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SECTION 3
CLEAN ENERGY OPTIONS

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CLEAN ENERGY OPTIONS

This section provides an overview of the various energy supply options and end-use applications as a basis for identifying regional priorities. Energy supply options include both fossil fuels and renewables, while energy efficiency options encompass supply-side options within the power sector and various end-use applications in the residential, commercial, and industrial sectors. The discussion centers on the six focus countries and includes an analysis of demand projections with respect to resource availability, current level of technology deployment, and expansion plans. The emphasis in the discussion is on providing a regional analysis of options and their relative merits and demerits. Detailed country-specific information is provided in the country reports (Annexes 1-6). Options such as geothermal energy, which is relevant to just two countries among the six, are also highlighted in the country reports. The section concludes with a comparative analysis of the various clean energy options in terms of cost of delivered energy, carbon abatement costs, cost reductions expected in the future, impacts on the environment, and employment generation potential.

3.1 SUPPLY-SIDE ANALYSIS

3.11 COAL AND CLEAN POWER GENERATION

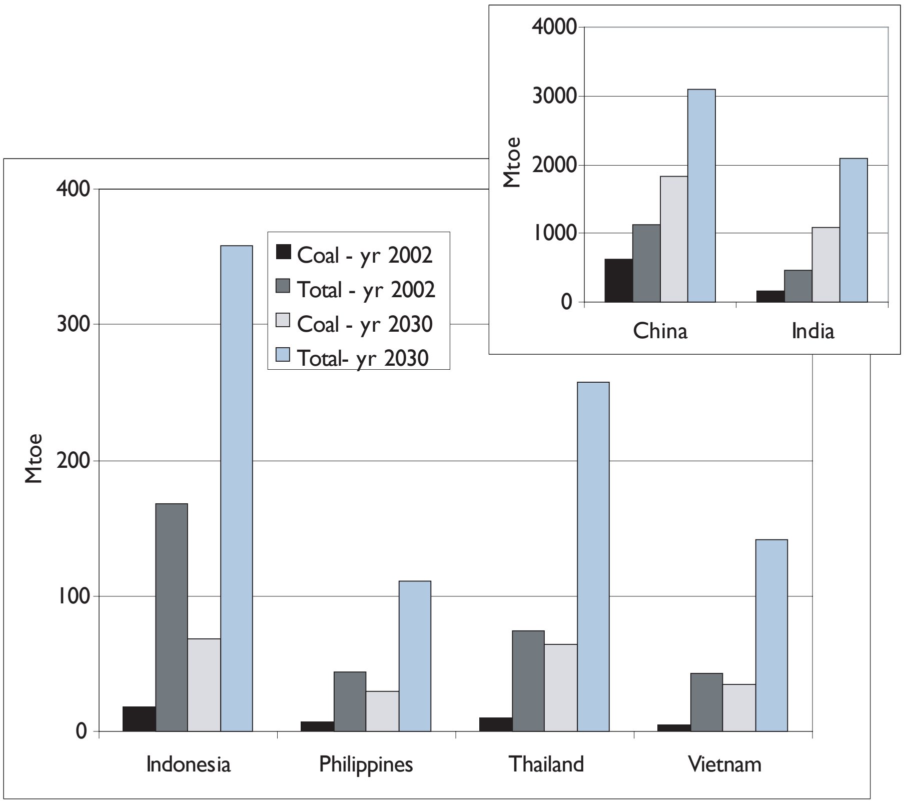
The increase in consumption of coal may well be the most dominant trend in the energy sector of developing Asian economies during the next three decades. Faced with rising oil and gas prices, power sector planners have reached out to a fuel that is seen to offer long-term stability in both price and volume. The use of coal in developing Asia is slated to increase nearly four-fold during the period 2006-2030.[1]

In terms of supply, coal resources are much larger in volume across Asia than oil and gas.[2] However, the Philippines and Thailand are dependent on coal imports (85 percent and 44 percent, respectively) and their import dependency is set to increase in the future. Further, the supply situation for coal faces pressure from increased transportation costs and inadequate infrastructure, and in Indonesia and China, export capacities are starting to decline, raising the prospect of regional shortages (Figure 13).

The ongoing coal expansion in Asia is associated with severe environmental impacts including: release of GHG emissions; emissions of mercury, NO_X, SO_X, and particulate matter; land degradation; and related impacts including reduction in water quality. Overall, the increased use of coal alone in the six countries is expected to result in annual emissions of around 13 billion metric tons (Bt) of CO_2 by 2030 (Figure 14), in addition to associated SO_x, NO_x, and NO_2 emissions. In comparison, the total global emissions of CO_2 in 2005 were just over 26 Bt (IEA, 2006).

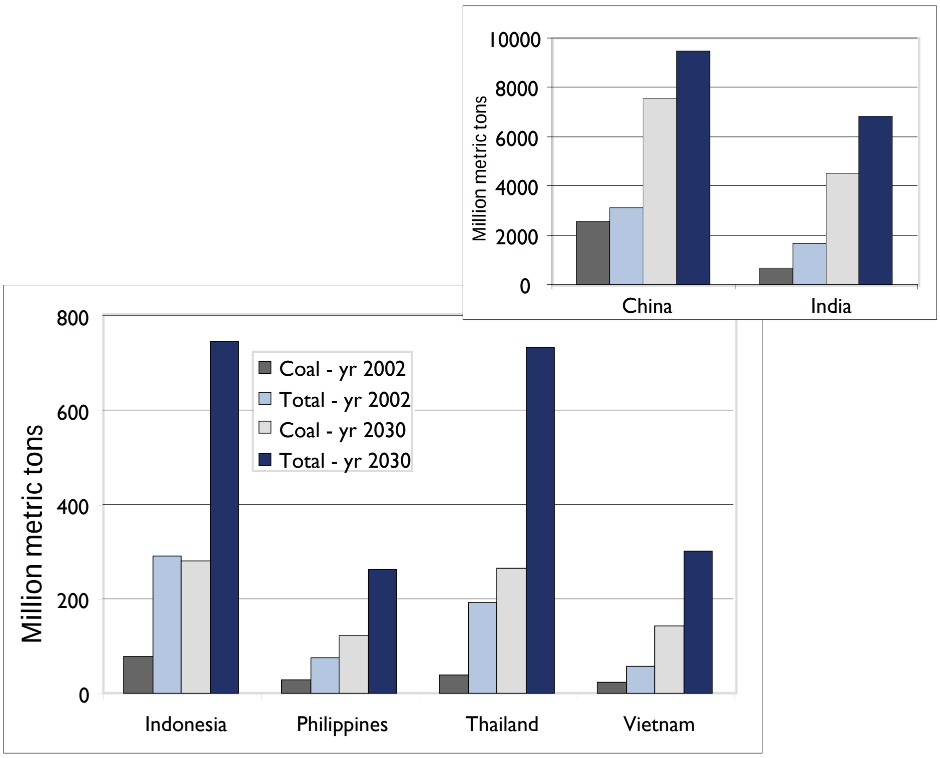
1. Together, China and India will consume 57 percent of the annual world coal supply in 2030, up from 40 percent in 2004. Indonesia's national generating utility will build 24 coal-fired power plants over the next three to five years to generate an additional 10,000 MW of electricity. Thailand and the Philippines intend to use coal to diversify their feedstock for power generation.
2. The reserve-to-production (R/P) ratio is currently estimated to range from several decades to nearly 300 years in the case of India (see Country Reports). R/P is the estimated size of the resource divided by the rate of production or use of the resource. It provides an indication of how long a given resource may last at a given production level. Both reserve estimates and actual production can be expected to vary, and therefore R/P ratios change from time to time. Since only estimates of proven reserves were used (probable resources were excluded), this estimate is conservative.

FIGURE 13. CONTRIBUTION OF COAL TO THE TOTAL PRIMARY ENERGY MIX IN SELECTED ASIAN COUNTRIES



Source: Compiled from APERC, 2006; TERI, 2006.

FIGURE 14. CONTRIBUTION OF COAL TO TOTAL CO2 EMISSIONS IN SELECTED ASIAN COUNTRIES



Source: APERC, 2006; TERI, 2006.

Since the 1980s, technological improvements captured under the concept of "clean coal" have offered promise in terms of overcoming limits on thermal efficiencies and providing better emissions control relative to traditional coal-based power generation technology.[2] According to one estimate, current clean coal technology (CCT) can reduce emissions of SO_X, NO_X, and particulate matter by 90 percent compared to CCT technology utilized in the early 1980's (JPOWER, 2004). With more advanced technologies, such as CO_2 capture and geological sequestration, it is even possible to conceptualize a zero-emissions power plant.[3]

Recent trends suggest that clean coal technologies are slowly gaining favor in India and China, as both countries have announced ambitious plans to pursue clean coal technologies. For instance, a new 1,000 MW ultra-supercritical plant in Wenzhou, China, delivers energy savings of 17 percent and CO_2 reductions of 14 percent, compared to a conventional plant with the same production capacity (Ansfield, 2007).

Given coal's importance in the Asian energy context, several international organizations are supporting technology development, technology transfer, and commercial application of clean coal technologies. Nevertheless, the uptake of clean coal technologies has been slow, owing to their relatively high cost as well as regulatory and institutional barriers, such as the lack of environmental regulations, and lax monitoring and compliance with existing emission standards in some instances.[4]

CARBON CAPTURE AND STORAGE

As coal use continues to rise throughout Asia, carbon capture and storage (CCS) options – which involve removing carbon from the waste gas stream and storing it permanently in geological reservoirs – are being proposed as a key component of GHG mitigation efforts. CCS can be deployed with coal or natural gas plants and it also enhances oil recovery applications. It currently has low adoption rates because it is perceived as an "unproven" technology with high capital and maintenance costs.[5] Global reduction potential for CCS is vast, ranging between 140 and 250 Bt of carbon (Riahi et al., 2004).[6] The cost of injecting CO_2 into geological reservoirs depends on many factors, including the type of reservoir (e.g. saline, ocean, coal seams), the type of CCS technology,[7] and the local costs of pipelines and other support infrastructure. The Carbon Sequestration Leadership Forum estimates that the capital costs for pulverized fuel (PF) and integrated combined cycle gasification (IGCC) plants, with carbon sequestration, range from US$1,900 to US$2,200 per kWe (Freund, 2002).[8] The cost of coal plants with CCS in terms of dollar per metric ton of CO_2 avoided is estimated to be -US$30 to US$20, US$10 to US$100, and -US$20 to US$160, respectively, for storage in depleted oil fields, depleted gas fields, and un-minable coal seams.[9] Due to incremental technology adoption, Riahi et al. (2004) predict CCS costs for coal technologies may drop by a factor of four by the end of the century, based on reaching a stabilization target of 550 parts per million by volume (ppmv).

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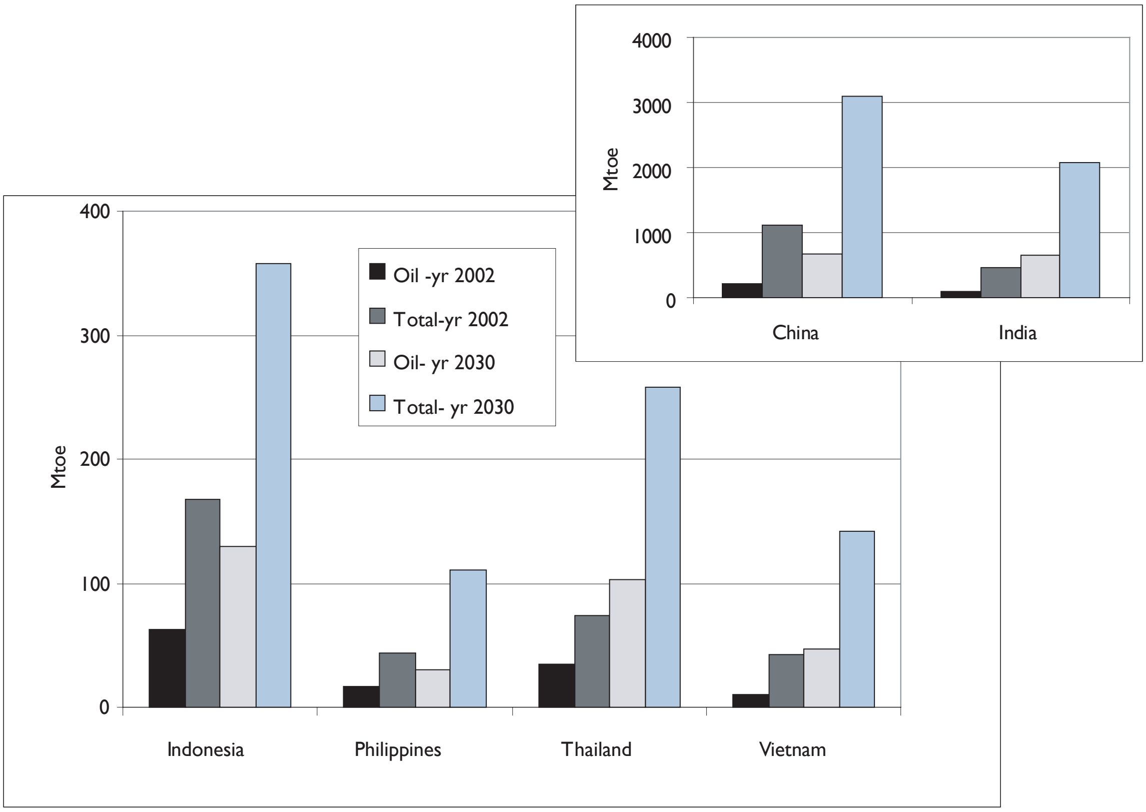
2. Additional information on clean coal technologies is available from the IEA at http://www.iea-coal.org.uk/site/ieaccc/homeww.
3. China will be the third country, after South Korea and India, to join the FutureGen program – a US$1 billion government-industry project to implement a "zero emissions" coal power plant by 2012 – announced in 2003 in response to President Bush's directive to develop a hydrogen economy.
4. For example, despite existing mandates, only 25 percent of China's coal is washed, resulting in higher emissions of ash and lower combustion efficiencies.
5. In fact, there are several concerns about its widespread use, including prospects for leakage and potential catastrophic increase in carbon emissions, and potential for geological disturbances, including seismic activity.
6. This assumes an atmospheric concentration stabilization target of 550 parts per million during the period 1990 to 2100.
7. For example, pulverized fuel (PF), integrated combined cycle gasification (IGCC), natural gas combined cycle (NGCC), and supercritical versus ultra-supercritical.
8. Without carbon sequestration, costs range from US$1,000 to US$1,500 per kWe (Freund, 2002).
9. Two other sources report cost of storage (US$ per tC) as US$156 per tC and US$196 per tC, based on a different set of assumptions (Sims, 2003; Riahi, 2004).

It is evident that coal will remain the dominant fossil fuel in Asia over the medium term, and it is critical that coal expansion is managed in a way which provides the energy supply to sustain economic growth while minimizing the environmental impacts that result from its use.

3.12 PETROLEUM

Oil consumption is expected to accelerate in developing Asia in the coming decades in response to increased activity in the transport, agriculture, and construction sectors. Of particular importance is the transport sector, due to an increased demand for personal mobility – as millions of people shift from non-motorized to motorized modes of transport or from two-wheelers to cars – and for passenger travel and freight transport over ground, sea, and air. If current trends continue, there will be around 250 million more cars and SUVs operating in China and India by 2035 (ADB, 2006).[10] The increased demand for personal motorized transportation will lead to a 2.6-fold increase in oil demand in developing Asia during the period 2002-2030, with average annual increases ranging from 3 percent in the Philippines to more than 13 percent in Vietnam (Figure 15).

FIGURE 15. CONTRIBUTION OF OIL TO THE TOTAL PRIMARY ENERGY MIX IN SELECTED ASIAN COUNTRIES



Source: APERC, 2006; TERI, 2006.

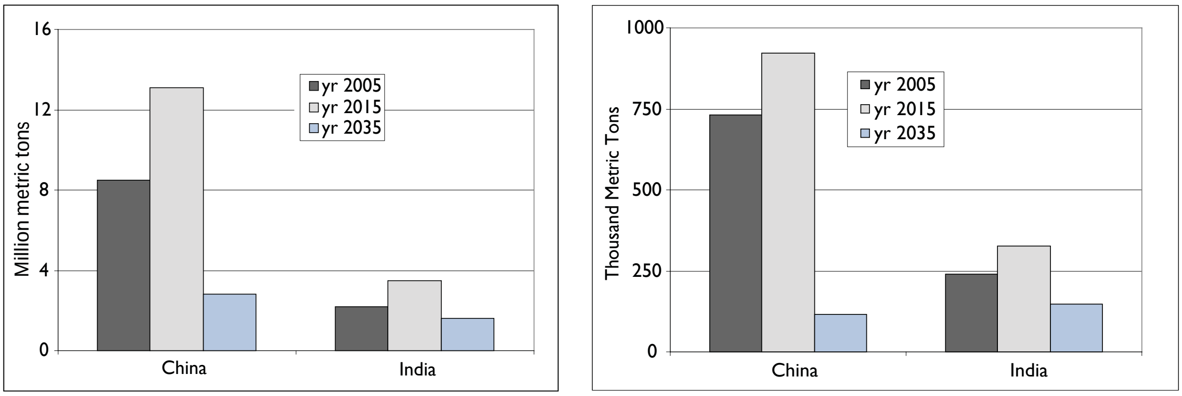
A matter of critical concern for energy policymakers in Asia is that the oil resources available in the region are not adequate to supply growth in demand. Oil reserves in developing Asia are limited. R/P ratios for petroleum resources in Asia range from around 22 years for India and Vietnam to fewer than 10 years for Thailand.[11] Indonesia, a member of the Organization of the Petroleum Exporting Countries

10. In 2005, there were an estimated 19.5 million cars and SUVs in China (ADB, 2006).
11. Since both reserve estimates and actual production can be expected to vary, R/P ratios change from time to time. Most oil analysts contend that the vast majority of oil resources in the world have been well studied and mapped, and that it is therefore unlikely that

Organization (OPEC), has now become a net importer, and Vietnam, which currently exports oil, can also be expected to become a net importer by 2030. During the period 2002-2030, China's oil import dependency will increase from 20 percent to more than 70 percent, and the Philippines and Thailand will continue to import more than 90 percent of their oil requirements. High import ratios combined with price volatility and the persistent geo-political risks in the Middle East – the primary source for Asian imports – will together create a situation of high vulnerability.[12]

The high reliance on petroleum is also linked to negative local and global climate impacts. An analysis of CO_2 emissions from oil consumption during the 2002-2030 period indicates that annual CO_2 emissions from petroleum use in developing Asian countries will increase from about 1.3 Bt to 4 Bt. Figure 16 presents an analysis of trends in PM10, and NO_X emissions levels over the next 25 years in China and India, while Figure 17 (next page) provides an analysis of trends in CO_2 emissions levels over the next 25 years in several Asian economies.

FIGURE 16. PROJECTED REDUCTIONS IN NO_X (LEFT PANEL) AND PM10 (RIGHT PANEL) EMISSIONS LEVELS FROM THE TRANSPORT SECTOR IN CHINA AND INDIA THROUGH 2035.



Source: APERC, 2006; ADB, 2006.

CO_2 emissions from on-road transport are projected to increase by 3.4 times for China and 5.8 times for India over the 30-year period to 2035 (ADB, 2006). PM10 and NO_X are expected to increase in the medium term and then dramatically decrease with the deployment of improved vehicle technologies and stricter environmental regulations.[13]

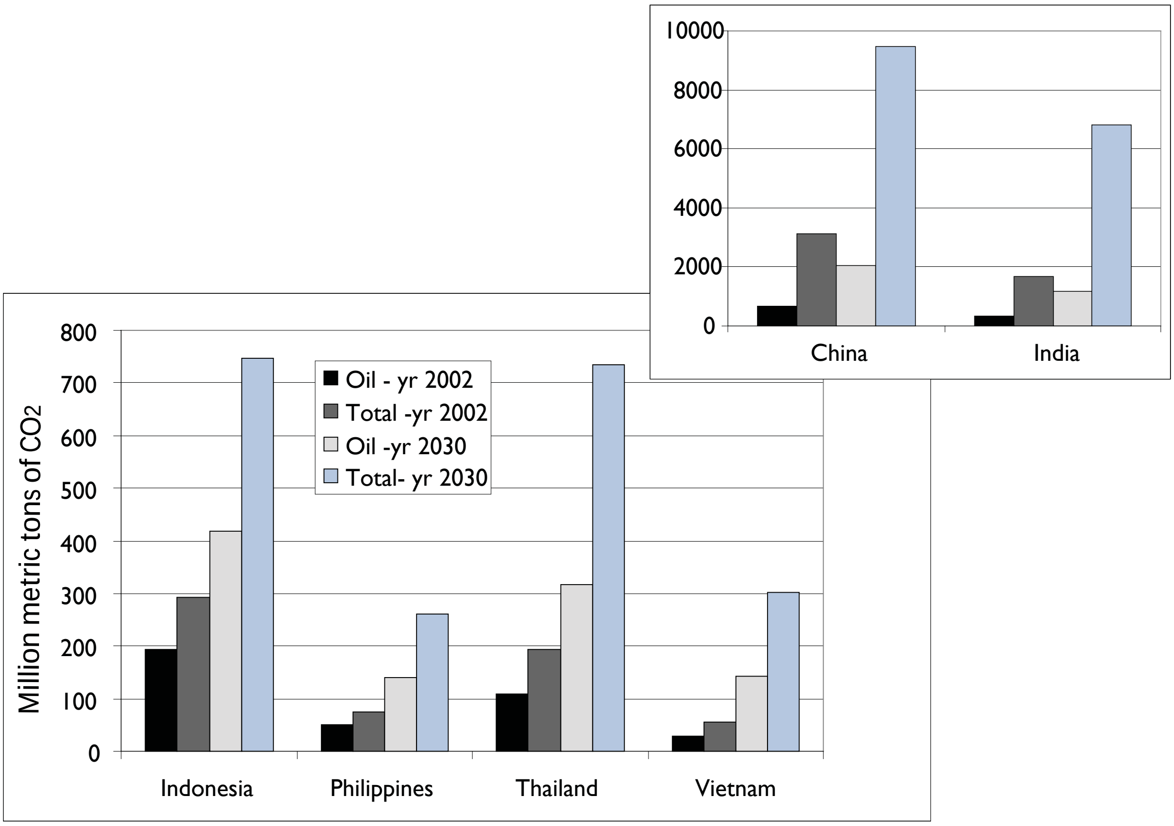
Being aware of their current and projected emissions footprints, many Asian governments have begun to make some inroads into instituting emission standards and mandating complementary fuel standards. All countries in emerging Asia now sell unleaded gasoline, which allows the implementation of vehicle emissions technology changes such as catalytic converters. The Philippines, Indonesia, and Vietnam have developed plans to attain the EURO II emissions standard, but have not yet finalized the way forward to EURO IV. China will move to the EURO IV standard in 2010. India will reach EURO III nationwide by 2010, although major cities in India are expected to achieve the EURO III standard prior to 2010.

significantly large new discoveries remain to be made. However, probable reserves plus exploration and technological development stimulated by high oil prices (enhanced oil recovery, synthetic crude production from bitumen and oil shale, oceanic deep water, etc.) can be expected to increase the total quantity of oil reserves to some extent in the near to medium term.

12. Both India and China have embarked on an ambitious global expansion plan that includes bidding on resource exploration contracts and acquiring or entering into joint ventures with firms in Africa, Latin America, Eastern Europe and Russia. However, it remains to be seen how these two countries and the smaller Asian economies will fare in the context of a potentially volatile and uncertain global oil market.
13. The ADB projections assume rapid penetration of new technologies and full compliance with strict emissions standards.

Thailand is set to attain the EURO IV light duty standard in 2009. However, in many Asian countries, rampant fuel adulteration, poor vehicle inspection and maintenance, and poor driving conditions reduce the benefits of these proposed policy measures.

FIGURE 17. CONTRIBUTION OF OIL TO TOTAL CO_2 EMISSIONS IN SELECTED ASIAN COUNTRIES



Source: APERC, 2006; TERI, 2006.

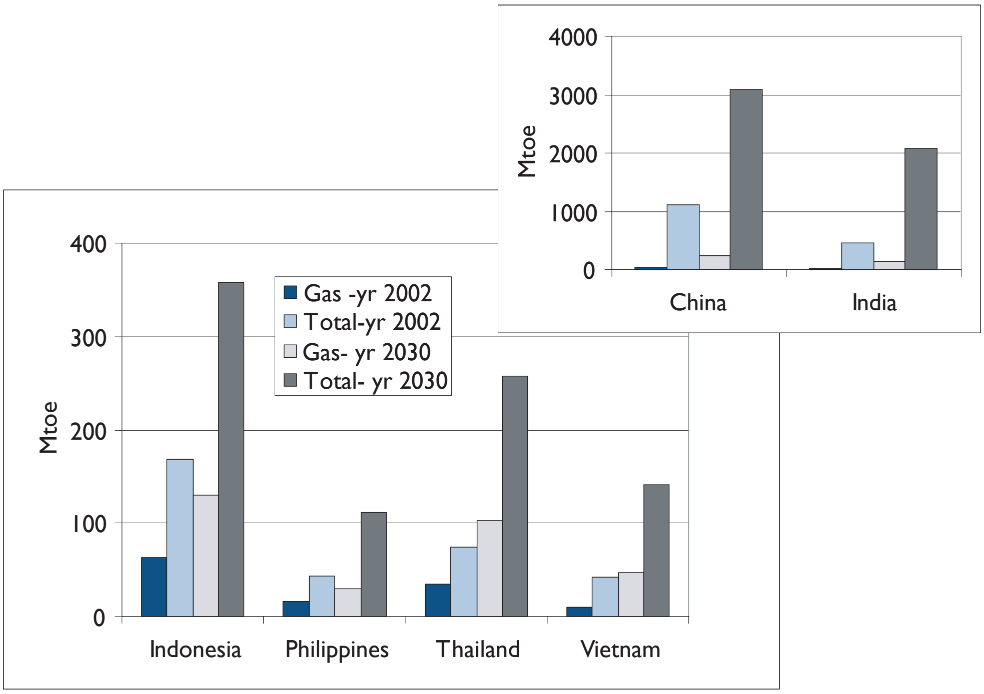
Liquid petroleum gas (LPG) is increasingly being used throughout developing Asia to help reduce vehicle emissions. Its ease of transport and storage makes it applicable even in smaller vehicles and LPG presents an opportunity as a vehicle fuel for cities that do not have pipeline or sea access to compressed natural gas (discussed in the following section). Thailand has introduced this fuel in its three-wheeler ("Tuk-Tuk") market.

In summary, Asia's access to petroleum from within the region is becoming extremely limited, and its use is linked to local and global air pollution. It is critical that Asia economizes on its petroleum consumption while investing in cleaner alternatives for transport fuels. See section 3.26 for a related discussion on transport energy efficiency, and section 3.14 for a discussion on biofuels in transport.

3.13 NATURAL GAS

In most of developing Asia, natural gas, with its higher cost and greater infrastructure requirements, has been considered a "premium fuel" relative to coal, hydropower, and biomass. The power sector has been the main consumer in most countries, and with continuing economic growth and investments in natural gas-related infrastructure, gas is now becoming available to a wider consumer base across all sectors. Natural gas consumption is expected to grow at an annual rate that is higher than the growth rate for both fossil fuels and primary energy demand. By 2030, natural gas consumption in developing Asia is expected to grow by a factor of 4.5 relative to consumption in 2005 (Figure 18).

FIGURE 18. CONTRIBUTION OF NATURAL GAS TO THE TOTAL PRIMARY ENERGY MIX IN SELECTED ASIAN COUNTRIES



Source: APERC, 2006; TERI (2006).

Although Asia possesses relatively large supplies of natural gas compared to its oil supplies, the R/P ratios are still unfavorable.[14] China, India, the Philippines, and Thailand are already net importers of gas, and their import dependency is expected to grow in the future. By 2030, China will need to import more than 50 percent of its gas needs, while the Philippines and Thailand will need to import 41 and 75 percent, respectively. Indonesia and Vietnam will remain net exporters throughout the period.

Compressed natural gas (CNG) is being promoted as a cleaner alternative to gasoline and diesel in many Asian countries. Research suggests that for current engine and vehicle technologies, the use of CNG reduces CO_2 emissions by 20 percent compared to gasoline and has the potential to reduce CO_2 emissions by up to 5-10 percent compared to diesel. However, these estimates are strongly dependent on fuel system design and conversion quality (ADB, 2006). As of 2005, approximately 4.75 million natural gas vehicles are estimated to be in use worldwide, with more than 1 million in developing Asia. Growth in the number of CNG vehicles has been very rapid during the last five years in China, India and Thailand, among other countries.[15] However, owing to the limited regional supply of CNG, limited options exist to expand its use.

Given the projected decline in regional production, an increasing amount of natural gas demand in several economies is expected to be supplied from economies both within and outside of the region. This gap is expected to be filled to some extent with liquefied natural gas (LNG). Since, LNG becomes competitive relative to pipeline transport over long-distances (exceeding 4,000 km), this fuel has a big

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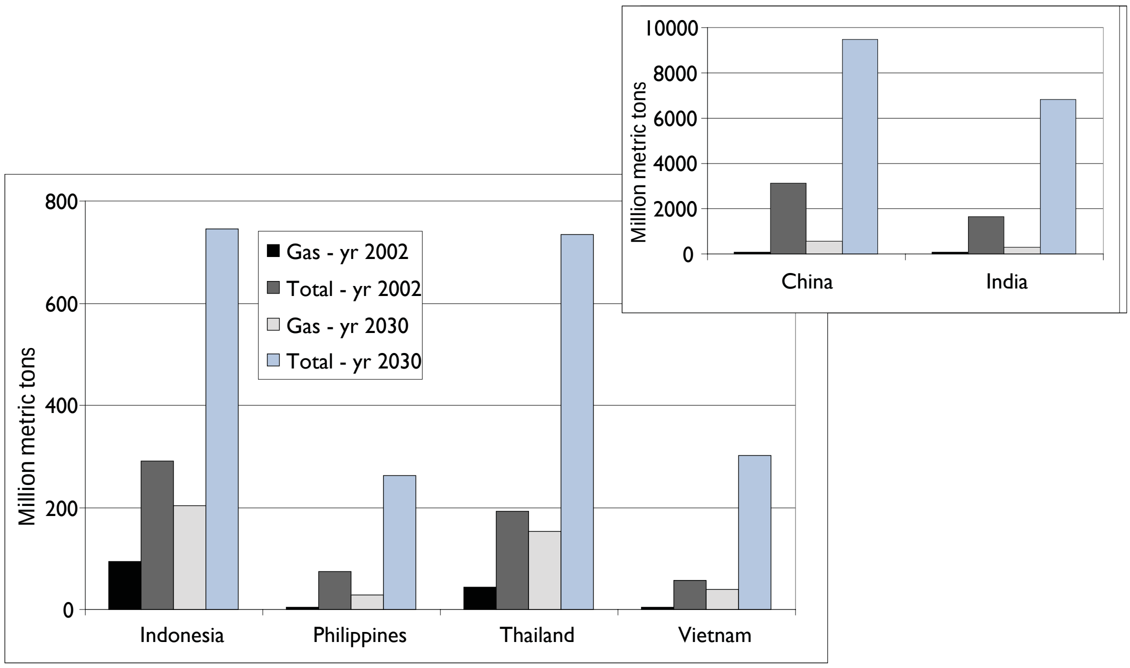
14. Reserve-to-production ratios for selected Asian countries range from 13 to 47 years, with Thailand and China being at the two extremes of the range, respectively.
15. The Thai government is aiming to convert half a million vehicles to run on compressed natural gas (CNG) by 2010 to help reduce the country's dependence on oil. In India, a Supreme Court ruling in 1998 mandated CNG as the fuel for public transport in Delhi to control pollution. In 2002, a further ruling directed the Union government to give priority to CNG in the transport sector, and four cities have implemented programs for urban transport.

potential to fill the gap between increasing demand and declining supply. India has two LNG receiving terminals, and in June 2006, China received its inaugural LNG delivery at the Guangdong terminal. The construction of other terminals is under consideration. Chinese LNG imports are projected to increase from 3 Mt in 2006 to 52.0 Mt in 2030. The Philippines is also expected to commence LNG imports during the next decade. Future growth in LNG imports however is somewhat uncertain given the high LNG prices in the global market.

Natural gas is considered a cleaner burning fuel relative to coal and oil because of its lower CO_2 emissions.[16] However, in comparison to renewable energy sources, it is still a net GHG producer. As Figure 19 indicates, except for Indonesia and Thailand, CO_2 emissions from gas are currently below 10 percent of total CO_2 emissions. By 2030, except for China and India, gas will account for more than 10 percent of total CO_2 emissions.

FIGURE 19. CONTRIBUTION OF NATURAL GAS TO TOTAL CO_2 EMISSIONS IN SELECTED ASIAN ECONOMIES



Source: APERC, 2006.

METHANE CAPTURE

Methane recovery projects offer significant GHG reduction opportunities in Asia owing to the relatively large global warming potential of methane.[18] Methane recovery projects are widely available in agriculture, coal mining, municipal landfills, and gas and oil systems, where the methane is captured and can be burned to produce electricity. Landfills and coal-bed methane are two sectors with tremendous potential to reduce GHG emissions in Asia.

Globally, landfill emissions are the third largest anthropogenic source of GHG emissions. China and India alone contribute 11 percent and 1 percent, respectively, to total landfill-based emissions. Landfills have a large potential in developing Asia because of the sheer number. In 1999, the US Environmental Protection Agency (EPA) identified large landfills (more than 20 Mt of waste in place) to be the most cost-effective for methane recovery, and it estimates electricity generating costs for landfill-gas projects to be US$0.03 to US$0.26 per kWh (EPA, 1999). The cost of conserved carbon is in the range -

16. In addition, it does not release any SO_X or NO_X emissions.

US$200 to -US$10 per ton of carbon. The ADB has recently partnered with the EPA on its Methane to Markets initiative to help facilitate landfill-methane projects in the region.

Coal-mine methane accounts for eight percent of total global methane emissions resulting from human activity. China produces the most coal-mine methane emissions in the world, about 40 percent of total emissions, while India adds another one percent. Reducing methane emissions provides immediate environmental and energy benefits. Methane is also the primary component of natural gas, so capturing and using methane as a clean fuel also provides immediate economic, environmental, and energy security benefits.

In summary, while natural gas could be a vital component of any plan to address developing Asia's clean energy demand and mitigate global climate change, a number of challenges need to be addressed before its potential is fully realized, especially in the power sector. Natural gas has to compete with coal, nuclear, and new renewables in terms of stability of cost and reliability of supply. Increased import dependency will make it harder for Asia's developing economies to secure long-term natural gas supplies amidst a rapidly changing and competitive market environment.

3.14 RENEWABLES

RENEWABLES FOR POWER GENERATION

Many countries in developing Asia are at the forefront globally in their implementation of renewable energy options.[17] China accounts for 37 GW of the 160 GW of renewable energy electricity capacity worldwide and possesses more than half of the world's small hydropower capacity. An ongoing boom in construction added nearly 4 GW of capacity in 2004. The use of sugarcane waste (bagasse) for power and heat production is significant in Thailand, India, and the Philippines. India and China were ranked fourth and tenth in the world, respectively, in terms of their installed capacity of wind power at the end of 2004. A few Asian countries, namely China, India, the Philippines, and Thailand, are engaged in the commercial production of biofuels.[18] Table 7 provides a breakdown by country of installed renewable energy capacity. China and India have by far the most installed capacity, and Vietnam has the lowest installed capacity (ARRPEEC, 2005). Small hydropower generation technology has the greatest penetration, particularly in off-grid situations. Solar PV technology has had the lowest penetration thus far.

TABLE 7. RENEWABLE ELECTRICITY GENERATION CAPACITY INSTALLED (MW) AS OF 2003

Renewable Energy Options	China		India		Indonesia		Thailand		Vietnam	
	Grid	Off-grid	Grid	Off-grid	Grid	Off-grid	Grid	Off-grid	Grid	Off-grid
Biomass	2,000	NS	563	NS	NS	178	300	NS	50	NS
Wind	560	25	1,870	NS	NS	0.38	NS	NS	NS	0.2
Solar	NS	50	NS	57	NS	0.88	NS	5.8	NS	NS
Small Hydro	13,000	17,000	1,509	NS	NS	21	NS	NS	130	NS
Geothermal	30	NS	NS	NS	310	NS	NS	NS	NS	NS
Total (MW)	15,590	17,075	3,942	57	310	200	300	5.8	180	0.2

Source: ARRPEEC, 2005. NOTE: Comparable data from the Philippines for 2003 were not available; however, the Philippines was the second largest producer of geothermal energy in the World (2006 est.), with a capacity of 1,930 MW. NS = Not significant.

17. In 2004, renewable energy provided from 1 to 40 percent of the primary energy in developing Asian economies, with India at the lower end of the range and the Philippines and Vietnam at the higher end of the range.
18. Total production in these countries ranged from 3.8 billion liters in China to 0.08 billion liters in the Philippines (Renewable Fuels Association, 2005 as cited in Worldwatch, 2005). Biodiesel is produced in small amounts in the Philippines and Indonesia.

An assessment of the installed capacity of renewable energy in Asia compared to the technical potential suggests that only a small fraction of renewable energy capacity has been tapped. For example, the installed capacity of wind power in China and India is estimated at 0.1 and 11.9 percent of the potential, respectively. Similarly, biomass utilization in Indonesia and India is 0.9 and 1.76 percent of its potential. Small hydro power, the technology with the highest penetration rate, still only accounts for between 7 and 24 percent of its potential across the countries.[19] After hydro power, solar thermal and solar PV are predicted to be the renewable energy sources with the greatest potential. According to a recent analysis by de Vries et al. (2006), the technical potential for solar PV is orders of magnitude higher than that of wind and biomass power. According to this analysis, the technical potential for solar PV across all of Asia is around 860,000 TWh/yr in 2050 (Table 8).[20]

TABLE 8. REGIONAL INSTALLATION AND TECHNICAL POTENTIAL FOR WIND, PV, AND BIOMASS IN 2000 AND 2050 (TWh/yr)

	Wind 2000	Wind 2050	Solar PV 2000	Solar PV 2050	Biomass 2000	Biomass 2050
South Asia (incl. India)	1,000	1,000	54,000	192,000	0	2,000
East Asia (incl. China)	1,000	2,000	58,000	640,000	0	11,000
Southeast Asia	0	0	17,000	25,000	0	1,000

Source: de Vries et al., 2006.

It is difficult to predict the proportion of primary energy that renewables will provide in 2030. Making projections using historical growth rates would suggest that only modest increases can be expected. However, if the growth rate over the past two to four years continues, and the ambitious renewable energy expansion plans[21] announced by several countries[22] come to fruition, we can expect a significant increase in renewable energy capacity.

Overall, the widespread use of renewable energy can be expected to lead to substantial reductions in GHG emissions, SO_X, and toxic pollutants such as mercury (see Section 3.3 for details). However, their use is also linked to some adverse impacts on the environment, especially in the case of biomass.[23]

The development landscape for renewable energy technologies is a rapidly evolving one and is attracting intense interest from a range of players including large commercial banks, investment banks, large energy equipment manufacturers, and niche players.[24] The current dynamism in the marketplace is bringing to

19. Estimates by research team based on the six country reports.
20. While the technical potential tends to be significantly higher than the corresponding economic potential, this analysis is useful in identifying the long-term relative importance of solar PV technology.
21. For example, China has set a national target to provide 10 percent of electric power capacity from renewable energy by 2010. This would amount to nearly 60 GW of capacity, which would involve a doubling of existing capacity. Thailand has set a target to supply 8 percent of its primary energy from renewable energy by 2011 (excluding traditional biomass). India is expecting to provide 10 percent of new electric power capacity, or at least 10 GW of renewables, by 2012. The Philippines is targeting nearly 5 GW of renewable energy by 2013, or a doubling of existing capacity.
22. Details on renewable energy sector plans and targets for the select countries are presented in the country reports (see Annexes 1-6).
23. Biomass combustion is linked to high levels of NO_x emissions relative to coal, and questions continue to be raised about the negative impacts of large-scale feedstock production for biofuels, including impacts on soil and water quality, biodiversity, and competition with food crops. Improvements in combustion technology and the adoption of sustainable land-use practices are necessary to limit these deleterious effects.
24. See Worldwatch, 2005 for a detailed review of the global renewable energy industry.

bear new competencies in finance, marketing, and production techniques, which can be expected to reduce current costs and promote greater adoption of these technologies.[25].

Costs of the most common renewable energy applications are still higher than conventional energy technologies. Higher costs and other market barriers mean that most renewable energy technologies continue to require policy support. While renewable energy policies and targets exist in almost all the focus countries,[26] there remains much to be done in terms of specifying implementing rules and regulations that will contribute to policy effectiveness and tailoring policies and incentives to specific situations.

While ample potential for renewable energy for power generation exists across Asia, the future role of renewable energy options in addressing Asia's clean energy challenge will depend on the extent to which the energy sector in Asia is able to combine the existing and new array of technology options with suitable enabling policy conditions to bring down the costs and increase the availability of these technologies. Without a sustained effort to promote wider adoption, the overall contribution of renewables to Asia's energy mix is unlikely to rise above 5 percent by 2015.

RENEWABLES FOR TRANSPORT

The liquid biofuels that are commercially available and suitable for road transport include ethanol and vegetable oil-based diesel substitutes for compression ignition (diesel) engines. The term "first generation biofuel" is used to refer to fuels for which commercial technology is widely available. This includes ethanol made from corn and sugar, as well as biodiesel fuels made from vegetable crops including soy, rape, and coconut oil. The term "next generation biofuels" covers bioethanol and biodiesel made from "energy crops" using conversion processes that are not yet commercially available for large-scale production.[27]

Several recent studies have outlined the potential costs and benefits that may accrue from the widespread use of biofuels within the transport sector (see ADB, 2006; IEA, 2005; World Bank, 2006). It should be noted that both benefits and costs would be scaled to the overall extent to which these fuels displace petroleum-based fuels.[28]

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25. Cost competitiveness is not a static concept. The issue is to what extent the cost of renewables declines relative to the decline in costs of conventional technology (e.g. improvements in gas turbine technology), as well as the stability of renewable energy costs relative to other energy resources. A key uncertainty about future competitiveness of renewables relates to future fossil fuel prices and availability, which affect conventional power costs but not the costs of renewables.
26. The range of policies being implemented in Asia include feed-in tariffs, renewable portfolio standards, direct capital investment subsidies or rebates, tax incentives and credits, sales tax and VAT exemptions, direct public investment or financing, and public competitive bidding for specified quantities of power generation. Some countries or states/provinces have established renewable energy funds (e.g. the Indian Renewable Energy Development Agency) that are used to directly finance investments, provide low-interest loans, or facilitate markets in other ways, for example through research, education, standards, and investments in public facilities.
27. In addition, fuel additives are also produced from biomass. These additives help increase the octane rating of gasoline and reduce engine knocking.
28. An analysis by the ADB (2006) suggests that even under the most optimistic assumptions ("high growth scenario") for the penetration of ethanol production and use, it will take more than two decades for ethanol to displace 25 percent of total gasoline use in Asia. Because the large-scale production of biodiesel fuels is not as advanced as it is for ethanol, an analogous scenario for biodiesel takes even longer. Under more realistic assumptions (the "moderate growth scenario"), the savings in annual GHG emissions by the year 2050 are 500 MT CO_2e which is about 20 percent of the total emissions in the year 2050. Other measures that would reduce fuel consumption by 20 percent over the next 45 years might be accomplished without the use of biofuels. Thus it will take a combination of rapid penetration of low-GHG fuels, coupled with rapidly decreasing fuel intensity in the transport sector (through modal shifts, improved vehicle efficiency and better in-use maintenance) to realize the needed dramatic reductions in GHG emissions from the transport sector by the year 2050.

Some of the potential benefits provided by biofuels include:

- improvement of energy security through diversification of supply and use of renewable domestic energy sources, and improvement of balance of payments for oil-importing countries;
- GHG reductions, if low-GHG biofuels are used on a strategic scale (e.g. 25 percent or more of total land transport fuel requirements);
- decreased vehicle emissions, especially of SO_2, total suspended particulates (TSP), and CO_2;
- expansion and diversification of rural and agricultural employment and products when feedstock is grown on land not suitable for food production; and
- waste management through conversion of biomass residues (forest products, wood waste), grease, and used oil into biodiesel fuels.

At the same time, there are a number of areas of concern that need to be addressed if biofuels are to become a viable alternative to petroleum fuels. First, on a practical basis, biofuels have higher base costs relative to gasoline and diesel.[29] Additionally, biofuels result in increases in some pollutant emissions. Moreover, the social and environmental consequences of large-scale biofuels production are not yet fully understood.[30] For example, little analysis has been done on the economic and social impacts of competition for land use to grow crops and alternate uses of feedstock. Some analysts predict that scaling-up of biofuels production may end up increasing the prices for many food commodities.[31] Data suggest that a majority of the deforestation in Malaysia and Indonesia in recent years has been caused by clearing of land for new palm oil plantations (Rosenthal, 2007).

The projected benefits and drawbacks of biofuels production have led to a spate of recent activity in both the public policy realm and in commercial sectors.[32] Both APEC and ASEAN have issued statements promoting the use of biofuels.[33]

In order for further development of biofuels to be effective and sustainable, the following key issues need to be addressed:

1. undertake comprehensive life-cycle analyses of crops and production processes in Asia in order to assess the relative energy and carbon emissions impacts of each fuel;
2. develop and enforce technical fuel standards critical for large-scale use of biofuels and for vehicle manufacturers to support their warranties for engines;
3. develop a harmonized set of biofuel standards for fostering both trade and investment; and

29. With an increased scale of production and ongoing technological advances, much of this cost differential may be eliminated.
30. Impacts include negative changes in land use, such as conversion of tropical forests to palm oil mono-crops, with associated loss of biodiversity and habitat, as well as expanded use of water, nutrient runoff, and loss of watersheds.
31. A recent report by Goldman Sachs indicates that demand for biofuels is pushing up crop prices, making it more expensive for food companies to source the raw materials used in their products. The report indicates that more than 60 percent of arable land in the European Union would be needed to meet the demands of the biofuel industry if the region were to replace 20 percent of the fossil fuels used in transport with biofuels.
32 . Biodiesel production has attracted new investments from a range of sources. A few examples from Asia include (1) the investment by D1 Oils (UK) in biodiesel development from jatropha in India, the Philippines, China, India and Thailand; (2) the recent inauguration by Chemrez Incorporated in Manila of Asia's largest biodiesel refinery; and (3) new investments in palm oil-based biodiesel production in Malaysia.
33. Recently, an APEC Biofuels Task Force issued a recommendation to energy ministers recognizing the following as key principles for effective promotion of biofuels in Asia: (i) near-term use of ethanol from sugar cane and cereal, and biodiesel from palm oil, but longer term emphasis on second generation biofuels from ligno-cellulosic feedstock; (ii) promoting trade opportunities through the establishment of performance-based biofuel standards, and (iii) removal of any trade barriers. A similar message is contained in the Bogor Initiative facilitated by ASEAN.

4. develop and implement comprehensive and internationally approved assessment methodologies which evaluate social and environmental impacts of biofuel projects.

In summary, biofuels can, in principle, reduce the GHG footprint of transport fuels by replacing a significant share of these fossil fuels. It will, however require several decades for commercial biofuels to displace a significant share (e.g. >20 percent) of the growing fossil fuels markets. Expanding the use of biofuels will require that the land-use and environmental impacts associated with large-scale biofuels production be adequately addressed.

3.15 NUCLEAR ENERGY[34]

While concerns about the operational safety of nuclear power plants and handling of spent fuel have constrained its use in other parts of the world, nuclear energy is expected to expand in Asia. Certain economic advantages, namely its low generation cost[35] and low fuel-price volatility, as well as reduced air pollution, have helped retain its position in Asia's future energy mix. Growth will be centered among the traditional nuclear powers, China and India, with the addition of Vietnam after 2015. The share of nuclear energy in primary energy supply is expected to increase in China from 0.6 percent today to 3.8 percent in 2030 and in India from 1.3 percent to 6.8 percent. Vietnam is expected to use nuclear energy to supply nearly 7.6 percent of its primary energy needs by 2030 (APERC, 2006).

Efforts are under way to develop advanced fission and fusion technologies that can address several of the economic, safety, waste management, and proliferation issues linked to nuclear energy. For advanced nuclear power plant designs, efforts are focused on making plants simpler to operate, inspect, maintain, and repair. Over the longer term, the focus is on innovative designs, several of which are in the small-to-medium range (up to 700 MWe). This envisions construction with factory-built components, including complete modular units for fast on-site installation, creating possible economies of series production instead of economies of scale. Some units are being designed for operation without on-site refueling. Other advantages foreseen for smaller units are easier financing, greater suitability for small electricity grids or remote locations, and their potential for district heating, seawater desalination and other non-electric applications. China is involved in two major international efforts to promote innovation for nuclear energy – the IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) and Generation IV International Forum (GIF).[36] Much of the current experimental and theoretical research on nuclear fusion is focused on the International Thermonuclear Experimental Reactor (ITER).[37]

34. This section draws extensively from the section on nuclear energy in APEC Energy Outlook 2006 (APERC, 2006).

35. A longstanding argument for nuclear power is that low generation costs offset the high capital costs; however, the cost of waste disposal and fuel recycling may impose significant additional costs that may adversely impact the economic competitiveness of nuclear energy.

36. INPRO published an initial report in 2003 that outlined the potential of nuclear power and specified guidelines and a methodology for evaluating innovative concepts. The next stage of INPRO is to facilitate assessments of innovative nuclear energy systems (INSs), and to define and model INS deployment scenarios that take into account strategies considered by participating economies. Canada, Japan, Korea, and the US are the APEC member economies participating in the Generation IV International Forum (GIF) project. GIF has reviewed a wide range of innovative concepts and, in 2002, selected six types of reactor systems for future bilateral and multilateral cooperation: gas cooled fast reactors, lead alloy liquid metal cooled reactors, molten salt reactors, sodium liquid metal cooled reactors, supercritical water cooled reactors, and very high temperature gas reactors.

37. The aim of ITER is to demonstrate the scientific and technological feasibility of fusion energy by constructing a functional fusion power plant. ITER would take about 8 years to build and would then operate for a further twenty years. It would be the first device in the world where a controlled nuclear fusion reaction would generate at least 5 times more power than it consumes. ITER's "engineering design activities" stage has been completed, and in June 2005, the Seven Parties to the ITER – the European Union, Russia, Japan, China, India, Korea and the United States – announced that it will be sited at Cadarache in France.

Nuclear energy represents an abundant source of GHG-free baseload energy but it must overcome two significant hurdles. The first is public skepticism about its safety and issues relating to waste disposal and proliferation. Safety records in the operation of nuclear plants are improving, and nuclear reactors in the future can be made even safer as more safety features are incorporated into new designs. Nevertheless, governments must undertake major oversight responsibilities to: ensure the continued safe operation of nuclear facilities – including the training of thousands of engineers to build, operate and decommission these plants; deal with the substantial technical challenges of waste management; make the required political decisions to develop and implement effective national waste management and strategies; and promote international action to strengthen non-proliferation controls. The second significant hurdle for nuclear power will be in terms of financing – both because nuclear power will have to compete with cheap sources of base-load power, such as natural gas and coal, and because investment banks that typically underwrite large power projects have been to date unwilling to finance nuclear power plants without significant government subsidies and guarantees.

3.2 ENERGY EFFICIENCY OPTIONS

On average, only one-third of the world's primary energy consumption is converted into useful energy – the rest is wasted due to conversion, transmission, and efficiency losses. As a result, significant energy efficiency (EE) opportunities exist in all aspects of modern energy production, distribution, and consumption.

3.21 OVERVIEW OF ENERGY EFFICIENCY OPTIONS AND POTENTIALS

Energy efficiency improvements yield direct benefits, such as affordability, reduced investment burdens for energy infrastructure expansion, improved access to modern energy through more-affordable energy services, and reduced emissions of GHGs and local air pollutants. Improved energy efficiency also yields social benefits, including enhanced energy security (through reduced reliance on imported fossil fuels) and job creation (as domestic energy efficiency industries are developed). Energy efficiency improvements – by extracting more light, heat, mobility, or other services from primary energy input – are the least expensive source of GHG emissions reduction. In fact, if the energy efficiency investment is cost-effective relative to traditional supply options, then *the reduced GHG emissions saved are achieved at negative cost*, i.e. at a financial gain (see cost tables in Section 3.3).

In the world's emerging economies, demand and economic growth have been closely correlated with energy demand growth for much of the past three decades. In these countries, economic growth has only recently begun to outpace growth in energy use, and the GDP-energy demand relationship is quite sensitive to structural and technology change and rapid growth of some consuming sectors (e.g. households and services). For example, Vietnam's elasticity of electricity demand growth (electricity demand growth versus GDP) is expected to fall from the current levels of 2 to 1.4 between 2006 and 2010 (World Bank, 2006). China's energy intensity dropped steadily until 2000 due to both structural change and technical improvements, but has since increased due to intensified industrialization. An important contributor to the gradual de-linking of economic growth and energy demand has been improved energy efficiency in vehicles, appliances, space heating, and industrial processes.

ENERGY SECTOR INVESTMENTS AND ENERGY EFFICIENCY

Large gaps remain between developed countries and developing countries in terms of realizing their energy efficiency potential, which creates an opportunity for immediate action on energy efficiency in the developing world. Meeting growing energy demand through greater reliance on energy efficiency is not without cost or investment. However, the additional capital required for improving supply-side and end-use efficiency are more than offset by lower investment requirements for additional energy production, plus lower energy use over the life of the efficiency investment.

In its World Energy Outlook for 2006, the International Energy Agency (IEA) estimated that the impact of energy efficiency. In its "Alternative Scenario," demand for primary energy is reduced by 10 percent due to energy efficiency, while GHG emissions are reduced by 16 percent compared to the BAU scenario. Demand for both oil and coal is forecast to decrease sharply, with resultant improvements in balance of trade and energy prices, especially for resource-poor economies.[38] In all, IEA estimates that about two-thirds (65 percent) of global GHG reductions through 2030 could come from energy efficiency measures in developing and transition countries.

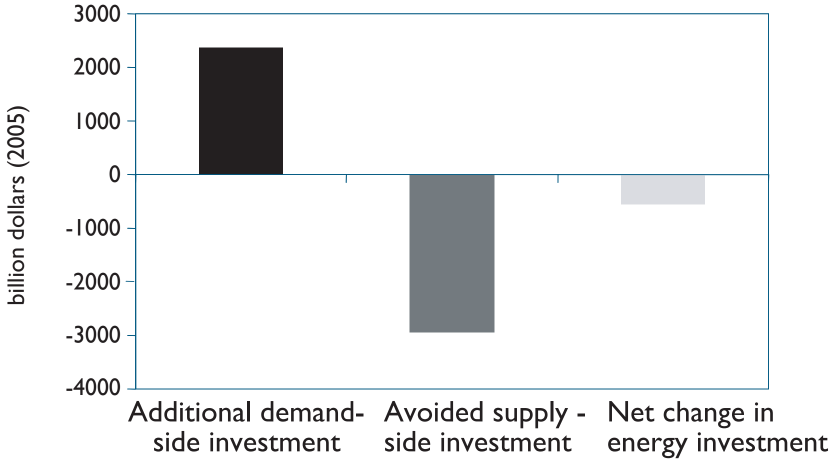
The IEA estimates that US$20 trillion will be required globally for investments in energy infrastructure during the period 2001 to 2030. A US$2.4 trillion investment in energy efficiency would be offset by a US$3 trillion reduction in investments in energy supply and infrastructure, and an additional US$8.1 trillion would be saved in consumer fuel costs. Overall, the IEA found that every US$1 invested in end-use efficiency would generate a savings of US$1.25 in energy infrastructure, and that this savings would also be enhanced by the long-term consumer benefits of reduced energy costs (Ellis, 2006; IEA, 2006).

ENERGY EFFICIENCY INVESTMENTS DELIVER ECONOMIC BENEFITS

An impressive demonstration of the feasibility to rapidly scale-up energy efficiency investment and improvements is the case of California. In California, an ongoing program of utility involvement in improving end-use efficiency has saved 15 percent of total statewide electricity use. As a result of government regulations combined with utility incentive programs, average electricity use in California is one-third less than that for the entire U.S.

Japan is the most energy efficient nation in the developed world. Japan consumed just 180 million KJ per person in 2001, around half of the United States' rate of 358 million KJ per person. This low consumption rate is primarily due to the rapid adoption of energy efficient technologies and government-mandated energy savings initiatives.

FIGURE 20. IMPACT OF INVESTMENTS IN DEMAND-SIDE ELECTRICAL EFFICIENCY ON SUPPLY-SIDE INVESTMENTS AS PER IEA ESTIMATES



Source: Ellis, 2006.

38. The IEA figures are borne out by experience from implementation of demand-side management (DSM) programs in Thailand. The World Bank carried out a fuel options study for Thailand in 1993, and projected that DSM (energy efficiency) would be the least-cost electricity resource, at 2.1 cents per kWh. In actuality, the Thai DSM effort was able to deliver 7,100 GWh per year of electricity savings over 10 years at a cost of saved energy of just 1.2 cents per kWh (Phumaraphand, 2001; EGAT, 2006).

The Asian Development Bank (ADB) estimates that the economic potential for energy efficiency in four countries – India, China, Thailand, and the Philippines – is 15 percent of primary energy demand.[39] The ADB further estimates that an investment program of US$14 billion per year over 10 years, or US$140 billion in total, would be required to realize this 15 percent savings. Regardless of these optimistic projections and large economic potential, the truth remains that significant market and non-market barriers continue to impede the uptake of energy efficiency options (see Section 4 for a further discussion of these barriers).

3.22 RANGE OF ENERGY EFFICIENCY OPTIONS

Reducing GHG emissions requires making investments in improved energy efficiency within the designs of long-lived infrastructure such as buildings, factories, equipment, and transport facilities.[40] Existing and newly emerging energy efficient devices and technologies offer many opportunities to economically reduce energy use with no productivity loss or reduction in comfort. In addition, there are substantial opportunities for improvement in the supply side of the power sector – generation, transmission, and distribution. Table 9 summarizes the main types of energy efficiency opportunities across an economy.[41]

TABLE 9. ENERGY EFFICIENCY OPPORTUNITIES ACROSS SUPPLY SIDE AND END USE SECTORS

END-USE	**Buildings and Appliances**	Integrated building design and measures such as better insulation, advanced windows, energy efficient lighting, space conditioning, water heating, and refrigeration technologies.
	Industry	Industrial processes, cogeneration, waste heat recovery, pre-heating, efficient drives (motor, pump, compressors).
	Municipalities	District heating systems, combined heat and power, efficient street lighting, efficient water supply, pumping, and sewage removal systems.
	Agriculture	Efficient irrigation pumping and efficient water use, such as drip irrigation.
	Transport	Efficient gasoline/diesel engines, urban mass transport systems, modal shifts to inter- and intra-city rail and water transport, improved fleet usage.
	Households	Lighting, appliance efficiency, improved cooking stoves.
SUPPLY-SIDE	**New thermal power plants**	Combined cycle, supercritical boilers, integrated gasification combined cycle (IGCC), etc.
	Existing generation facilities	Refurbishment and re-powering (including hydro), improved operation and maintenance practices, and better resource utilization (higher plant load factors and availability).
	Reduced transmission and distribution losses	High voltage lines, better insulated conductors, capacitors, efficient and low-loss transformers and improved metering systems and instrumentation.

Source: USAID ECO-Asia Clean Development and Climate Program

39. Economic potential was defined as investments with an expected simple payback of three years or less.
40. For example, half of China's urban residential and commercial buildings will be built within the next fifteen years, and this building stock will remain in use for the following 50 to 100 years.
41. One of the most comprehensive assessments of the potential for energy efficiency measures to reduce CO_2 emissions was carried out for the U.S. government in 1997. Dubbed the "Five Lab Study on Carbon Emissions", the report concludes that energy-efficient technologies could cost-effectively reduce projected U.S. carbon emissions in 2010 by approximately 20 percent (390 MtC/year vs. 2010 projections of 1,730 MtC/year). The study also found the following share of sectoral reductions: 16 percent for buildings, 24 percent for industry, 26 percent for transportation, and 34 percent for utility supply (LBNL, 1997).

3.23 ENERGY EFFICIENCY POTENTIAL IN FOCUS COUNTRIES

Table 10 shows substantial potentials that have been identified for the building and industrial sectors by the ADB and in other regional analyses.[42] The main observation with regard to these figures is that the potentials are quite significant (on the order of at least 15-20 percent per sector), and only a fraction of this has been realized, due to a number of barriers, relating to access to technology, institutional barriers in program design, awareness levels among decision-makers, and access to financing.

TABLE 10. SUMMARY OF MEDIUM-TERM ENERGY EFFICIENCY (EE) POTENTIAL AND INVESTMENT NEEDS IN FOCUS COUNTRIES

Country	Commercial/ Residential Sector EE Potential	Industrial Sector EE Potential
India	4,439 GWh, or 1,935 MW[a] (Commercial only)	49,056 GWh, or 7,000 MW
	21,000 GWh for refrigerators and room air conditioners[b]	11,000 GWh for motors and transformers[b]
Indonesia	Large potential, especially air conditioning and lighting systems	Conservative estimate of 20 percent potential
China	Up to 50 Mtoe and 29 TWh of electricity (Commercial only)	Technical potential of 483 to 644 TWh/year; market potential of 70 TWh/year; savings of 4.5 percent to 13.3 percent between 2005-2010 for 4 key sectors.[h]
Philippines	Up to 3.2 MBFOE[43] by 2014 (Commercial only)	41.9 MBFOE
Thailand[g]	Range of 127 to 522 GWh/year (Commercial only)	Range of 1,894 to 5,503 GWh/year
	5,396 GWh/year in 2011 (9.2 percent) and 15,328 GWh/year in 2016 (20.0 percent) [i]	8,842 GWh/year (8.5 percent) and 4,119 Ktoe (10 percent) in 2016 [i]
Vietnam	24,600 GWh technical and 3,500 GWh near-term achievable potential (7 percent of total national electricity use). [c]	Energy audits show savings potential of 25,000 Gwh/yr [d]

Source: ADB, 2006, except where otherwise noted. Notes: (a) Most of this (84 percent) is in the municipal sector; (b) McNeil, 2005; (c) EVN DSM Screening Report; (d) Electricity of Vietnam, 2006; (e) Commercial and industrial sectors only; (f) Change in industrial sector and peak load shifting; (g) Thai data for conservative and optimistic scenarios of energy efficiency potential in commercial and industrial sectors; (h) He, 2006; and (i) JGSEE, 2007.

3.24 SUPPLY-SIDE EFFICIENCY

Supply-side efficiency opportunities include more efficient power plants, advanced transmission systems, and low-loss gas and electricity distribution networks. Considerable untapped potential for energy efficiency improvements exists, particularly along the production and delivery chains of newly-industrialized countries.

In thermal power generation, there are substantial opportunities for improving plant efficiency. Typical thermal efficiencies for power plants in industrialized countries are in the range of 35-40 percent, and they are often 10-15 percent lower in Asian countries. There is a particular opportunity for improvement of coal-fired power plants, which will be the greatest source of electric power and by far

42. In the reviews of energy efficiency technologies and practice in the focus countries, it was clear that there is a high degree of ongoing activity. The programs and achievements in the area of energy efficiency are described in detail in the country reports (Annexes 1-6).
43. MBFOE refers to million barrels of fuel oil equivalent.

the single largest source of greenhouse gas emissions in Asia during the coming two decades. The ADB estimates that the thermal efficiency of India's coal power plants could be increased from 30.5 percent to 42 percent using the best available technology.[44] This would reduce coal requirements by 274 Mt of coal per year (ADB, 2006). Thailand is also working on heat-rate improvements for its power generation. Options being considered include incorporation of heat recapture and cogeneration into its power plants.

Significant improvements are also available in the management and operation of the power grid, including dispatch, transmission, and generation. Among the focus countries, Vietnam has a strong program of supply-side efficiency improvement, which is being implemented by Electricity of Vietnam (EVN). EVN has improved the heat rate of power plants, especially oil-fired plants, obtaining a 20 percent improvement in operating efficiency. EVN also has reduced transmission and distribution (T&D) losses from 17 percent to 11 percent, with the further goal of a 0.6 percent improvement per year to an ultimate goal of 9 percent by 2008. The modalities are rehabilitation of medium voltage lines, increasing transmission capacity, modern technical tools for dispatch (e.g. SCADA), and improved management (Khanh, 2006).

3.25 DEMAND SIDE EFFICIENCY

ELECTRICITY END USES

The operating cost of electrical equipment is not reflected in the purchase cost. The effect is the greatest for electric motors, as the operating costs for electric motors in the first year alone are often several times the purchase price.[45] This simple fact is the major reason that end-use equipment is much less efficient than its cost-effective potential. However, when consumers purchase efficient units, the payback period ranges from as little as a few months to just a couple of years.

Motors: Electric motors are ubiquitous devices that are used in factories and buildings worldwide. They represent one of the largest potentials for saving electricity in the industrial sector.[46] Electric motors typically account for 60-70 percent of the electrical energy used in factories in Asia. The IEA estimates a technical potential to improve the energy efficiency of industrial electric motor systems of 20-25 percent, representing a total of 7 percent of global electricity demand (IEA, 2006).

A recent study of the energy efficiency potential in India found a technical savings potential in the range of 20-39 percent for industrial motors and 12 percent for agricultural motors (see Case Study). The cost of saved energy for industrial motors ranged from 1.1 to 2.5 US cents per kWh, which is much lower than the average industrial electricity price in India of 7.6 US cents per kWh (McNeil et al., 2005).

Lighting: Lighting is a major end-use in all buildings, and can account for as little as 5-10 percent of electricity use in buildings and factories, to as much as 80-90 percent in households in newly electrified rural villages. Globally, the IEA estimates that the cost of energy, lighting equipment, and labor related to electric lighting is approximately US$360 billion per year, which is roughly one percent of global GDP. The electrical energy used globally for lighting is equivalent to 70 percent of the energy used by passenger vehicles worldwide (OECD/IEA, 2006).

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44. Options for improvements in coal plant efficiency are discussed in Section 3.11.

45. For lighting equipment, household appliances, and electric motors, the lifetime operating costs are often higher than the purchase price. However, the difference between operating costs and purchase price is higher in the case of electric motors .

46. A small fraction (approximately 10 percent) of the savings come from replacement of the motor itself. Most of the savings come from proper sizing and placement of motors; optimization of the complete system, including the driven equipment (pumps, fans, etc.) and distribution system (pipes, valves, etc.); use of adjustable speed drives; proper maintenance and repair; and acceptable power quality (IEA, 2006).

The IEA recently reported that lighting electricity use will increase 80 percent by 2030, and that without further policy initiatives, lighting-related CO_2 emissions will increase from 1.9 Bt of carbon per year today, to almost three Bt of CO_2 per year by 2030 (OECD/IEA, 2006). The report also found that policies currently in place have led to an eight percent reduction in lighting energy use and a 1.67 Bt reduction in CO_2 emissions. These policies, if left in place, would reduce lighting energy use 17.5 percent in 2030 and would reduce CO_2 emissions by 449 Mt annually, or cumulatively by 10.3 Bt of CO_2. A more ambitious set of lighting policies, recommended by the IEA, would reduce lighting energy use in 2030 by an additional 38.4 percent and would reduce CO_2 emissions by 970 Mt annually, or cumulatively by 16.2 Bt of CO_2 (OECD/IEA 2006).

The research team identified a number of planned and ongoing regional programs focusing on lighting efficiency. These include initiatives supported by the Asian Development Bank, Asia Pacific Economic Cooperation, Asia-Pacific Partnership on Clean Development and Climate, Global Environment Facility, International Finance Corporation, and United Nations Development Program. In addition, a number of jurisdictions have recently announced plans to ban or phase out incandescent lamps in favor of compact fluorescent lamps (CFLs). In early 2007, Australia, the State of California, European lighting suppliers, and Thailand each separately announced their intention to phase out incandescent lamps and replace them with CFLs.

ENERGY EFFICIENCY POTENTIAL IN INDIA: A CASE STUDY

A recent comprehensive assessment of electricity efficiency potential for India (McNeil et al., 2005) examined the technical potential and cost effectiveness for four major types of electricity-using products: refrigerators, room air conditioners, electric motors, and distribution transformers. Savings and cost effectiveness for various products installed (2010-2020) as presented in this study are given below.

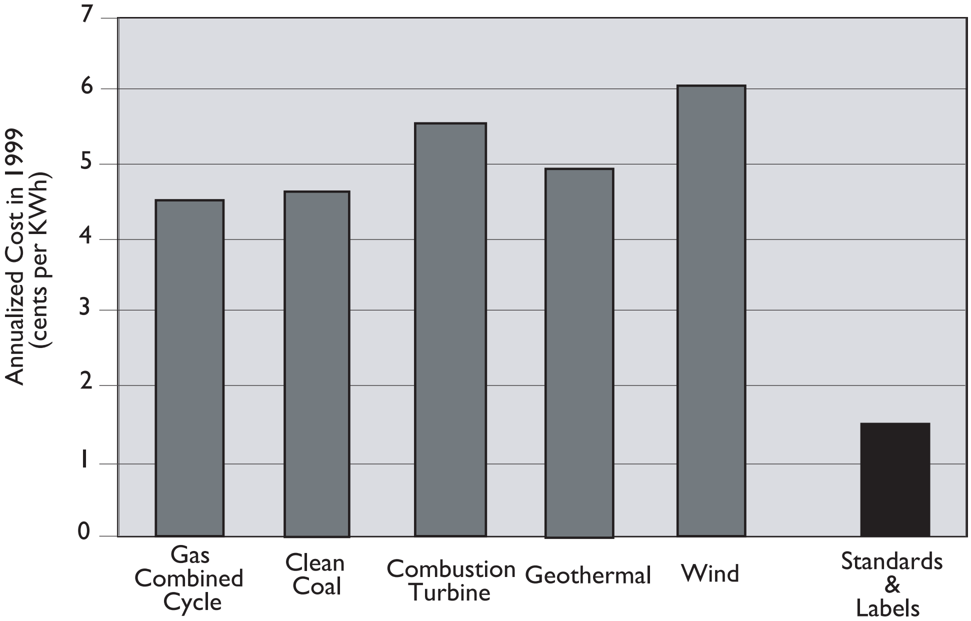
Product	Energy Savings		GHG Reductions MT CO_2	Saved Energy (US cents/KWh)	Efficiency Improvement (% unit energy consumption)
	Mtoe	TWh			
Refrigerator	77	16	259	1.0-3.0	45%
Room air conditioner	23	5	78	1.1-2.5	6%
Electric Motor	14	4	47	1.3-5.2	12-39%
Distribution transformer	45	7	153	3.4-3.9	56-62%
Total	159	31	538	1.0-5.2	6-62%

Appliances: Energy used in buildings accounts for 42 percent of total global energy consumption, and 36 percent of energy-related CO_2 emissions (Price et al. 2005). A number of international reports document that improvements to appliance efficiency are among the most cost effective options, and that these gains can be achieved primarily through a combination of energy labeling and minimum energy performance standards (APEC, 2006; Weil and McMahon, 2006).[47]

47. The U.S. experience has shown that dramatic improvements are available through labeling and standards programs for appliances. For example, the average refrigerator sold in the U.S. in 2005 used 74 percent less electricity than a 1974 model, while being significantly larger and offering more convenience features. (CLASP 2006) Similar, but smaller gains have been made with refrigerators in Thailand, which became approximately 30 percent more efficient over a five year period during the late 1990s, due to an innovative energy labeling program (Monenco, 2000). Korea has had perhaps the most successful appliance efficiency programs in Asia. Using a systematic and regularly updated scheme of MEPS supported by energy labeling, the Koreans have been able to improve the efficiency of appliances sold in their stores on the order of 40-60 percent over a period of just a few years.

In cost-effectiveness comparisons between options to expand supply of electricity and demand-side efficiency options, the demand-side options come out consistently ahead. A recent comparison in the US revealed that appliance efficiency measures cost 70-80 percent less than supply-side electricity options.[48]

FIGURE 21. THE COST OF ELECTRICITY IN THE U.S. FROM VARIOUS NEW SOURCES



Source: Wiel and McMahon, 2006.

Standby Power: Standby power is the energy consumed by an appliance or piece of electronic equipment (e.g. TVs, stereos, computers) when it is not performing its primary function. While standby power has been largely ignored by energy policymakers until recently, the IEA estimates that losses from standby power account for between 3 to 13 percent of residential electricity demand in developed countries (AGO, 2006).

Fortunately, technical solutions to the problem of standby power exist, are cost-effective, and are already being implemented. Japan has been active in this area, and on-site monitoring shows that annual standby energy use in a typical Japanese house has fallen from 437 to 308 kWH per year over the past four years (AGO, 2006). In 2000, the IEA launched a ground-breaking international effort to set a target of maximum standby power levels of one watt for all electronic equipment within ten years. A number of countries have announced plans and targets, and specific plans and timetables have been developed by Australia and Korea.[49]

48. The figure for appliance efficiency in Thailand is similar, at US$0.012 per kWh for a combination of measures including refrigerators, air conditioners, and fluorescent lighting, compared to the levelized cost for a new coal-fired power plant of approximately US$0.05 per kWh.

49. The Australian target is to regulate all electronic products to the IEA level of one watt by 2012. Korea has an ambitious target, backed up with government R&D support, to lower standby power of all electronic devices to one Watt by 2010. A recent international conference on standby power concluded that standby power currently is responsible for 5-10 percent of global household electricity use, and that the technology is available to reduce standby power by 50 percent or more without significant cost impacts (AGO, 2006).

Standby power represents an example of a product area in which a product is globally traded, and there exists through regional and international cooperation, the opportunity to make significant energy efficiency improvements. With leadership from the IEA, and active participation from governments such as Australia, China, Japan, Korea, and the US, progress is being made in this area.[50]

Electricity use in the Aluminum Industry: Various steps involved in the production of aluminum (mining, smelting, and extrusion and prefabrication) consume large amounts of energy and offer significant opportunities for energy efficiency investments. The technology used for aluminum production has been in existence since 1886. While there have been a number of technological breakthroughs that have greatly improved the energy efficiency and environmental performance of the industry, the basic core technology (carbon anode/cathode cell) remains in use to this day. The APP's Aluminum Task Force report highlights smelting as one of the key areas where technology development could be focused. Smelting results in emissions of perfluorocarbons (PFCs), which are extremely potent, long-lived greenhouse gases. Advanced technologies using inert anodes and drained cathode cells offer energy savings and PFC emissions reductions and are in development by various private sector entities. The rapid dissemination of these advanced technologies can lead to significant reductions in PFCs and forms a significant focus area of the APP.

Thermal Energy End Use Efficiency: Half to three-quarters of final energy demand in factories is supplied by thermal fuels (i.e. gas, oil, coal) rather than electricity. There is substantial opportunity to reduce thermal energy use through both "low-cost, no-cost" housekeeping measures, as well as more systematic attempts to examine heat flows in processes and to improve process efficiency.

In the European Union today, the market potential for industrial energy savings is approximately 10 percent if commercially available energy efficiency equipment and processes are applied. But little of this energy saving potential is realized because there is limited focus on energy efficiency in general, and the financial criteria that industry applies to feasible energy efficiency measures are often extreme (e.g. one to two year pay-back period) (DEDP, 2001). Similarly, economic studies in the United States have found the achievable thermal efficiency potential savings to be about 9 to10 percent (Nadel, 2004).

A comprehensive review of energy audits conducted for factories in Thailand found that the sub-sectors with the highest achievable market potential for fuel savings per facility are paper (8.1 percent), textile (7.2 percent), and food and beverage (5.3 percent). The study also found boiler efficiency improvement measures had fuel-savings potentials in the range of 7-8 percent of factory energy usage. Overall, air-conditioning and lighting measures do not have very high potential for electricity savings per facility among the industrial sub-sectors. According to the IIEC (2001), the industrial sub-sectors that appear to have the highest achievable market potential for electricity savings per facility include textiles (10.5 percent), fabricated metal (7.4 percent), and non-metallic industries (4.3 percent).

An industrial energy auditing program planned for Vietnam could result in achievable savings of more than 25,000 GWh per year in industry in 2025; most of these savings are from thermal energy efficiency. These savings amount to about 12 percent of industrial energy use in the base-case load forecast scenario in 2025 (Electricity of Vietnam, 2006).

To overcome various barriers to implementing thermal end-use efficiency measures (e.g. unwillingness to invest, information and transaction costs, profitability barriers, lack of skilled personnel, and market barriers), it has been recommended that a system be established for data benchmarking in major industrial sectors (DEDP, 2001).

50. The Asia-Pacific Partnership for Clean Development and Climate (APP) has a project focusing on standby power (APP-BATF, 2006).

Combined Heat and Power and Decentralized Energy:[51] The continuing high energy prices have provided further impetus for decentralized energy production and cogeneration. The World Survey of Decentralized Energy 2006 (www.localpower.org) estimates that the share of decentralized power generation in the world market has increased to 7.2 percent by 2004, up from 7 percent in 2002. At current growth rates, this could reach 20 percent by 2025. In other words, annual decentralized energy capacity additions would reach around 120 GW_e. It is also estimated that in 2005, the share of decentralized energy in new capacity was around 25 percent – up from 13 percent four years ago. Among Asian countries, India and China have significant potential for activity in decentralized energy. In India, the new Electricity Law is supporting rejuvenated activity for "captive" plants, particularly in the industrial sector. In China, the government's National Development and Reform Commission (NDRC) is considering the introduction of new incentive frameworks for combined cooling, heating, and power in 2006 or 2007.

Decentralized energy and combined heat and power are gaining support among large corporations, particularly among large energy users. For example, at the end of 2005, BP announced the creation of *BP Alternative Energy* to accelerate investment in 'clean' power generation, including high efficiency combined heat and power plants at its refineries and industrial sites. The sum of money it is committing to this new business area is $8 billion over 10 years. More recently, the US energy company, AES, announced in April 2006 that it was also establishing an Alternative Energy Group, with a view to investing $1 billion in low emission generation over the next three years. Yet, despite the accelerating market in 2005, there remain persistent challenges that constrain the full potential of this sector. These challenges are: (i) widespread existence of policy / regulatory barriers to decentralized energy in every country or region, (ii) awareness among policymakers and other opinion formers as to the economic effectiveness of decentralized energy, (iii) skepticism among various stakeholders about the environmental benefits of decentralized energy, especially where it is based on the use of fossil fuels, and (iv) failure of the industrial end-user sector to promote decentralized energy.

3.26 ENERGY EFFICIENCY IN TRANSPORT

The transport sector in Asia is faced with runaway demand fueled by an explosion in personal transport. Correspondingly, the CO_2 emissions from on-road transport can be expected to increase by 3.4 times for China and 5.8 times for India over the next 30 years. This situation is further exacerbated by inefficient vehicle fleets, poor maintenance of in-use vehicles, congested roads leading to fuel wastage, and inadequate fuel quality and emissions standards that lead to high levels of fuel use and emissions per passenger-mile or freight-mile. Policymakers in Asia's mega-cities now realize that congestion cannot be addressed by building more and larger roads.[52] Given the substantial increase in private-vehicle demand and the ever-increasing space requirement caused by the move from two- to four-wheelers, any attempt to increase road space will quickly be overwhelmed by higher car ownership and use, with no long-term improvement in traffic speeds, air quality, or GHG emissions. No single policy measure alone will work in this context. A broad range of policies and actions will be required to systematically address the need for more efficient transport systems and fostering fuel diversity in Asia. Initiatives can be broadly classified as follows:

- improve engine and fuel technology to enhance the energy efficiency of new vehicles;
- ensure modal shift towards public transportation by adopting integrated transportation planning;

51. This section has drawn heavily from the research conducted by the World Alliance on Decentralized Energy (www.localpower.org).
52. The recently adopted Urban Transport policy in India is focused on a more equitable road space, and it emphasizes pedestrian and non-motorized vehicles as opposed to more vehicles (GOI-MUD, 2006).

- promote urban reform and land use planning to lower the need to travel;
- expand the use of biofuels with lower GHG emissions; and
- improve maintenance of in-use vehicles to deliver better energy efficiency.

The above policy options vary in their implementation time and ease of implementation. Changing the urban design is obviously the most challenging and requires the longest timeframe, while the improvement of maintenance of in-use vehicles can be introduced in the short term with measurable impact.

Proper maintenance is important to control emissions over the life of the vehicle. It has been shown that an effective inspection and certification program, supported by adequate maintenance, can bring about reductions in NO_x emissions of 2-5 percent, PM10 emissions of 2-15 percent, and fuel consumption and GHG emissions by around the same amount (2-17 percent). The higher numbers were achieved for the less advanced vehicle fleets, which are common in Asia (ADB, 2006). Nevertheless, the majority of inspection and certification programs in Asia have been less than effective (USAID, 2004). Appropriate monitoring equipment, strict enforcement and the requisite political will and institutional capabilities are critical to success. Wherever such programs have succeeded, inspection and certification (I/C) programs offer a cost-effective emissions mitigation strategy that affords immediate results, especially in heavily polluted cities that contain older vehicular stock. Effective inspection and certification programs require setting in-use emission standards that are achievable by a majority of vehicles with good maintenance, and tightening these standards over time with the objective of removing grossly-polluting vehicles from the road. Over time, however, given that much of the future vehicular stock in Asia will be new, the most significant GHG reductions can be realized by enacting minimum energy performance and environmental standards throughout developing Asia for all forms of motorized personal transport, following China's lead.[53]

Accomplishing a reduction in the growth of GHGs in the transport sector will require addressing substantial barriers including: (i) lack of awareness and consistent knowledge of international best practices on climate change and sustainable transport among national, sub-national, and local government planners and decision-makers; (ii) weak coordination between urban planning, transport planning, energy, and environmental agencies at various levels of the government; (iii) lack of accounting for externalities in making transport planning decisions (e.g. congestion, pollution, climate change, travel cost and time etc); and (iv) inadequate access to capital and operating budgets to invest in transport energy efficiency equipment and programs.

3.27 CONCLUSIONS

An analysis of the energy efficiency potential in Asia argues strongly for considering energy efficiency as a critical clean energy option for improving regional energy security while also achieving GHG reductions. It can be deployed readily (unlike power plants or petroleum refineries), and it reduces investment risk because it is a flexible and readily scalable option. In addition to achieving energy savings, energy efficiency gains can alleviate affordability constraints for the poorest consumers, increase the competitiveness of industry, reduce the fiscal burden of energy subsidies, and mitigate the adverse impacts to consumers of retail energy price increases.

3.3 COMPARATIVE EVALUATION OF CLEAN ENERGY OPTIONS

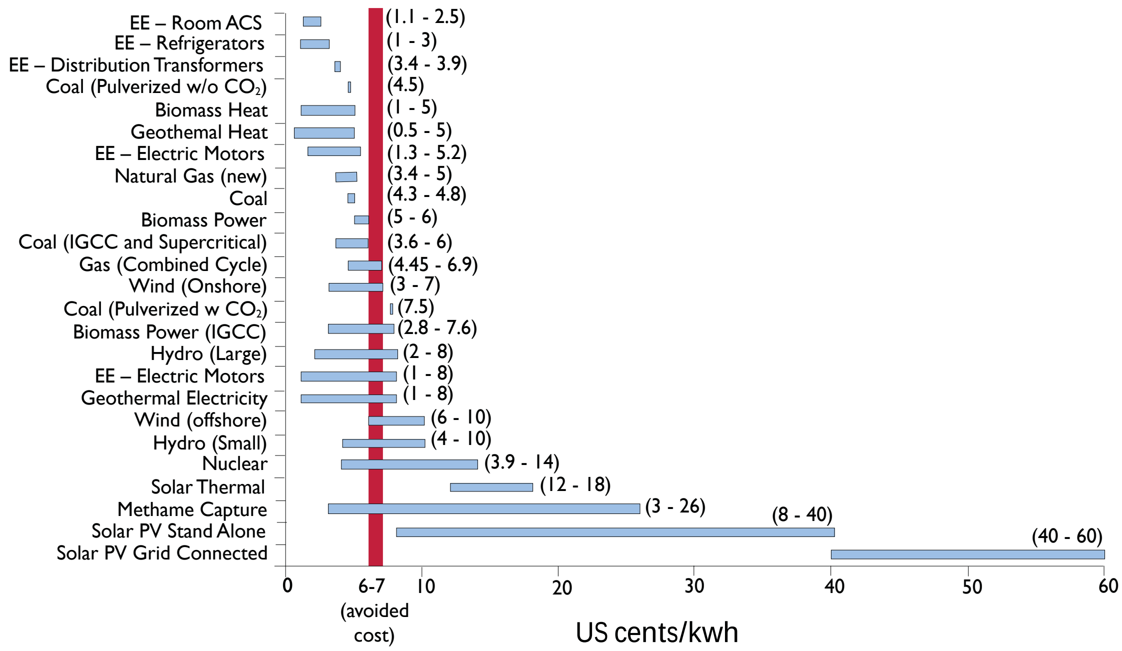
53. China's Medium and Long Term Energy Conservation Plan, introduced in 2004, requires reducing the unit energy consumption of vehicles from 8.2 to 6.7 liters per 100 kilometers (see China country report in Annex 1).

Following the overview of various energy supply and energy efficiency options in Section 3.1 and 3.2, this section presents a comparative evaluation on the basis of the cost of delivered (generated vs. saved) energy, pollution impacts, carbon reduction potential, and employment potential. Since country-specific costs or even Asia-specific costs for these parameters often do not exist, we have obtained data, where necessary, from global studies or studies undertaken in the European Union or North America.[54] Further, given the large range in these costs (owing to their global aggregate nature), it would be futile to force a strict quantitative ranking. Our analysis focuses primarily on the power sector. This reflects the reality that globally, much of this research is conducted on power generation and electricity-end use technologies.[55] Wherever available, we have incorporated transport-related data.[56]

3.31 COMPARISON BASED ON GENERATION COSTS AND COST OF SAVED ENERGY

Estimates of the generation costs and the cost of saved energy for various clean energy options are presented below (Figure 22). Relative to a typical avoided cost of electricity generation of 6 to 7 cents per kilowatt-hour, energy efficiency, coal combustion without CO_2 capture, biomass, geothermal heat, natural gas, IGCC, and supercritical coal have the lowest cost of delivered energy. Various solar energy technologies have the highest cost of delivered energy.

FIGURE 22. GENERATION COST ESTIMATES OF ALTERNATIVE ENERGY OPTIONS (WITHOUT EXTERNAL COSTS)



Source: Compiled from Sims et al, 2003; Sawin 2004; McNeil et al., 2005 and IEA, 2006.

54. Some of the estimates incorporate cost data from China and India.

55. From a monitoring and compliance point of view, GHG emissions are easier to monitor and control from centralized, large power stations than from millions of vehicles and even the agricultural sector. Therefore the electricity sector is likely to become a prime target for GHG mitigation efforts in the future. In addition, the majority of energy-related CO_2 emissions in 2030 are projected to result from electricity generation.

56. Cost-effective energy savings and resultant CO_2 emissions are abundant in the transport sectors; however, there are limited data on their cost effectiveness in terms of CO_2 reductions.

3.32 COMPARISON BASED ON EXTERNALITIES

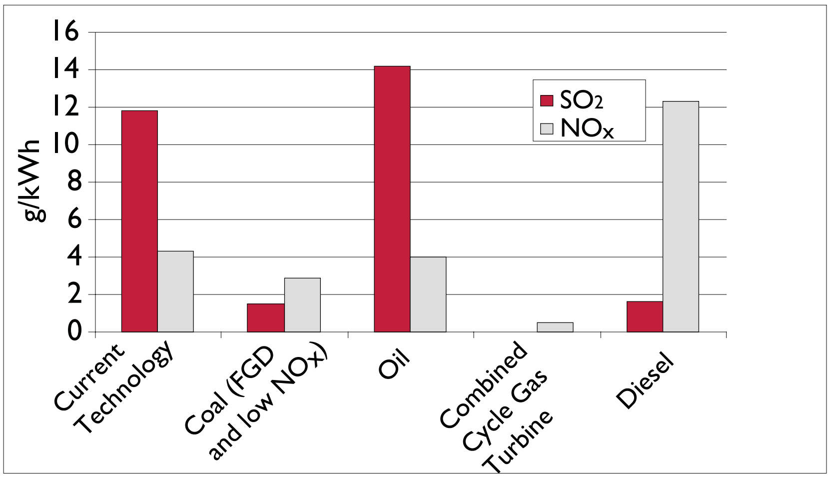
The above comparison does not take into account the pollution impacts of the various energy options. Renewable energy is usually more environmentally friendly[57] than alternative fossil or non-fossil fuel energy sources, especially when it comes to air quality impacts. Current estimates of life-cycle emissions from the main renewable energy technologies and conventional electricity generation are shown in Table 11 and Figure 23 (Table 12 lists the corresponding CO_2 values for Figure 23). While the results are inexact, they portray the relative differences between the various options. While this data set does not include nuclear energy, it should be noted that nuclear power generation releases neither SO_2 nor NO_x and little CO_2, although its toxic legacy remains a concern to policy-makers. The life-cycle emissions of these three gases fall within the ranges shown for non-hydroelectric renewable energy.

TABLE 11. AIR POLLUTION EMISSIONS BASED ON LIFE-CYCLE ANALYSIS FOR RENEWABLE ENERGY (g/kWh)

	Energy Crops		Hydro Small-scale	Hydro Large-scale	Solar (PV)	Solar (Thermal)	Wind	Geothermal
	Current	Future						
CO_2	17-27	15-18	9	3.6-11.6	98-167	26-38	7.9	79
SO_2	0.07-0.16	0.06-0.08	0.03	0.009-0.024	0.20-0.34	0.13-0.27	0.02-0.09	0.02
NO_x	1.1-2.5	0.35-0.51	0.07	0.003-0.006	0.18-0.30	0.06-0.13	0.02-0.06	0.28

Source: IEA (1998). Note: Emissions are inclusive of feedstock development, transportation and processing, as well as power plant construction, operation and decommissioning.

FIGURE 23. AIR POLLUTION EMISSIONS BASED ON LIFE-CYCLE ANALYSIS FOR FOSSIL FUEL SOURCES



Source: IEA (1998). Note: FGD = flue gas desulfurization

57. Renewable energy can result in a variety of potential environmental impacts. On the negative side, renewable energy can degrade land, disrupt marine life, bird life and flora/fauna, and produce visual and noise pollution. Geothermal plants may release gaseous emissions into the atmosphere during their operation. Emissions can be managed through strict regulations and by control methods used by the geothermal industry to meet these regulatory requirements. Wind power generation can adversely impact the environment through visual effects, noise, electromagnetic interference, and endangering of birds. These potential environmental impacts tend to be site-specific, and there are a number of ways to minimize the effects, which are usually small and reversible. On the positive side, hydroelectric schemes can improve water supplies and facilitate reclamation of degraded land and habitat; although hydroelectric dams can also have significant adverse impacts on local ecosystems and populations. The use of bioenergy can have many environmental benefits if the resource is produced and used in a sustainable way. If the land from which bioenergy is produced is replanted, the carbon released during combustion can be considered to be recycled into the next generation of growing plants (IEA, 2005).

Table 11 shows life-cycle emissions for renewable energy. In terms of CO_2, solar PV has the highest emissions, while wind and hydropower have the lowest. Solar-thermal has the highest life-cycle emissions of SO_2 and large-scale hydropower has the lowest emissions of SO_2; wind, geothermal and small-scale hydro are roughly equivalent into the upper range of SO_2 emissions from large-scale hydropower. Life-cycle NO_x emissions are highest for energy crops and lowest for large-scale hydropower.

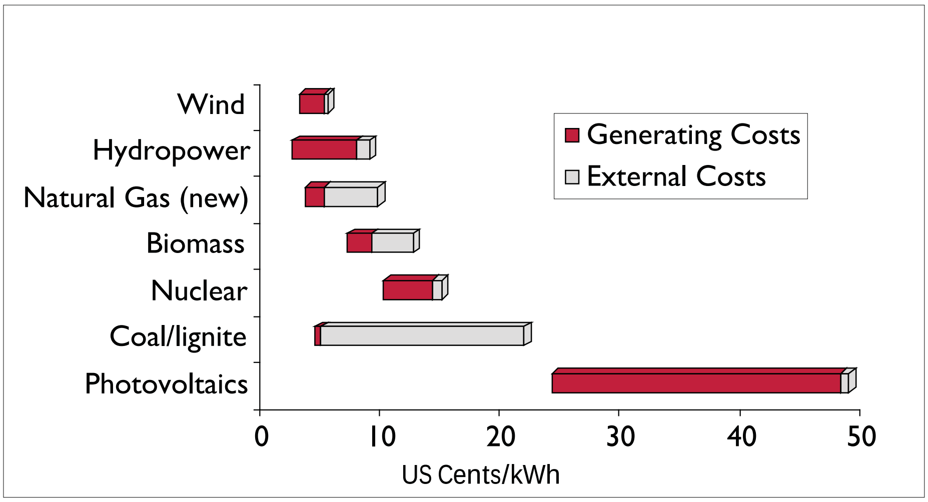
TABLE 12 : CO_2 LIFE-CYCLE AIR POLLUTION EMISSIONS FROM FOSSIL FUEL SOURCES

	Current Technology	Coal (FDG and low NO)	Oil	Combined Cycle Gas Turbine	Diesel
gCO_2/kWh	955	987	818	430	772

Source: IEA, 2002; Boudri et al. 2002. Note: Emissions are inclusive of feedstock development, transportation and processing, as well as power plant construction, operation and decommissioning.

Figure 24 provides an analysis of the increase in generation costs that can be expected if externalities[58] are duly accounted for. In this analysis, coal is no longer the cheapest source of energy (6.6-22 cents/kWh). Natural gas, owing to its lower carbon content, is in the range of 4.5-9.6 cents/kWh; and nuclear energy costs range from 10 to 15 cents/kWh. Wind and hydropower end up being the cheapest forms of energy supply (exclusive of energy efficiency options) owing to their relatively low externality costs.

FIGURE 24. COSTS OF ELECTRICITY OPTIONS: GENERATION PLUS EXTERNALITY COSTS



Source: Sawin, 2004.

3.33 COMPARISON BASED ON LEARNING CURVES AND COST REDUCTIONS

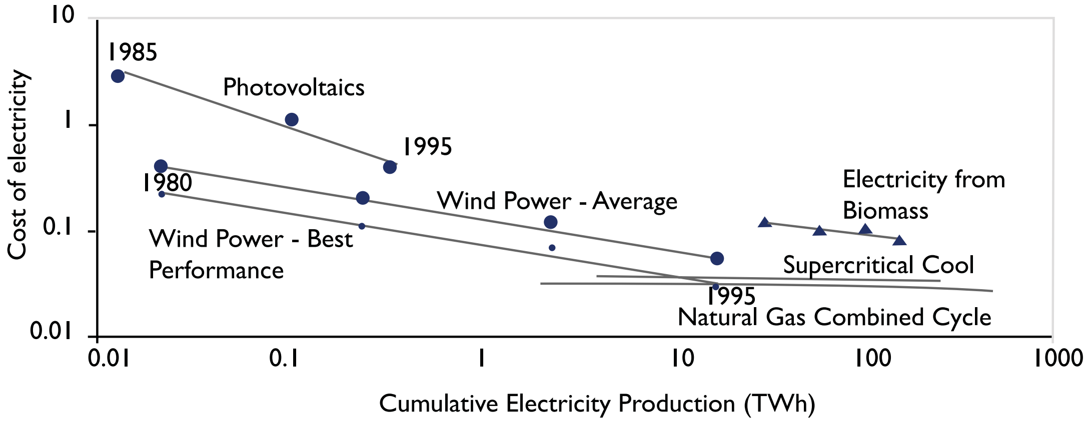
Several recent analyses indicate that the costs of electricity generated using a specific technology is a function of the cumulative installed capacity of that technology (IEA, 2002; Worldwatch, 2005). Thus with expansion of the market and achievement of economies of scale, a reduction in prices leading to a further acceleration of demand can be expected to accelerate additional demand.[59] Figure 25 presents

58. Negative impacts resulting from energy use are categorized as "externalities."

59. The key message is that cost competitiveness is not a static concept. The issue is the extent to which the cost of renewables declines relative to the decline in costs of conventional fossil technology (e.g. improvements in gas turbine technology). The uncertainty about

the average costs of energy supply over time since the 1980s for a number of energy supply fuels and technologies that are at different stages of development and deployment.

FIGURE 25. LEARNING CURVES FOR SELECT CLEAN ELECTRICITY TECHNOLOGIES IN THE EUROPEAN UNION (1980-1995)

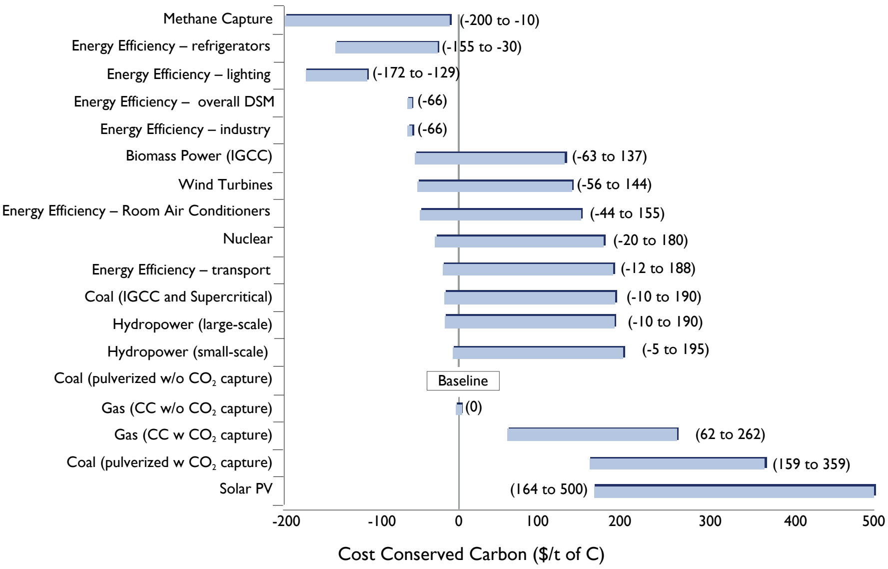


Source: IEA, 2002.

3.34 COMPARISON BASED ON CARBON ABATEMENT COSTS

The next criterion for comparing alternative clean energy options is their cost-effectiveness in terms of carbon reduction when integrated into a GHG mitigation strategy (Figure 26). The baseline in this case is assumed to be pulverized coal technology (with flue-gas desulfurization (FGD) and NO_X control). It is clear that the cost of energy options varies widely. There are a range of "win-win" opportunities that can reduce emissions at zero cost or with financial gains (the options that show a negative cost). Where a net positive cost is indicated, the cost can be considered to be indicative of the carbon offset value needed for the project to proceed.

FIGURE 26. COST OF CARBON REDUCED THROUGH ALTERNATIVE CLEAN ENERGY OPTIONS



Source: Atkinson (1991) Halsnaes (1994); Sims et al. (2003); IEA (2006)

future competitiveness of renewables relates to future fossil fuel prices and availability, which affect conventional power costs but not the costs of renewables (with the possible exception of specific biofuels).

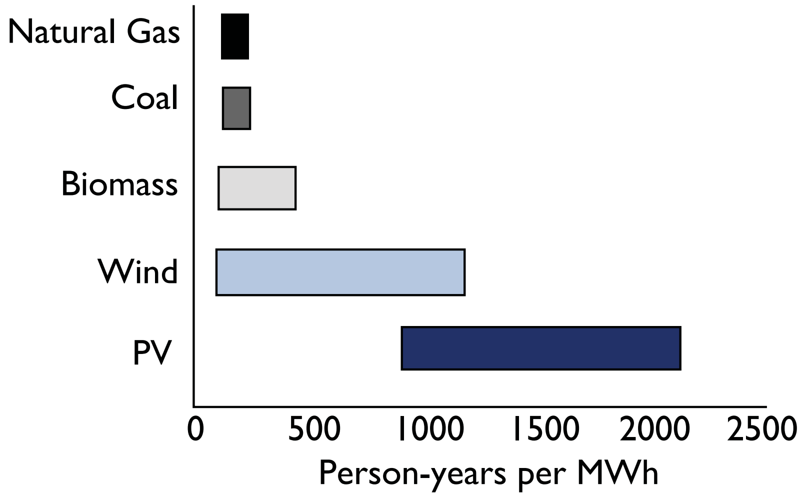
The analysis indicates that energy efficiency options provide the lowest-cost abatement opportunities owing to the fact that energy savings inherently generate reductions in GHG emissions. The costs of abatement range from -US$12 to -US$155 per ton of carbon emissions avoided, reflecting a financial gain.[60] In terms of generation options, the analysis indicates that where an abundant supply of cost-effective gas and the requisite infrastructure exists, combined cycle (CC) gas turbines offer the cheapest carbon abatement opportunity. Failing that, hydro, wind and biomass power projects (on good sites) can provide the cheapest carbon abatement potential.

3.35 COMPARISONS BASED ON EMPLOYMENT IMPACTS

Finally, from a public policy perspective it is important to also consider the non-energy related impacts that a particular clean energy option might have on the economy, particularly in terms of employment generation.

The employment benefits of clean energy sources, while a matter of great public policy interest, are not easy to estimate.[61] Some existing general estimates are provided below. A study conducted in the late 1990s noted that energy efficiency activities have larger employment impacts compared to fossil fuel power plants and specifically concluded that end-use efficiency created 1.5 to four times as many jobs as supply-side options (IIEC, 1999). A recent study suggests that every 100 MW of wind capacity creates 375 manufacturing jobs, 200 construction jobs, two to five permanent operations and maintenance jobs, and US$1 million in local property tax revenue (American Energy, 2006). Another study compared the number of person-years for an equivalent MWh generated from renewable and from fossil-fueled energy sources. It concluded that wind, PV, and biomass often created significantly greater number of jobs per MWh than either coal or natural gas, with a greater spillover effect throughout the entire economy.

FIGURE 27. ESTIMATE OF JOBS CREATED PER UNIT ELECTRICITY PRODUCED FROM A RANGE OF RENEWABLE AND FOSSIL-FUEL ENERGY SOURCES



Source: Worldwatch, 2006.

60. The only exception is that in the case of certain industrial energy efficiency measures, applying a high discount rate and/or a short payback period could result in a low positive cost (up to US$17 per metric ton).

61. Employment impacts of renewable energy development are generally difficult to measure in a precise way, especially if total employment figures – including both direct and indirect jobs – are to be estimated. Ideally, one would build an econometric input-output analysis model and derive employment multipliers with which to predict the number of jobs (direct and indirect) created by sales increases from a given sector or industry, including spillover effects that might occur throughout the economy. This analysis has instead adopted a more simplified and less accurate approach of aggregating employment coefficients that have been published in the literature. Most of these estimates are based on sector experience in the developed world (e.g. the US and Germany).

These numbers were developed for the US, and given the significantly lower degree of mechanization these estimates for job creation can be expected to be higher in the Asian context.

Other estimates of employment potential are cited by WorldWatch (2005), which states that employment potential ranges from a high of 7 jobs per MW (including manufacturing, installation, O&M) for solar PV, to a low of 3 jobs per MW for wind, with small hydro and biomass being intermediate. Biofuels production in Brazil is reported to create 33 direct jobs per million liters of production.[62]

A concrete example of renewable energy's direct job creation potential is the case of the Chinese solar hot water industry, which in 2004 was estimated to employ more than 200,000 people (Li, 2005 as cited in Worldwatch, 2005). Another recent study estimated that renewable energy manufacturing and maintenance operations worldwide provide approximately two million jobs per year (Worldwatch, 2006).

Overall, these studies clearly indicate that, owing to its dispersed nature of deployment and relatively high labor requirements, energy efficiency has the highest employment generation potential. Among energy generation options, renewables, especially PV, wind, and biomass have high employment generation potential relative to coal and natural gas options.

3.36 CONCLUSION

Based on the analysis in this section, it is evident that energy efficiency is the least expensive source of energy in the power and transport sectors, and provides the cheapest source of carbon abatement when the baseline is coal-based generation. Even in terms of employment generation, due to its more labor-intensive nature, energy efficiency holds the greatest potential to create more jobs per unit investment or electricity saved. In terms of new generation options, the "lowest cost" clean energy option(s) would vary greatly depending on the cost structure that society is willing to adopt. If one were to account only for direct, private financial costs (and disregard social, health, and broader economic costs), then burning of coal with limited air emissions control would be the cheapest option. In contrast, when social, health, and broader economic concerns are taken into account, clean energy options (such as combined cycle gas turbines, onshore wind power, biomass, integrated gasification combined cycle, small hydropower) offer greater benefits.

62. A set of employment coefficients for a range of renewable energy sources and references for these estimates are available in the Notes and References Companion Document of the REN 21 report (Worldwatch, 2005).