	ExternalityCost
LCost	●	●	●	
$\text{LCost}^{\text{-Inv}}$		●	●	
$\text{LCost}^{\text{+Ext}}$	●	●	●	●
$\text{LCost}^{\text{-Inv+Ext}}$		●	●	●

[16] APERC (2004), p.34

LIMITATIONS OF NEW CAPACITY CONSTRUCTION

Two time periods are considered: 2005 to 2010 and 2011 to 2020, based on the previous 2002 APERC Outlook projections for electricity demand. It is assumed that for each given technology, any increase in electricity production will require expansion of generation capacity (i.e. the necessity to build new power production assets), while decline will mean a simple switching off of existing capacity.

Assumptions for maximum available additional generation capacity for each technology are based on two sources:

- Official projections for fuel and nuclear power plant construction (applicable for *Coal, Natural Gas, Petroleum, and Nuclear* electricity production)
- Possible renewable capacity construction for renewable energy resources, where **physical and technical obstacles** to erect generation facilities and associated infrastructure – roads, grids, construction capacity – are **the only restrictions** considered (applicable for *NRE technologies*).

Authors were responsible for raw estimates of possible additional renewable electricity generation capacity construction as little data is available for renewable electricity technological (neither natural nor economic) potential. High limitations on NRE capacities were assumed to encourage governments to consider different types of renewable electricity, as well as making room for NRE development in case of competitiveness to conventional power generation technologies.

Domestic electricity production should be the only source to meet future electricity needs. This means that within each economy no interconnections were considered, while new generating capacity construction is the only option to meet growing projected demand. This is in accordance with the APEC projections for each economies domestic power generation; in which the interconnections issue has already been discussed[17]. The only exception is Hong Kong, where wind and nuclear-sourced electricity have to be imported from nearby Guangdong province.

TOOLS IMPLEMENTED

To determine the least-cost electricity production the model is used with and without externality accounting in objective function for minimising total leveraged cost for each APEC economy's projected electricity production in the year 2020. For more detailed definitions please see Appendix II. The difference in the solutions for the two objective functions would equate to the effect of internalisation of externality costs for electricity production.

Assessments of renewable electricity subsidies (if there is a need for it) were done by equalising the leveraged cost of NRE electricity production to that of conventional technologies, like coal, petroleum, natural gas, or nuclear. Specific investment costs per kW of installed renewable energy facilities were calculated, which could provide an idea of the competitiveness of NRE with conventional power generation technology. For more detailed definitions please see Appendix II.

ECONOMY SPECIFIC INFORMATION

Power generation technologies are aggregated to eleven groups; five of them are fuel-driven (including biomass) while others are fuel-free renewable energies, see Table 3. The latest data for fuel prices, construction and operation costs, as well as average capacity factors and energy efficiency were collected from national economy sources/databases wherever possible.

[17] APERC (2002a)

Table 3 List of aggregated technologies for electricity production

Technology	Comments
Coal	Conventional steam turbine technology
Petroleum	Conventional steam turbine technology
Natural Gas	Conventional steam, and/or gas turbine, and/or combined cycle technologies, depending on economy
Nuclear	Conventional nuclear technologies
Biomass	Conventional steam turbine technology, based on burning biomass in boilers. The main source of biomass could be agriculture and forestry wastes, municipal garbage for small economy, like Hong Kong, Singapore, Brunei Darussalam, and/or specially grown up plants
Wind	Traditional and/or offshore windmills
Ocean energy	Usually current technology is considered, rather then tidal, wave or OTEC (Ocean Thermal Energy Conversion)
Hydro	Here we combine both small and conventional hydro power plants, as it is very difficult to find data for splitting between them
Geothermal	Hot springs and/or dry rock technology is considered, depending on economy
Solar thermal	Technology for converting solar power to electricity through thermal cycle via conventional steam turbine
Solar photovoltaic	Direct conversion of solar power to electricity

However default values were utilized in cases where economy specific information was not available. Default values are based primary on the Annual Energy Outlook 2005 published by the Energy Information Administration (EIA), Department of Energy, United States of America[18]. For nuclear fuel, default values are borrowed from Japanese nuclear generation cost breakdown as this data includes information on the costs of fuel procurement, reprocessing and waste management[19].

The costs of feedstock collection, pre-processing and transportation to a utility are included in the default value of 20 US$/toe for biomass fuel. Averaged for a specific economy prices for petroleum products, natural gas and coal refer to the latest available real data, where possible. Fuel prices usually are treated as confidential and are very sensitive information in business.

Lead-time is seen as the average time period for actual construction works. Lifetime is assumed to be the number of years from construction to decommissioning/renovation of the production equipment. Interest rates were set to 5 percent for all of APEC economies, as there is not enough information for future economic and financial environments of each economy.

Power plant thermal efficiency is assumed as an average for the aggregated technology. This parameter makes sense only for coal, natural gas and petroleum based technologies in the model described.

Capacity factor parameter is used for conversion from the electricity produced to power generation capacity and vice verse. This could lead to the mismatch of calculated and actual available capacities for given technology.

Limitations on new capacity construction for coal, natural gas, petroleum and nuclear technologies were derived from official projections, where possible. For renewable energy technologies, "reasonable" restrictions were set, based on physical availability of such resources, as opposed to previously made projections, outlooks, forecasts and other estimations for renewable energy utilisation.

[18] EIA (2005)

[19] APERC (2004), p.34

CURRENT AND FUTURE ELECTRICITY PRODUCTION

The structure of electricity production for the 2005 base year by technology is set for each APEC economy as is currently fixed in the APERC (2002a) projection database while the total electricity production for years 2010 and 2020 should meet target levels, please see Table 4.

ECONOMY CASE STUDIES

Assessments were made for each APEC member economy as individual case studies through the following steps:

- economy-specific technology cost and fuel price information collection. Energy policy surveying, in particular proposed construction of new generation facilities for convention power generation technology, and technical potentials for renewable electricity
- leveraged cost of electricity production calculations
- renewable electricity investment cost depreciation to the level of economically competitiveness against conventional technologies of power generation assessments
- optimisation model runs and comparison of results for BAU and "Externality" cases

Results of the analyses for each of the 21 APEC member economies are presented in Appendix I.

Two exercises were done to understand robustness of results obtained and estimate it sustainability and sensitivity. First, overnight costs for all NRE technologies were increased by 20 percent and operation and management costs by 7 percent, in an attempt to compensate for the additional cost of transmission line construction and dispatching costs due to the intermittency of renewable energy technologies. Second, variations of adopted externality cost for all power generation technologies were applied, making it vary uniformly for "Externality" case from 1/3 to 4/3 of initial values.

In the following chapter, results of the analysis and its implications for renewable electricity in the APEC region under policy of externality internalisation are described.

Table 4 Projected electricity production in the APEC region, TWh

Economy	2005	2010	2020
Australia	232.6	258.8	315.3
Brunei Darussalam	2.9	3.3	4.5
Canada	607.2	657.7	749.3
Chile	53.8	69.5	131.0
China	1696.3	2194.5	3559.8
Hong Kong, China	40.0	52.9	91.5
Indonesia	121.9	170.9	322.5
Japan	1123.9	1229.0	1396.1
Korea	373.7	498.0	700.3
Malaysia	92.5	116.0	2185.5
Mexico	266.0	374.3	609.0
New Zealand	41.3	44.5	50.0
Papua-New Guinea	2.6	3.0	4.0
Peru	21.6	27.2	43.8
Philippines	53.7	74.3	134.5
Russia	1036.1	1190.5	1602.1
Singapore	42.1	53.3	80.2
Chinese Taipei	208.8	256.4	362.3
Thailand	103.1	138.9	259.7
United States	4010.0	4322.0	5085.0
Viet Nam	53.0	97.5	220.0

Source: *APERC (2002a)*

CHAPTER III

STUDY RESULTS

This chapter provides detailed discussion on the impact of internalising externality costs on the share of renewable electricity in electricity production within APEC region. Discussions will focus on comparative cost benefits of internalising externality in power generation against that of the business as usual (BAU) case.

In order to minimize the uncertainties due to methodological and information flaws, comparative differences instead of absolute values (associated with BAU and "Externality" cases) were analysed.

To evaluate the validity of the results against that of the reference externality cost values used, including other cost assumptions (i.e. investment and O&M costs for renewable), the authors deemed it necessary to run a sensitivity analysis of the results based on upper and lower value assumptions.

IMPACT ON RENEWABLE ELECTRICITY SHARE

Renewable electricity production in the "Externality" case will increase by 433 TWh against that of the BAU case, which will equate to about 2.7 percent of the total projected APEC electricity production in the year 2020. The main reason for this difference is the shift from "cheap" but more polluting coal to renewable energy technologies. This estimation is considered the 'upper limit' or the highest possible share for renewable electricity based on the following restrictions:

- High limitations on new NRE generation capacity (assumed for all APEC economies), which reflects technical possibilities for such construction rather than official projections for renewable electricity development or economically effective projects.
- High externality costs assumptions for all APEC economies, thus significantly lowering competitiveness for conventional technologies.
- Underestimation of transmission and dispatching cost in leveraged electricity production costs for optimisation model, thus making renewable electricity more competitive to conventional fuels.

Some NRE technologies are already cost-effective in the sense that the leveraged cost of electricity production and overnight capital cost for these technologies have been declining, especially for wind and photovoltaic technologies. More NRE technologies gain competitiveness towards conventional fuel-based power generation technologies when externalities are internalised.

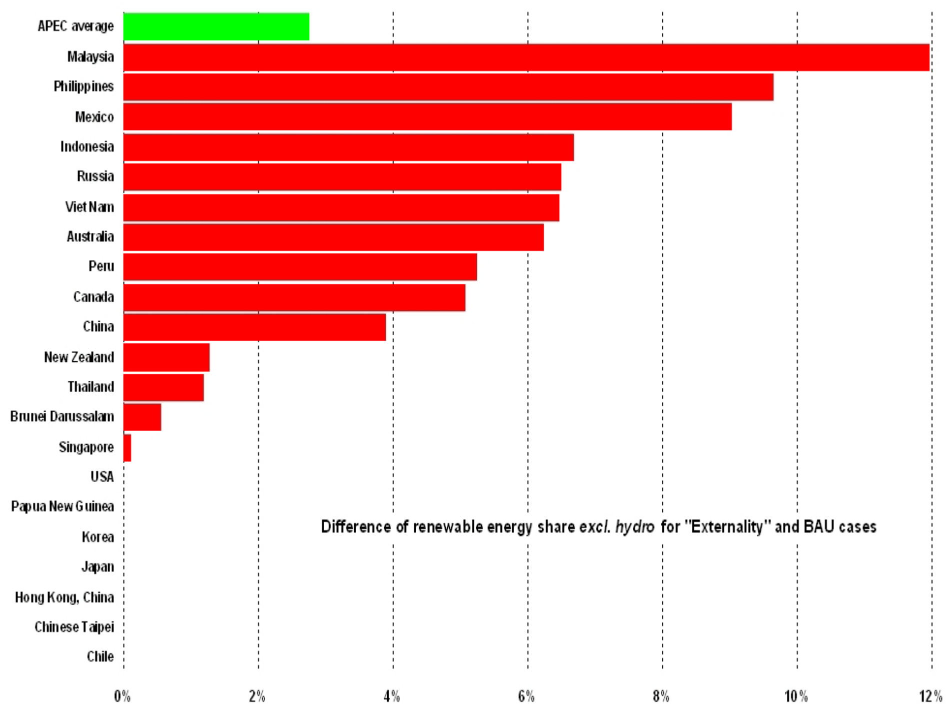
Nevertheless, there are a lot of physical and technical constraints preventing the use of renewable energy to generate electricity. Small coastal economies like Brunei Darussalam, Hong Kong and Singapore, usually lack hydro and biomass resources, and are not in the wind prone areas. The construction of ocean energy facilities in these economies is likewise prohibitive because it would obstruct sea lane transport, an industry vital to these economies. For other economies, with renewable energy resources located "far" from electricity load centres (or large electricity customers), viability limits its production. Determination of "far" is relative to the scale of electricity demand, and for remote off-grid small consumers, where distributed generation could be possible; the distance could be as far as a few kilometres. In addition, despite being well placed and have cheap power generation facilities, there are problems of intermittency for wind, solar and hydro technologies. If local or regional power grids have insufficient interconnection capacities then a large share of NRE electricity generators could cause losses in efficiency for conventional power generation[20] because of low demand.

There is a difference of sensitivity among economies within the APEC region when internalising externalities. Nine of the 21 APEC member economies are expected to be most affected by externality

[20] IIASA(2003a)

internalisation (see Figure 4). For these economies additional share of NRE in total electricity production ranges from 5 to 12 percent, looking at the difference between "Externality" and BAU cases. The only economy which will gain more than 10 percent by year 2020 is Malaysia, while the other seven economies could expect increases of 5 percent to 10 percent. Indonesia is close to this group but have less then 5 percent for above mentioned indicator. Modest changes are expected for Brunei Darussalam, China, New Zealand and Thailand. The list of least affected economies include Chile, Chinese Taipei, Japan, Hong Kong China, Korea, Papua-New Guinea, Singapore and USA. The underlying reasons for internalisation of externality costs in power generation for these economies could be synergy effects of higher weight of fuel cost versus externality cost, lack of renewable energy resources, and the high investment cost for renewable electricity versus conventional technologies. It should be noted that hydro electricity production is not presented in Figure 4, as this technology already has the lowest total electricity production cost for all economies within the APEC region. The reason is that it has low operation and management cost and high capacity factor, despite the highly sensitive nature of hydropower projects at project sites that have solid external cost.

Figure 4 APEC economies sensitivity to internalisation of externality cost for power generation



A summary of the main indicators for electricity production within the APEC region under the "Externality" and BAU cases is shown in Table 5. Average annual growth rate for renewable electricity production for APEC as a whole in the "Externality" case is 3 percent higher than in the BAU case. The average leveraged cost of electricity production in 2020, which include externality costs, would be 2.3 times more expensive under "Externality" case than in the BAU case, i.e. 7.1 cents per kWh against 3.1 cents per kWh. The share of renewable energy (excluding hydro) is assumed to increase slightly by 2.7 percent from 6.7 percent for BAU case to 9.4 percent for "Externality" case. Electricity production cost per unit would be 7 percent or around 0.2 cents per kWh higher if externalities are taken into account, but this would gain the benefit from avoiding 0.5 cents per kWh externality cost in BAU case.

Table 5 Summary table of main indicators for APEC region under BAU and "Externality" cases

Indicators	**Unit**	**2005**	**2020**		
			Externality case	***BAU***	***Difference***
Electricity production	TWh	10 185	15 722	15 722	-
incl. RE (without hydro)	TWh	198	1 482	1 049	433
Leveraged production cost	Billion USD	329	512	482	30
Externality costs	Billion USD	453	617	694	-77
Leveraged production cost	cents per kWh	3.2	3.2	3.1	0.2
Externality costs	cents per kWh	4.5	3.9	4.4	-0.5
Total cost with externalities	cents per kWh	7.7	7.1	7.5	-0.4
Share of renewable energy (excluding hydro) in electricity production	%	2.0	9.4	6.7	2.7
Average annual growth rate for renewable electricity production	%	-	15	12	3

The values shown in Figure 4 and Table 5 accumulate the impact of different factors finalised in the model's optimal solutions for BAU and "Externality" cases. The major factors influencing the results obtained are:

- absolute value of leveraged cost for power generation technologies, where most important parameters are: investment cost, fuel prices, transformation efficiency and capacity factor
- share of power generation technologies with high externality cost in total electricity production for economy under consideration in the starting base year
- ranking of power generation technologies by externality weight in total leveraged electricity production cost
- limitations on possible construction of new power generation capacities ("availability" of energy sources)
- growth rate of projected total electricity production for economy under consideration

The results show high sensitivity of power generation structure to externalities internalisation for Asian developing economies, as well as for Russia, Mexico, Australia and Canada. Nevertheless, results obtained should be considered with precautions, as there are important constraints in leveraged cost calculations. Total leveraged cost of electricity production doesn't include either the cost of constructing new and/or improvements in existing transmission lines, or increased cost of dispatching because of higher power supply system's exposure to renewable energy intermittency. Good examples are Russia with huge wind potential along Arctic Ocean coast, and Chile with proximity to El-Nino ocean current, both with prohibitively high cost of long distance transmission lines from sources of renewable electricity to main load centres.

EXTERNALITY YIELD

Externality yield is the avoided externality cost per kWh. It could be thought of as benefits (cost benefit) derived from preventing external costs to be paid by the society as whole. In this case, zero values means there is no actual externality cost reductions (or benefits to society) when externality costs are internalised.

By 2020, there are about 433 TWh of additional generation capacity needed to shift from the BAU to the "Externality" case which could well be supplied by RE, but with an added capital cost of about US$30 billion (see Table 5). However, this amount would be offset by US$77 billion of avoided cost from environmental, health and other kinds of damages, reflected in externality costs, which would actually be paid by the society as a whole. For most APEC member economies (see Table 6), these parameters vary over a wide range. The most sensitive economies are Peru, Russia and Malaysia, which all correspond to an AAGR of 20 percent, 18 percent and 13 percent in the BAU case respectively.

The highest rise in leveraged electricity production cost per kWh for "Externality" case occurs in Chile, Indonesia and Malaysia at 0.9 ¢ per kWh, 0.8 ¢ per kWh and 0.6 ¢ per kWh, respectively. Other APEC economies have modest increases, less than 0.4 ¢ per kWh.

Indonesia, Chile, Malaysia and Thailand are the most likely economies to decrease externality costs (or, in other words, to have the most health and environment benefits) per kWh of electricity produced. Corresponding values of "externality yield" for those economies are -1.8 ¢ per kWh, -1.6 ¢ per kWh, -1.4 ¢ per kWh and -1.3 ¢ per kWh.

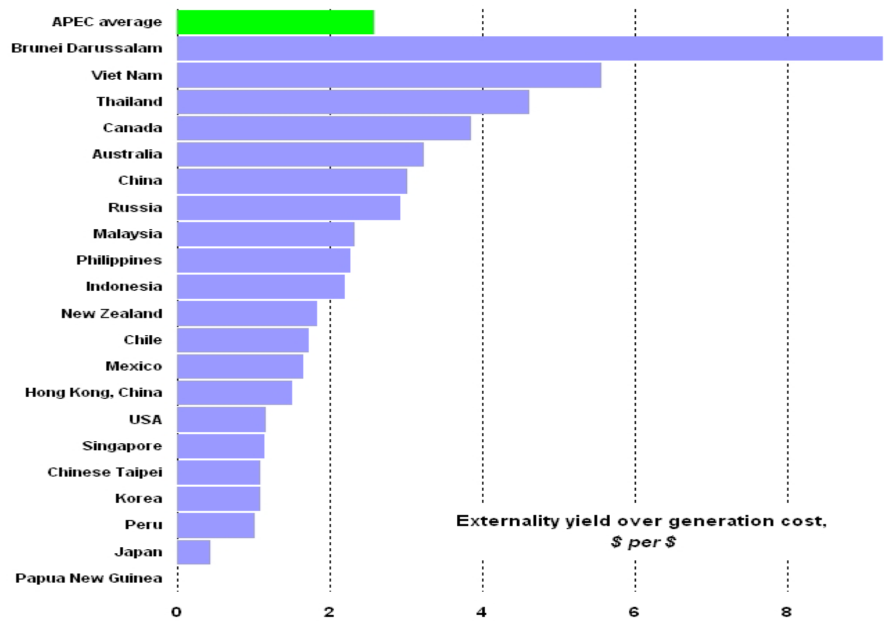
Table 6 Impact of externality cost factor to renewable electricity production within APEC region

Economy	AAGR for RE	Leveraged electricity production cost		Externality cost	
	%	Bln USD	¢/kWh	Bln USD	¢/kWh
Australia	8	0.86	0.3	-2.80	-0.9
Brunei Darussalam	-	*negl.*	*negl.*	*negl.*	*negl.*
Canada	9	0.83	0.1	-3.20	-0.4
Chile	-	1.19	0.9	-2.06	-1.6
China	3	11.79	0.3	-35.54	-1.0
Chinese Taipei	-	0.14	*negl.*	-0.15	*negl.*
Hong Kong, China	-	0.03	*negl.*	-0.04	*negl.*
Indonesia	4	2.67	0.8	-5.87	-1.8
Japan	-	0.40	*negl.*	-0.2	*negl.*
Korea	-	0.08	*negl.*	-0.09	*negl.*
Malaysia	13	1.09	0.6	-2.52	-1.4
Mexico	8	2.67	0.4	-4.40	-0.7
New Zealand	-	0.04	0.1	-0.06	-0.1
Papua-New Guinea	-	*negl.*	*negl.*	*negl.*	*negl.*
Peru	20	0.05	0.1	-0.05	-0.1
Philippines	3	0.54	0.4	-1.22	-0.9
Russia	18	3.58	0.2	-10.49	-0.7
Singapore	-	0.35	0.4	-0.40	-0.5
Thailand	1	0.75	0.3	-3.43	-1.3
USA	-	2.52	*negl.*	-2.95	-0.1
Viet Nam	6	0.30	0.1	-1.68	-0.8
Total APEC	2.6	29.9	0.2	-77.1	-0.5

Note: *values are calculated as differences of corresponding parameters for "Externality" – BAU case for year 2020.*

One of the study's key findings is a wide range of "externality yield" among member economies in APEC region, as it is shown in Figure 5. On average for APEC, the resulting "externality yield" would reach US$2.60 per dollar paid for additional electricity production. This wide range for "externality yield" is a reflection of the unique combination of renewable energy availability, fuel prices, construction and operation costs, capacity factors, thermal efficiency, *etc.* available for each economy. All APEC member economies except Papua-New Guinea and Japan could benefit from internalising externalities, as their "externality yield" is in the range of US$1.01 (for Peru) to US$9.25 (for Brunei Darussalam) per dollar of additional electricity production cost. The hyper sensitivity of Brunei Darussalam could be interpreted as effect of structural changes in small economy environment in the absence of renewable electricity production for the base year 2005. There is no additional renewable electricity production in "Externality" case against that of the BAU case for Papua-New Guinea. In the case of Japan only 44 cents of "externality" yield could be achieved per additional dollar of leveraged electricity production cost. For Peru, this value stands for 1.01 US$/US$, while for the Viet Nam economy whose share of renewable electricity is increasing rapidly it equals 5.6 US$/US$.

Figure 5 APEC economies externality "yield"



ASSESSMENT OF SUBSIDIES FOR RENEWABLE ELECTRICITY

Assessment of subsidies for NRE can be substantiated by calculations of required NRE investment cost depreciation to compete with conventional power generation technologies. It will be recalled that strictly on-site electricity cost production is compared, without considering transmission and dispatching costs. The amount of subsidies is assumed to be equal to that of total R&D costs, including the start up costs to develop NRE.

In the BAU case, hydro technologies, in comparison with conventional fuel technologies, does not need any subsidies because of its lower production cost.

However when the competitiveness of NRE versus coal-based electricity production is considered, there is a wide range of subsidy requirements for wind generation: from zero subsidy in Japan to 81 percent, 85 percent, 93 percent and 99 percent in USA, Malaysia, Indonesia and Australia, respectively. The main reason for such strong differentiation is the availability of cheap coal and low construction cost for coal-fired power plants. Biomass technology is competitive in Papua-New Guinea, Thailand and Viet Nam, with moderate 7 to 10 percent subsidy requirements for Japan and USA. Biomass electricity is prohibitively expensive in China as construction and O&M costs are high, while capacity factor is high for coal technology. Geothermal electricity is competitive to coal generation in Chile and Papua-New Guinea, with the lowest level for subsidy requirement (at 14 percent) in Viet Nam. Other economies need to subsidise more then seventy five percent of geothermal generation cost, except Japan (26 percent) and Mexico (28 percent). Ocean electricity should be subsidised in all APEC member economies, except Japan and Viet Nam which have the lowest level at 26 percent and 27 percent, respectively. Solar technologies are the last in the list to compete with coal, as they require almost a 100 percent subsidy.

High oil prices dictate unattractiveness of petroleum as fuel for electricity production, therefore any NRE other then solar is competitive, however, a few exemptions exist. Solar thermal cycle does not need subsidies in Chile, Japan, New Zealand and Chinese Taipei, and require an almost negligible amount of 2 percent in subsidies in Papua-New Guinea. On the contrary, ocean energy is expensive in Peru and Mexico with 22 percent and 26 percent subsidy requirements.

For NRE's competitiveness against natural gas, APEC economies are categorised in three groups depending on the level of natural gas prices. All renewable electricity but solar energy is competitive to natural gas for Chile, Japan, Korea, New Zealand, Chinese Taipei, USA, and ocean energy which is competitive for China and Thailand. For Brunei Darussalam, Russia, Peru (except for hydro power) and Singapore there is no NRE competitive to natural gas without huge subsidies. Remaining APEC member economies also require subsidies for RE, except hydro and biomass electricity, to compete with natural gas.

For NRE versus nuclear generation the picture is even more complicated. The only economy where any kind of NRE is competitive to nuclear is Korea; however, other NRE technologies are competitive in one or number of economies. Hydro electricity is competitive for all economies. Wind electricity is competitive in Japan, Mexico, Chinese Taipei, Thailand, USA and Viet Nam. Biomass is competitive in Australia, China, Indonesia, Malaysia, Papua-New Guinea, Russia and Chinese Taipei. Geothermal electricity is competitive in Chile, China, Japan, New Zealand, Papua-New Guinea, Peru, Philippines and Chinese Taipei.

Based on the analysis of the effects of subsidy requirements in "Externality" case, after the internalisation of externality cost in electricity production cost:

- Hydro electricity remains the cheapest option.
- All but solar technologies for renewable electricity became competitive against coal, making it more expensive for any APEC economy.
- Lower subsidies are required by NRE in contrast with natural gas, and wind electricity became competitive with natural gas in most economies except Indonesia, Malaysia and Russia.
- Nuclear power remains competitive against all renewable electricity (except hydro) for all APEC economies with existent or proposed nuclear facilities except Japan (vs. wind), Korea (vs. wind and geothermal), Mexico (vs. wind), Philippines (vs. geothermal) and Thailand (vs. wind and geothermal).
- Solar electricity is not competitive in any economy and will require substantial subsidies. The only exemptions are petroleum-based generation in Chile, New Zealand and Papua-New Guinea, including Japan and Chinese Taipei where externality is not accounted for in electricity production cost.

Therefore, externality internalisation could eliminate subsidies for wind, biomass, ocean and geothermal electricity in order to be competitive to coal for power generation. Other conventional technologies would not be affected, except biomass and ocean electricity which would be less competitive to nuclear technology.

SENSITIVITY ANALYSIS

Sensitivity analysis to evaluate the robustness of the results was conducted. Here, variations in externality cost values and investment and O&M costs for renewable energy were assumed. Variable factors to externality cost were implemented on the basis of a) less than 2/3; b) less than 1/3; c) at normal level and d) more than 1/3; when applied to externality cost values adopted for aggregated power generation technologies. It order to reflect some negative cost effects of renewable energy as more sparsely located generation facilities and dispatching because of renewable intermittency, an increase of 20 percent in capital cost and 7 percent in operation and management costs for all renewable energy technologies was applied. The results are presented in Table 7, as well as in Figures 6 to 9.

In Table 7, the first value for each indicator refers to results, associated with basic assumptions for leveraged cost calculations, the second value (except for the lines 10 to 12) – with leveraged cost calculations under increased capital and O&M costs for renewable energy.

Table 7 Summary for APEC economies sensitivity analysis on externality cost changes

Line #	Indicator	Units	Externality cost values			
			-2/3	-1/3	basic	+1/3
1	*2*	*3*	*4*	*5*	*6*	*7*
1	Number of economies above 5% difference* for renewable electricity share in total electricity production (excluding hydro)		0 – 1	7 – 8	9 – 9	10 – 10
2	Renewable electricity production, basic investment cost	TWh	181	398	433	435
3	Renewable electricity production, increased investment cost for renewable electricity	TWh	273	489	535	558
4	Average cost of electricity production within APEC region, "Externality" case	*¢/kWh*	3.11 – 3.20	3.20 – 3.28	3.23 – 3.32	3.27 – 3.37
5	Difference for average electricity production cost within APEC region	*¢/kWh*	0.06 – 0.06	0.14 – 0.15	0.19 – 0.20	0.21 – 0.23
6	Average externality cost within APEC region	*¢/kWh*	1.37 – 1.37	2.67 – 2.68	3.92 – 3.94	5.20 – 5.20
7	Difference for average externality cost of electricity production within APEC region	*¢/kWh*	-0.09 – -0.08	-0.29 – -0.28	-0.49 – -0.48	-0.67 – -0.68
8	Difference of annual average growth rates for renewable electricity generation over 15 years term	%	1.2 – 1.9	2.4 – 3.2	2.6 – 3.4	2.6 – 3.5
9	Number of economies above 200% yield for externality to generation costs		4 – 2	7 – 4	10 – 8	11 – 11
10	Difference for externality cost (economies with externality yield more then 200%)	bln USD	-0.7	-30.5	-66.8	-99.5
11	Difference for additional NRE investments during 2005-2020 term (economies with externality yield more then 200%)	bln USD	6.7	171.0	338.6	335.1
12	Average pay-back term for NRE investments	year	9.6	5.6	5.1	3.6

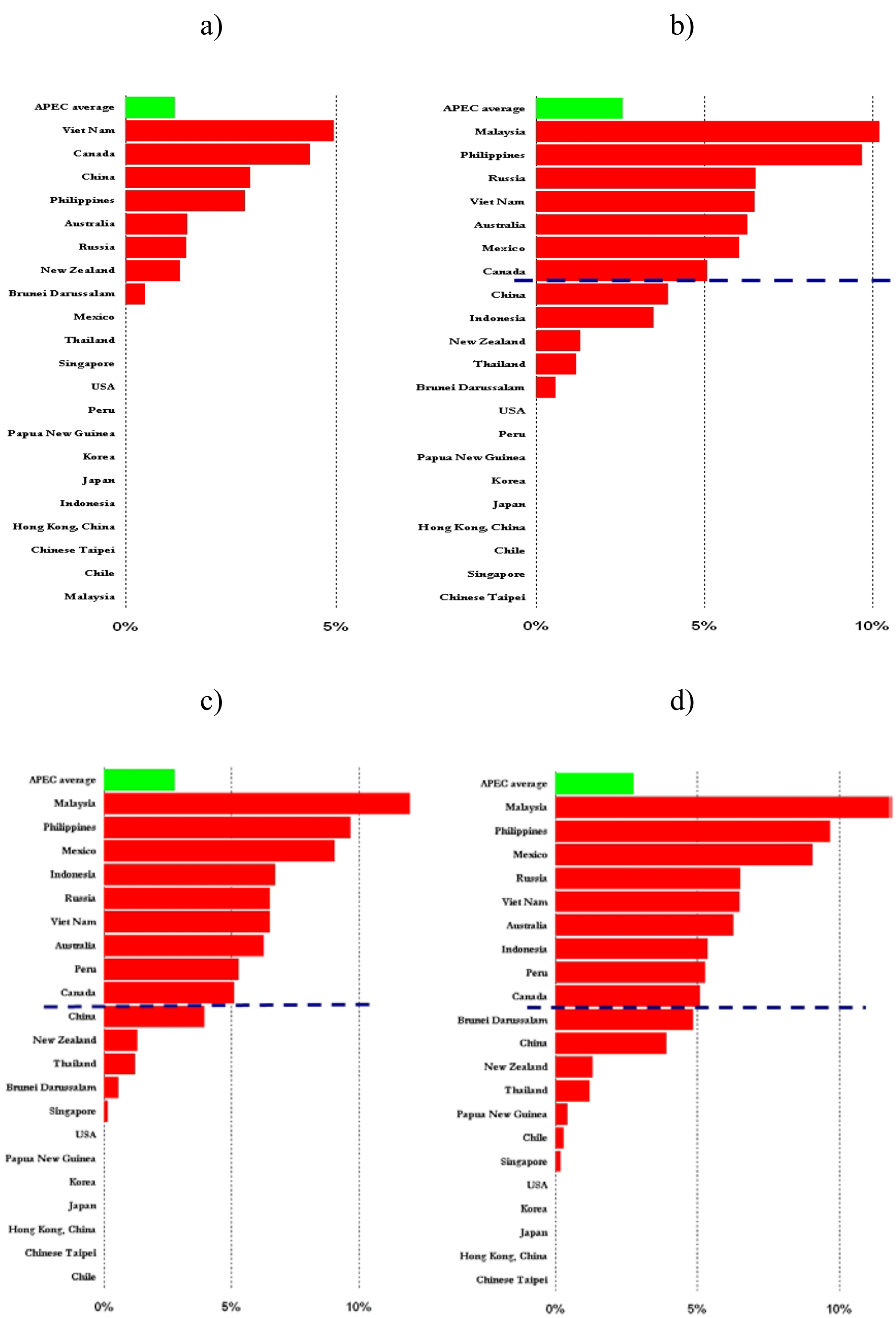
*Note *For any parameter "difference" mean difference of value for corresponding parameter under "Externality" and BAU cases for year 2020.*

Sensitivity analysis has shown that the results are sustainable for changes in externality costs in ±1/3 range from adopted basic values.

Eight to sixteen APEC economies could increase NRE share in electricity generation, while seven to nine economies could contribute over five percent of electricity generation to NRE, with the exception of Malaysia that could break the ten percent barrier, see Figure 6b-d. It is not surprising that increasing the absolute level of external cost leads to benefits for most economies, in terms of external cost reduction.

The APEC economies are categorised into three groups such as highly sensitive, moderate and insusceptible. The latter consist of eleven economies (New Zealand to Chile), see Figure 6c. Malaysia and Philippines are the most sensitive economies to externality internalisation as they have the highest difference in the NRE share of total electricity production between "Externality" and BAU cases, see Figure 6b-d. Other economies demonstrate moderate sensitivity of electricity generation structure to externality internalisation.

Figure 6 Sensitivity analysis for renewable electricity share to externality cost: a) externality cost 2/3 less from basic; b) externality cost 1/3 less from basic; c) normal (basic) level of externality cost; d) externality cost 1/3 more then basic



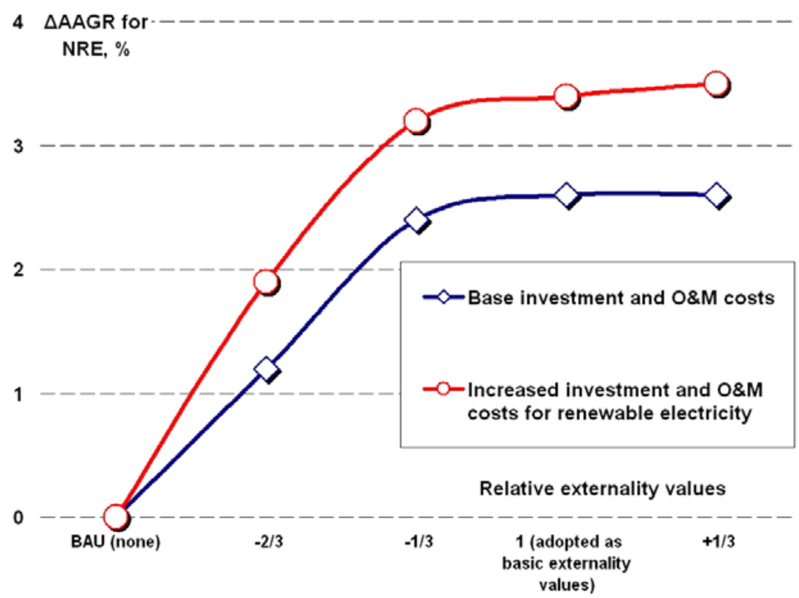
Average cost of electricity production within APEC region has low sensitivity to externality cost. The increment is between 5.1 – 5.3 percent (from 3.11-3.20 to 3.27-3.37 cents per kWh) in response to a four-fold increases in externality costs, see line 4 in Table 7. This reflects the dominance of conventional power generation technologies up to year 2020. Differences in the electricity production cost for the

BAU and "Externality" cases increased between 350 – 417 percent (from 0.06 to 0.21-0.23 cents per kWh), which correspond to the growth in externality cost; see line 5 in Table 7.

There is non-linear relation of externality costs growth and NRE share in total electricity production. This fact is illustrated in Figure 7 for basic and increased capital costs for renewable electricity technologies. It shows that **the maximum additional average growth rate of NRE in electricity production for the APEC region in 15 years could not exceed 2.6 – 3.5 percent** (line 8), even if the cost of renewable electricity didn't include additional cost for transmission lines and dispatching. Calculating additional renewable electricity production in lines 2 and 3 to total electricity production in APERC region in year 2020 will lead to the conclusion that maximum incremental share of NRE could not exceed 2.8 – 3.5 percent. Decreasing rate of NRE penetration with increasing externality cost is imminent when comparing higher growth rate of (740-680 percent) of externality cost difference (from 0.09-0.08 to 0.67-0.68 cents per kWh, see line 7 in Table 7) with the externality cost growth of 380 percent (from 1.37 to 5.20 cents per kWh, see line 6 in Table 7), because of higher externality costs of convention power generation technologies.

The sensitivity analysis provides us with the idea of how high the external cost should be to be optimal for NRE development promotion in the APEC region. In Figure 7, curves could be interpreted as saturation functions for NRE development. There is no difference for NRE share in total electricity production when zero values for external costs are implemented. Low external costs (33 percent to corresponding *ExternE*-based values) result in moderate additional average growth rate of renewable electricity in 1 to 2 percent. **Internalising external costs close to *ExternE* estimations are considered as being optimal for the purpose of renewable electricity promotion**.

Figure 7 Impact of externality cost internalisation to the average growth rate of renewable electricity in the APEC region, difference of "Externality" to BAU cases

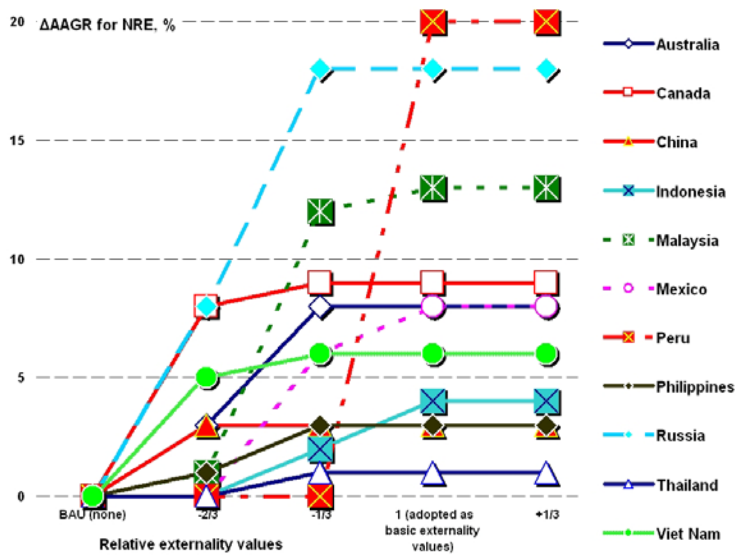


Lower externality costs would lead to poor performance of NRE's competitiveness with that of conventional power generation. This means that not one economy would gain more then a 5 percent difference in NRE share of electricity generation (excluding hydro) between the BAU and "Externality" cases. A reasonable gain of 2.6-3.8 percent could be reached only if externality cost is almost the same or exceeds that of average generation costs. In those cases, about a third or half of APEC economies could experience higher growth rates for NRE, resulting in additional 490 – 560 TWh of renewable electricity, see line 3 in Table 7.

The sensitivity of renewable electricity production's average growth rate to internalising of externalities costs for selected APEC economies is shown in Figure 8. The highest level of sensitivity to externality internalisation is shown by Peru – up to 20 percent, followed by Russia (18 percent), and Malaysia (13 percent). Other APEC economies have average growth rates for renewable electricity of less then 10 percent. The main factors affecting NRE growth rates are cost competitiveness taking into account externality costs (externality internalisation), technical availability of NRE resources and official policies toward implementation of conventional power generation technologies, including nuclear energy.

Total external cost of electricity production (for both "Externality" and BAU cases) is calculated by multiplying electricity produced by aggregated power generation technology with its respective value for externality cost. Difference for total external cost in the year 2020 for "Externality" and BAU cases is proportional to absolute values for externalities. This difference reflects positive effect to environment, human health, *etc.* caused by a shift towards deployment of less costly electricity producing technologies, where externality costs is monetised and internalised in electricity production cost. Starting with a modest value of about US$0.7 billion difference for "Externality" and BAU cases for externality cost less then 2/3 of basic values for externality costs, adopted for this study, difference for externality cost in year 2020 accounts for US$66.8 billion for basic externality cost, and US$99.5 billion for 1/3 more than the values of basic externality cost, see line 10 in Table 7.

Figure 8 Sensitivity of renewable electricity average growth rate to externality cost internalisation for selected APEC economies, difference of "Externality" to BAU cases



According to the assessment of economic efficiency for NRE projects, total investments for development of renewable electricity production was summarised for economies, which have more than 200 percent externality yield in year 2020. For externality costs less than 2/3 of the basic difference for NRE investments within the APEC region during the 2005-2020 time period was equal to US$6.7 billion, while the basic externality costs for NRE investments amounted to US$338.6 billion, see line 11 in Table 7. Analysis of the difference in externality cost and difference in NRE investments within the APEC region during the 2005-2020 period showed a reverse functional dependence for average pay-back term to the level of externality costs values for NRE investments. Average pay-back term for NRE investments, calculated for basic externality costs, was equal to 5.1 years, see line 12 in Table 7.

Sensitivity analysis of "externality yield" could provide more insight on the impact of externality cost internalisation to renewable electricity in APEC region. "Externality yield" of more than 100 percent indicates a positive externality cost effects occurring in 2020, this also reflects a shift in power generation mix caused by investments to NRE made in previous years. Positive "externality yield" could be achieved in 12 to 21 APEC economies, while 4 to 11 economies could achieve more than 200 percent "externality yield", depending on externality cost values, see Figure 9a-d.

Figure 9 Sensitivity analysis of externality yield to externality costs in the APEC region: a) externality cost 2/3 less from basic; b) externality cost 1/3 less from basic; c) normal (basic) level of externality cost; d) externality cost 1/3 more then basic

CHAPTER IV

SUMMARY OF RESULTS AND POLICY IMPLICATIONS

Renewable electricity production in the "Externality" case increase by 433 TWh against the BAU case, and account for 2.7 percent of total projected APEC electricity production in 2020. This incremental NRE share however should be considered in the high assessment level because:

- High limitations on new NRE generation capacity were assumed for all APEC economies, reflecting technical possibilities for such construction rather then official projections for renewable electricity development
- High and uniform externality costs were adopted to for all APEC economies, thus lowering competitiveness for coal technology
- Underestimation of transmission and dispatching cost in the optimisation models, thus making NRE more competitive to conventional fuels

Renewable energy has attracted so much attention as a non-fuel source for power generation when energy prices sky rocketed. The high leveraged cost of electricity production, because of some negative inherent features of renewable energy, prevented renewables from gaining a larger share of power generation.

Internalising externality costs in electricity production within the APEC region would:

- Increase the share of renewable electricity in total electricity production of the APEC region by about 3 or 4 percent (or between 430 and 600 TWh).
- Increase the average annual growth of renewable electricity production by about 3 to 4 percent from the business-as-usual case.
- Increase the average generation cost of electricity, twice that of its current level.

Further analyses have shown that:

- Varying degrees of avoided externality cost per KWh or "externality yield" among member economies exist.
- An average of 2 to 3 yield of externality cost per renewable electricity investment cost could be expected.
- Additional investments for renewable electricity will reach about US$200 billion in the next 15 years.
- Externality costs based on *ExternE* assessments are considered to be close to optimal for the purpose of renewable electricity promotion.

Infrastructure constraints and cost of access to renewable energy resources are critical issues (among others) for renewable energy economics and development.

Regardless of externality, solar technologies have to be subsidised by up to 80 percent of investment cost to compete with traditional power generation technologies; hydro will remain as one of the cheapest options among power technologies; externality accounting would make any type of renewable electricity (except solar) competitive with coal generation in any APEC member economy.

Some least sensitive to externality internalisation economies as US, Japan, Korea and Chinese Taipei could have economic and social benefits as a result of the consequential increase in equipment orders for renewable electricity generation.

The study confirms the importance of institutional framework and background studies for assessments of government subsidies for NRE. However to further promote renewable electricity within the APEC region, studies should be based on a fair market competition approach for different power generation technologies, comprehensive renewable energy resource data, power interconnections evaluation and research and development (R&D) efforts to decrease the per unit cost of renewable electricity.

IMPLICATIONS AND POSSIBLE APPROACHES TO INTERNALISE EXTERNALITY COSTS IN POWER GENERATION

Once the monetary values are estimated and external costs of different combustion technologies and renewable energy are accounted, the next step is to find an effective mechanism that will internalise them into the electricity price.

One approach is to impose a tax penalizing the 'polluter'. Taxes imposed would differ according to the estimated damages resulting from the type of fuel used; one example of this is carbon tax. However a simple carbon tax alone would not be effective to ensure the competitiveness of renewable energy or the necessary burden to other technologies and distribution of benefits to the consumer.

Another approach would be to introduce 'environmental credits' for the uptake of renewable energy technologies. Credits however do not 'internalise' the social costs of energy production but rather subsidize renewables.

Various strategies and policy options have been tested and applied but some are still found unsustainable. Some examples of the successful approaches could be in either one of two categories, economic or technology.

ECONOMIC INSTRUMENTS

Economic mechanisms involve the imposition of taxes in the form of pollution taxes, which penalizes fossil fuels on the amount of carbon emissions (carbon tax) or in this case other environmental impacts as a result of its combustion. Pollution taxes (including carbon emission taxes) have been imposed in Brazil, Denmark, Finland, Italy, Latvia/Lithuania, Sweden, and the United Kingdom (which funds its Renewable Purchase Obligation subsidies with electricity taxes). Sweden, since 1991, has instituted environmental taxes and included NO_x emissions in 1992[21].

However some economies may find pollution taxes politically difficult since they inevitably affect some other energy-intensive industries. But if pollution taxes are offset by reductions in other taxes (for example: business taxes), the taxes could produce a net economic benefit[22]. The political difficulty could be illustrated by the fact that in a number of economies which legislated such taxes, major industries have been exempted to avoid competitively disadvantaging domestic production.

Other economic policies which tend to reduce costs and pricing related barriers include: a) renewable portfolio standards (RPS); b) electricity feed-in laws; c) renewable electricity 'green' certificates and d) competitive bidding for NRE obligations[23].

IMPROVEMENT IN TECHNOLOGY THROUGH EXPANDED RESEARCH AND DEVELOPMENT

Temporary incentives to bring new technologies into the market often help to promote public acceptance and later mass deployment. Government-sponsored research, development,

[21] DET (2000)
[22] ETR (1997)
[23] APERC (2004a)

and demonstration projects have dramatically reduced the cost and increased the performance of renewable resources.

Technology transfer is critical if developing economies are to take advantage of renewable technologies. Because technical assistance and education of key energy players is essential to success, governments and international agencies currently sponsor many such efforts around the world.

Improved technology could boost the use of modern renewable technologies in developing economies by simply adopting cleaner technologies from the very start, therefore avoiding the economic and pollution costs of more expensive traditional polluting fossil fuels and then replacing or retrofitting them to meet pollution standards, as industrialized countries have done in the past.

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APPENDIX I

INTRODUCTION

Each APEC member economy is provided with a specific case study section, which is further categorized into, Information and Results Sub-sections. The information subsection compiles the economy-specific information necessary for the application of the methodology, described in Chapter II. Relevant information and the results of the assessments for fuel prices; structure of electricity production in 2005 and projections for 2010 and 2020; including some background information for costs calculations and constrains for new capacities are then presented in Tables 1, 2, and 3 respectively.

The resulting subsection on leveraged cost of electricity production, competitive investment cost for renewable energy and impact of externality internalisation on rational electricity production mix are presented as Figure 1, Table 4, Figure 2 and Table 5, respectively. The calculated leveraged cost of electricity production by each aggregated technology is presented, according to rank in ascending order and their cost components, in Figure 1.

The depreciation of NRE overnight cost per kW is shown in Table 4. The values referred to are the share of overnight cost per kW which should be compensated for renewable electricity technology that is under consideration in order to reach the level of competitiveness towards a corresponding conventional power generation technology. Competitiveness of renewable electricity production toward conventional power generation technology is shown in Table 4 by a "+" sign. Otherwise, percent of required overnight cost depreciation for renewable electricity technology is calculated. In the case of an even zero investment cost for renewable technology could not provide competitiveness (because of non-zero O&M cost, biomass cost, or externality cost), the "–" sign is indicated in Table 4. The numerator value is attributed to BAU case competitiveness, while the denominator value is attributed to "Externality" case competitiveness.

The optimisation model is used to apply the least-cost approach and calculate the corresponding structure of **additional** electricity production under given target levels for total electricity production in base years 2010 and 2020. Differences of electricity production in comparison with the maximum allowed for Business-As-Usual and "Externality" cases are illustrated in Figure 2. Figure 2 shows the difference of new electricity production structure for BAU and "Externality" cases in comparison with the allowable constraints for such production under limitations on new capacity construction. In Table 5, the main indicators characterising the results obtained are gathered. Finally a brief summarization of the most important results of calculations and analysis are presented.

AUSTRALIA

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1 Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	323.4
Natural gas	USD/toe	115.8
Coal	USD/toe	28.0
Biomass	USD/toe	10.0

Source: *ABARE (2003a), author's estimations*

Table 2 Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Coal	171.6		
Petroleum	2.4		
Biomass	6.5		
Natural Gas	33.0		
Hydro	18.6		
Wind	0.6		
Total	*232.6*	*258.8*	*315.3*

Source: *APERC outlook 2002, database*

Table 3 Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1050	24.36	80	37	30	3,000	7,250
Petroleum	3	395	10.72	20	32	20	40	100
Natural Gas	3	560	10.35	65	51	20	1,500	3,000
Nuclear	6	1957	60.06	85	*non appl.*	30	-	-
Wind	2	1134	26.81	20	- " -	20	1,000	5,000
Biomass	2	1757	47.18	65	35	30	200	500
Ocean	3	5000	40	35	*non appl.*	50	500	1,000
Hydro (all)	6	1451	12.5	42	- " -	50	500	1,000
Geothermal	3	3108	104.98	73	- " -	20	100	500
Solar thermal	3	2960	50.23	20	- " -	20	100	1,000
PV	1	4500	10.34	15	- " -	20	100	500

Source: *EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

Owing to its low cost compared with other fossil fuels, coal is the mainstay for power generation. However, the use of natural gas for power generation has increased in recent years, but due to the increased cost of fuel procurement vis-à-vis coal, the overall share of natural gas remains relatively low. Petroleum is used for peak generation, supply stability and in cases of emergency. Coal, natural gas and petroleum are all produced domestically, and while Australia is an important supplier of uranium to the international market, at this stage the introduction of commercial scale nuclear generation is still under debate. Biomass in Australia is essentially from two sources, bagasse from the sugar cane and wood, and wood waste products. A small amount of biogas is also used, which is derived from municipal solid waste. Data for new available coal, natural gas and petroleum-based capacities are gathered from latest available government projections.

RESULTS

Figure 1 Leveraged electricity cost by technology considered

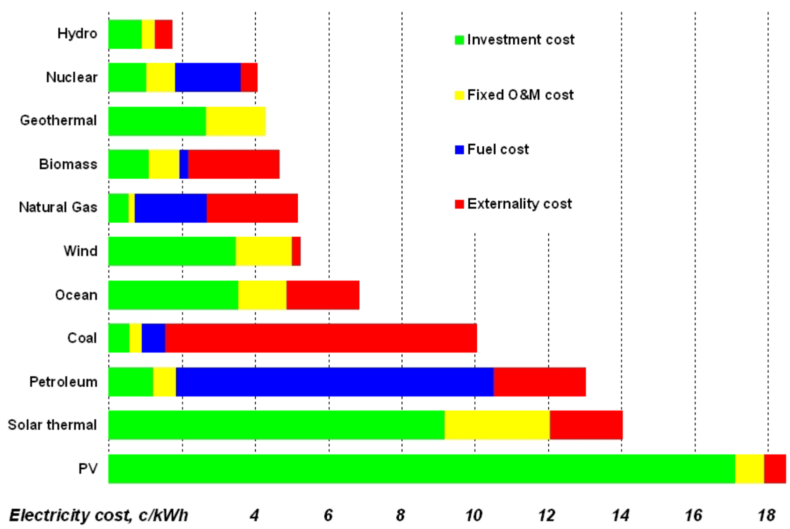


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	99/+	+/+	67/2	40/34
Biomass	56/+	+/+	+/+	+/55
Ocean	93/+	+/+	62/47	35/78
Hydro	+/+	+/+	+/+	+/+
Geothermal	-/+	+/+	61/+	25/8
Solar Thermal	-/44	17/18	-/96	92/-
PV	96/49	43/36	89/78	83/84

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete with corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Based on the figure above, if externality cost is considered, biomass, wind, geothermal capacities could run in full scale due to the proposed high rate of demand growth; new generation facilities should then be constructed in the future. However, the most probable options are NGCC and nuclear since there are not enough NRE resources.

Figure 2 Electricity generation by additional capacities during 2005-2020

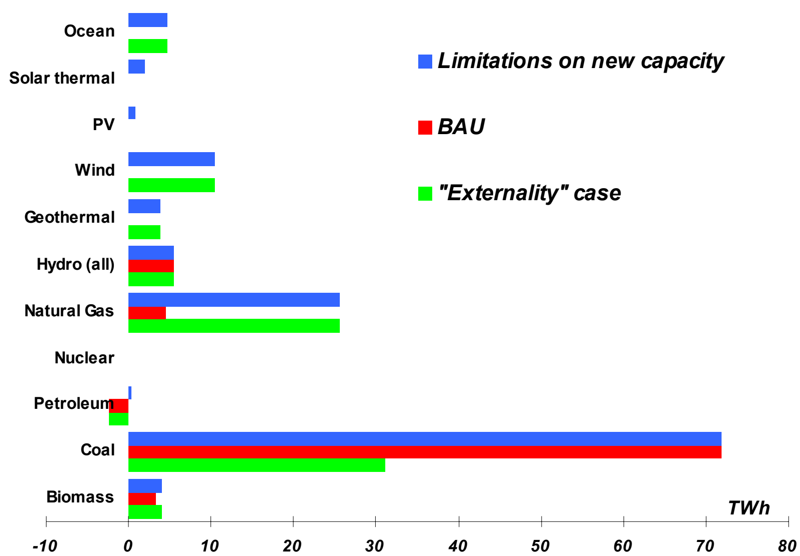


Table 5 Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	19.9	4.1	25.3	5.3	20.0
Externality cost	Bln USD	15.7	-	19.2	22.0	3.5[1]
Average electricity cost	¢ per kWh	8.5	1.8	8.0	1.7	6.3

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to almost five times of cost increasing for electricity production from 5.3 billion USD to 25.3 billion USD in the year 2020.
- Geothermal, biomass, wind, and ocean utilities are competitive with natural gas and petroleum without accounting for externalities.
- After introducing externalities coal has moved from the cheapest option (after hydro) to most expensive one (after solar technologies).
- All renewable energies benefit from externality accounting except solar technologies.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 19.7 TWh of renewable electricity, or 6.2 percent to economy’s total electricity production in year 2020.

BRUNEI DARUSSALAM

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1 Fuel prices

	Unit	Value
Natural gas	USD/toe	60
Biomass	USD/toe	50

Source: *author's estimations*

Table 2 Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Natural Gas	2.9		
Total	*2.9*	*3.3*	*4.5*

Source: APERC *database for projections 2002*

Table 3 Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,100	30	80	37	30	-	-
Petroleum	3	400	13	20	32	20	-	-
Natural Gas	3	560	12	65	51	20	75	150
Nuclear	6	2,000	70	85	*non appl.*	30	-	-
Wind	3	1,200	20	25	- " -	20	10	100
Biomass	3	2,000	20	50	35	20	10	20
Ocean	4	5,000	40	35	*non appl.*	50	10	100
Hydro	2	2,500	20	45	- " -	50	1	5
Geothermal	4	5,000	110	90	- " -	20	10	20
Solar thermal	3	3,000	40	20	- " -	20	10	50
PV	2	5,000	12	15	- " -	20	10	50

Source: *EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

Brunei Darussalam is an oil and natural gas exporting economy, but lacks renewables. Wind technology stands next to natural gas in terms of competitiveness, followed by geothermal, biomass, and ocean technologies. Natural gas is the number one choice in both cases.

RESULTS

Figure 1 Leveraged electricity cost by technology considered

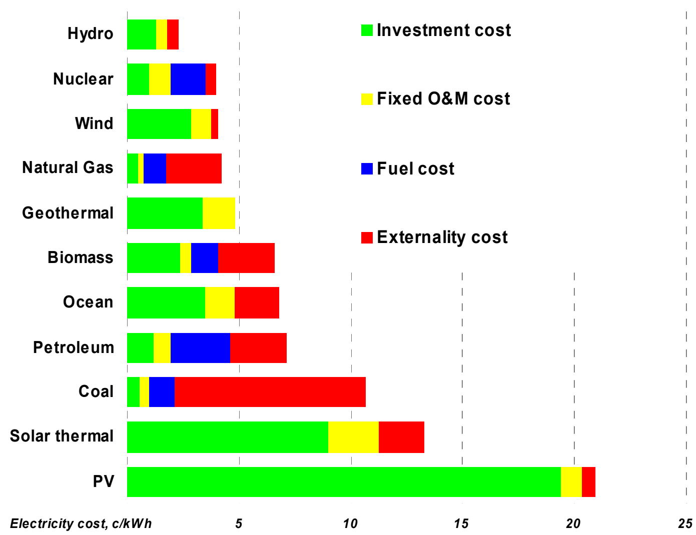


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	58/+	+/+	72/+	11/4
Biomass	80/+	+/6	97/95	24/-
Ocean	76/+	7/12	88/72	37/80
Hydro	+/+	+/+	8/+	+/+
Geothermal	78/+	7/+	90/18	38/25
Solar Thermal	-/31	74/76	-/99	86/-
PV	94/55	82/75	96/86	87/88

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2 Electricity generation by new capacities: maximum possible available, without and under externality consideration

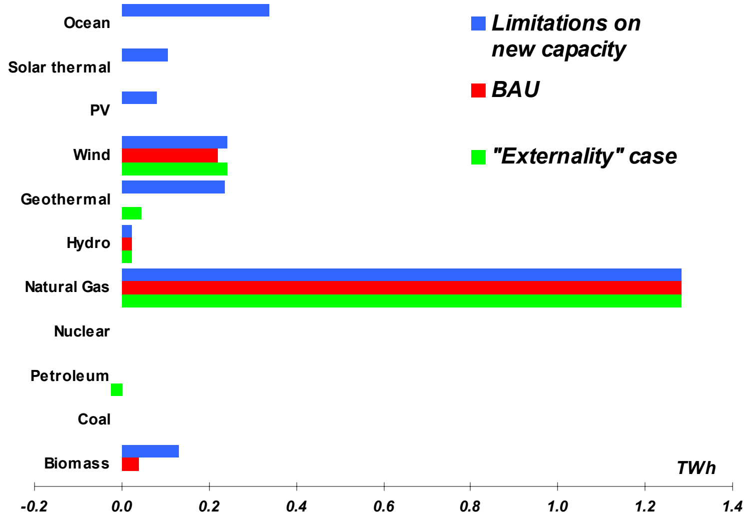


Table 5 Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	0.12	0.05	0.19	0.08	0.11
Externality cost	Bln USD	0.07	-	0.1	0.1	0.03[1]
Average electricity cost	¢ per kWh	4.3	1.8	4.2	1.9	0.1

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to two times higher in the cost of electricity generation from 0.08 billion USD to 0.19 billion USD in the year 2020.
- With the low cost of NGCC, introducing externalities does not affect the competitiveness of renewable energy.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 24.5 MWh of renewable electricity, or 0.5 percent to economy's total electricity production in year 2020.

CANADA

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1 Fuel prices

	Unit	Value
Petroleum (fuel oil)	USD/toe	200
Natural gas	USD/toe	100
Coal	USD/toe	50
Nuclear	mills/kWh	16
Biomass	USD/toe	30

Source: *author's estimations*

Table 2 Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Petroleum	2.0		
Biomass	7.1		
Coal	106.9		
Natural Gas	33.6		
Hydro	357.0		
Ocean	0.7		
Nuclear	100.1		
Wind	0.7		
Total	*608.2*	*657.7*	*749.4*

Source: APERC *database for projections 2002*

Table 3 Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,100	30	80	37	30	2,000	5,000
Petroleum	3	400	13	20	32	20	-	-
Natural Gas	3	560	12	65	51	20	5,000	10,000
Nuclear	6	2,000	70	85	*non appl.*	30	-	-
Wind	3	1,200	20	25	- " -	20	1,000	5,000
Biomass	3	2,000	20	50	35	20	500	2,000
Ocean	4	5,000	40	35	*non appl.*	50	500	1,000
Hydro	2	2,500	20	45	- " -	50	200	500
Geothermal	4	3,100	110	80	- " -	20	500	2,000
Solar thermal	3	3,000	40	20	- " -	20	100	500
PV	2	5,000	12	15	- " -	20	100	500

Source: *EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

RESULTS

Figure 1 Leveraged electricity cost by technology considered

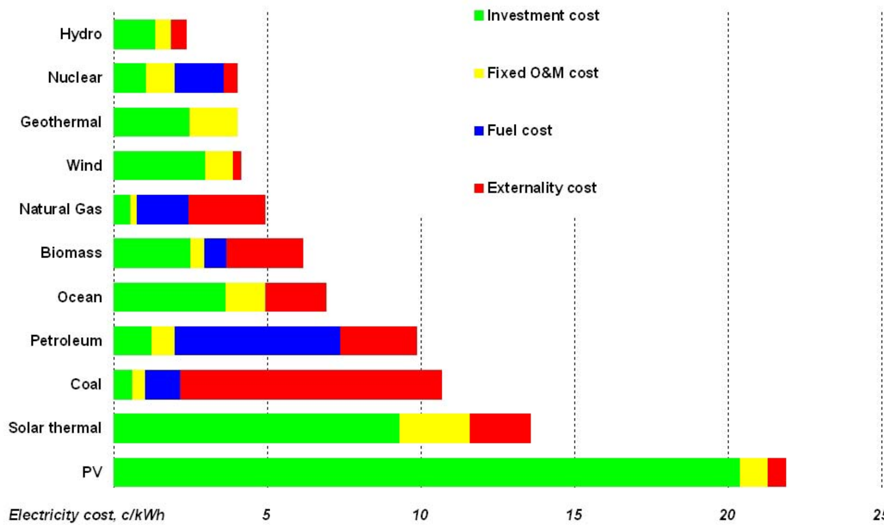


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	**Petroleum**	**Natural Gas**	**Nuclear**
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	58/+	+/+	49/+	11/4
Biomass	61/+	+/+	50/48	4/87
Ocean	76/+	+/+	69/54	37/80
Hydro	+/+	+/+	+/+	+/+
Geothermal	76/+	+/+	65/+	19/0
Solar Thermal	-/31	45/47	98/93	86/-
PV	94/55	68/62	93/83	87/88

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2 Electricity generation by new capacities: maximum possible available, without and under externality consideration

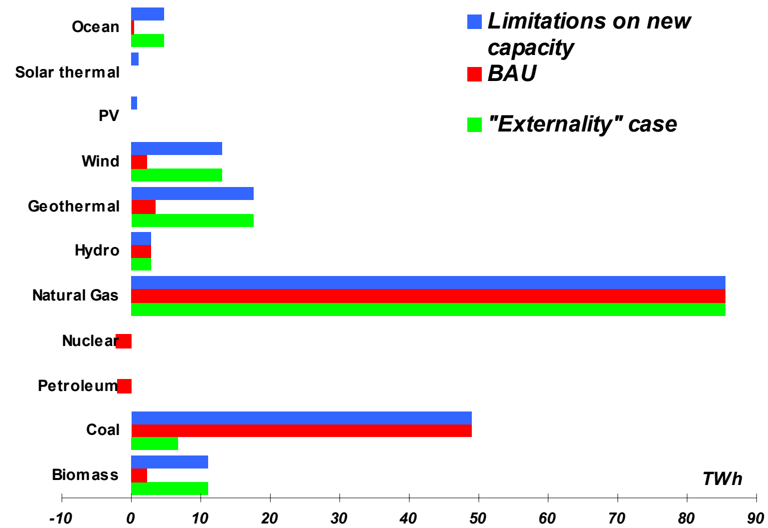


Table 5 Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	26.2	13.8	33.5	17.1	16.4
Externality cost	Bln USD	12.4	-	15.5	18.7	3.1[1]
Average electricity cost	¢ per kWh	4.3	2.3	4.5	2.3	

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to an 80 percent increase in the cost of electricity generation in the year 2020 from 17.1 billion USD to 33.5 billion USD.
- Introduction of externalities make geothermal, wind, biomass and ocean technologies competitive.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 38.0 TWh of renewable electricity, or 5.1 percent to economy's total electricity production in year 2020.

CHILE

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1 Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	488
Natural gas	USD/toe	310
Coal	USD/toe	60
Biomass	USD/toe	70

Source: *Chile (2005), author's estimations*

Table 2: Structure of electricity generation in 2005, TWh

	2005	2010	2020
Coal	13.1		
Petroleum	1.1		
Natural Gas	16.7		
Hydro	21.8		
Total	*53.8*	*69.5*	*131*

Source: APERC *database for projections 2002*

Table 3 Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,225	73.2	80	37.9	30	800	3,600
Petroleum	3	400	13	20	32	20	-	-
Natural Gas	2	405	24.2	50	47	30	3,045	4,125
Nuclear	6	2,485	70	85	*non appl.*	30	-	-
Wind	3	1,200	20	25	- " -	20	1,000	5,000
Biomass	3	2,000	20	50	35	20	100	1,000
Ocean	4	5,000	40	35	*non appl.*	50	1,000	5,000
Hydro	4	1,064	22	80	- " -	50	482	403
Geothermal	3	1,421	146	80	- " -	30	100	1,000
Solar thermal	3	3,000	40	20	- " -	20	100	200
PV	1	5,000	12	15	- " -	20	100	300

Source *EIA (2005), ICRE (2004), IIASA (2003), Chile (2005), author's estimations*

In 2004 Chile had difficulties in using natural gas because of supply restriction from Argentina. Petroleum is used for peak generation, and in case of emergency. Coal and natural gas are partially imported. Thermal-generated electricity accounted for 59 percent and hydropower for the rest.

RESULTS

Figure 1: Leveraged electricity cost by technology considered

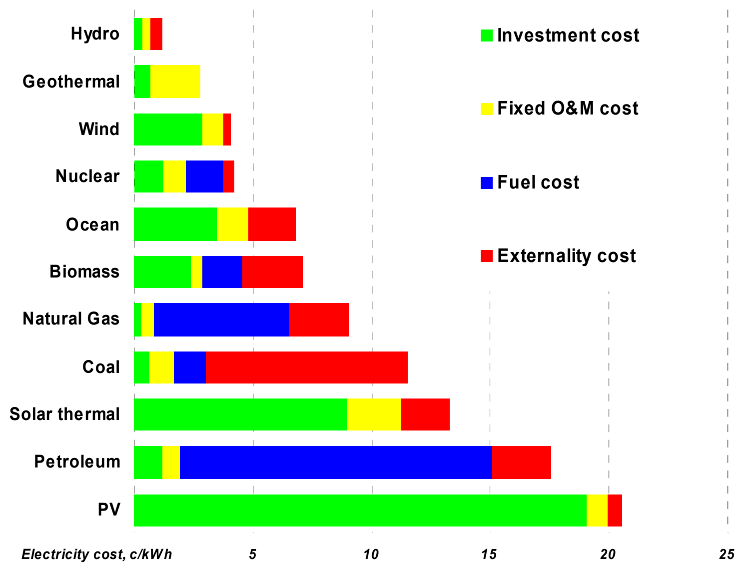


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	28/+	+/+	+/+	2/+
Biomass	65/+	+/+	+/+	34/-
Ocean	52/+	+/+	+/+	31/79
Hydro	+/+	+/+	+/+	+/+
Geothermal	+/+	+/+	+/+	+/+
Solar Thermal	92/22	+/+	54/45	83/-
PV	89/47	25/19	70/59	85/85

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2: Electricity generations by additional capacities during 2005-2020

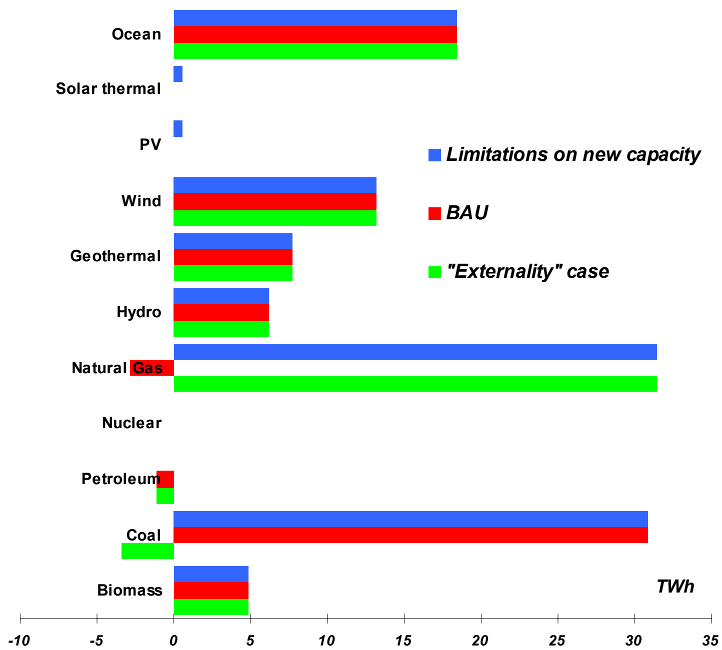


Table 5 Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	3.6	1.9	8.3	4.3	3.9
Externality cost	Bln USD	1.7	-	2.7	4.8	1.0[1]
Average electricity cost	¢ per kWh	6.6	3.4	6.3	3.3	3.0

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to almost twice the cost of electricity generation from 4.3 billion USD to 8.3 billion USD in the year 2020.
- Coal is the most attractive option, but becomes less competitive after externalities are introduced.
- All renewable energies benefit from externalities except solar energy.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost did not lead to any incremental production of renewable electricity.

CHINA

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1 Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	274
Natural gas	USD/toe	193.7
Coal	USD/toe	53.4
Nuclear	mills/kWh	16
Biomass	USD/toe	50

Source: *calculated from various source, author's estimations*

Table 2: Structure of electricity generation in 2005, TWh

	2005	2010	2020
Coal	1144		
Petroleum	50		
Nuclear	65		
Natural Gas	111		
Hydro	326		
Total	*1696*	*2195*	*3560*

Source: *APERC database for projections 2002*

Table 3: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	550	16.5	82.5	38	40	50,000	100,000
Petroleum	3	400	9.6	80	35	30	-	-
Natural Gas	3	480	8.6	80	50	30	1,000	10,000
Nuclear	6	1,400	84	90	*non appl.*	40	9,814	20,000
Wind	2	1,000	30	30	- " -	20	10,000	30,000
Biomass	1	1,200	20	50	35	30	3,500	14,000
Ocean	4	5,000	40	35	*non appl.*	50	1,000	10,000
Hydro	6	1,000	22	50	- " -	50	50,000	75,000
Geothermal	3	6,500	26.3	80	- " -	50	5,000	25,000
Solar thermal	3	3,000	40	20	- " -	20	100	1,000
PV	1	7,500	37.5	15	- " -	20	450	1,000

Note: *According to official proposals additional installed capacity for coal and natural gas power plants should be as high as 89 GW and 24GW in 2010; 213 GW and 80 GW in 2020.*

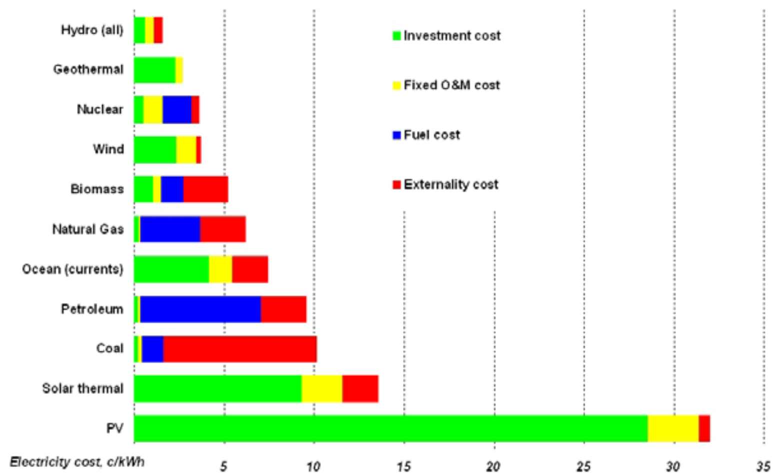
Source: *author's estimations based on various domestic sources, EIA (2005), ICRE (2004), IIASA (2003)*

Currently, about 74.5 percent of the total installed capacity comes from thermal plants, 24.1 percent hydro, and 1.3 percent nuclear. Coal and nuclear power plants are used for base-load electricity generation. Gas combined cycle will start after 2005. Natural gas will be used for peak generation. Biomass assumed agriculture wastes and forest biomass utilization for distributed generation facilities.

Biomass resources are assumed to come from agriculture and national forestry. Data for new wind, biomass, geothermal, solar thermal and photovoltaic are taken from ERI's estimations. Data for new available coal, hydro, natural gas-based capacities were coordinated with the latest ERI's projections. New nuclear power capacity is based upon the governmental plan. O&M cost is assumed at ¼ that of default value for USA.

RESULTS

Figure 1: Leveraged electricity cost by technology considered



Biomass, wind, geothermal capacities should run full scale with the proposed high rate of demand growth and construction of new generation facilities. The only possible option is NGCC and nuclear , as there are not enough resources for renewable.

Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	78/+	+/+	+/+	13/5
Biomass	-/+	+/+	+/+	+/-
Ocean	92/+	+/+	43/31	55/92
Hydro	+/+	+/+	+/+	+/+
Geothermal	45/+	+/+	+/+	+/+
Solar Thermal	-/37	49/43	85/80	90/-
PV	-/77	85/79	97/90	99/99

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2 Electricity generation by additional capacities in year 2020

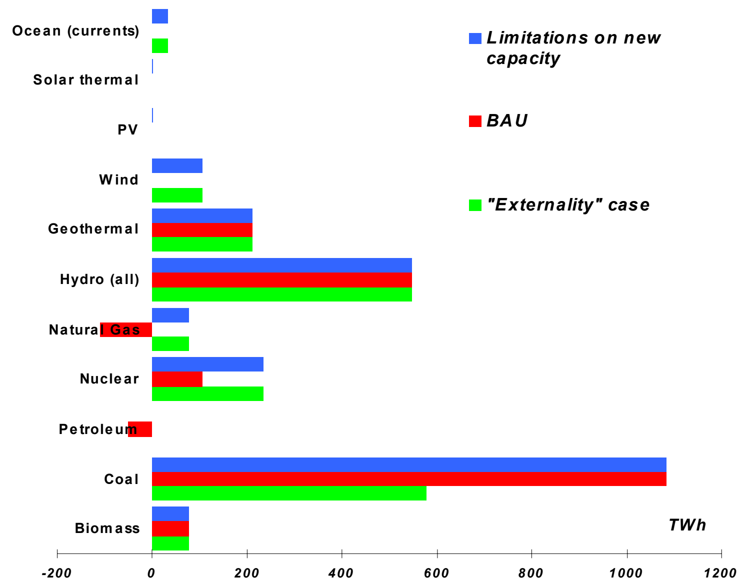


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	135.1	32.1	231.8	59.3	172.5
Externality cost	Bln USD	103.0	-	160.7	196.3	57.7[1]
Average electricity cost	¢ per kWh	8.0	1.9	6.5	1.7	4.8

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to a four times increase in cost of electricity generation, from 59 billion USD to 232 billion USD in the year 2020.
- Introducing externalities will shift coal from being cheapest option (after hydro) to most expensive (after solar technologies).
- All renewable energies benefit from externality accounting except solar technologies.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 138.8 TWh of renewable electricity, or 3.9 percent to economy's total electricity production in year 2020.

HONG KONG, CHINA

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	290
Natural gas	USD/toe	307
Coal	USD/toe	63.5
Nuclear	mills/kWh	16
Biomass	USD/toe	50

Source: *HK (2004)*

Table 2: Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Coal	27.5		
Petroleum	0.3		
Natural Gas	12.2		
Total	*40*	*52.9*	*91.5*

Source: APERC *database for projections 2002*

Table 3 Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,100	30	80	37	30	-	-
Petroleum	3	400	13	20	32	20	-	-
Natural Gas	3	560	12	65	51	20	700	1,500
Nuclear*	6	2,000	70	85	*non appl.*	30	1,200	3,800
Wind*	3	1,200	20	25	- " -	20	100	1,000
Biomass (municipal)	3	2,000	20	50	35	20	20	50
Ocean	4	5,000	40	35	*non appl.*	50	-	-
Hydro	2	2,500	20	45	- " -	50	-	-
Geothermal	4	5,000	110	90	- " -	20	-	-
Solar thermal	3	3,000	40	20	- " -	20	-	-
PV	2	5,000	12	15	- " -	20	10	50

* *Nuclear electricity is imported from nearby Guangdong province, as well as most of wind-generated electricity*

Source: *EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

Coal and natural gas are the main fuels for power generation, while petroleum is used for peak generation, supply stability and emergency. Natural gas turbines started to convert to combine cycle from year 2002. Coal, natural gas and petroleum are all imported, as well as nuclear power. Biomass is assumed to come from municipal wastes utilization. Data for new wind, biomass, and photovoltaic are author's estimations as no data is available for maximum renewable energy resources. Geothermal and ocean technologies are not available for Hong Kong. Data for new available coal, natural gas and petroleum-based capacities are gathered from latest available government projections. Hong Kong is suffering of space to place wind and solar thermal utilities, while some capacities are under construction in nearby Guangdong province. The only way to meet demand under restrictions for new conventional capacities construction in Hong Kong is to increase import from this province. It is supposed that one of the main supply sources would be new nuclear units in Daya Bay.

RESULTS

Figure 1: Leveraged electricity cost by technology considered

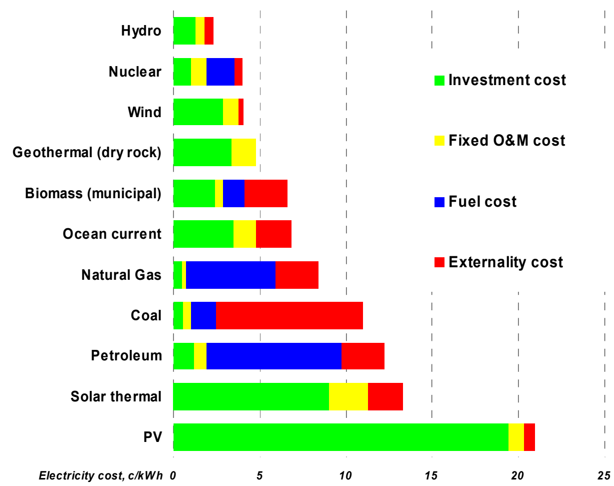


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	47/+	+/+	+/+	11/4
Biomass	68/+	+/+	+/+	24/-
Ocean	67/+	+/+	+/+	37/80
Hydro	+/+	+/+	+/+	+/+
Geothermal	69/+	+/+	+/+	38/25
Solar Thermal	98/28	20/21	61/55	86/-
PV	92/54	57/50	75/66	87/88

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Biomass, wind, geothermal capacities should run full scale due to proposed high rate of demand growth and construction of new generation facilities. The only possibility is NGCC and nuclear options, as there are not enough resources for NRE.

Figure 2 Hong Kong, China: Electricity generation by new capacities: maximum possible available, without and under externality consideration

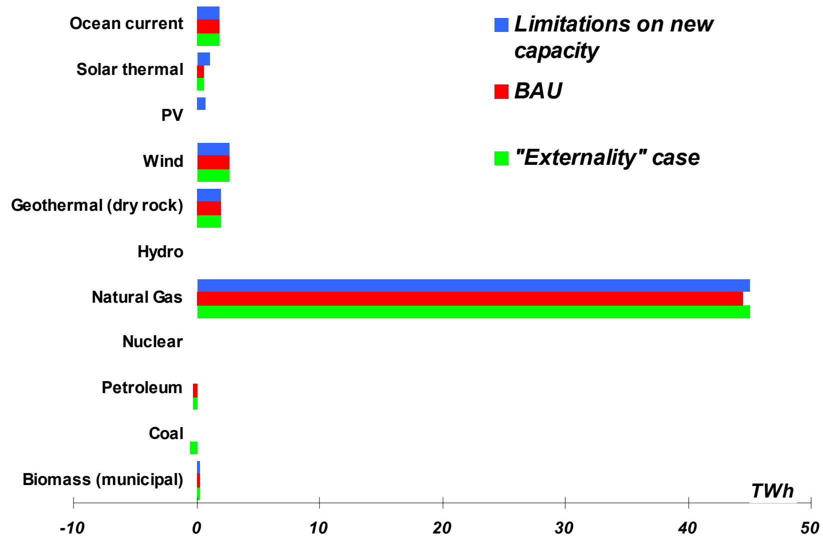


Table 5 Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	4.1	1.4	6.3	3.2	3.1
Externality cost	Bln USD	2.6	-	3.1	3.1	0.5[1]
Average electricity cost	¢ per kWh	10.2	3.6	6.9	3.5	3.4

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Renewable resources are not enough to satisfy a huge growth of electricity demand.
- Externalities accounting leads to two times higher cost of electricity generation from 3.2 billion USD to 6.3 billion USD in the year 2020.
- Not one renewable benefit from externality accounting, as coal option is prohibited.
- Natural gas is the most expensive option (except solar) in any case.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost did non lead to any incremental production of renewable electricity.

INDONESIA

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	307
Natural gas	USD/toe	119
Coal	USD/toe	18.9
Nuclear	mills/kWh	16
Biomass	USD/toe	20

Source: *Pertamina (2005), author's estimations*

Table 2: Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Coal	42.2		
Petroleum	16.5		
Biomass	0.3		
Natural Gas	45.1		
Hydro	12.9		
Geothermal	5.1		
Total	*121.9*	*171.0*	*322.5*

Source: *APERC database for projections 2002*

Table 3: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	3	1,204	18.06	80	30	25	10,800	15,000
Petroleum	2	550	10.72	60	35	20	400	1,000
Natural Gas	3	1,402	34.21	57	47	25	3,040	10,000
Nuclear	6	2,000	70	85	*non appl.*	30	-	2,000
Wind	2	3,750	26.81	30	- " -	20	300	2,000
Biomass	3	2,000	30	50	35	30	1,000	5,000
Ocean	4	5,000	40	35	*non appl.*	50	100	2,000
Hydro	2	2,500	20	45	- " -	50	500	1,000
Geothermal	4	5,000	110	90	- " -	20	100	500
Solar thermal	3	3,000	40	20	- " -	20	50	500
PV	1	5,500	10.34	13	- " -	20	100	1,000

Source: *MEMR (2005), EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

Indonesia is an archipelago, and the population are unevenly distributed. In 2003, of the total 24.4 GW installed capacity 33 percent was fuelled by petroleum. Coal fired power generation started in 1983 and reached 7.5 GW in 2003. In 2003 total capacity for natural gas power plant consist of 5.4 GW combined cycle gas power plant. The remainder comes from hydro and geothermal.

Total generating capacity is barely enough to meet peak load demand in Java and Bali. In some regions of the economy, the installed capacity does not even meet the peak load. In such a case there is no merit order for electricity generation. All available generation are used to meet the demand. Moreover, Indonesia aspires to reduce oil consumption by replacing natural gas and geothermal energy in power industry.

RESULTS

Figure 1: Leveraged electricity cost by technology considered

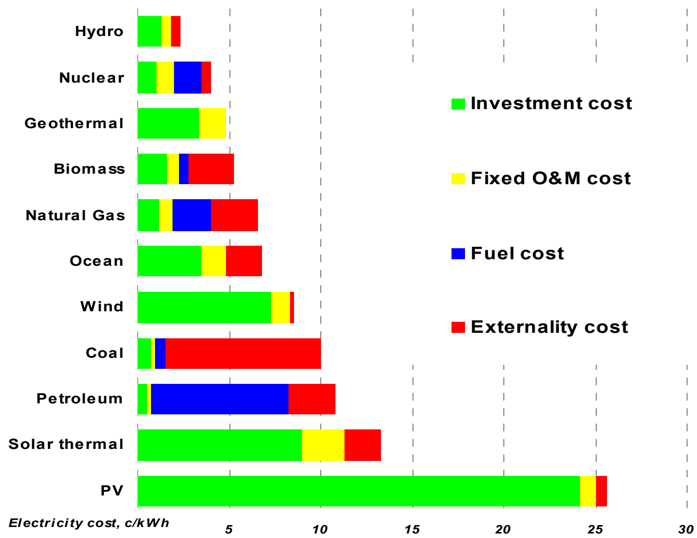


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	93/+	5/+	60/37	67/64
Biomass	78/+	+/+	+/+	+/79
Ocean	93/+	+/+	23/23	37/80
Hydro	23/+	+/+	+/+	+/+
Geothermal	96/+	+/+	24/+	38/25
Solar Thermal	-/38	35/28	81/80	86/-
PV	97/65	69/61	87/81	89/90

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Only hydro and biomass should run in full scale in any cases. Geothermal can be considered to run in full scale if “externality” is taken into account. Wind and ocean energy may be competitive only when externalities affecting generation cost and coal will lose its share to nuclear and natural gas, as well as to the above mentioned renewables.

Figure 2 Electricity generation by additional capacities in year 2020

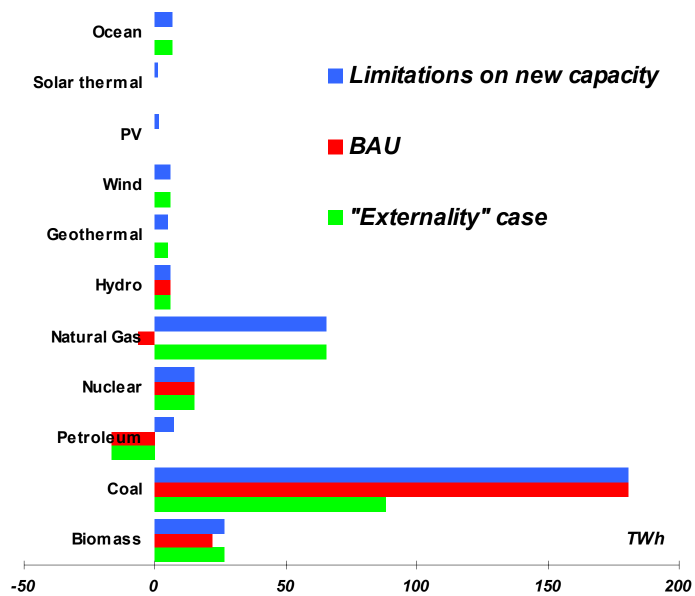


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	9.5	4.3	24.2	6.7	17.4
Externality cost	Bln USD	5.2	-	14.8	20.6	9.6[1]
Average electricity cost	¢ per kWh	7.8	3.5	7.5	2.1	5.4

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to over three times higher that of the electricity generation cost from 6.7 billion USD to 24.2 billion USD in the year 2020.
- Renewable energy resources are not enough to satisfy the huge demand.
- Geothermal, ocean, and wind benefit from externality accounting.
- Natural gas is the most attractive option both with and without externality accounting, while coal is the cheapest option without externalities.
- After introducing externalities geothermal technologies is more attractive compare to natural gas, adding ocean and wind technologies stands for more efficient position before coal.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 21.6 TWh of renewable electricity, or 6.7 percent to economy's total electricity production in year 2020.

JAPAN

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	310
Natural gas	USD/toe	230
Coal	USD/toe	100
Nuclear	mills/kWh	16
Biomass	USD/toe	50

Source: *author's estimations*

Table 2: Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Coal	233.9		
Natural Gas	244.1		
Petroleum	160.9		
Nuclear	345.9		
Biomass	20.9		
Hydro	99.5		
Geothermal	3.9		
Wind	7.2		
Solar	7.6		
Total	*1124*	*1229*	*1396*

Source: APERC *database for projections 2002*

Table 3: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	2,365	30	73	40	30	-	-
Petroleum	3	2,339	13	15	38	20	-	-
Natural Gas	3	1,426	12	53	42	20	20,000	4,000
Nuclear	6	2,426	70	74	*non appl.*	30	-	5,000
Wind	3	1,200	20	25	- " -	20	2,000	10,000
Biomass	3	2,000	20	50	35	20	500	2,000
Ocean	4	5,000	40	35	*non appl.*	50	1,000	10,000
Hydro	2	6,365	20	45	- " -	50	500	2,000
Geothermal	4	5,000	110	90	- " -	20	500	5,000
Solar thermal	3	3,000	40	20	- " -	20	100	5,000
PV	2	5,000	12	15	- " -	20	100	1,000

Source: *EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

As there is no possibility to build new nuclear plants beyond 2010, and the construction of new coal/petroleum facilities is prohibited, the only reasonable option for additional electricity generation is natural gas facilities and renewables.

RESULTS

Figure 1 Leveraged electricity cost by technology considered

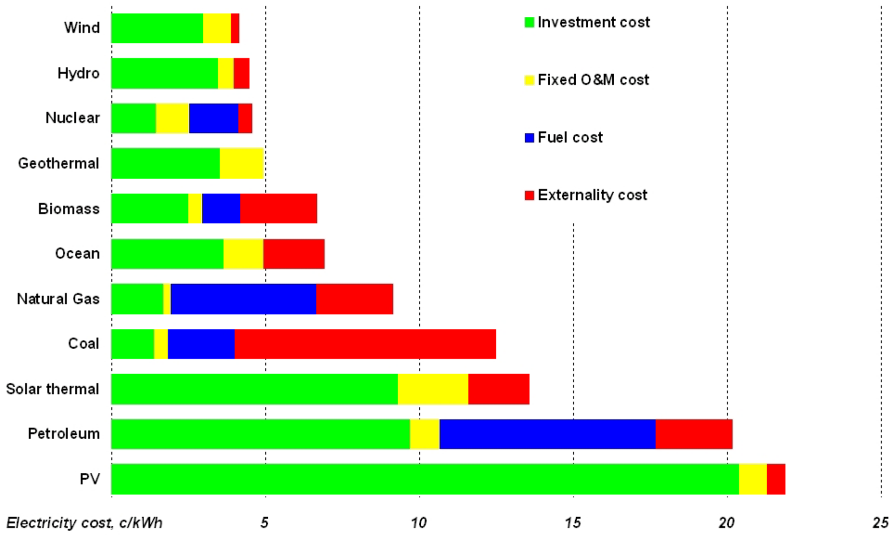


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	+/+	+/+	+/+	+/+
Biomass	7/+	+/+	+/+	2/84
Ocean	26/+	+/+	+/+	22/65
Hydro	+/+	+/+	+/+	+/+
Geothermal	26/+	+/+	+/+	23/10
Solar Thermal	82/12	+/18	53/51	80/97
PV	85/46	18/49	72/64	84/85

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2: Electricity generation by new capacities: maximum possible available, without and under externality consideration

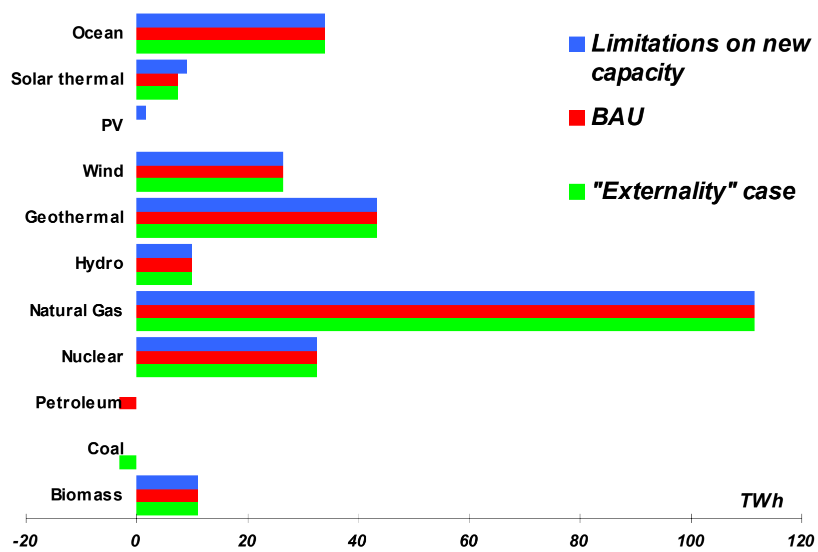


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	107.5	74.9	126.5	89.5	37.0
Externality cost	Bln USD	32.6	-	36.5	36.7	3.9[1]
Average electricity cost	¢ per kWh	9.6	6.7	9.1	6.4	2.6

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to a 40 percent increase in electricity generation cost from 90 billion USD to 127 billion USD in the year 2020
- Even without externality accounting wind generation is competitive to coal-based generation; and biomass, geothermal and ocean are competitive to natural gas.
- Introducing externalities didn't affect the competitiveness of renewable energy.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost did not lead to any incremental production of renewable electricity.

KOREA

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	206,3
Natural gas	USD/toe	282,3
Coal	USD/toe	60,6
Nuclear	mills/kWh	50
Biomass	USD/toe	50

Source: *MOCIE (2005), author's estimations for nuclear and biomass*

Table 2: Structure of electricity generation in 2005 and outlook to 202, TWh

	2005	2010	2020
Coal	160.4		
Petroleum	11.0		
Nuclear	123.9		
Natural Gas	63.9		
Hydro	6.2		
Biomass	0.8		
Total	*373.7*	*430.0*	*512.0*

Source: APERC *database for projections 2002*

Table 3 Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,015	41.2	88	39.2	30	2,427	2,224
Petroleum	3	893	36.8	44.5	37.6	30	491	333
Natural Gas	3	580	43.6	35.6	41.8	30	2,055	2,313
Nuclear	6	1,453	37.6	94.2	*non appl.*	40	1,872	2,664
Wind	3	1,200	20	25	- " -	20	2,000	5,000
Biomass	3	2,000	20	50	35	20	500	1,000
Ocean (currents)	4	5,000	40	35	*non appl.*	50	1,000	1,000
Hydro (small)	2	2,500	20	45	- " -	50	100	400
Geothermal (dry rock)	4	5,000	110	90	- " -	20	500	2,000
Solar thermal	3	3,000	40	20	- " -	20	200	1,000
PV	2	5,000	12	15	- " -	20	100	1,000

Source: *EIA (2005), ICRE (2004), ILASA (2003), author's estimations*

As O&M cost for coal, petroleum, gas and nuclear technology are 3-9 times less than that for US, renewables O&M costs are supposed to be two times less than the default values.

Possible hydro, wind, biomass, geothermal, ocean, solar thermal and photovoltaic capacities construction are purely author's estimations and did not refer to any official projections.

RESULTS

Figure 1: Leveraged electricity cost by technology considered

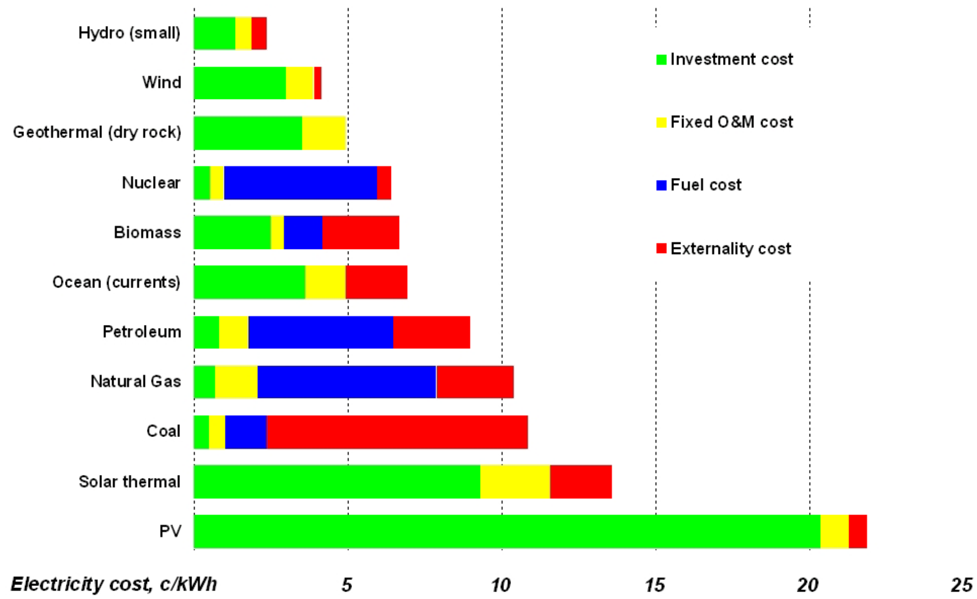


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	52/+	+/+	+/+	+/+
Biomass	73/+	+/+	+/+	+/10
Ocean	71/+	+/+	+/+	+/14
Hydro	+/+	+/+	+/+	+/+
Geothermal	73/+	+/+	+/+	+/+
Solar Thermal	99/29	55/53	40/37	60/77
PV	93/54	73/65	66/57	75/76

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
\+ *renewable energy is competitive to corresponding conventional technology*
– *uncompetitive to corresponding conventional technology even without investment cost*

Figure 2: Electricity generation by new capacities: maximum possible available, without and under externality consideration

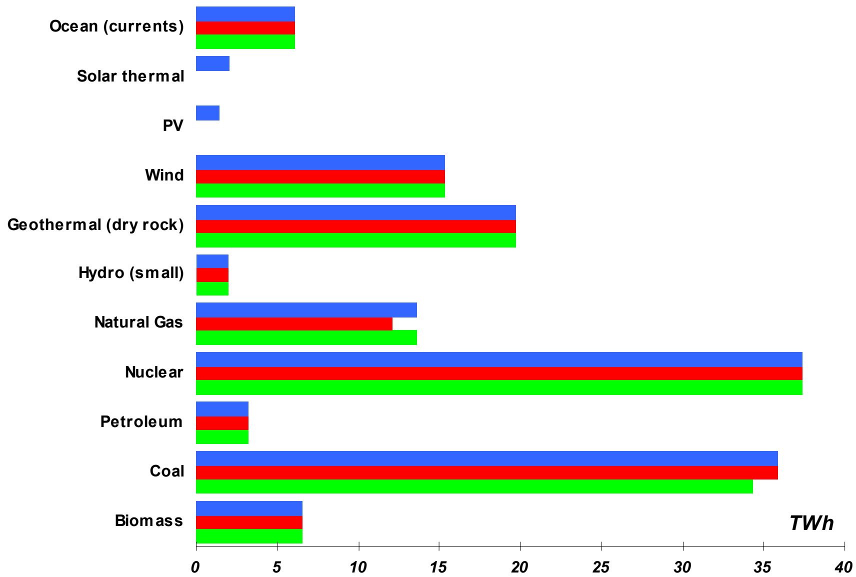


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	*BAU*	*Externality case*	*BAU*	*Difference*
Total electricity production cost	Bln USD	33.6	17.3	44.0	23.7	20.2
Externality cost	Bln USD	16.3	–	20.1	20.2	3.8[1]
Average electricity cost	¢ per kWh	9.0	4.6	8.6	4.6	3.8

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to almost twice the cost of electricity generation from 23.7 billion USD to 44.0 billion USD in the year 2020.
- Under current cost and fuel price conditions most of renewable technologies are already competitive with those powered by fossil fuels.
- None of renewable technologies benefit from externality accounting.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost did not lead to any incremental production of renewable electricity.

MALAYSIA

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

.

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	275
Natural gas	USD/toe	67
Coal	c/kWh	1.18
Nuclear	mills/kWh	16
Biomass	USD/toe	25

Source: *GTZ (2005), author's estimations*

Table 2: Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Biomass	0.2		
Coal Steam	25.3		
Oil-Based	3.6		
Natural Gas	51.8		
Hydro	11.6		
Total	*92.5*	*116.0*	*185.0*

Source: *APERC database for projections 2002*

Table 3: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,100	30	80	37	30	3,000	7,000
Petroleum	3	400	13	20	32	20	100	500
Natural Gas	3	1,402	34.21	57	47	25	2,000	4,000
Nuclear	6	2,000	70	85	*non appl.*	30	-	-
Wind	2	3,750	26.81	30	- " -	20	100	1,000
Biomass	3	700	47.18	50	35	30	500	1,000
Ocean	4	5,000	40	35	*non appl.*	50	1,000	5,000
Hydro	2	2,500	20	45	- " -	50	200	500
Geothermal	4	5,000	110	90	- " -	20	10	100
Solar thermal	3	3,000	40	20	- " -	20	500	1,000
PV	2	5,000	12	15	- " -	20	100	1,000

Source*: PTM (2005), EIA (2005), ICRE (2004), IIASA (2003), author's estimations, PTM (2005)*

RESULTS

Figure 1: Leveraged electricity cost by technology considered

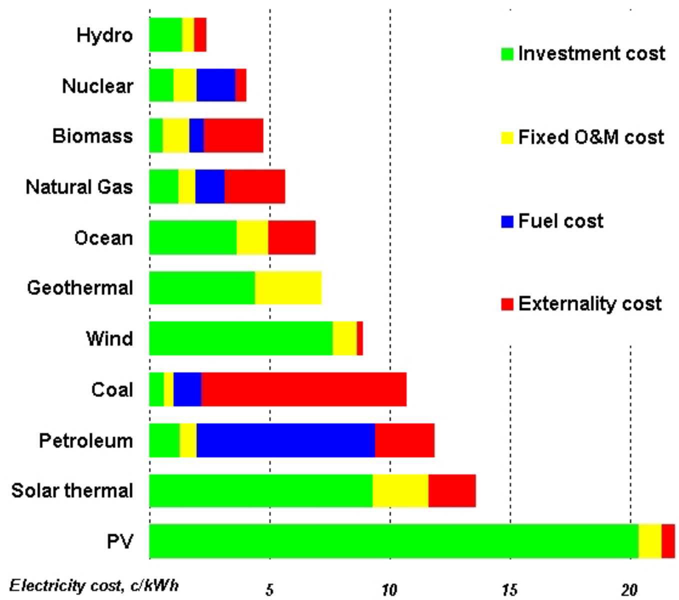


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	85/+	+/+	72/51	67/64
Biomass	14/+	+/+	+/+	+/-
Ocean	76/+	+/+	50/53	37/80
Hydro	+/+	+/+	+/+	+/+
Geothermal	-/+	+/+	92/50	82/72
Solar Thermal	-/31	24/26	91/92	86/-
PV	94/55	58/52	89/83	87/88

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2: Electricity generation by additional capacities during 2005-2020

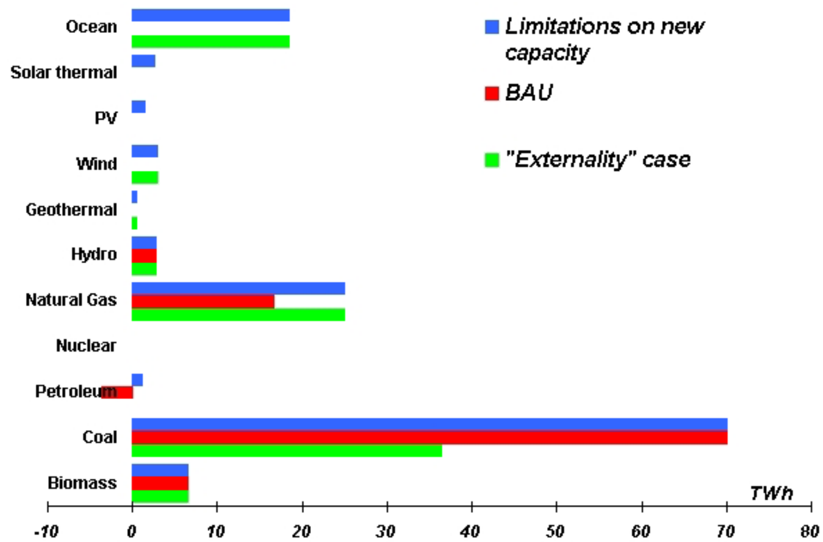


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	6.3	2.7	13.3	4.6	7.0
Externality cost	Bln USD	3.6	-	7.5	10.6	3.9[1]
Average electricity cost	¢ per kWh	6.8	1.9	7.2	2.5	4.7

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to more than two times higher the cost of electricity generation from 4.6 billion USD to 13.3 billion USD in the year 2020.
- Without externalities only hydro and biomass technologies are competitive to natural gas, and the cost of biomass is slightly smaller than coal.
- Ocean (in smaller degree), geothermal, and wind will have a benefit from externality accounting.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 22.2 TWh of renewable electricity, or 12.0 percent to economy's total electricity production in year 2020.

MEXICO

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	298
Natural gas	USD/toe	199
Coal	USD/toe	79
Nuclear	USD/kWh	0,04
Biomass	USD/toe	77

Source: Mexico (2004), *author's estimations*

Table 2 Structure of electricity generation in 2005, TWh

	2005	2010	2020
Coal	18,2		
Petroleum	74,7		
Natural Gas	114,1		
Nuclear	10,1		
Biomass	1,6		
Geothermal	7,4		
Wind	0,2		
Hydro	39,7		
Total	*266*	*374*	*609*

Source: APERC *database for projections 2002*

Table 3 : Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,100	30	80	37	30	2,000	5,000
Petroleum	3	400	13	20	51	20	21	50
Natural Gas	3	560	12	65	32	20	15,000	25,000
Nuclear	6	2,000	70	85	*non appl.*	30	-	3,000
Wind	4	1,200	20	25	- " -	20	1,000	5,000
Biomass	4	2,000	20	50	35	20	100	1,000
Ocean	4	5,000	40	20	*non appl.*	50	1,000	7,000
Hydro	4	2,000	15	45	- " -	50	1,000	5,000
Geothermal	4	3,100	110	45	- " -	20	960	10,000
Solar thermal	3	3,000	40	20	- " -	20	100	200
PV	2	5,000	12	15	- " -	20	100	300

Source: *EIA (2005), ICRE (2004), IIASA (2003), Pertamina (2005), author's estimations*

Natural gas is the main fuel for power generation; petroleum is used for peak generation, supply stability and in cases of emergency. Coal and natural gas are partially imported, including nuclear. Biomass is assumed to come from municipal wastes and 44 concessions were considered.

RESULTS

Figure 1: Leveraged electricity cost by technology considered

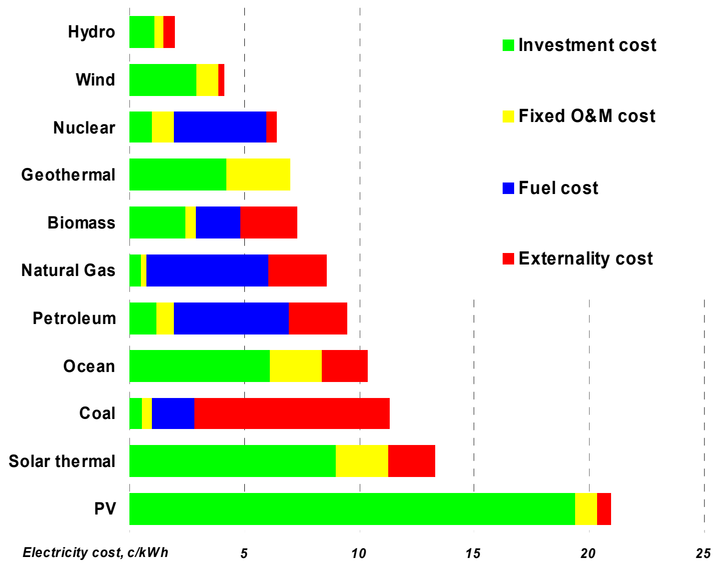


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	37/+	+/+	+/+	+/+
Biomass	80/+	+/+	+/+	+/38
Ocean	91/+	26/28	40/31	42/66
Hydro	+/+	+/+	+/+	+/+
Geothermal	99/+	4/+	24/+	27/17
Solar Thermal	94/24	49/51	59/53	60/77
PV	91/52	70/64	75/65	75/76

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
\+ *renewable energy is competitive to corresponding conventional technology*
– *uncompetitive to corresponding conventional technology even without investment cost*

Figure 2: Electricity generation by additional capacities during 2005-2020

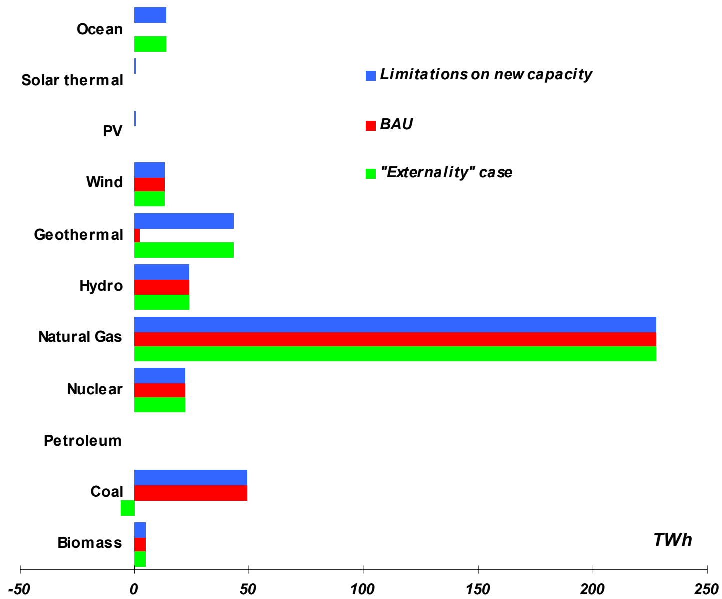


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference in 2020
Total electricity production cost	Bln USD	21.0	14.5	47.4	32.3	15.1
Externality cost	Bln USD	6.6	–	12.4	16.8	5.8[1]
Average electricity cost	¢ per kWh	7.9	5.4	7.8	5.3	2.5

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to a 50 percent increase in cost for electricity generation from 32.3 billion USD to 47.4 billion USD for the new capacity installed in the year 2020.
- After introducing externalities coal will lose its place to renewable energies except solar technologies.
- Wind and biomass are competitive even without externalities.
- Geothermal and probably ocean renewable benefit from externality accounting.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 55.0 TWh of renewable electricity, or 9.0 percent to economy's total electricity production in year 2020.

NEW ZEALAND

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	381,4
Natural gas	USD/toe	318,6
Coal	USD/toe	100,6
Biomass	USD/toe	50

Source: MOED (2005), *author's estimations*

Table 2: Structure of electricity generation in 2005, TWh

	2005	2010	2020
Coal	0.6		
Natural Gas	10.6		
Hydro	25.9		
Geothermal	3.3		
Wind	0.2		
Biomass	0.6		
Total	*41.2*	*44.5*	*50.0*

Source: *APERC database for projections 2002*

Table 3: Cost assumptions by technologies

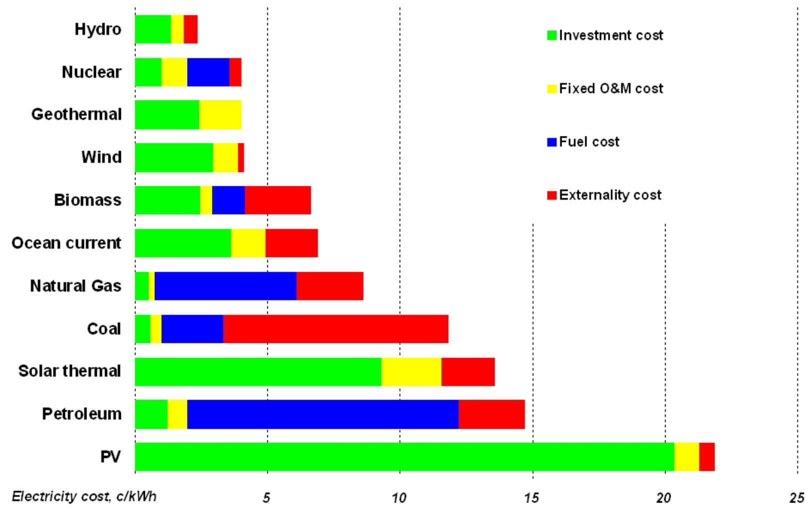
	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1100	30	80	37	30	-	-
Petroleum	3	400	13	20	32	20	-	-
Natural Gas	3	560	12	65	51	20	500	2,000
Nuclear	6	2000	70	85	*non appl.*	30	-	-
Wind	3	1200	20	45	- " -	20	100	1,000
Biomass	3	2000	20	50	35	20	100	200
Ocean current	4	5000	40	35	*non appl.*	50	500	1,000
Hydro	2	2500	20	45	- " -	50	100	1,000
Geothermal	4	3100	110	80	- " -	20	500	1,000
Solar thermal	3	3000	40	20	- " -	20	100	1,000
PV	2	5000	12	15	- " -	20	100	1,000

Source: *MOED (2004,2005a), EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

Hydro and natural gas dominate electricity production; renewables are also advanced relative to other APEC economies. Biomass resources are assumed to come from agriculture and national forestry. Data for new wind, biomass, hydro, geothermal, solar thermal and photovoltaic are author's estimations as no data was available for maximum renewable energy resources. New natural gas capacities were considered to meet demand after all possible renewables were utilised.

RESULTS

Figure 1 Leveraged electricity cost by technology considered



Biomass, wind, geothermal capacities should run for a full scale due to proposed high rate of demand growth and construction of new generation facilities. The only possibility is NGCC and nuclear, since there are not enough NRE resources.

Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	18/+	+/+	+/+	11/4
Biomass	33/+	+/+	+/+	24/-
Ocean	44/+	+/+	+/+	37/80
Hydro	+/+	+/+	+/+	+/+
Geothermal	28/+	+/+	+/+	19/+
Solar Thermal	89/19	+/+	59/53	86/-
PV	88/49	44/38	74/65	87/88

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2 Electricity generation by new capacities: maximum possible available, without and under externality consideration

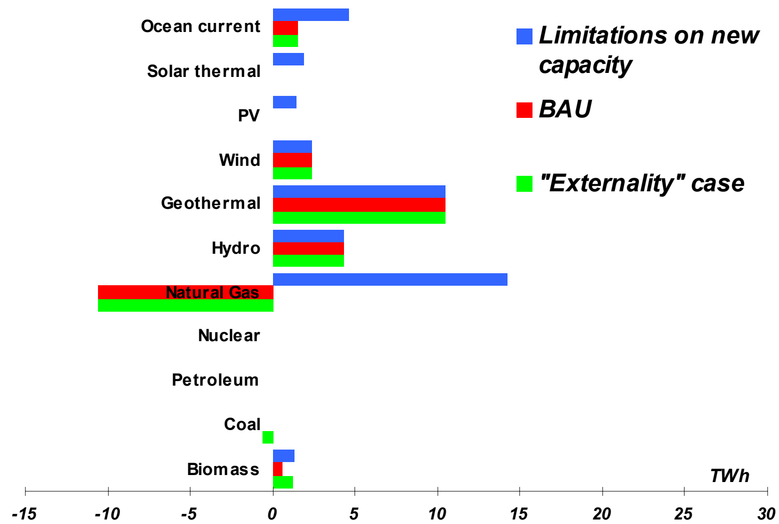


Table 5 New Zealand: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	1.8	1.3	1.7	1.4	0.2
Externality cost	Bln USD	0.5	-	0.2	0.3	0.3[1]
Average electricity cost	¢ per kWh	4.3	3.2	3.3	2.8	0.5

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to some increment in the cost of electricity generation – from 1.437 billion USD to 1.737 billion USD in 2020. Total expenses and average electricity price would be even less at the end of the term.
- Under the current cost and fuel price conditions all renewable technologies but solar are already competitive with those that are powered by fossil fuels.
- After introducing externalities only wind technologies became about the same competitiveness as natural gas.
- Not one but biomass benefit from externality accounting by replacing existing coal capacities.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 640 MWh of renewable electricity, or 1.3 percent to economy's total electricity production in year 2020.

PAPUA-NEW GUINEA

INPUT DATA AND ASSUMPTIONS

Table 1: Fuel prices

	Unit	Value
Petroleum	USD/toe	516.70
Natural gas	USD/toe	219.14
Biomass	USD/toe	39.25

Source: PNG (2005)

Table 2 Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Petroleum	0.83		
Natural Gas	0.61		
Hydro	1.16		
Total	*3,1*	*4,4*	*8,6*

Source: *APERC database for 2002 Outlook*

Table 3 Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Efficiency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*Years*	*MW*	*MW*
Coal	4	1,100	30	80	35	30	-	-
Petroleum	3	400	8,8	65	41	20	-	-
Natural Gas	3	1,500	43	90	45	20	90	130
Nuclear	6	2,000	70	85	*non appl.*	30	-	-
Wind	3	1,200	20	25	- " -	20	10	100
Biomass	3	1,686	45	90	35	30	30	80
Ocean	4	5,000	40	35	*non appl.*	50	10	100
Hydro	4	2,000	15	45	- " -	50	5	20
Geothermal	3	1,600	50	60	- " -	50	15	30
Solar thermal	3	3,000	40	20	- " -	20	10	10
PV	2	5,000	12	15	- " -	20	10	10

Source: PNG (2003), PNG (2004), *EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

Petroleum fuel is the source for power generation whilst natural gas and biomass accounts for a small percent of the power generation needs in PNG. Prior to mid 2004, PNG was heavily dependent on imported petroleum fuels. Since Napa Napa Oil Refinery starts it operations in 2004 the domestic demand for petroleum fuels is met while 35 percent of the refined fuel is exporting to other nations. Geothermal power generation is a relatively new technology to PNG and the private sector is basically developing this technology to meet the demand for electricity. Data for biomass is author's estimates. National grid is on its starting stage, complicated by island nature of the country and rather small and distributed consumption.

RESULTS

As there is no evidence or policy for new coal or nuclear facilities, hydro, geothermal and biomass are considered the cheapest options without externalities accounting, followed by wind and ocean utilities in the range of 1.5-2 cents per kWh. Due to the high cost of diesel, the cost of generation between petroleum-based and solar are about the same. As there is no options for nuclear and coal, and with small natural gas plant, all renewable except solar technologies should be used in full capacities. Even tradeoffs between solar thermal and petroleum occur.

Since power grids have to be developed gradually the transmission cost should influence great to the competitiveness of the renewable capacities.

Figure 1: Leveraged electricity cost by technology

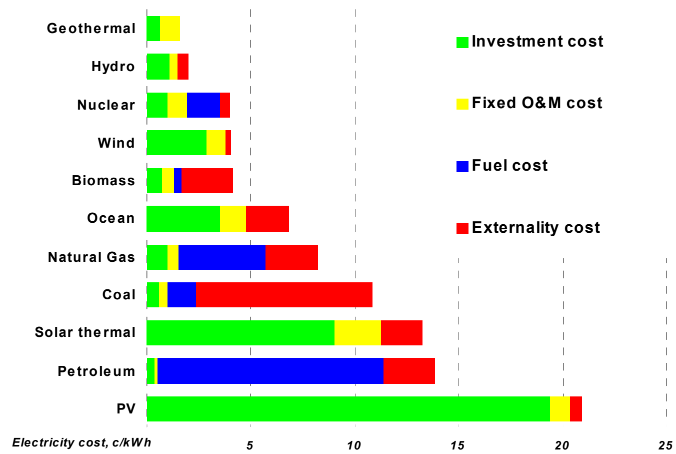


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	51/+	+/+	+/+	11/4
Biomass	+/+	+/+	+/+	+/-
Ocean	71/+	+/+	+/+	37/80
Hydro	+/+	+/+	+/+	+/+
Geothermal	+/+	+/+	+/+	+/+
Solar Thermal	99/29	2/+	63/62	86/-
PV	93/54	49/38	76/69	87/88

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
\+ *renewable energy is competitive to corresponding conventional technology*
– *uncompetitive to corresponding conventional technology even without investment cost*

Figure 2 : Electricity generation by additional capacities in year 2020

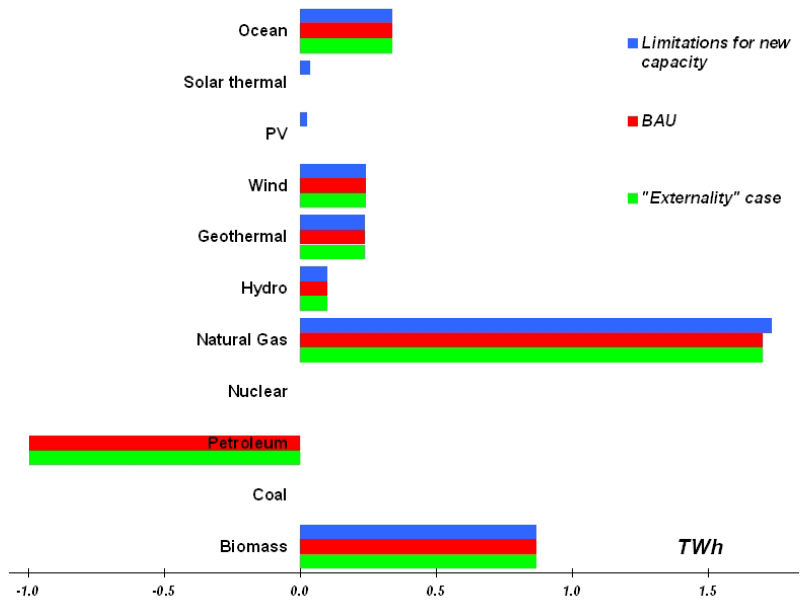


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	0.23	0.18	0.64	0.37	0.27
Externality cost	Bln USD	0.05	-	0.27	0.27	0.22[1]
Average electricity cost	¢ per kWh	7.3	5.6	7.5	4.3	3.1

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to increase in cost of electricity generation over 70 percent from 0.37 billion USD to 0.64 billion USD for the new capacity installed in the year 2020.
- As there is no options for nuclear and coal generation, all renewables but solar technologies are competitive to natural gas even in the absence of externality accounting
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost did not lead to any incremental production of renewable electricity.

PERU

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	313
Natural gas	USD/toe	69
Coal	USD/toe	120
Biomass	USD/toe	70

Source: *OSINERG (2005)*

Table 2: Structure of electricity generation in 2005, TWh

	2005	2010	2020
Coal	0.9		
Petroleum	0.8		
Biomass	0.2		
Natural Gas	2.3		
Hydro	14.5		
Total	*21,6*	*27,2*	*43,8*

Source: APERC *database for projections 2002*

Table 55 Peru: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	3	770	10.4	84	41.9	25	135	-
Petroleum	3	400	13	20	51	20	-	-
Natural Gas	3	582	5.17	80	45	25	1,025	1,125
Nuclear	6	2,000	70	85	*non appl.*	30	-	-
Wind	4	1,200	20	25	- " -	20	50	1,000
Biomass	4	2,000	20	50	35	20	10	100
Ocean	4	5,000	40	20	*non appl.*	50	100	2,000
Hydro	4	1,064	24.2	80	- " -	50	140	1,369
Geothermal	4	3,100	110	45	- " -	20	50	200
Solar thermal	3	3,000	40	20	- " -	20	100	200
PV	2	5,000	12	15	- " -	20	100	300

Source: *OSINERG (2005), EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

RESULTS

Figure 1: Leveraged electricity cost by technology considered

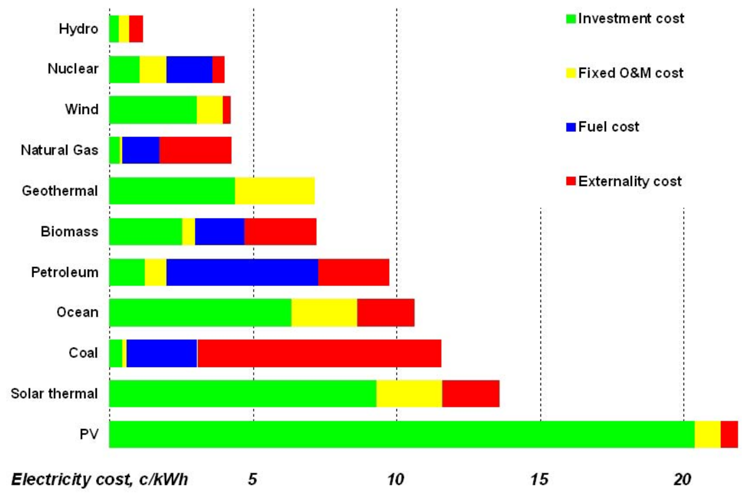


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	**Petroleum**	**Natural Gas**	**Nuclear**
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	30/+	+/+	72/+	13/6
Biomass	65/+	+/+	-/-	45/-
Ocean	88/+	22/26	-/99	80/-
Hydro	+/+	+/+	+/+	+/+
Geothermal	94/+	+/+	-/64	82/72
Solar Thermal	92/22	47/50	-/99	86/-
PV	89/51	69/63	96/86	87/88

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2: Electricity generations by additional capacities in 2020

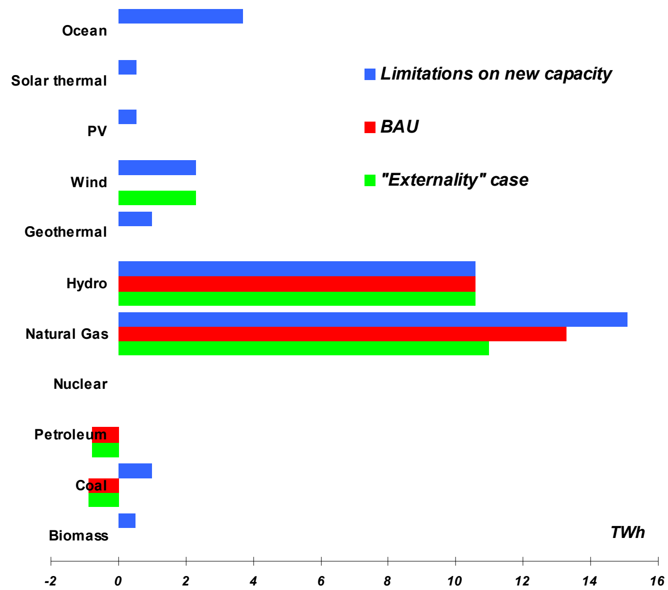


Table 5 Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	0.5	0.25	1.0	0.47	0.53
Externality cost	Bln USD	0.25	–	0.48	0.5	0.23
Average electricity cost	¢ per kWh	2.3	1.1	2.3	1.1	1.2

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to two times higher cost of electricity generation for the new capacity in the year 2020.
- Natural gas is the most attractive option even in case of externality accounting.
- Only wind technologies benefit from externality accounting.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 2.3 TWh of renewable electricity, or 5.2 percent to economy's total electricity production in year 2020.

PHILIPPINES

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (diesel oil)	USD/toe	200
Natural gas	USD/toe	80
Coal	USD/toe	50
Nuclear	mills/kWh	16
Biomass	USD/toe	40

Source: *author's estimations*

Table 2: Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Petroleum	5.0		
Biomass	0.1		
Coal	13.9		
Natural Gas	12.1		
Hydro	9.8		
Geothermal	12.5		
Wind	0.2		
Total	*53.7*	*74.3*	*134.5*

Source: APERC *database for projections 2002*

Table 3: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,100	30	80	37	30	300	900
Petroleum	3	600	13	80	32	20	-	-
Natural Gas	3	560	12	65	51	20	2,500	4,500
Nuclear	6	2,000	70	85	*non appl.*	30	-	-
Wind	3	1,200	20	25	- " -	20	1,000	2,000
Biomass	3	2,000	20	50	35	20	50	200
Ocean	4	5,000	40	35	*non appl.*	50	1,000	2,000
Hydro	2	2,500	20	45	- " -	50	1,000	4,000
Geothermal	4	3,100	110	80	- " -	20	500	1,500
Solar thermal	3	3,000	40	20	- " -	20	100	500
PV	2	5,000	12	15	- " -	20	100	500

Source: *EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

RESULTS

Figure 1 Leveraged electricity cost by technology considered

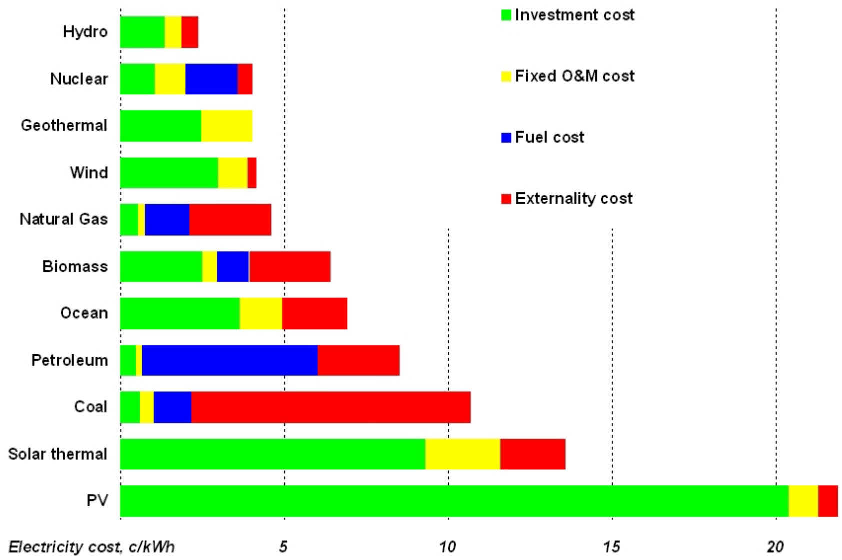


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	58/+	+/+	6/+	11/4
Biomass	70/+	+/+	74/72	14/97
Ocean	76/+	+/+	78/63	37/80
Hydro	+/+	+/+	+/+	+/+
Geothermal	76/+	+/+	79/+	19/+
Solar Thermal	-/31	60/53	-/96	86/-
PV	94/55	75/65	94/85	87/88

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2 Electricity generation by new capacities: maximum possible available, without and under externality consideration

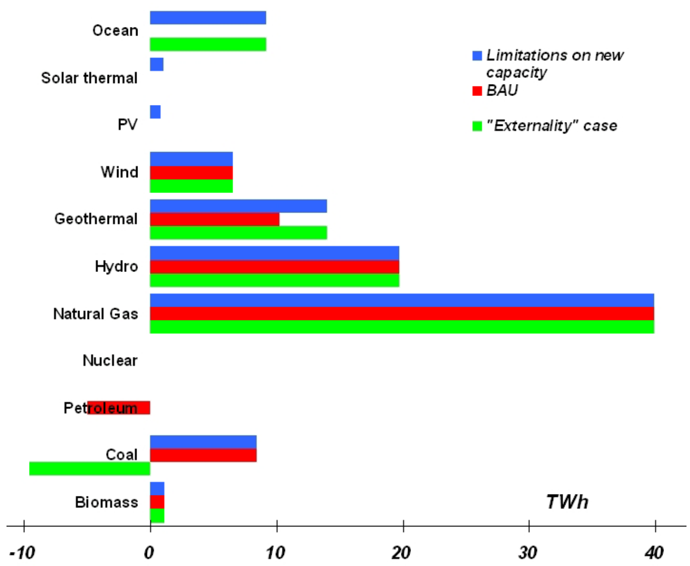


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	3.2	1.6	5.4	3.3	2.1
Externality cost	Bln USD	1.7	-	2.2	3.4	0.5[1]
Average electricity cost	¢ per kWh	6.0	2.9	4.5	2.5	2.0

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to 60 percent increase in the cost of electricity generation from 3.3 billion USD to 5.4 billion USD in the year 2020.
- Introducing externalities can benefit to geothermal, wind and ocean technologies.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 13.0 TWh of renewable electricity, or 9.7 percent to economy's total electricity production in year 2020.

RUSSIA

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1 : Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	116,9
Natural gas	USD/toe	15,2
Coal	USD/toe	38,6
Nuclear	mills/kWh	16
Biomass	USD/toe	10

Source: *GKS (2005), author's estimations for nuclear and biomass*

Table 2 : Structure of electricity generation in 2005, TWh

	2005	2010	2020
Coal	276,0		
Petroleum	22,0		
Nuclear	136,0		
Natural Gas	424,0		
Hydro	176,1		
Biomass	2,0		
Total	*1036*	*1191*	*1602*

Source: APERC *database for projections 2002*

Table 3 : Cost assumptions by technology

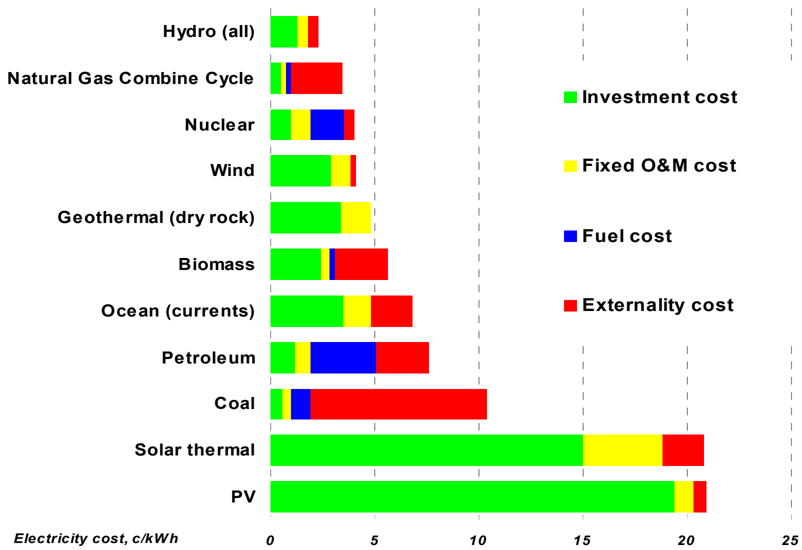
	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,100	30	80	37	30	5,000	20,000
Petroleum	3	400	13	20	32	20	-	-
Natural Gas Combine Cycle	3	560	12	65	51	20	10,000	20,000
Nuclear	6	2,000	70	85	*non appl.*	30	5,000	20,000
Wind	4	1,200	20	25	- " -	20	2,000	10,000
Biomass	3	2,000	20	50	35	20	500	1,000
Ocean (currents)	4	5,000	40	35	*non appl.*	50	1,000	10,000
Hydro (all)	2	2,500	20	45	- " -	50	5,000	10,000
Geothermal (dry rock)	4	5,000	110	90	- " -	20	1,000	5,000
Solar thermal	3	3,000	40	12	- " -	20	200	1,000
PV	2	5,000	12	15	- " -	20	100	1,000

Source: *MOIE(2003), EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

Natural gas is used for power steam turbines. There are few combine cycle utilities in operation now. Abandoned from renewables, Russia could not tap most of them because of long distance to the main consumption areas. Conversion from steam to combined cycle operation and nuclear would lead to electricity generation development. Possible hydro, wind, biomass, geothermal, ocean, solar thermal and photovoltaic are author's estimations based on available resources of renewable energy from IEA (2003).

RESULTS

Figure 1: Leveraged electricity cost by technology considered



In general relatively cheap investment and O&M costs lead to greater importance of externality factor. If taken into account, ocean energy may become more attractive than coal-fired power plants.

Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	67/+	+/+	90/14	13/6
Biomass	51/+	+/+	79/77	+/67
Ocean	83/+	+/+	-/87	37/80
Hydro	+/+	+/+	47/+	+/+
Geothermal	85/+	+/+	-/33	38/25
Solar Thermal	-/70	91/93	-/-	-/-
PV	95/56	79/73	98/89	87/88

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*

+ renewable energy is competitive to corresponding conventional technology

– uncompetitive to corresponding conventional technology even without investment cost

Figure 2: Electricity generation by new capacities: maximum possible available, without and under externality consideration

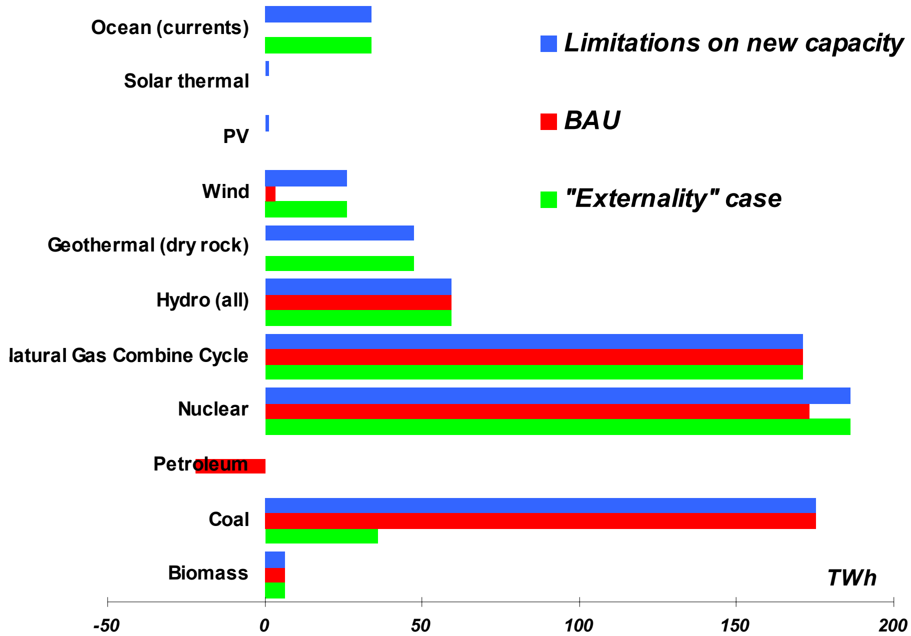


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	55.9	19.8	81.0	31.9	49.1
Externality cost	Bln USD	36.1	–	45.5	56.0	9.4[1]
Average electricity cost	¢ per kWh	5.4	1.9	5.4	2.0	3.4

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to factor 2.6 increase in the cost of electricity generation in the year 2020 from 31.9 billion USD to 81.0 billion USD.
- Natural gas is the most attractive option even in case of externality accounting.
- All renewables but solar benefit from externality accounting in replacing coal generation.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 104.1 TWh of renewable electricity, or 6.5 percent to economy's total electricity production in year 2020.

SINGAPORE

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	250
Natural gas	USD/toe	180
Coal	USD/toe	80
Nuclear	mills/kWh	16
Biomass	USD/toe	50

Source: *author's estimations*

Table 2: Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Petroleum	10.0		
Biomass	1.0		
Natural Gas	31.1		
Total	*42.1*	*53.3*	*80.2*

Source: APERC *database for projections 2002*

Table 3: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,100	30	80	37	30	500	1,000
Petroleum	3	400	13	20	32	20	-	-
Natural Gas	3	560	12	65	51	20	2,000	4,000
Nuclear	6	2,000	70	85	*non appl.*	30	-	-
Wind	3	1,200	20	10	- " -	20	50	100
Biomass	3	2,000	20	50	35	20	20	50
Ocean	4	5,000	40	35	*non appl.*	50	-	-
Hydro	2	2,500	20	45	- " -	50	-	-
Geothermal	4	5,000	110	90	- " -	20	-	-
Solar thermal	3	3,000	40	20	- " -	20	10	50
PV	2	5,000	12	15	- " -	20	50	200

Source: *EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

Singapore has to import all fuels to feed her economy, and lack of renewable. Wind technology is competitive to natural gas, followed by biomass, geothermal, and ocean technologies.

RESULTS

Figure 1: Leveraged electricity cost by technology considered

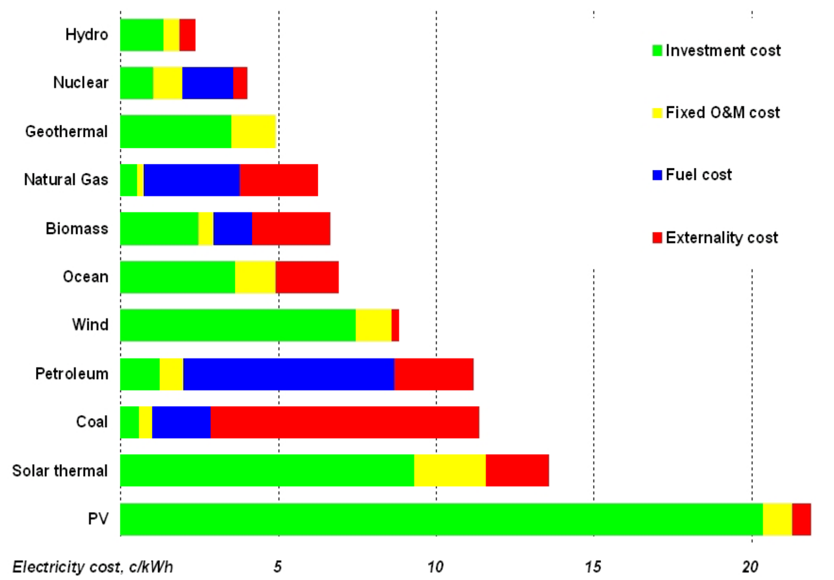


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	34/+	+/+	4/+	11/4
Biomass	52/+	+/+	16/14	24/-
Ocean	57/+	+/+	32/17	37/80
Hydro	+/+	+/+	+/+	+/+
Geothermal	58/+	+/+	32/+	38/25
Solar Thermal	94/24	31/33	84/78	86/-
PV	90/52	62/56	86/76	87/88

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2: Electricity generation by new capacities: maximum possible available, without and under externality consideration

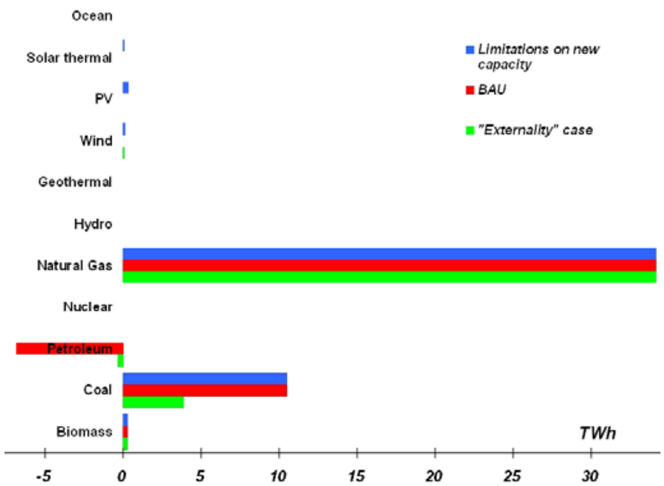


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	3.1	2.0	5.7	3.1	2.6
Externality cost	Bln USD	1.1	-	2.2	2.6	1.1[1]
Average electricity cost	¢ per kWh	7.4	4.9	7.1	3.9	3.2

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

:

- Externalities accounting leads to 50 percent increase in the cost of electricity generation for the new capacity installed in the year 2020 from 3.1 billion USD to 5.7 billion USD.
- Introducing externalities can benefit to geothermal energy only.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 88 MWh of renewable electricity, or 0.1 percent to economy's total electricity production in year 2020.

CHINESE TAIPEI

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	264
Natural gas	USD/toe	364
Coal	USD/toe	47
Nuclear	mills/kWh	30
Biomass	USD/toe	50

Source: *TP (2005), author's estimations for biomass*

Table 2: Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Coal	101.1		
Petroleum	13.6		
Nuclear	65.3		
Natural Gas	19.2		
Hydro	9.7		
Total	*208.8*	*256.4*	*362.3*

Source: APERC *database for projections 2002*

Table 3: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	5	1,392	36	82.5	37.8	40	703	6,100
Petroleum	3	668	6.2	10	29	20	61	90
Natural Gas	5	853	7.5	50	46.4	30	7,058	5,000
Nuclear*	6	1,290	86.9	87	*non appl.*	40	2,700	(1,272)
Wind	2	1,483	33.3	30	- " -	20	2,000	10,000
Biomass	2	1,757	47.18	65	35	20	100	1,000
Ocean (current)	3	5,000	40	30	*non appl.*	50	1,000	4,000
Hydro (small)	3	2,940	29.4	35	- " -	50	100	500
Geothermal (dry rock)	3	6,500	80	80	- " -	30	100	1,000
Solar thermal	3	2,960	50.23	20	- " -	20	100	4,000
PV	1	9,270	29.4	14.2	- " -	20	100	1,000

Source: *TP (2005), EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

*Planning to switch-off nuclear reactor

RESULTS

Figure 1: Leveraged electricity cost by technology considered

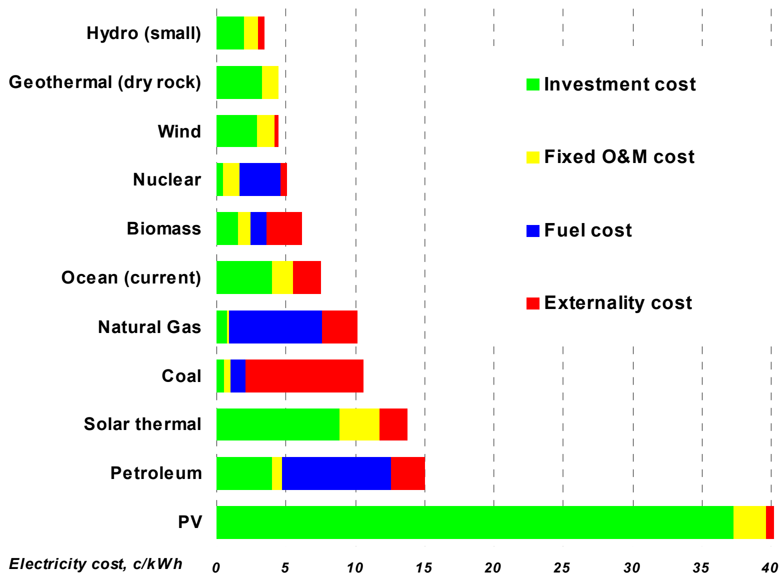


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	72/+	+/+	+/+	+/+
Biomass	97/+	+/+	+/+	+/68
Ocean	86/+	+/+	+/+	25/62
Hydro	45/+	+/+	+/+	+/+
Geothermal	71/+	+/+	+/+	+/+
Solar Thermal	-/37	+/27	48/45	81/98
PV	-/79	72/77	86/81	94/94

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ *renewable energy is competitive to corresponding conventional technology*
– *uncompetitive to corresponding conventional technology even without investment cost*

Figure 2: Electricity generation by additional capacities during 2005-2020

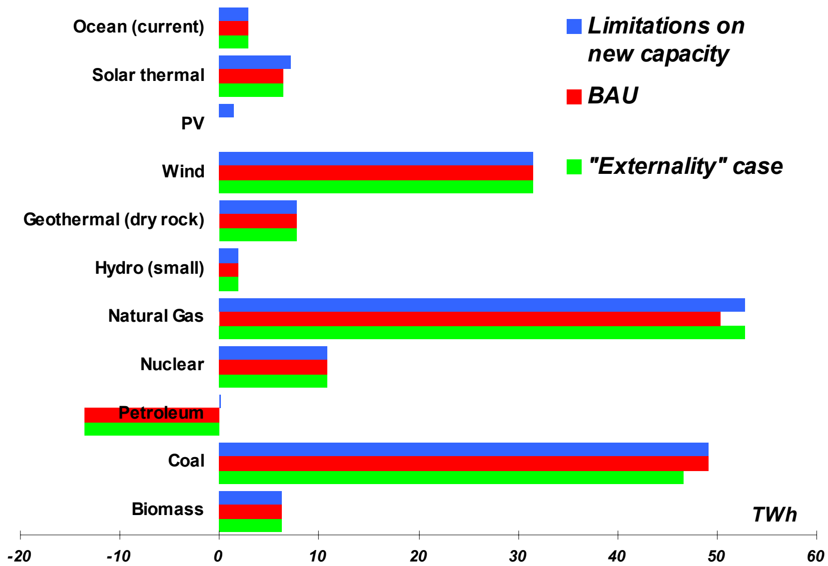


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	18.4	8.6	30.6	15.2	15.3
Externality cost	Bln USD	9.8	-	15.2	15.3	5.4[1]
Average electricity cost	¢ per kWh	8.8	4.1	8.4	4.2	4.2

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to two times higher for electricity generation cost from 15.2 billion USD to 30.6 billion USD in the year 2020.
- Natural gas is the most attractive option even in case of externality accounting.
- Even without externalities all renewables but solar are competitive to natural gas.
- None of renewable benefit from externality accounting.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost did not lead to any incremental production of renewable electricity.

THAILAND

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	218
Natural gas	USD/toe	134
Coal (Lignite)	USD/toe	44
Nuclear	mills/kWh	16
Biomass	USD/toe	37

Source: *EGAT (2004), DEDE (2003), author's estimations*

Table 2: Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Coal	16.6		
Petroleum	15.7		
Biomass	0.5		
Natural Gas	63.1		
Hydro	7.2		
Total	*103.1*	*138.9*	*259.7*

Source: *APERC database for 2002 Outlook*

Table 3: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,237	43	90	33	30	4,117	6,000
Petroleum	2	450	9.6	80	35	30	-	-
Natural Gas	3	1,000	20	90	45	20	18,458	4,000
Nuclear	6	1,600	60	90	*non appl.*	40	-	2,000
Wind	1	1,120	23.3	30	- " -	20	100	5,000
Biomass	1	1,400	42	80	35	30	200	1,000
Ocean	4	5,000	40	35	*non appl.*	50	500	1,000
Hydro	2	2,500	20	45	- " -	50	100	1,000
Geothermal	4	500	110	80	- " -	50	100	1,000
Solar thermal	3	3,000	40	20	- " -	20	100	1,000
PV	2	5,000	12	15	- " -	20	100	1,000

Source: *EPPO (2004), EIA (2005), ICRE (2004), IIASA (2003), author's estimations*

Electricity production is predominantly based on thermal and combined cycle generation, with natural gas accounting for 71 percent and lignite about 16 percent. The remainder is made up of 5 percent large-scale hydropower, 4 percent fuel oil, and 4 percent others (mainly imports from Laos and less than 1 percent from renewables) (FY 2004 statistics).

RESULTS

Figure 1 Leveraged electricity cost by technology considered

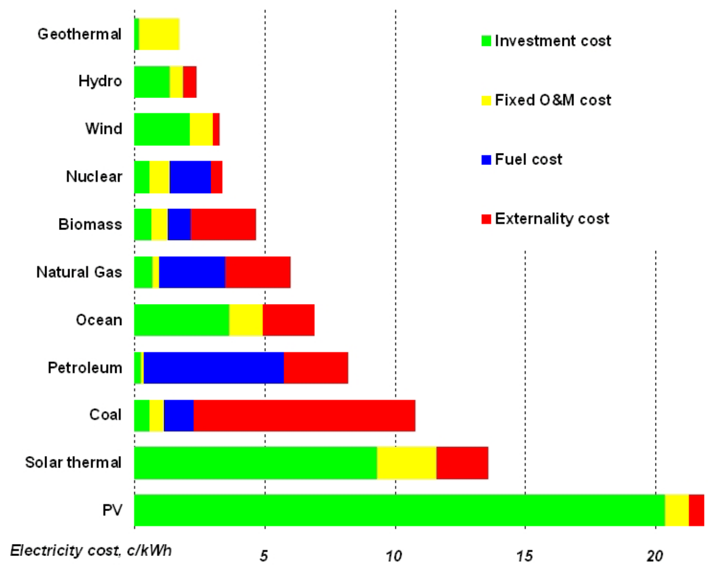


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	35/+	+/+	+/+	3/+
Biomass	+/+	+/+	+/+	+/-
Ocean	73/+	+/+	39/29	55/97
Hydro	+/+	+/+	+/+	+/+
Geothermal	56/+	+/+	+/+	13/+
Solar Thermal	-/30	63/54	87/83	93/-
PV	93/55	76/65	87/78	90/91

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2: Electricity generation by additional capacities in year 2020

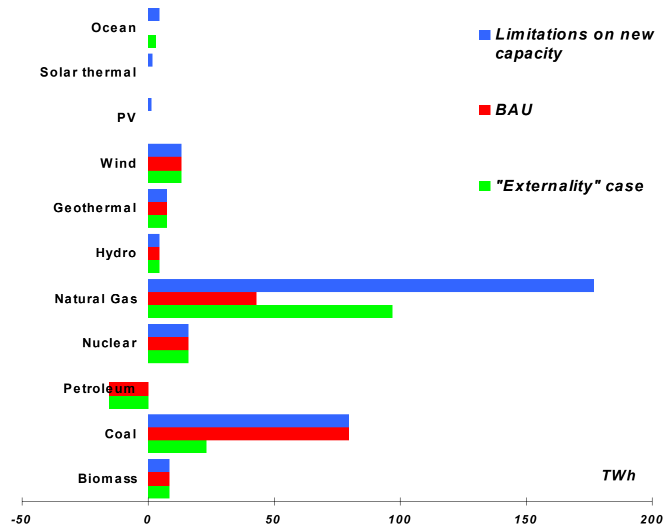


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	7.0	3.6	15.8	7.3	8.5
Externality cost	Bln USD	3.4	-	7.8	11.2	4.4[1]
Average electricity cost	¢ per kWh	6.8	3.5	6.1	2.8	3.3

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- There is a big gap between APERC 2002 outlook and current government projections for electricity production – almost 100 TWh for year 2020
- Externalities will lead to higher cost of electricity generation from 7.3 billion USD to 15.8 billion USD in the year 2020 for the new capacity installed.
- Hydro and geothermal options are the cheapest technologies even with taking into account externalities.
- Introducing externalities will bring coal to the most expensive options, thus providing advantages to biomass and wind utilities
- Ocean energy is competitive to natural gas combined cycle turbines in any cases under given assumptions
- Internalisation of externalities in electricity production cost could lead to incremental production of 3.1 TWh of renewable electricity, or 1.2 percent to economy's total electricity production in year 2020.

UNITED STATES

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Fuel oil	USD/toe	203.9
Natural gas	USD/toe	262
Coal	USD/toe	55.2
Nuclear	mills/kWh	18
Biomass	USD/toe	50

Source: *EIA (2005), author's estimation*

Table 2 Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Coal	1993		
Petroleum	99		
Nuclear	789		
Gas	716		
Hydro	261		
Other Renewables	89		
Other	6		
Total	*4010*	*4322*	*5085*

Source: *APERC database for projections*

Table 3: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,050	24.36	80	37	30	15,000	40,000
Petroleum	3	395	10.72	20	32	20	6,000	35,000
Natural Gas	3	560	10.35	65	51	20	32,000	50,000
Nuclear	6	1,957	60.06	85	*non appl.*	30	-	2,000
Wind	2	1,134	26.81	20	- " -	20	2,000	10,000
Biomass	2	1,757	47.18	65	35	30	500	1,000
Ocean	3	5,000	40	35	*non appl.*	50	5,000	20,000
Hydro (all)	6	1,451	12.5	42	- " -	50	1,000	10,000
Geothermal	3	3,108	104.98	73	- " -	20	1,000	5,000
Solar thermal	3	2,960	50.23	20	- " -	20	200	1,000
PV	1	4,500	10.34	15	- " -	20	100	1,000

Source: *EIA (2005), ICRE (2004), IIASA (2003), author's estimation*

RESULTS

Not enough capacity for proposed increase in electricity generation under assumptions used. Then extra capacities of 50 GW in 2010-2020 are needed; 15 GW coal up to 2010, additional with 10 GW during 2010-2020, as well as 10 GW of gas capacity. In this case all renewables but solar technologies should run at full scale. The difference is only coal and petroleum generation.

Figure 1: Leveraged electricity cost by technology considered

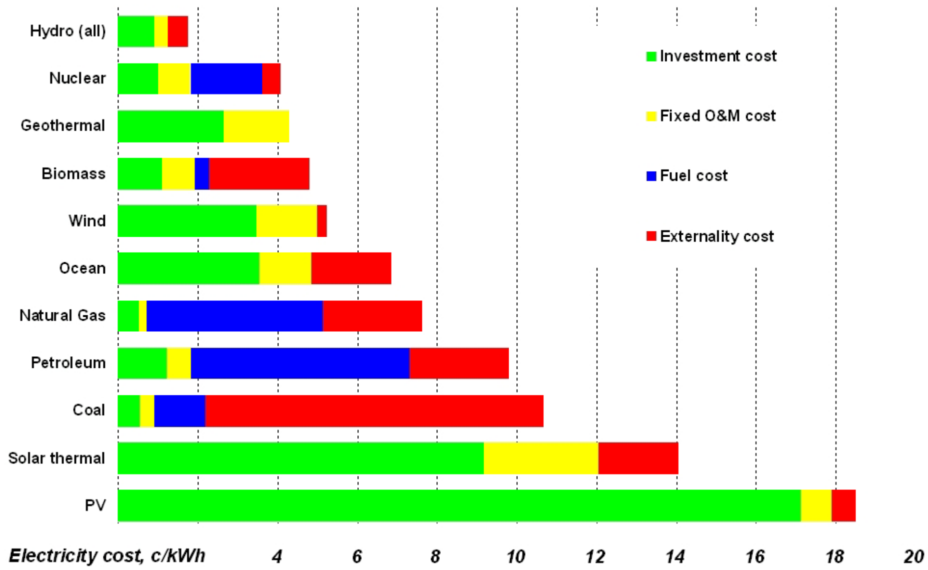


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	81/+	+/+	+/+	40/37
Biomass	10/+	+/+	+/+	+/66
Ocean	75/+	+/+	+/+	35/78
Hydro	+/+	+/+	+/+	+/+
Geothermal	79/+	+/+	+/+	25/8
Solar Thermal	-/37	52/53	75/70	92/-
PV	92/46	62/55	75/63	83/84

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*

\+ *renewable energy is competitive to corresponding conventional technology*

– *uncompetitive to corresponding conventional technology even without investment cost*

Figure 2: Electricity generation by additional capacities to year 2020

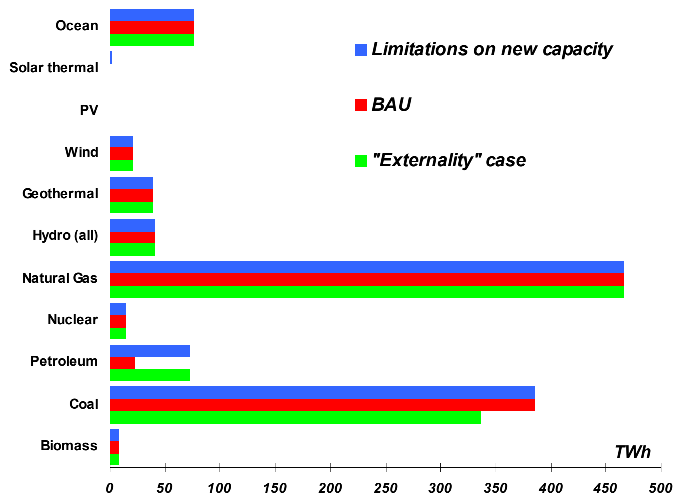


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	322.6	123.6	410.8	165.1	245.7
Externality cost	Bln USD	199.1	-	243.2	246.1	44.1[1]
Average electricity cost	¢ per kWh	8.0	3.1	8.1	3.2	4.9

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to the increase of cost of electricity generation from 165 billion USD to 411 billion USD for the new capacity in the year 2020.
- However, without externalities geothermal, biomass, geothermal, wind, and ocean utilities are competitive with natural gas and petroleum.
- Introducing externalities will move coal from the cheapest option (after hydro) to the most expensive (after solar technologies).
- None of the renewable technologies benefit from externality accounting.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost did not lead to any incremental production of renewable electricity.

VIET NAM

INPUT DATA AND ASSUMPTIONS

INPUT DATA ON PRICES, TECHNOLOGY COST AND NEW PERSPECTIVE CAPACITIES

Table 1: Fuel prices

	Unit	Value
Petroleum (Fuel oil)	USD/toe	327
Natural gas	USD/toe	132
Coal	USD/toe	63
Nuclear	mills/kWh	16
Biomass	USD/toe	60

Source: *author's estimation*

Table 2: Structure of electricity generation in 2005 and outlook to 2020, TWh

	2005	2010	2020
Coal	18.1		
Natural Gas	6.6		
Hydro	17.1		
Total	*53.0*	*97.5*	*220.0*

Source: APERC *database for projections 2002*

Table 3: Cost assumptions by technology

	Lead time	Overnight Capital cost	Fixed O&M	Capacity factor	Effi-ciency	Lifetime	New capacity to 2010	New capacity 2011-2020
	Years	*USD/kW*	*USD/kW*	*%*	*%*	*years*	*MW*	*MW*
Coal	4	1,100	30	70	38	30	3,500	7,600
Petroleum	3	800	13	20	32	20	-	-
Natural Gas	3	625	12	70	51	25	2,100	4,600
Nuclear	6	1,650	70	85	*non appl.*	40	-	2,000
Wind	2	1,000	30	30	- " -	20	100	1,000
Biomass	3	2,000	20	50	35	30	100	1,000
Ocean	4	5,000	40	35	*non appl.*	50	100	1,000
Hydro	5	1,000	30	46	- " -	50	4,800	7,100
Geothermal	3	5,000	110	90	- " -	20	100	1,000
Solar thermal	3	3,000	40	20	- " -	20	100	1,000
PV	2	5,000	12	15	- " -	20	100	1,000

Source: *EIA (2005), ICRE (2004), IIASA (2003), author's estimation*

In 2020, hydropower and natural gas will become the most important sources for power generation, together accounting for about 3/5 of the total installed capacity. Share of coal will increase considerably and reach to about 20-23 percent of the total capacity generation. Nuclear power and imported electricity will be really new sources in the national power system, and account for about 11-13 percent. Renewable energy is a good potential but its actual development will be moderate as this source is considered to essentially serve for electrification programs in remote areas. Oil-fuelled power source will reduce explicitly to 3-6 percent of total installed capacity of the national system.

RESULTS

Figure 1: Leveraged electricity cost by technology considered

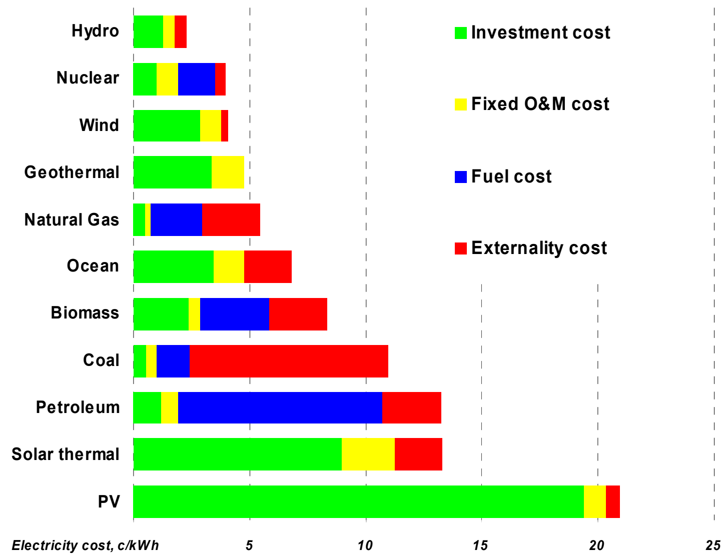


Table 4 Required depreciation in renewable energy investment cost to compete conventional technology, % to current cost assumptions for renewable electricity overnight cost

	Coal	Petroleum	Natural Gas	Nuclear
	BAU/ Externality	BAU/ Externality	BAU/ Externality	BAU/ Externality
Wind	32/+	+/+	56/+	46/40
Biomass	+/+	+/+	+/+	+/58
Ocean	27/+	+/+	54/39	40/84
Hydro	+/+	+/+	+/+	+/+
Geothermal	14/+	+/+	51/+	33/16
Solar Thermal	89/18	16/17	99/94	94/-
PV	82/36	43/35	87/76	85/86

Note: *Numbers represent percent of current cost assumptions for renewable electricity generation technology overnight cost, which should be subsidised in order to compete corresponding conventional technology*
+ renewable energy is competitive to corresponding conventional technology
– uncompetitive to corresponding conventional technology even without investment cost

Figure 2: Electricity generation by new capacities: maximum possible available, without and under externality consideration

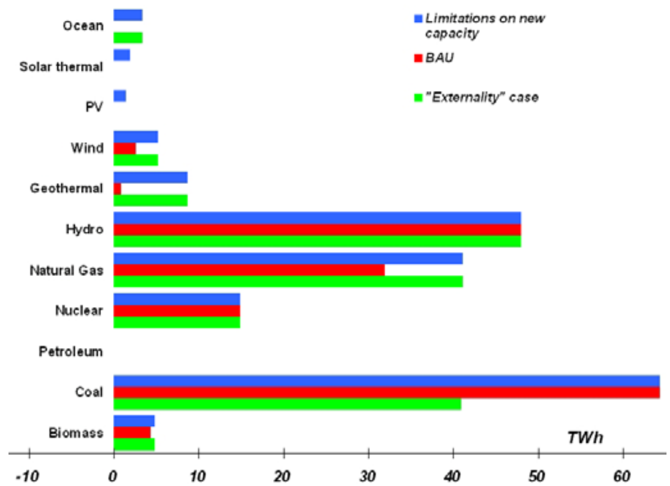


Table 5: Basic comparisons for electricity generation cost

	Unit	2005		2020		
		Externality case	BAU	Externality case	BAU	Difference
Total electricity production cost	Bln USD	2.8	1.2	12.0	5.2	6.8
Externality cost	Bln USD	1.5	-	6.5	8.2	5.0[1]
Average electricity cost	¢ per kWh	5.2	2.3	5.5	2.4	2.2

[1] *Difference for externality cost in year 2020 and externality cost in year 2005*

- Externalities accounting leads to more than two times higher of generating cost for the new capacity installed in the year 2020.
- With externalities, wind and geothermal technologies become competitiveness to natural gas while ocean and biomass can be competed with coal.
- Grid development and dispatching cost should be accounted for more accurate implications.
- Internalisation of externalities in electricity production cost could lead to incremental production of 14.2 TWh of renewable electricity, or 6.5 percent to economy's total electricity production in year 2020.

APPENDIX II

MODEL WITH EXTERNALITY ACCOUNTING

To determine the least-cost electricity production the following objective function is used:

$$\sum_i W_i^{2005} \times LCost_i^{-Inv+Ext} + \sum_i (W_i^{new\ 2010} + W_i^{new\ 2020}) \times LCost_i^{+Ext} -$$
$$\sum_i (W_i^{off\ 2010} + W_i^{off\ 2020}) \times LCost_i^{-Inv+Ext} \rightarrow \min; \quad (1)$$

for each technology $i \in [1, I]$

where:

W_i^{2005} - is an electricity, produced in year 2005 by technology *I* on already existing capacities

$W_i^{new2010}$ - is a part of electricity, produced in year 2010 by technology *i* on new capacities, constructed during 2005-2010 time period

$W_i^{new2020}$ - is a part of electricity, produced in year 2020 by technology *i* on new capacities, constructed during 2010-2020 time period

$W_i^{off\,2010}$ - is a decrement of electricity production, caused by switching-off generation capacities of technology *i* during 2005-2010 time period

$W_i^{off\,2020}$ - is a decrement of electricity production, caused by switching-off generation capacities of technology *i* during 2010-2020 time period

$LCost_i^{-Inv+Ext}$ - is a leveraged cost without investment cost but with externality cost

$LCost_i^{+Ext}$ - is a leveraged cost with externality cost

Next restrictions and limitations under consideration should be keeping:

- The level of electricity production (target) in year 2020 should be achieved:

$$\sum_i (W_i^{2005} + W_i^{new2010} + W_i^{new2020} - W_i^{off\,2010} - W_i^{off\,2020}) = D^{2020}; \quad (2)$$

where:

D^{2020} - is a target electricity production in year 2020

- Electricity generation for each technology *i* could not be more then it is allowed by restrictions for new capacity construction under model assumptions:

$$W_i^{new2010} \le \overline{W_i^{2010}}, \qquad W_i^{new2020} \le \overline{W_i^{2020}}; \qquad i \in [1, I]; \text{ where:} \quad (3)$$

$\overline{W_i^{2010}}$ - is a maximum amount of electricity, produced in year 2010 by technology *i* on new capacities, commissioned during 2005-2010 time period, for each technology *i*

$\overline{W_i^{2020}}$ - is a maximum amount of electricity, produced in year 2020 by technology *i* on new capacities, commissioned during 2010-2020 time period, for each technology *i*

- Reduction in electricity generation for each technology i could not be more than existing capacity is allowed to generate:

$$0 \le W_i^{off\,2010} \le W_i^{2005}, \quad 0 \le W_i^{off\,2020} \le W_i^{2005} - W_i^{off\,2010}; \qquad i \in [1, I]; \quad (4)$$

MODEL WITHOUT EXTERNALITY ACCOUNTING

To determine the least-cost electricity production without internalisation externalities into power generation costs, the following objective function is used:

$$\sum_i W_i^{2005} \times LCost_i^{-Inv} + \sum_i (W_i^{new\ 2010} + W_i^{new\ 2020}) \times LCost_i - \sum_i (W_i^{off\ 2010} + W_i^{off\ 2020}) \times LCost_i^{-Inv} \rightarrow \min; \qquad (5)$$

for each technology $i \in [1, I]$

under the same constraints and limitations (2)-(4).

The difference of solutions for both models would be impact effect of externality costs internalisation to electricity production.

SUBSIDIES ASSESSMENT FOR RENEWABLE ELECTRICITY

Sustainable development of renewable electricity should be based on achievement of economic competitiveness to consumer. This mean that leveraged cost of NRE electricity production shell be about equal to conventional technologies (CT), like coal, natural gas, or nuclear (see Equation 6). Conservative assessments could be obtained without accounting of additional transmission cost (to feed renewable electricity to national grid), and dispatching cost (because of NRE intermittency and conventional technologies efficiency decreasing).

LeveragedCost (RE) = LeveragedCost (CT) (6)

Main parameter to control technology is specific investment cost per kW of installed capacity. Subsidies for NRE (if there is need for it) could be calculated on basis of least investment cost per kW to make NRE leveraged cost equal to leveraged cost of competitive technology (see Equations 7 and 8).

Leveraged cost of renewable electricity in BAU case is competitive toward conventional power generation technology, if sum of all cost ingredients for NRE is equal or less then sum of all cost ingredients for respective CT:

InvestmentCost(RE) + O&Mcost(RE) + FuelCost(RE) =

InvestmentCost(CT)+O&Mcost(CT)+FuelCost(CT) (7)

Leveraged cost of renewable electricity in "Externality" case is competitive toward conventional power generation technology, if sum of all cost ingredients for RE, including externality cost, is equal or less then sum of all cost ingredients for respective CT:

InvestmentCost(RE) + O&Mcost(RE) + FuelCost(RE) + ExternalityCost(RE) =

InvestmentCost(CT)+O&Mcost(CT)+FuelCost(CT)+ExternalityCost(CT) (8)

Specific investment cost for NRE could be separated from investment cost definition (see Equation 9) :

$$\text{InvestmentCost(RE)} = \frac{\text{Specific\_cost(RE)} \times \text{Loan\_coefficient(RE)}}{\text{Lifetime(RE)} \times \text{Capacity\_factor(RE)}} \quad (9)$$

In order to assess specific investment cost per kW of installed renewable energy facility, which could provide competitiveness of NRE toward conventional power generation technology, Equations 7 - 8 transformation lead to expression of NRE specific investment cost for BAU (Equation 10) and "Externality" cases (Equation 11).

Competitive renewable electricity specific investment cost for BAU case:

$$\text{Specific\_cost(RE)}^{\text{BAU}} =$$

$$\left[\text{InvestmentCost(CT)} + (\text{O \& Mcost(CT)} - \text{O \& Mcost(RE)}) + (\text{FuelCost(CT)} - \text{FuelCost(RE)})\right] \times \frac{\text{Lifetime(RE)} * \text{Capacity\_factor(RE)}}{\text{Loan\_coefficient(RE)}} \quad (10)$$

Competitive renewable electricity specific investment for "Externality" case:

$$\text{Specific\_cost(RE)}^{\text{Ext}} =$$

$$\begin{bmatrix} \text{InvestmentCost(CT)} + (\text{O \& Mcost(CT)} - \text{O \& Mcost(RE))} + (\text{FuelCost(CT)} - \text{FuelCost(RE)}) \\ + (\text{ExternalityCost(CT)} - \text{ExternalityCost(RE))} \end{bmatrix} \times \frac{\text{Lifetime(RE)} * \text{Capacity\_factor(RE)}}{\text{Loan\_coefficient(RE)}} \quad (11)$$

For each APEC member economy depreciation of NRE specific investment cost required to get desired market signals set for fair competition of electricity producing technologies was calculated. This table is provided for corresponding economy section in Appendix. For both BAU case and "Externality" case depreciation for specific cost per kW of renewable electricity installed capacity to reach competitiveness toward corresponding conventional power generation technology (competitive specific investment cost) is shown. Amount of subsidies required to support NRE industry could be calculated by multiplying difference of real and competitive specific investment costs for renewable electricity to projections on corresponding new NRE utilities construction.