ADB

Improving Energy Security and Reducing Carbon Intensity in Asia and the Pacific

Asian Development Bank

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Abbreviations

ADB	–	Asian Development Bank
ASEAN	–	Association of Southeast Asian Nations
CCS	–	carbon capture and storage
CDM	–	Clean Development Mechanism
CER	–	certified emission reduction
CFLs	–	compact fluorescent lamps
DAP	–	Developing Asia and Pacific
DMC	–	developing member country
ERIA	–	Economic Research Institute for ASEAN and East Asia
ESCAP	–	Economic and Social Commission for Asia and the Pacific
ESCO	–	energy service company
FITs	–	feed-in tariffs
GDP	–	gross domestic product
GHG	–	greenhouse gas
GJ	–	gigajoule
GW	–	gigawatt
IEA	–	International Energy Agency
IGCC	–	integrated gasification combined cycle
kcer	–	kilo certified emission reduction
KWh	–	kilowatt-hour
LNG	–	liquefied natural gas
Mtoe	–	Million tons of oil equivalent
MW	–	megawatt
NGCC	–	natural gas combined cycle
OECD	–	Organisation for Economic Co-operation and Development
PPP	–	purchasing power parity
PRC	–	People’s Republic of China
PV	–	photovoltaic
R&D	–	research and development
REC	–	renewable energy certificate
RPOs	–	renewable purchase obligations
TWh	–	terawatt-hour
UNDP	–	United Nations Development Programme
UNEP	–	United Nations Environment Programme
UNFCCC	–	United Nations Framework Convention on Climate Change
WEM	–	World Energy Model

Foreword

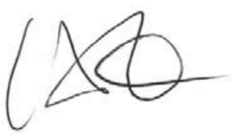
The Asian Development Bank (ADB) under the regional technical assistance (RETA) project, Addressing Climate Change in the Asia and Pacific Region, financed studies on topics that are among the most important issues for policy makers in the region: improving energy security and reducing carbon intensity, building climate resilience in the agriculture sector, and climate change and migration. Together, the three studies address climate change challenges to the key drivers of the region's development—food, fuel, and people.

This report discusses the real and present challenges in improving energy security and reducing carbon intensity in Asia and the Pacific. The region needs expanding supplies of energy to improve the lives of the poor through continued rapid economic growth, while simultaneously ensuring that this development is locally and globally environmentally sustainable. Given the current patterns of consumption, developing countries in the region are projected to account for 39% of global demand for primary energy by 2030.

The dual interest of the region in decoupling future economic growth from greenhouse gas emissions and enhancing energy security are the themes of this study. By improving energy efficiency, by expanding production from domestic and renewable energy sources, and by reducing reliance on fossil fuel sources, the region has the potential to achieve these goals. Going forward, a more aggressive deployment of energy-efficient and clean energy technologies and adequate financing will be crucial for mitigating energy security concerns as well as climate change.

Preparation of the report was led by the dedicated and expert team of The Energy and Resources Institute (TERI), under the direct supervision of Dr. Leena Srivastava, Executive Director. The Climate Change Program Coordination Unit of the Regional and Sustainable Development Department (RSDD) of ADB supervised the implementation of the study. ADB extends its gratitude to TERI for leading this highly relevant and timely work on climate change and energy in Asia and the Pacific.

Through this joint undertaking between ADB and TERI, ADB hopes to contribute to regional efforts in effectively addressing climate change challenges in Asia and the Pacific by improving the knowledge and understanding of climate change and energy security issues. This includes recent experience in promoting end-use energy efficiency, higher efficiency in fossil fuel energy production, and expanding energy production from renewable sources. Responses to energy security challenges and recommendations are offered for financing, technology transfer, and associated policy and institutional reforms.



Xianbin Yao
Director General
RSDD, ADB

Acknowledgments

This study was implemented under a regional technical assistance (TA) project of the Asian Development Bank (ADB), Addressing Climate Change in the Asia and Pacific Region. The study team from The Energy and Resources Institute (TERI), led by Dr. Leena Srivastava, prepared the report. Other members of the TERI team were Jiahua Pan, Yukari Yamashita, Ucok WR Siagian, Qwanruedee Chotichanathawewong, Amit Kumar, Pradeep Kumar Dadhich, Xu Xiangyang, and N. Vasudevan. Rajendra K. Pachauri and Pradipto Gosh provided guidance to the TERI team.

From ADB, a Working Group and an Internal Review Team provided feedback to the TERI team throughout the study period. An External Review team, engaged by ADB, reviewed the annotated outline of the study and the draft final report, participated in the review workshop, and provided valuable comments and suggestions that enriched the quality of the study.

The overall supervision of the regional TA was initiated by Diwesh Sharan (Director, Budget, Personnel, and Management Systems Department [BPMSD]) then later continued by Robert Dobias (Senior Advisor for Climate Change Program, Regional and Sustainable Development Department [RSDD]) while Jong-Inn Kim (Principal Energy Specialist, RSDD) and Anil Terway (Senior Advisor, RSDD) managed the implementation of the study. Annie Idanan (Climate Change Officer, RSDD) and Valerie Pacardo (Consultant, RSDD) provided support to the study.

The Working Group reviewed and commented on the draft terms of reference of the consultants, outline of chapters, and the final report; provided suggestions on identifying suitable consultants to undertake the study and resource persons to review the outputs; reviewed and provided useful feedback on the various draft outputs, which significantly enhanced the quality of the report; identified relevant ADB studies which were used as inputs to the study; attended periodic meetings; and participated in various workshops. The members of the Working Group included Cabral Priyantha Wijayatunga (Energy Specialist, South Asia Department), Diwesh Sharan (BPMSD), Duy-Thanh Bui (Energy Economist, Southeast Asia Department [SERD]), Kangbin Zheng (Senior Energy Economist, East Asia Department [EARD]), Sujata Gupta (Principal Investment Specialist, Private Sector Operations Department), and Toru Kubo (Senior Clean Energy and Climate Change Specialist [RSDD]). The Internal Review Team reviewed and provided comments on various draft outputs and on the final draft of the report. Members of the Internal Review Team included Anil Terway (RSDD), Anthony Jude (Director, Southeast Asia Department [SERD]), Jong-Inn Kim (RSDD), Jun Tian (Advisor, RSDD), Tae Yong Jung (Senior Climate Change Specialist, EARD), and Woochong Um (Director, RSDD).

The External Review Team members included Hoesung Lee (IPCC Vice-Chair and Dean, College of Environment, Keimyung University, Republic of Korea), Dadi Zhou (Director General [Emeritus], Energy Research Institute, National Development and Reform Commission, People's Republic of China), Nebojsa Nakicenovic (Professor of Energy Economics, Vienna University of Technology; and Deputy Director, International Institute for Applied Systems Analysis), and Ram Shrestha (Professor of Energy Economics, Asian Institute of Technology).

Judy Burke edited the draft manuscript of the study for consistency and technical content. Ma. Priscila del Rosario (Senior Copy Editing Officer, Department of External Relations [DER]) coordinated the copy editing of the manuscript, making it ready for printing and publication. The cover was designed by Josef Ilumin and pre-press production was coordinated by Vicente Angeles (DER). The publication would not have been possible without the cooperation of the Logistics Management Unit of the Office of Administrative Services. Ann Quon (Principal Director, DER) and Jason Rush (Media Relations Specialist, DER) assisted in disseminating the results of the study through study launches and other media events.

Ursula Schaefer-Preuss (Vice-President, Knowledge Management and Sustainable Development) and Xianbin Yao (Director General, RSDD) provided valuable guidance and support at various stages of the study. The Climate Change Unit of RSDD, including David McCauley (Principal Climate Change Specialist, RSDD) and Lauren Sorkin (Young Professional [Climate Change, RSDD]) assisted in disseminating the study results through media events and preparation of the brochure.

The ADB Study Team would like to thank all developing member country representatives who participated in the inception meeting, review workshop, and presentation of study results during the Climate Change and Clean Energy Week, for their valuable contributions to this study; policy makers from various government agencies for providing policy advice; and staff of the Thailand Resident Mission for their support in organizing the inception meeting and the study launch.

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Executive Summary

Developing Asia and the Pacific (DAP) is at a critical juncture today, needing energy to continue its rapid economic growth and provide for the millions of its poor while at the same time facing the challenge of developing in a more sustainable manner than it is now. A detailed analysis of the socioeconomic conditions and the energy resource endowment within countries of the region, their perceptions of energy vulnerability, and an assessment of what are perceived to be real options to overcome the vulnerability and the barriers to exercising these options reveals an interesting, but challenging, mosaic of issues that would need to be addressed to facilitate the transition to a clean and secure energy future.

Development is the overriding priority. Given high poverty levels, low levels of development, and a grossly inadequate access to energy, rapid rates of economic growth are of paramount importance for the DAP region. This region accounts for more than half of the world's population (54%), with a majority of the countries having more than 30% of their population living with incomes less than $2 per day.

Energy security concerns are rooted in the inescapable need for development. According to the Human Development Report (UNDP 2007), of the 1.6 billion people in the world who lack access to electricity, about 60% live in this region. Energy security concerns, therefore, are not viewed merely in terms of ensuring a sustained supply but in the wider context of energy being an essential driver for development— based on access, affordability, and quality.

Energy vulnerability is increasing. Energy access, affordability, and quality all seem to be under increasing threat in the DAP region because of (i) widening gaps between supply and demand, which are reducing the quality of supply while depriving the rural and poor populations of energy access; (ii) growing dependency on energy imports, both from within and outside the region, with consequent exposure to price volatility that is most often not completely driven by free markets; (iii) high reliance on traditional biomass fuels, with negative fallout on income-earning opportunities, health, and education; (iv) predominance of a single energy form in a country's energy mix, subjecting the country to that energy form's weaknesses; and (v) the increasing threat of not being able to rely on the conventional fossil fuels that are in relative abundance, easy to use, and cheap and that have in living memory energized our existence! As a result, the issue of energy security weighs heavy on the minds of policy makers in the region.

Fossil fuels still dominate energy security choices, threatening to lock in infrastructure and investment patterns. Traditional energy security responses, as identified here, relate to the building of strategic petroleum reserves, securing fossil energy assets abroad by way of equity investments, and expanding the exploration and production activities. These responses are possibly based on the fact that the current energy supply and delivery infrastructure largely caters to a fossil fuel-driven economy and that the levels of confidence and comfort with such energy forms are high. The silver lining on the cloud, however, is the wide recognition that energy efficiency and renewable energy sources, along with rational pricing and a larger role for the private sector, have a significant effective role to play in enhancing energy security. This recognition would need to be nudged into effective action by addressing the related barriers.

The DAP region is progressing rapidly on the learning curve vis-à-vis energy efficiency and renewable energy. While energy efficiency, in particular, has been a common refrain in the countries of the region, success with efficiency improvements has been low. However, experience with various financial incentives for energy efficiency (e.g., in the buildings sector or with energy service companies [ESCOs]), along with access to new technologies, is yielding better results. The learning has been particularly rapid in the adoption of renewable energy mechanisms, such as feed-in tariffs and renewable purchase obligations (RPOs). The concept of the smart grid, which enables a better integration of renewable energy sources into the grid, is also finding favor, being an especially attractive option for meeting the needs of rural areas in a decentralized, distributed-generation mode.

The region is well endowed with clean energy resources but faces constraints in developing them. The region is well supplied with clean, and renewable energy sources. Hydropower resources are spread across the region, with concentrations in parts of South Asia and in Central Asia. However, geographical and investment constraints limit the utility of these resources to countries in the region. Similarly, Kazakhstan has one of the largest uranium resources in the world—and Uzbekistan, Mongolia, and others have much smaller but significant supplies—but regulations on the use of this fuel result in its export either to the developed countries or to major developing countries, such as the People's Republic of China (PRC) and now, potentially, India.

The region is also well endowed with renewable energy resources that have increasing potential as the technologies for harnessing them improve. A key barrier remains the issue of how to reconcile the high initial costs of such technologies with the challenge of affordability, both at an individual level and country level, if one were to consider fiscal subsidies. The need for rational pricing, referred to above, results in the already low-cost conventional energy forms being made cheaper for the millions of poor—making the large-scale use of renewable energy a daunting task.

International financial support is essential but has been completely inadequate. From the DAP region's point of view, the flow of financing from the developed world, be it through market-based mechanisms or through international financial institutions in the form of grants, soft loans, aid, etc., is of paramount importance. It is needed not only to leverage private investment but also to build the dynamism and the economic institutions that will attract more international as well as domestic financing, private as well as public.

The countries in this region are dependent upon the official development assistance and loans from multilateral financial organizations for financing their energy efficiency and renewable energy projects. Such support from multilateral institutions helps in leveraging financing from other sources, but that is limited to those developing member countries (DMCs) that already have a fairly developed finance sector, along with relatively high levels of economic activity. Thus, despite the existence of targeted programs of multilateral and bilateral financial institutions, the least-developed economies in the region are highly marginalized in terms of access and availability of finance. Access is further restricted by the lack of knowledge among the project developers in such countries, along with the complex, long, and highly bureaucratic procedures. There is a clear need for enlarged financial support from multilateral financial institutions with simple and accessible procedures.

Market-based mechanisms to promote energy efficiency and renewable energy are promising but need to be strengthened. An analysis of activities under the Clean Development Mechanism (CDM), established by the Kyoto Protocol, suggests that market-based mechanisms offering incentives for new investments in renewable energy and energy efficiency may be the best way to boost private investment. However, it also highlights the fact that market-based mechanisms excite the private sector only in countries that have already achieved a fair degree of economic development. The clearly unequal distribution of CDM projects across countries can be explained by the lack of developed markets and entrepreneurship in the least-developed countries, and also reflects the inability to develop baseline estimates. The fact that support to the Pacific island countries is largely grant-based shows the inadequacy of market-based mechanisms in economies where market size is below a certain minimum. It is also important to design these mechanisms carefully so that desired activities do not get marginalized, as is the case with end-use energy efficiency in CDM.

Solar and biomass technologies, among a few others, emerge as clear winners. Given the region's energy resource endowments, the following technologies will clearly play a key role in development: solar, biomass (including biofuels), clean coal, hydropower, nuclear energy, and end-use, energy-efficient technologies in buildings and the transport sector. Although some of the countries have access to these technologies, most lack the infrastructure to absorb and deploy these technologies on a large scale. Therefore, research and development collaboration between developed and developing countries would help not only to promote the uptake of cleaner technologies but also to speed up the deployment phase and lower the manufacturing cost.

Technological and institutional capabilities are high but skewed. Several developing countries in the region, such as India, the PRC, Republic of Korea, and some countries in the Association of Southeast Asian Nations (ASEAN), have well-developed institutions and technical capacities to provide the environment for a fast-track introduction—and indeed development—of innovative approaches to sustainable energy. However, many others lack this macroenvironment. They are also hampered by the smallness of their markets.

Key energy markets of the PRC and India will provide options for the rest of Asia. The rapidly growing markets of the emerging economies in Asia will provide an opportunity to scale up and reduce the costs of renewable energy and energy-efficient technologies in the region. Solar and wind power are outstanding examples from the PRC and India. The PRC is also fast emerging as a leader in the manufacture of clean coal technologies, which are currently at about 50% of the price that is available globally. And it is taking the lead in photovoltaic (PV) and solar water-heating technologies. Regional technology cooperation will significantly help in the scaling up and rapid deployment of clean and renewable energy technologies. Several excellent case studies show how innovative financing has been used in the region to deploy renewable energy. These should be showcased and replicated.

Large-scale adoption of energy efficiency is challenging because of split incentives, lifestyle issues, and inadequately defined risk-sharing mechanisms. Urbanization is a rapidly growing phenomenon in the DAP region, one that demands immediate attention as energy consumption rises in the building and transport sectors. In both these sectors, the investors in energy efficiency could be different to the ultimate beneficiaries, creating the split incentive problem. It is difficult but important to try to set energy standards quickly as the infrastructure is developed. The key lies in innovative financing that can leverage international funds as well as in forward-looking regulations that internalize environmental and social cost considerations.

Governance needs to improve. Most countries in the DAP region lack the ability to implement policies in energy efficiency and renewable energy technologies, indicating an underdeveloped enforcement and monitoring infrastructure. Political and social priorities in most DAP countries clash with the objective of providing sustainable energy, focusing instead on meeting the short-term energy needs of the people and often resulting in a degraded environment and economic crisis. The governments of the region need to create financial and institutional mechanisms to promote renewable energy and energy efficiency, but this will require a major campaign to educate the public.

CHAPTER 1

Climate change and the role of the energy sector

The threat of climate change is affecting every country in the world, albeit in somewhat different ways. While the developed countries have been historically responsible for the accumulation of greenhouse gases (GHGs) in the Earth's atmosphere, the developing countries would bear the brunt of its impact because of their low adaptive capacity, and they may emerge as significant contributors to GHG emissions in the future. It is in their interest to participate in the containment of this threat. However, as recognized by the United Nations Framework Convention on Climate Change (UNFCCC) and reiterated in the Bali Action Plan, the development priorities of the developing countries come first. These nations face the dual challenge of meeting rising energy needs for achieving higher levels of development while ensuring that "anthropogenic interference with the climate system" does not cross the "dangerous" level.[1]

The science of climate change and role of the energy sector

As stated in the UNFCCC, climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has shown that warming of the climate system is unequivocal, as is evident from increases in global average air and ocean temperatures, widespread

1 See the United Nations Framework Convention on Climate Change. 2007.

melting of snow and ice, and rising global average sea level (IPCC 2007). Changes in the atmospheric concentrations of GHGs and aerosols, land cover, and solar radiation alter the energy balance of the climate system and are drivers of climate change. They affect the absorption, scattering, and emission of radiation within the atmosphere and at Earth's surface. The resulting positive or negative changes in energy balance due to these factors are expressed as radiative forcing, which is used to compare warming or cooling influences on global climate.

According to the IPCC (2007), global GHG emissions due to human activities have grown since preindustrial times, with an increase of 70% between 1970 and 2004. Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions had grown between 1970 and 2004 by about 80%, from 21 to 38 gigatons (Gt), and represented 77% of total anthropogenic GHG emissions in 2004. The rate of growth of CO_2-equivalent emissions was much higher during the recent 10-year period of 1995–2004 (0.92 Gt CO_2-equivalent per year) than during the previous period of 1970–1994 (0.43 Gt CO_2-equivalent per year). The largest growth in GHG emissions between 1970 and 2004 had come from energy supply, transportation, and industry, while residential and commercial buildings, forestry (including deforestation), and agriculture have been growing at a lower rate. Therefore, to address climate change, interventions in the energy sector—in both supply and demand—are crucial. From developing countries' point of view, their developmental challenges, particularly poverty alleviation and industrialization, would require higher levels of energy consumption. According to the International Energy Agency (IEA), a large part of the growth in future global energy demand, and consequently the GHG emissions, is expected to originate in the developing countries (IEA 2008a).

It is essential, therefore, that special attention be given to the energy pathways in developing countries.

Country positions in the climate change negotiations

Although the urgency of addressing climate change is recognized by all countries, there are different views of how to mitigate the change and who should take what responsibility. The differences are largely along the North–South divide and are best articulated in the text of the UNFCCC. Article 4 of the UNFCCC says:

> All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall...take climate change considerations into account, to the extent feasible, in their relevant social, economic, and environmental policies and actions, and employ appropriate methods...with a view to minimizing adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change.

It also says:

> The extent to which developing country Parties will effectively implement their commitments under the Convention will depend on the effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology and will take fully into account

> that economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties.

Fifteen years after the adoption of the UNFCCC in 1992, the Bali Action Plan reaffirmed that "economic and social development and poverty eradication are global priorities" and decided to "launch a comprehensive process to enable the full, effective and sustained implementation of the Convention…by addressing…enhanced national/international action on mitigation of climate change, including, inter alia, consideration of…[n]ationally appropriate mitigation actions by developing country Parties, in the context of sustainable development, supported and enabled by technology, financing, capacity building in a measurable, reportable and verifiable manner." Pursuing sustainable development is essential for building the adaptive capacity of developing countries to climate change, the provision of energy access being an important element of, and facilitator for, all development goals.

The 2007 wording clearly shows that there has been little change in the developmental concerns and constraints for developing countries, which have a direct bearing on their positions in climate change negotiations. As a matter of fact, while the developed countries have been arguing for binding emission-reduction commitments for major developing economies, particularly the People's Republic of China (PRC) and India, citing their growing emissions and higher growth rates, the proposals submitted by developing countries on various issues, particularly on "shared vision," financing, and technology development and transfer, suggest that developed countries have not fulfilled their obligations under the UNFCCC with respect to emission reductions, as well as technological and financial assistance to developing countries.[2]

This study

Because of its share in the emission of GHGs, the energy development path of the developing countries has come under severe scrutiny. Among the top 25 GHG-emitter countries accounting for 83% of world emissions, there are five non-Annex 1 countries from developing Asia and the Pacific (DAP) (which are also members of the Asian Development Bank): PRC (15%), India (5.6%), Republic of Korea (1.5%), Indonesia (1.5%), and Pakistan (0.8%). These countries also saw a 50%–100% increase in their emissions between 1990 and 2002. Despite these facts, the per capita emissions of most of the developing countries of Asia and the Pacific, including the PRC and India, remain low, and concerns with energy security—both at a macro level and in terms of energy access—remain high. Commitments under the climate change regime not only require the developing countries to focus their attention on "nationally appropriate mitigation actions" (NAMAs) but also open up opportunities for accessing requisite financing and technology to move along a more sustainable-energy development pathway.

Energy security measures typically call for a diversification of energy sources (including toward a higher share of renewable energy), an increase in their longevity and spread (by ensuring the most efficient use of scarce resources) and, especially

2 See submissions to the UNFCCC by Japan, the European Union, Australia, G77, India, the People's Republic of China, and Brazil.

in the case of import-dependent countries, the establishment of strategic reserves. Renewable energy and enhanced energy-efficiency measures are also critical for climate change mitigation. The energy security goals of the DAP countries can, therefore, be nicely integrated with their mitigation actions, with the pace of movement along this optimal path being determined both by the stage of development of a country and its ability to access technical and financial resources in support of their programs.

However, not all paths leading to energy security converge with a low-carbon path. For instance, for countries such as the PRC, India, and Indonesia, which have large coal reserves, extensive use of coal for power generation is important from an energy security point of view, at least in the short and medium run, but this is not in line with the climate change mitigation objectives. These countries have developed extensive infrastructure and capacity to use their large coal reserves to meet the rapid growth of energy demand. To switch from coal will entail serious energy security risks for them until a similar infrastructure is put in place for an alternate energy source.

The challenge for the DAP countries, therefore, is to fast-track an energy-efficient development paradigm, along with building an infrastructure suitable for harnessing renewable energy. This study attempts to address itself to this dual objective of promoting DAP countries' energy security concerns, as well as the climate change concerns. The approach followed toward this end included rigorous literature review, regional overviews, select country case studies, and an expert survey. Details on this approach, along with key research questions are provided in Appendix 1.1.

CHAPTER 2

Energy supply and demand

Energy demand depends on population, economic growth, fuel prices, energy consumption patterns, and the technology in use. Developing Asia and the Pacific (DAP), comprising the 44 developing member countries (DMCs) of the Asian Development Bank (ADB), is highly populated.[3] Three of the top five and five of the top 10 most populated countries in the world today are in the region. These are the People's Republic of China (PRC) (population: 1.3 billion), India (1.1 billion), Indonesia (219 million), Pakistan (165 million), and Bangladesh (153 million).[4]

Led by the PRC and India, the region is among the fastest-growing areas in the world today. It includes countries with high-energy demands, such as Singapore, Republic of Korea, Thailand, and Hong Kong, China (Table 2.1), as well as countries, such as Solomon Islands and Papua New Guinea, where energy use is low.

Access to commercial energy in the region is low, and reliance on traditional fuels is high. According to the *Human Development Report* (UNDP 2007), of the 1.6 billion people in the world who lack access to electricity, about 60% live in this region. The region is highly dependent on traditional energy resources, which has far-reaching socioeconomic and gender implications. These are discussed in detail in Chapter 3. Literature shows that there is a strong positive correlation between per capita electricity consumption in a country and its level of development. Thus,

3 The "region" throughout this report shall refer to these 44 developing member countries of ADB.

4 2005 data from United Nations Population Division.

Table 2.1: Gross Domestic Product and Energy Intensity in the Region

Country	GDP (per capita PPP $, 2005)	Energy Intensity (Kgoe/$1,000 GDP, PPP 2003)
Hong Kong, China	34833	91
Singapore	29663	220
Republic of Korea	22029	237
Thailand	8677	199
People's Republic of China	6757	220
India	3452	191
Solomon Islands	2031	–
Papua New Guinea	25633	–

GDP = gross domestic product; Kgoe = kilogram of oil equivalent, PPP = purchasing power parity.
Source: *Human Development Report* 2007/2008, *ADB Basic Statistics* 2007.

the region needs energy both to stimulate and sustain economic growth and for broader human development.

Energy Supply and Demand

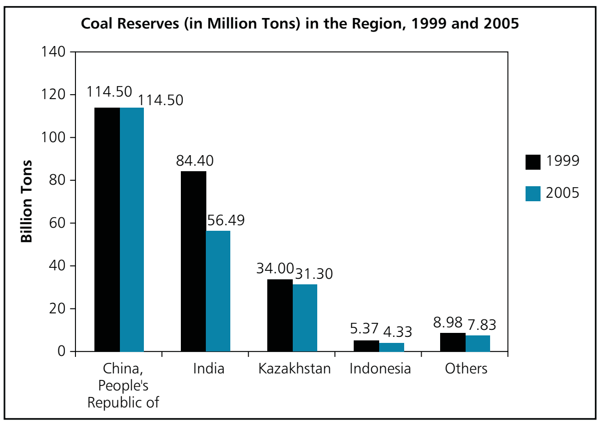
Coal

The region is well endowed in coal reserves. In 2005, it accounted for almost one quarter, i.e., 214.5 billion tons or 108,232.4 million tons of oil equivalent (Mtoe), of the total recoverable coal reserves in the world. However, the distribution of these reserves is skewed, with the PRC (114.5 billion tons) and India (56.5 billion tons) accounting for almost 80% of the coal reserves in the region (Figure 2.1).

The production of coal in the region is increasing (Figure 2.2). However, given the growing domestic demand for coal, most countries are able to produce for self-consumption only. In 2006, the PRC produced 1,330 Mtoe of coal, which was more than 76% of the total production of the region and almost 40% of world coal production—almost all of which was consumed domestically. In the same year, India produced 233 Mtoe of coal, which was more than 6% of world coal production, but this was not sufficient to meet even the country's own demand (Figure 2.3). A notable exception is Indonesia, which has the advantage of low-sulfur coal reserves. Indonesia exported nearly 90% of the 125 Mtoe of coal it produced in 2006 (Table 2.2).

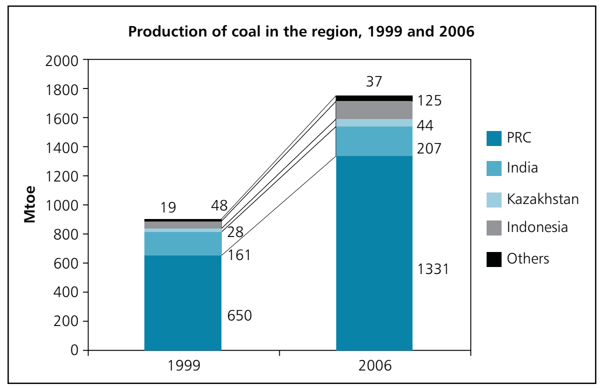
Coal consumption in the region is also increasing, both in absolute terms and as a proportion of world coal consumption, largely on account of demand for power generation. The PRC and India accounted for 45% of the world coal consumption (IEA 2007a). In 1999, the region accounted for almost 40% of the world coal consumption; this proportion almost doubled (growing 81%) by 2006. This share is expected to rise further, as the

Figure 2.1: Coal Reserves
(Billion tons)



Source: Data from Energy Information Agency (EIA) database, last accessed March 2009 http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=7&aid=6

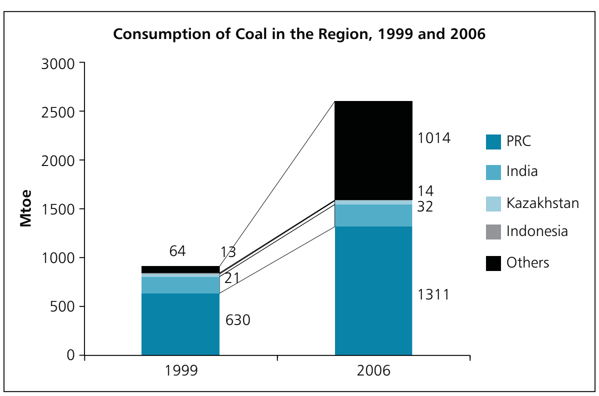
Figure 2.2: Coal Production
(Mtoe)



PRC = People's Republic of China, Mtoe = Million tons of oil equivalent.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009. http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=7&aid=1

Figure 2.3: Coal Consumption
(Mtoe)



PRC = People's Republic of China, Mtoe = Million tons of oil equivalent

Source: Using data from EIA database, last accessed March 2009. http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=1&aid=2

region continues to grow and depend even more on coal and as the demand for coal in the European Union drops because of its policies to promote less carbon-intensive power generation technologies. Consequently, coal-related greenhouse gas (GHG) emissions from the region are also expected to grow.

Of concern from an energy security point of view, however, is the fact that, while production of coal in the region grew at 10% per year from 1999 to 2006, consumption grew at 16% per year over the same period. As a result, in 2006, coal consumption (aggregated over the countries) outstripped production by almost 860 Mtoe, signifying huge import dependence at the country level. At the regional level, net imports of coal to the region increased from 8.9 Mtoe in 1999 to 47.7 Mtoe in 2006, leading to an import dependency of 23% for the region (Table 2.2).[5] Countries, such as the

5 Import dependence can be calculated as 1 (self-sufficiency) where self-sufficiency is calculated as the proportion of consumption that is met by domestic production.

Table 2.2: Coal Trade of Different Countries
(Mtoe)

Country	Import		Export		Import/ Consumption (%)		Export/ Production (%)		Self-Sufficiency (%)	
	1999	2006	1999	2006	1999	2006	1999	2006	1999	2006
Kazakhstan	0.93	0.68	7.96	13.26	4.35	2.15	28.42	29.88	130.33	139.54
China, People's Republic of	0.878	20.008	26.356	42.906	0.14	1.53	4.05	3.22	103.16	101.48
Hong Kong, China	4.13	7.36	0.00	0.00	100.01	100.06	–	–	0.00	0.00
Korea, Republic of	34.88	50.37	0.00	0.00	95.11	94.78	0.00	0.00	5.47	2.51
India	14.32	31.02	0.58	0.77	8.09	13.33	0.36	0.37	90.96	89.07
Pakistan	0.66	2.94	0.00	0.00	30.75	63.18	0.00	0.00	70.06	36.82
Malaysia	1.39	8.40	0.01	0.08	96.12	97.54	4.37	12.68	12.78	6.90
Indonesia	0.13	0.00	35.72	110.77	1.01	0.00	74.10	88.71	382.89	885.59
Viet Nam	0.00	0.17	1.92	13.21	0.00	1.88	33.46	59.28	129.07	240.98
Total Region			**8.94***	**47.74***					**100.04**	**67.00**

Mtoe = Million tons of oil equivalent, – = no data.
* Net exports of coal from the region to the rest of the world.
Source: Using data from Energy Information Agency EIA database, last accessed March 2009.
http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=1&aid=3
http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=1&aid=4

PRC, that were net exporters of coal have also turned into net importers since 2007. Viet Nam and Australia are the largest suppliers of coal to the PRC. Other major importers are India, Malaysia, Pakistan, and Republic of Korea. India imports coal, despite relatively high reserves, because of the poor quality of its indigenous coal.

Natural Gas

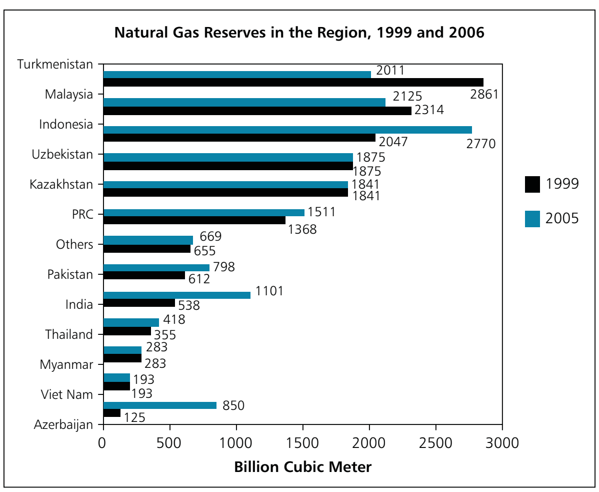
The region accounts for 10% of the world reserves of natural gas (Figure 2.4), which is primarily exploited for domestic consumption, and 16% of the world's production. Natural gas production in the region grew at 6.4% per year from 1999 to 2006, which was more than twice as fast as the world average growth rate (2.91% per year).[6] Central Asia and Southeast Asia account for almost 70% of the natural gas production in the region, and the PRC, India, and Pakistan account for another 25% (Figure 2.5). Given that exports of gas from the region are low, the rapid increase in production has been fulfilling the region's growing demand for gas.

[6] Growth in regional production was 5.7% per year for 1999–2007. Corresponding data for the world for 2007 were not available.

Consumption of gas in the region is also growing at a much faster pace (7.6% per year from 1999 to 2006) than in the rest of the world (2.9% per year).[7] The PRC, Uzbekistan, India, Thailand, Malaysia, and Pakistan are the largest consumers of natural gas in the region (Figure 2.6).

Given its relatively clean and efficient performance, natural gas is a preferred fuel over coal, which explains its increasing demand worldwide. This has spurred exploration of natural gas and has led to increased reserves in the region (Figure 2.4). Most of these increased reserves are being consumed domestically.

Figure 2.4: Natural Gas Reserves (bcm)

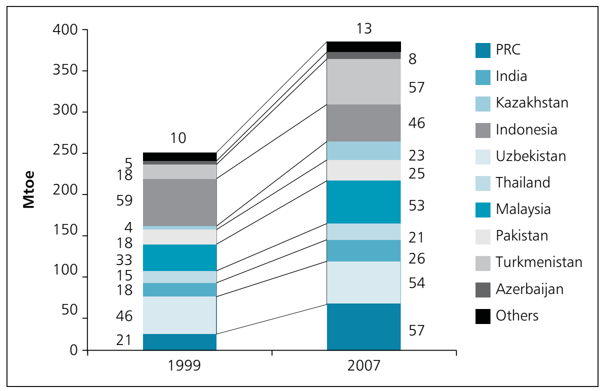


PRC = People's Republic of China.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=3&pid=3&aid=6

Figure 2.5: Production of Natural Gas (Mtoe)

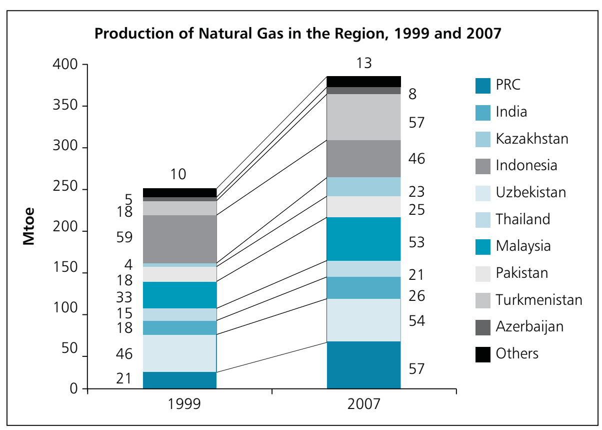


PRC = People's Republic of China, Mtoe = Million tons of oil equivalent.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

http://tonto.eia.doe.gov/ cfapps/ipdbproject/IEDIndex3.cfm?tid=3&pid=3&aid=1

Figure 2.6: Consumption of Natural Gas (Mtoe)



PRC = People's Republic of China; Mtoe = Million tons of oil equivalent.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=3&pid=26&aid=2

[7] Growth in regional consumption was 8.07% per annum for 1999–2007. Corresponding data for the world for 2007 were not available.

Trade of natural gas within the region, and between the region and the rest of the world, is also increasing. The region is a net exporter of gas; however, as Table 2.3 shows, the proportion of imports in consumption has risen since 1999, while exports as a proportion of production, have fallen. Consequently, the self-sufficiency of the region has fallen by 8% since 1999. The Republic of Korea is the largest importer of gas in the region (27.23 Mtoe, more than 40% of the imports of natural gas to the region) and is among the largest gas importers in the world. However, in 2006, the PRC and India also became gas buyers. Southeast Asia may soon become a consumer of liquefied natural gas (LNG), with the Philippines planning to take LNG from Indonesia. Singapore is also considering taking LNG, and Indonesia may ship LNG into Java from Indonesian Papua. Thus, intra-regional trade is likely to expand because of policies emphasizing energy resilience in the region and the favorable economics of shipping LNG within the Pacific.

Table 2.3: Natural Gas Trade of Different Countries
(Mtoe)

	Import		Export		Import/ Consumption (%)		Export/ Production (%)		Self-Sufficiency (%)	
Country	**1999**	**2006**	**1999**	**2006**	**1999**	**2006**	**1999**	**2006**	**1999**	**2006**
Turkmenistan	0.00	0.00	13.79	37.24	0.00	0.00	74.89	71.36	398.21	349.17
Indonesia	0.00	0.00	32.30	28.40	0.00	0.00	55.13	60.25	222.86	251.54
Kazakhstan	9.08	10.73	1.65	6.27	80.88	41.87	43.48	29.63	33.82	82.61
PRC	0.00	0.77	2.50	2.48	0.00	1.64	12.03	5.12	113.67	103.67
Azerbaijan	0.00	3.70	0.00	0.00	0.00	39.65	0.00	0.00	100.00	60.35
Uzbekistan	0.00	0.00	12.63	10.44	0.00	0.00	27.52	20.16	137.97	125.25
India	0.00	6.60	0.00	0.00	0.00	20.44	0.00	0.00	100.00	79.56
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100.00
Malaysia	0.00	0.00	17.97	24.62	0.00	0.00	54.06	48.10	217.68	192.67
Myanmar	0.00	0.00	0.07	7.41	0.00	0.00	5.23	71.27	105.52	348.07
Thailand	0.07	7.41	0.00	0.00	0.51	26.97	0.00	0.00	99.49	73.03
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100.00
Republic of Korea	13.99	27.23	0.00	0.00	100.10	102.41	–	–	0.00	1.61
Total Region			**49.58***	**58.36***	–	–			**125.20**	**114.98**

PRC = People's Republic of China, Mtoe = Million tons of oil equivalent, – = no data.

* Net exports of natural gas from the region to the rest of the world.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=3&pid=26&aid=3

http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=3&pid=26&aid=4

Almost all trade of gas to and from the region is currently in the form of LNG. As the import dependence of the region increases, greater investment in infrastructure, such as pipeline networks and LNG terminals, will be needed. Issues of availability of gas, cost, and geopolitics will become important considerations. There have often been disruptions in gas trade in Central Asia, and this could have a bearing on the energy security of the region.

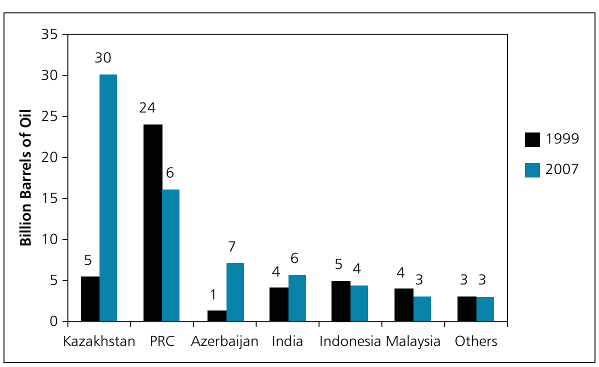
Oil

The region accounts for 5% (68.8 billion barrels or 3.3 trillion tons in 2007) of the world crude oil reserves (Figure 2.7) and about 11% (471 Mtoe) of the world production. The PRC is the largest producer of oil in the region (the fifth largest in the world), followed by Kazakhstan and Indonesia (Figure 2.8).

Oil consumption in the region grew 4.4% per year between 1999 and 2006—much faster than the world average (1.7% per year). Most of this oil demand is fueled by the transport sector, which is growing the fastest in this region. In 2007, three countries from the region were among the top 10 consumers of oil in the world. The PRC was the second largest consumer (362 Mtoe), followed by India (fifth largest with 134 Mtoe) and Republic of Korea (ninth largest with 106 Mtoe). Together, they accounted for 67.5% of the oil consumption in the region (Figure 2.9).The PRC also accounts for the largest increase in oil consumption since 1999 in absolute terms.

The rising demand for oil has outstripped the rapid increase in production of oil in the region, leading to an increasing and acute dependence on crude oil (condensate) imports (Table 2.4). The PRC and Republic of Korea are the largest importers in the region, followed by India and other countries

Figure 2.7: Crude Oil Reserves (Billion Barrels)

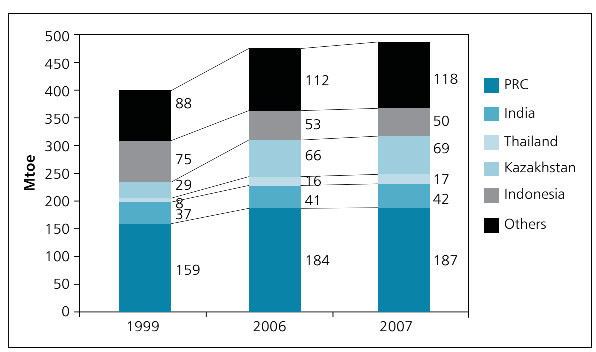


PRC = People's Republic of China.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=57&aid=6

Figure 2.8: Production of Crude Oil (Mtoe)

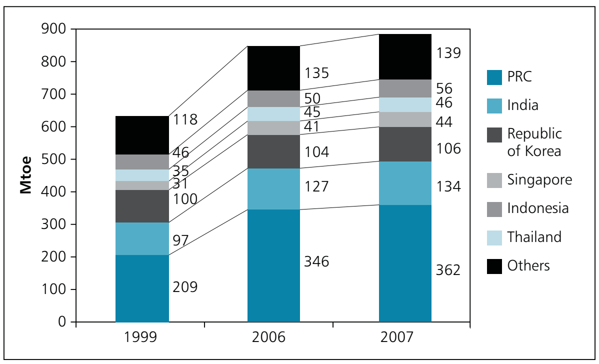


PRC = People's Republic of China, Mtoe = Million tons of oil equivalent.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=53&aid=1

Figure 2.9: Consumption of Crude Oil (Mtoe)



PRC = People's Republic of China, Mtoe = Million tons of oil equivalent.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=54&aid=2

in Southeast Asia. In 2007, the region's major importers of oil were among the largest oil importers in the world, and imports accounted for a significant proportion of their consumption. The PRC was the third largest importer of oil in the world, importing 175 Mtoe of oil, or 48% of its total oil consumption that year. The Republic of Korea, at number five, imported 104.5 Mtoe, which was 98.6% of its consumption. India, at number six, imported 68.5% of its consumption (91.81 Mtoe). Singapore imported about 43.39 Mtoe. Kazakhstan and Indonesia have been the largest exporters of crude oil from the region. Indonesia has, traditionally, been a net exporter of oil; however, imports of oil have been increasing sharply and, in 2005, imports accounted for 30% of domestic consumption (more than a threefold increase since 1999).

The region also accounts for almost 20% of the world's imports of refined petroleum products and 17% of the total exports of refined petroleum products. Southeast Asia and East Asia account for more than 80% of the product imports. Singapore and the PRC are the largest importers of refined petroleum products in the region. Singapore, Republic of Korea, the PRC, and India are the largest exporters of refined petroleum products in the region.

Non-fossil energy resources

Non-fossil energy sources account for less than 20% of the commercial energy consumed in the region. However, the region has tremendous renewable energy potential that has not been developed adequately. This potential, particularly for wind, hydro, and nuclear energy (nuclear restricted largely to the PRC and India), if tapped into, could go a long way in addressing the region's energy security concerns. As access to commercial energy is low, the region depends heavily on biomass for its energy needs. The inefficient use of biomass is both an energy security issue and a climate change concern for the region.

Nuclear energy

As of end of 2003, the region had 1.1 million tons of uranium reserves, about 27% of the world's total. Of this, about 75% of the reserves are in Kazakhstan alone. Reserves are also found in the PRC, India, Mongolia, and Uzbekistan. India also has 360,000 tons of thorium reserves, which are the largest reserves held by any country in the world.[8]

Commercially, uranium is produced in 19 countries in the world. Kazakhstan (third largest in 2005) and

[8] Department of Atomic Energy, Government of India. www.dae.gov.in/publ/doc10/pg30.htm

Table 2.4: Crude Oil Trade of Different Countries
(Mtoe)

Country	Import		Imports/ Consumption (%)		Export		Export/ Production (%)		Self-Sufficiency (%)	
	1999	2005	1999	2005	1999	2005	1999	2005	1999	2005
Kazakhstan	0.7	3.6	9	32	22.2	54.9	77	83	353	592
China, People's Republic of	35.6	124.3	17	36	6.9	7.7	4	4	76	53
Korea, Republic of	115.0	111.5	115	107	0.0	0.0	0	0	–	–
India	41.8	92.7	43	73	2.2	0.0	6	0	38	–
Indonesia	11.0	19.9	24	34	39.3	22.5	52	43	163	91
Malaysia	2.1	7.4	9	30	19.0	17.7	50	51	175	140
Myanmar	0.6	0.0	37	0	0.0	0.0	0	0	–	–
Philippines	15.5	10.5	88	69	0.0	0.0	0	0	0	–
Singapore	42.5	50.0	138	122	0.0	0.2	0	39	1	1
Thailand	33.4	38.5	95	86	0.8	2.8	10	18	22	35
Viet Nam	0.0	0.0	0	0	14.0	18.6	101	107	–	
Others	7.9	12.5	12	15	11.2	17.3	23	24	72	89
Total Region	**190.79***	**329.16***	–	–	–	–	–	–	**62**	**55**

Mtoe = Million tons of oil equivalent, – = no data.

Note: Net imports of crude oil into the region from the rest of the world.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=54&aid=3

http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=54&aid=4

Uzbekistan are among the top nine countries in the production of uranium.[9] Together, they produce 20% of the uranium in the world.

Wind energy

Based on a World Bank–Asia Alternative Energy Programme study, there are good-to-excellent wind resource areas for large-scale wind generation in central and southern Viet Nam, the central area of the Lao People's Democratic Republic, and central and western Thailand. Furthermore, coastal areas of southern and south-central Viet Nam show exceptional promise for wind energy both because of strong winds and their proximity to population centers. Table 2.6 shows the wind energy potential in selected Southeast Asian countries.

[9] World Energy Council. 2008. *Survey of Energy Resources.*

Table 2.5: Reserves of Uranium in the Region (2003 figures)

Country	Tons	% of World Total
Kazakhstan	0.85	19.8
Uzbekistan	0.12	2.8
Mongolia	0.06	1.4
India	0.06	1.4
China, People's Republic of	0.05	1.2
Viet Nam	0.006	0.2
Indonesia	0.001	<0.05
Subtotal	**1.145**	**26.708**
World	**4.3**	**100**

Source: *Energy Security and Sustainable Development in Asia and the Pacific* (ESCAP 2008).

Asia was expected to be the fastest-growing region in the world in wind generation capacity in 2008, driven mainly by the PRC. Proven wind energy reserves in the PRC total 3,200 gigawatts (GW), according to the China Meteorological Administration. The Worldwatch Institute estimates the technical on-shore wind potential in the PRC at 250 GW, while more recently, the off-shore wind potential has been estimated at 750 GW. The country has experienced a rapid expansion in wind power development in recent years as the Government aims to meet its ambitious targets of 4 GW of installed capacity by 2010 and 20 GW by 2020. It has the third largest total installed wind capacity in the world (12,210 megawatts [MW], or 10.1% of the world total).[10] Of this, 6,300 MW was added in 2008. India has a wind potential of 45,000 MW and the fourth largest installed capacity in the world (9,645 MW, or 8% of world total).[11] Of this, 1,800 MW was added in 2008. Other DAP countries with new capacity additions in 2008 are Taipei,China (81 MW, for a total of 358 MW) and Republic of Korea (43 MW, for a total of 236 MW).

Solar potential

A large number of countries in the region have enormous solar potential which, if harnessed, could help meet a sizable portion of the countries' energy requirements. However, only a small fraction of this potential has been developed so far.[12] The PRC's annual solar power potential has been estimated to be 1,680 billion tons of oil equivalent or 19,536,000 terawatt-hours (TWh). It

[10] *Wind Energy Outlook 2008.*

[11] Ministry of New and Renewable Energy. The Indian Wind Turbine Manufacturers Association estimates that at heights of 50–60 meters, the potential for wind development in India is 65–70 GW.

[12] World Energy Council. 2008.

Table 2.6: Wind Energy Potential in Selected Southeast Asian Countries

Country	Characteristic	Poor (<6 m/s)	Fair (6–7 m/s)	Good (7–8 m/s)	Very Good (8–9 m/s)	Excellent (> 9 m/s)
Cambodia	Land Area (sq. km)	175,468	6155	315	30	0
	% of Total Land Area	96.40	3.40	0.20	0.00	0.00
	MW Potential	NA	24,620	1,260	120	0
Lao PDR	Land Area (sq. km)	184,511	38,787	6,070	671	35
	% of Total Land Area	80.20	16.90	2.60	0.30	0.00
	MW Potential	NA	155,148	24,280	2,684	140
Thailand	Land Area (sq. km)	477,157	37,337	748	13	0
	% of Total Land Area	92.60	7.20	0.20	0.00	0.00
	MW Potential	NA	149,348	2,992	52	0
Viet Nam	Land Area (sq. km)	197,342	100,361	25,679	2,187	113
	% of Total Land Area	60.60	30.80	7.90	0.70	0.00
	MW Potential	NA	401,444	102,716	8,748	452
		(5.6–6.4 m/s)	(6.4–7 m/s)	(7–8 m/s)	(8–8.8 m/s)	(8.8–10/1 m/s)
Philippines	Land Area (sq. km)	14,002	5541	2,841	2,258	415
	% of Total Land Area	4.70	1.86	0.95	0.76	0.14
	MW Potential	9,7000	38,400	197,00	15,600	2,900

Lao PDR = Lao People's Democratic Republic, m/s = meter per second, NA = not available, sq. km = square kilometer.

Source: www.ec-asean-greenippnetwork.net/dsp_page.cfm?view=page&select=97

installed about 50 MW of solar capacity in 2008. In Hong Kong, China, the resource potential estimated by a government study in 2002 suggested that solar photovoltaic (PV) power could generate up to several thousand gigawatt-hours (GWh) per year. India's Solar Energy Programme is among the largest in the world and plans to utilize India's estimated solar power potential of 20 MW/km^2

and 35 MW/km^2 solar thermal. India's overall potential for solar water-heating systems has been estimated to be 140 million m^2 of collector area but so far, only about 1 million m^2 of collector area has been installed. Indonesia's daily average insolation level, estimated at 5 kilowatt-hours per square meter (kWh/m^2), makes it highly suitable for the installation of solar energy devices, especially for the huge rural population and in remote areas. The solar thermal installations in Indonesia are used for domestic water heating, agriculture or crop drying, and cooking. Thailand has appreciable solar energy resources. The average daily solar intensity is 18.2 mega joule per square meter (MJ/m^2). In 2005, installed PV capacity was 23,700 kilowatt peak (kWp). Solar thermal technology for power generation has not been tapped in the region in spite of its ease of manufacture and installation.

Hydroelectric potential

The region is well endowed with hydroelectric potential. The PRC has 13% and India has 6% of the world's total hydroelectric potential. Indonesia, Pakistan, and Bhutan also have good hydro potential; however, only a small proportion of this potential has been developed (Table 2.7).

Possible reasons for limited utilization of hydro potential in the region could be that countries, such as Bhutan, Nepal, Pakistan, Sri Lanka, and Myanmar, do not have adequate technical and financial resources to exploit this potential. However, countries such as India are constrained in utilizing this vast potential primarily because of the human population concerns of resettlement and rehabilitation.

Table 2.7: Hydroelectric Potential in the Region

Country	Potential (MW)	Developed (MW)	Portion of Potential Developed
Afghanistan	745	262	35.2
Bangladesh	755	230	30.5
Bhutan	23,760[a]	1,488[b]	6.7
India	84,000[c]	32,300	38.5
Nepal	43,000[a]	600	1.4
Pakistan	54,000	6,500	12.0
Sri Lanka	9,100	1,250	13.7
Kazakhstan	20,000	2,000	10.0
Tajikistan	40,000	4,000	10.0
Kyrgyz Republic	26,000	3,000	11.5
Myanmar	39,720	747	1.9

MW = megawatt.

[a] Techno-economically feasible potential.

[b] Department of Energy 2007.

[c] At 60% load factor (for large hydro).

Source: *Energy Security and Sustainable Development in Asia and the Pacific* (ESCAP 2008).

Biomass resources

As access to commercial energy in the region is low, a large population depends on biomass, which is in abundance, for its energy needs. According to the World Energy Assessment, the biomass technical potential in "developing Asia" in 2000 was between 311 and 502 Mtoe, which is 5%–6% of the world's total. This figure is likely to be much higher as the availability of agricultural residue in India alone is 539 million tons, as estimated by the Ministry of New and Renewable Energy, Government of India. Forestry wastes, such as twigs and bark, have not been counted in this estimate.

Southeast Asia also produces huge amounts of agricultural crops, led by rice and oil-palm fruit. Table 2.8 shows the potential availability of bagasse in 2005. Indonesia was the largest producer of three key crops that year, providing

Table 2.8: Estimated Bagasse Potential Availability, 2005
(Thousand tons)

Country	At 50% Humidity	Dry Matter
Azerbaijan	6	3
Bangladesh	391	196
People's Republic of China	29,839	14,920
India	49,604	24,802
Indonesia	7,938	3,969
Malaysia	261	130
Myanmar	489	245
Nepal	424	212
Pakistan	9,215	4,607
Philippines	7,119	3,559
Sri Lanka	196	98
Taipei,China	147	73
Thailand	14,960	7,480
Viet Nam	2,851	1,426
Total Asia	**123,861**	**61,931**

Note: Bagasse potential availability is based on production of sugarcane published in the *Sugar Yearbook 2005*, International Sugar Organization. Bagasse potential availability conversion factor is from United Nations *Energy Statistics Yearbook 2004* (assumes a yield of 3.26 tons of fuel bagasse at 50% humidity per ton of sugarcane produced).

Source: World Energy Council (2008).

33% of the region rice, 46% of the maize, and 44% of the cassava. Thailand was the largest producer of sugarcane, producing 37% of the total, while Malaysia topped in oil-palm fruit production with a share of 52%.[13] The region, thus, has huge potential for utilizing biomass resources.

Electricity

Electricity generation by fuel

More than 82% of the electricity produced in the region in 2007 was from conventional thermal electricity sources. Most of this was produced in coal-fired power plants. The use of oil for generation is small. Hydroelectricity amounted to 14% of the region's net electricity generated (711 TWh). The PRC and India accounted for more than 78% of this hydroelectricity generation. The potential for hydroelectricity power generation is fairly well distributed throughout the region, but this potential has not been developed beyond 10% in some countries.

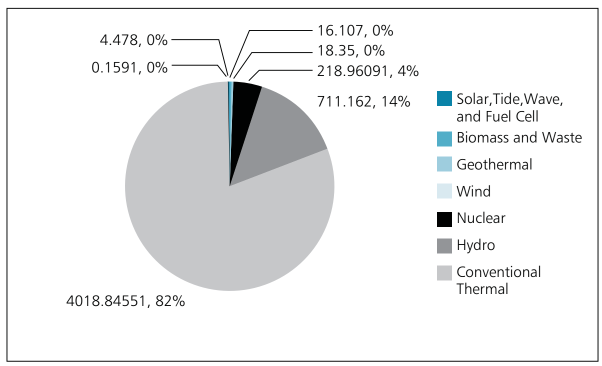
More than 219 TWh of electricity in the region was generated from nuclear energy in 2007 (Figure 2.10). This was 4% of the region's net electricity generation and more than 8% of the total nuclear electricity generated in the world.

Net nuclear electricity generation in the region is higher than the world average. But this is largely restricted to the PRC, Republic of Korea, and India. In 2005, less than 0.5% of the region's total electricity produced was geothermal. The Philippines is the third-largest geothermal producer worldwide, while Indonesia ranks fifth.

Net generation

Though access to electricity in the region is still very low, electricity generation is increasing rapidly to meet the rising demand. Electricity generation grew 10% per year from 1999 to 2006, which meant it doubled in that time (Figure 2.11). In 2006, the region accounted for 22% (3,973 TWh) of the total electricity generated in the world. Generation is growing at 22.5% in Cambodia, 14.0% in the Maldives, 11.0% in Afghanistan, 9.5% in Bangladesh, 8.7% in Bhutan, and 7.9% in Nepal.[14]

Figure 2.10: Fuel Mix in Electricity Generation in the Region, 2007
(Mtoe)



Mtoe = Million tons of oil equivalent.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

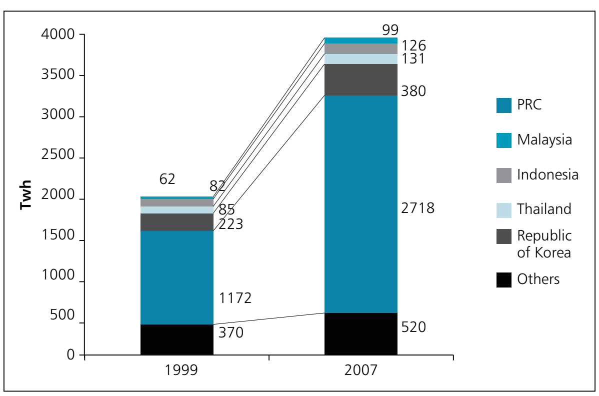
[13] World Energy Assessment, 2000. http://undp.org/energy/activities/wea/drafts-frame.html

[14] Calculated from Energy Information Agency (EIA), Department of Energy, United States, data.

Electricity Consumption

Electricity consumption in the region has grown 9.8% per year since 1999, which is almost three times the growth rate for the world (3.7% per year). In 2006, the region consumed one fourth (4,192 TWh) of the electricity used worldwide; one fourth of this was in the PRC (Figures 2.12 [a] and [b]). The other large consumers are India, Republic of Korea, Indonesia, Malaysia, and Thailand. Power shortages in the region are frequent and increasing, given the rapidly increasing demand and the high transmission and distribution losses, which amounted to 11% of the electricity consumed in 2006. Transmission and distribution losses were as high as 37% of total consumption in India, 35% in Bhutan, 32% in Nepal, and 39% in Myanmar.[15]

Figure 2.11: Net Electricity Generation in the Region, 1999 and 2006



Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

Energy consumption mix

The data in this section have been taken primarily from the International Energy Agency (IEA). The projections of energy demand depend crucially on the underlying assumptions of the model used. For this section, the region will be divided into the PRC, including Hong Kong, China; India; Indonesia; Central Asia; and Other Developing Asia (ODA).[16] Figure 2.13 shows the primary energy consumption using this classification system, with a total of 3,381 Mtoe in 2006.

Fuel mix in 2006

An analysis of the fuel mix in 2006 shows that the region is highly dependent on fossil fuels, which account for about 80% of the total primary energy consumption (Figure 2.14). Renewable energy accounts for less than 2.5%. Access to commercial energy in the region is low, and many people depend on biomass and waste for their energy needs (WEO 2008). In India, for example, there are 412 million people who do not have access to electricity, and 668 million people still used fuelwood and dung for heating and cooking (2005 figures).

Of the region's total final consumption (TFC)[17] of 503 Mtoe of coal in 2006, 78% was consumed in the PRC. The country also accounted for 46% of the oil, 25% of the gas, 62% of electricity, 41% of biomass energy, and 75% of the renewable energy consumed. India accounted for 15% of the total final energy consumed (9% of the coal, 18% of the oil, 11% of the gas, 13% of the electricity, and 29% of the biomass and waste energy consumed in the region (Figure 2.15).

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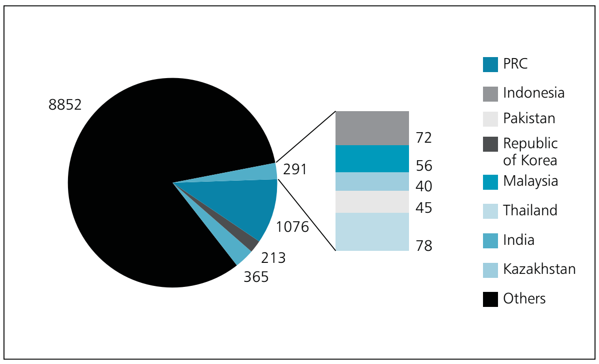
[15] Calculated from EIA data.

[16] Central Asia is defined as Armenia, Azerbaijan, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. Other Developing Asia means developing countries in Asia and the Pacific (as defined for the study), excluding the People's Republic of China, India, Indonesia, and Central Asia.

[17] Total final energy consumption (TFC) is the sum of consumption by different end-use sectors: industry (including manufacturing and mining); transport; other (including residential, commercial and public services, and agriculture/forestry and fisheries); non-energy use (including petrochemical feedstock); and nonspecified.

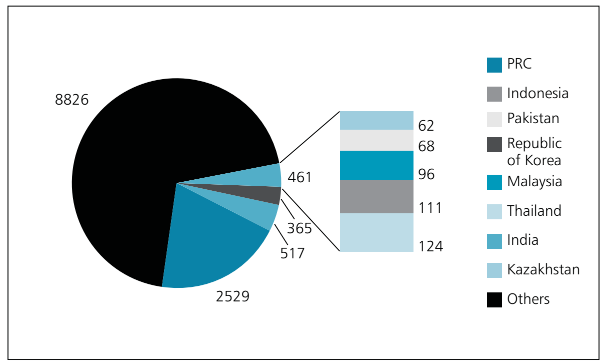
Figure 2.12 (a): Electricity Consumption, 1999 (TWh)



TWH = terrawatt-hour.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

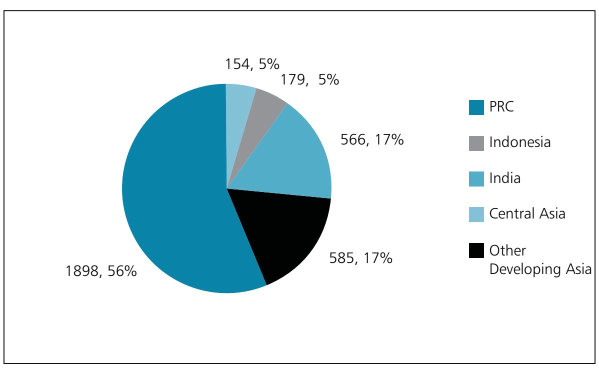
Figure 2.12 (b): Electricity Consumption, 2006 (TWh)



TWH = terrawatt-hour.

Source: Using data from Energy Information Agency (EIA) database, last accessed March 2009.

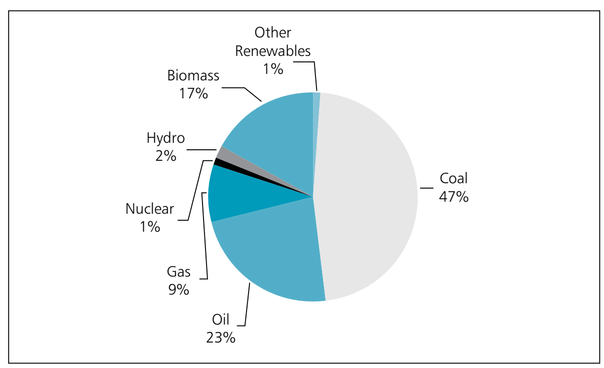
Figure 2.13: Primary Energy Consumption, 2006 (Mtoe)



Mtoe = Million tons of oil equivalent.

Source: International Energy Agency.

Figure 2.14: Fuel Mix in the Region, 2006 (Mtoe)



Mtoe = Million tons of oil equivalent.

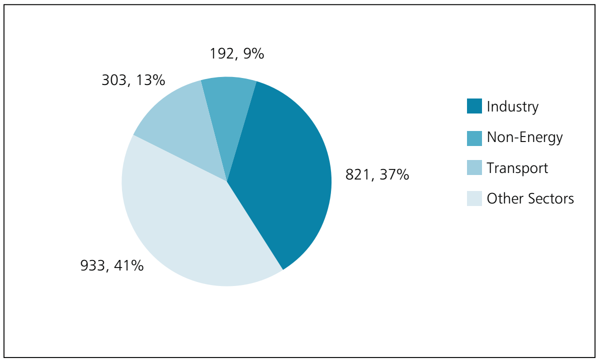
Sector-wise energy consumption

In 2006, the energy consumed in different end-use sectors—TFC—was 2,249 Mtoe. Industry accounted for 37% of the total; transport, 13%; other sectors, 41%; and non-energy use, 9% (Figure 2.16). Of the final energy consumption, coal accounted for 22%, oil 29%, electricity 15%, and biomass and waste 24%. Almost three-fourths of the energy—71%—was consumed in the PRC and India. Indonesia consumed 6%, and Central Asia, 5%.

The industry sector (including manufacturing and mining) consumed 821 Mtoe. Of this, 48% was accounted by coal, 23% by electricity, and 12% by oil (Figure 2.17). The PRC consumed 64% of the total energy used, 57% of which was met through coal. India consumed 13.3%, Indonesia 4.3%, and Central Asia 3.4%.

The transport sector consumed 303 Mtoe. The PRC accounted for 44% of this, and the energy used was almost exclusively oil (96%). Other end-use sectors (including residential, commercial and public services, agriculture/forestry and fisheries) consumed 933 Mtoe, 53% of which was met through biomass and waste (electricity and oil provided 14% each and coal, 9%). This is indicative of the widespread use of traditional forms of energy versus commercial forms, especially in the residential sector. In this sector, 49% of the energy in the PRC and 68% of the energy in India was met through biomass and waste.

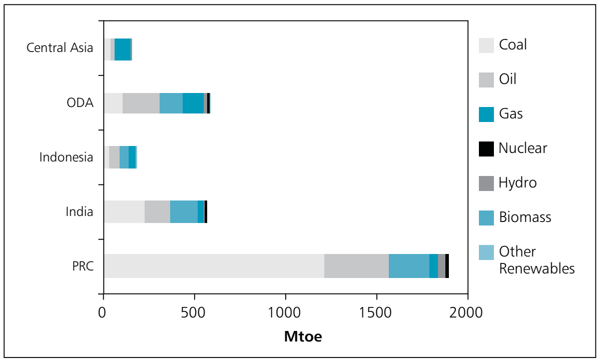
Figure 2.16: Region's Total Final Energy Consumption by Sector, 2006 (Mtoe)



Mtoe = Million tons of oil equivalent.

Source: International Energy Agency.

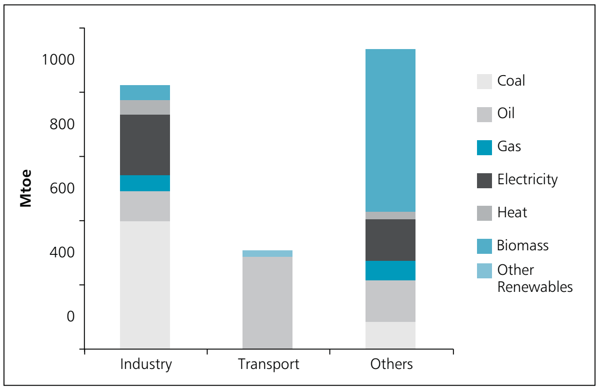
Figure 2.15: Fuel Mix in Countries in the Region, 2006 (Mtoe)



ODA = Other Developing Asia, PRC = People's Republic of China, Mtoe = Million tons of oil equivalent.

Source: International Energy Agency.

Figure 2.17: Region's Fuel Mix by Sector, 2006 (Mtoe)



Mtoe = Million tons of oil equivalent.

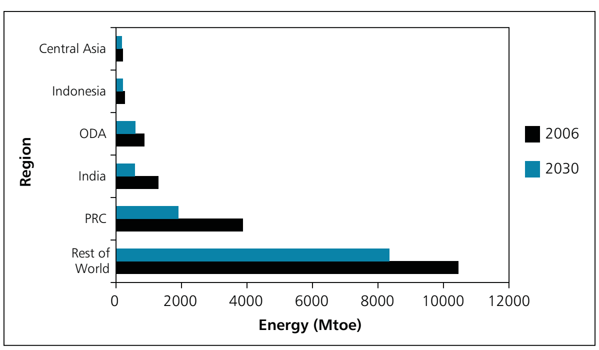
Source: International Energy Agency.

Energy consumption projections

Global primary energy demand is projected to grow at 1.6% per annum between 2006 and 2030, reaching 17,014 Mtoe. Total primary energy demand in the region's developing countries is forecast to grow to 6,547 Mtoe by 2030. Demand is expected to grow much faster in the PRC (3%) and India (3.5%), with the two countries accounting for more than 30% of the demand. The DAP region's total share would be 38.5% (Figure 2.18).

Steady economic growth, industrial expansion, population increase, and higher urbanization rates drive energy demand. Replacement of fuelwood and charcoal with gas and oil also plays a major role. Because of their strong economic growth, the PRC and India account for over half of the region's increase in demand for primary fuel. The steep rise in the PRC's demand due to rapid economic and population growth in 2006–2030 surpasses that of all other countries. The projected fuel mix of the major energy-consuming countries in the region is shown in Figure 2.19. The predicted increase in demand of almost 2,000 Mtoe is almost four times as high as the combined increase in demand of all the countries in Africa and Latin America and more than three times the increase within the Organisation for Economic Co-operation and Development (OECD).

Figure 2.18: Primary Energy Demand, 2006 and 2030 (Mtoe)



ODA = Other Developing Asia, PRC = People's Republic of China, Mtoe = Million tons of oil equivalent.

Source: International Energy Agency.

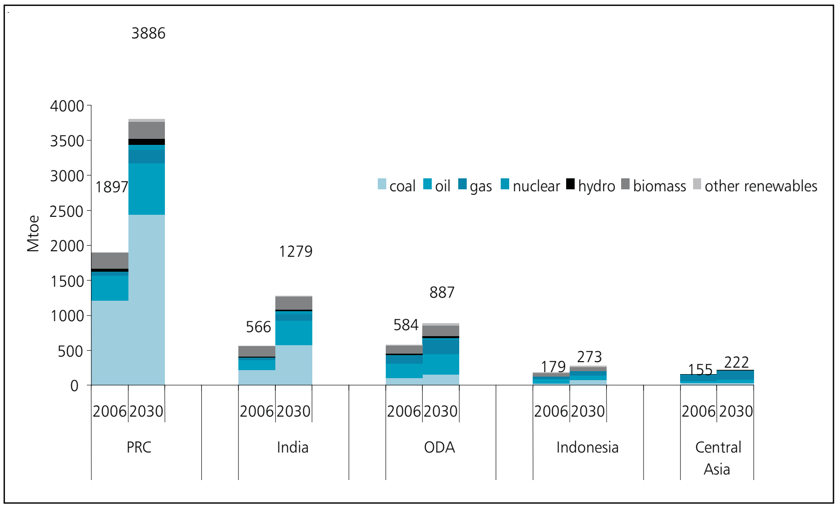
Projections by fuel

The region's reliance on coal is likely not only to persist but also to become stronger, with coal rising from 47% of the fuel mix in 2006 to 51% (Figure 2.20). Demand for coal is expected to grow 3.04% per year (compared with 2% worldwide), hitting 3,278 Mtoe in 2030.

Fuels with the fastest-growing use are forecast to be nuclear (6.3%) and "other renewables" (7%). However, their combined share in the primary energy mix is expected to remain under 4%. Although nuclear energy is projected to increase by a modest 103 Mtoe (from 31 Mtoe in 2006 to 134 Mtoe in 2030), the DAP region is expected to account for the largest increase in nuclear energy in the world.

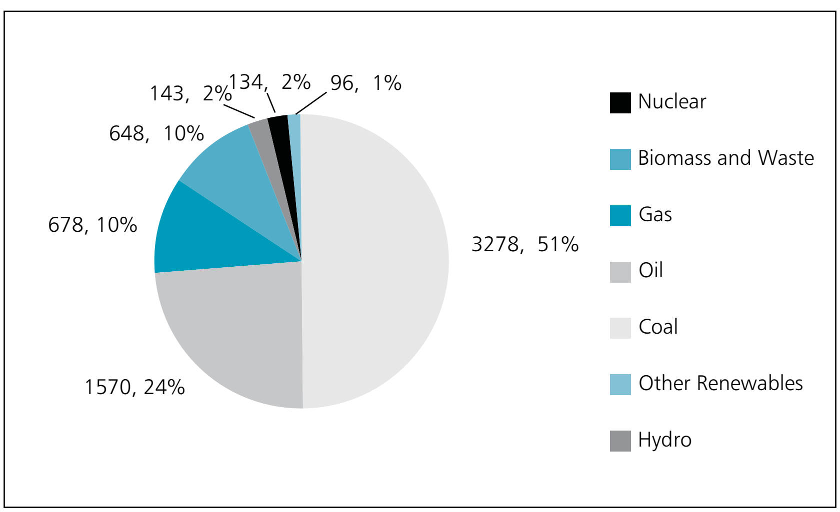
Global primary demand for oil (excluding biofuels) is expected to rise by 1% per year, from 4,067 Mtoe in 2007 to 5,072 Mtoe in 2030. India is projected to see the fastest growth in oil demand at 3.9% per year, followed by the PRC at 3.5%. A sharp increase in demand is expected from the transport sector—not only in those two countries but also in Indonesia and Central Asia—which may account for 51% of the demand in 2030. The share of gas in the fuel mix is forecast at 10%.

Figure 2.19: Projected Fuel Mix in Different Countries, 2030
(Mtoe)



ODA = Other Developing Asia, PRC = People's Republic of China, Mtoe = Million tons of oil equivalent.
Source: International Energy Agency.

Figure 2.20: Region's Projected Demands by Fuel, 2030
(Mtoe)



Mtoe = Million tons of oil equivalent.
Source: International Energy Agency.

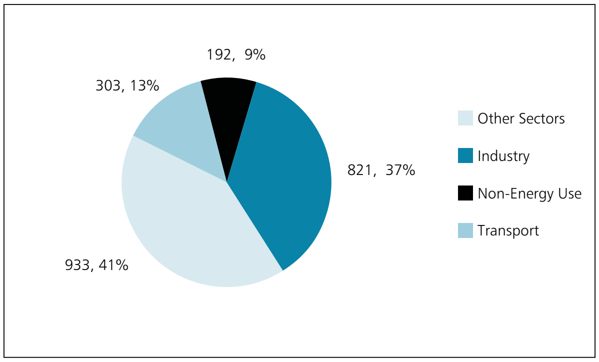
Projected fuel mix in different sectors

Among the end-use sectors in the region, energy demand in transportation is expected to grow the fastest at 4.4%, reaching 849 Mtoe by 2030. Of this, 95% is expected to be provided by oil (Figure 2.21). (This is a marginal decrease from 96% in 2006, which can be partly attributed to the emerging use of biofuels.) The biggest expansion of light-duty vehicle stock is expected to occur in the PRC, accounting for almost one-third of the global increase in cars. In addition to the transport sector, the industry, residential, services, and agriculture sectors are expected to see significant growth in demand for oil.

The industry sector's demand for energy is predicted to grow 3% per year. Although coal is likely to remain dominant (at 42% by 2030), electricity consumption is expected to grow 6.6% per year, accounting for 40% of the energy used in the sector by 2030.

The demand for energy in the other sectors (residential; commercial and public services; and agriculture/forestry and fishery) is forecast to grow at 0.4% per year to 1,306 Mtoe. Half of this demand is expected to come from the PRC, another 22% from India. Biomass and waste are expected to continue to provide 35% of the energy for these uses in 2030. However, as access to commercial energy increases, demand for energy from biomass and waste is forecast to decline by 0.4% per year. The share provided by electricity is projected to grow to 28%, gas 10%, and oil 16%.

Figure 2.21: Projected Fuel Mix in Different Sectors, 2030 (Mtoe)



Mtoe = Million tons of oil equivalent.

Electricity

Demand

Global demand for electricity jumped nearly 25% between 2000 and 2006, with nearly three-fourths of the increase coming from non-OECD countries and more than 40% coming from the PRC alone, as its demand doubled. Calculated annually, the world's demand was growing at an average rate of 3.6% for those years, compared with data from ADB that show consumption in the DAP countries growing 8.1% per year from 1997 to 2004. The growth in demand is expected to slow down. The global projection is 3.2% annual growth in 2006–2015, dropping to 2% in 2015–2030. In the PRC, the annual rate is expected to drop from its recent 14% to 7.6% until 2015 and then average 4.6% over the entire projection period, as the country shifts from heavy industry toward less energy-intensive industries.

Electricity generation/supply

In the World Energy Outlook (WEO) 2008 reference scenario, global electricity generation rises from 18,921 TWh in 2006 to 33,265 TWh by 2030. In the DAP countries, electricity generation rises from 4,787 TWh in 2006 to 13,196 TWh by 2030. As a share in the world's power generation, the region rises from 25% in 2006 to 40% by 2030, while the OECD countries fall from 55% to 40%.

Coal remains the main fuel for power generation worldwide, with its share actually growing from 41% in 2006 to 44% by 2030. In the region, coal's share rises from 66% in 2006 to 69% by 2015 and then drops marginally to 67% by 2030 (Figures 2.22 [a] and [b]).

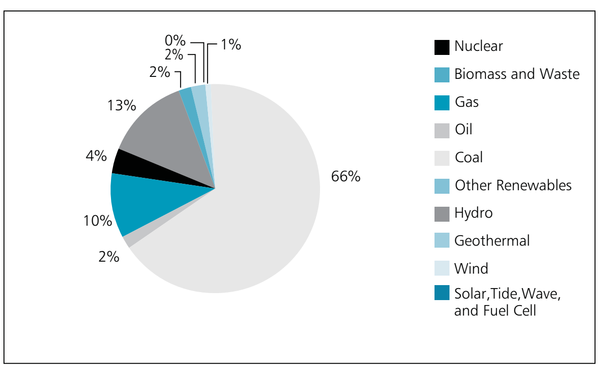
CO_2 emissions

This section uses data from the IEA and discusses the CO_2 emission figures and projections for the DAP countries. The reference scenario in the World Energy Model of the IEA embodies the effect of those government policies that were enacted or adopted by mid-2008, even though many of them may not yet have been fully implemented. Some measures not directly addressed in the energy sector have important consequences for the energy market and have been taken into account. Possible, potential, and likely future actions are not taken into account. For this reason, projections in this scenario cannot be considered forecasts of what is likely to happen. Instead, they should be seen as a baseline vision of how energy markets are likely to develop if government policy does not develop any further.

Even in the reference scenario, how the policies are implemented varies by country and fuel. For example, nuclear energy is an option for countries that have not banned it, but the pace of construction of new plants varies. Pricing and other market reforms are also assumed to be implemented at different rates. In most non-OECD countries, some forms of energy are subsidized. Most countries have policies to eventually phase out these subsidies, but at varying rates across countries.

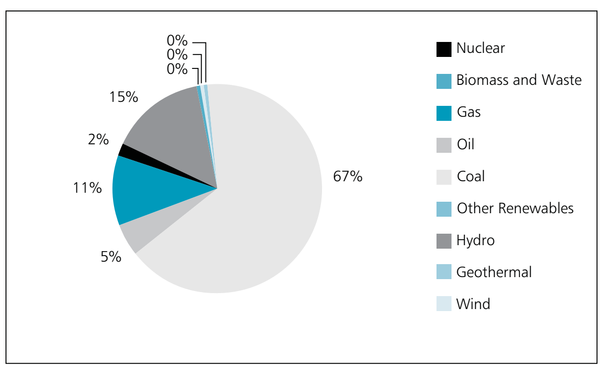
Global CO_2 emissions in the reference scenario are expected to increase by 45%, from 28 gigaton (Gt) in 2006 to 41 Gt by 2030. This is a compound annual growth rate of about 2%. Over the same

Figure 2.22: (a) Region's Fuel Mix in Electricity Generation, 2006



Source: International Energy Agency.

Figure 2.22: (b) Region's Fuel Mix in Electricity Generation, 2030



Source: International Energy Agency.

period, emissions are expected to increase by 6.1 Gt (3.1% per year) in the PRC and by 2 Gt (4.1% per year) in India (Figure 2.23). For Asia and the Pacific as a whole, CO_2 emissions are expected to increase 3% per year. The PRC is projected to have much higher emissions than the other countries in the region.

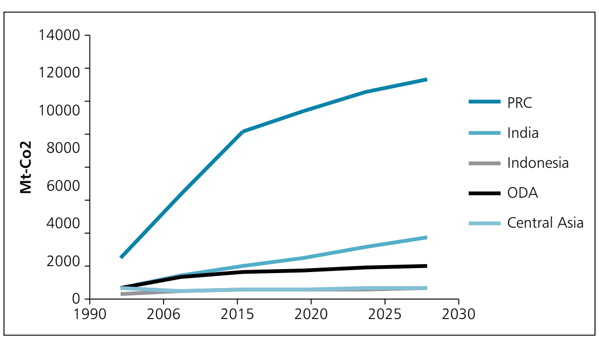
The power generation and transport sectors contribute more than 70% of the world's projected increase in energy-related CO_2 emissions. In the DAP countries, the power generation sector's demands are expected to jump 117% by 2030, while the transport sector's demand for oil almost triples (a 185% increase).

In Asia and the Pacific, CO_2 emissions from coal, oil, and gas are projected to rise more than 2% per year (Figure 2.24). All emissions from the three fuels are expected to double in the time frame (2006–2030). However, emissions from oil in the power-generation sector are seen as dropping in India (-0.2%), Indonesia (-1.6%), and Central Asia (-1.6%) and rising only slightly (0.2%) in the PRC, as these countries consciously attempt to move away from oil-based power generation. Emissions from oil are projected to increase the fastest in the transport sector, with more vehicles on the roads and no alternate fuel to switch to.

These projections hinge on assumptions about economic growth. If gross domestic product (GDP) increases much faster than assumed, the emissions will rise even faster than projected. But with expectations for growth dropping in 2008, the WEO is projecting significantly lower consumption of fossil fuels—mainly oil. Higher prices for fossil fuels (as assumed in WEO 2008) would stimulate more energy conservation and uptake of more efficient end-use technologies. They also would promote faster deployment of low-carbon supply-side technologies, such as renewables and nuclear power.

There being no single authoritative source for projections, the following section presents the

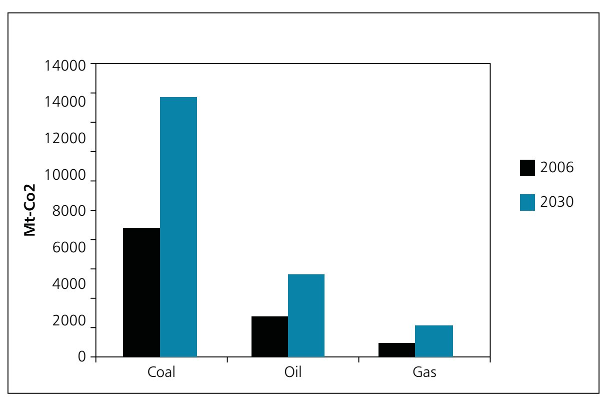
Figure 2.23: CO_2 Emissions Projections ($Mt\text{-}CO_2$)



$Mt\text{-}CO_2$ = Million tons of carbon dioxide, ODA = Other Developing Asia, PRC = People's Republic of China.

Source: International Energy Agency.

Figure 2.24: Region's CO_2 Emissions by Fuel, 2006 and 2030



$Mt\text{-}CO_2$ = Million tons of carbon dioxide.

Source: International Energy Agency.

energy demand projections for the PRC, India, and Indonesia, the three major DMCs in Asia and the Pacific, from three different sources: World Energy Outlook 2008,[18] Energy Security and Sustainable Development in Asia and the Pacific,[19] and study by the Economic Research Institute for ASEAN and East Asia (ERIA).[20]

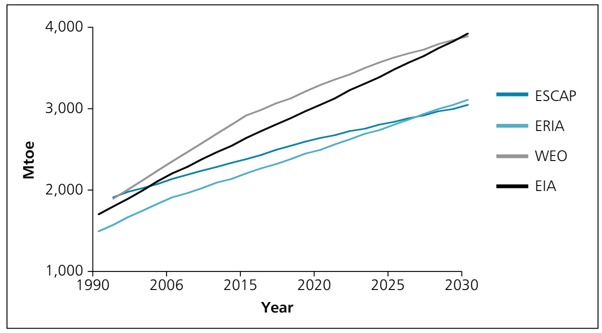
Energy projections of major energy-consuming countries of the region

People's Republic of China

Rapid economic growth in the PRC has fueled a large demand for energy. According to statistics published by ADB, between 1997 and 2007, demand rose at an annual average rate of 4.9% for coal, 1.8% for crude oil, and 9.7% for electricity. Up to 2030 and possibly beyond, the PRC is expected to have the highest rate of increase in the demand for energy among the major economies of the world and is expected to look at a variety of sources to satisfy this demand.

Estimates of demand for primary energy in the PRC by 2030 vary from 3,110 Mtoe (ERIA 2008) to 3,991 Mtoe (EIA 2008) (Figure 2.25). One of the reasons for the variation is the assumption of different annual growth rates of energy demand (ESCAP: 1.9%, WEO and ERIA: 3%, and EIA: 3.4%). WEO has projected an average annual increase of 6.1% per annum in GDP for 2006–2030, whereas ERIA has assumed 6.2% per annum GDP growth rate in 2005–2030. Both projections estimate an annual rate of population growth of 0.4%.

Figure 2.25: Range of Projections of Demand for Primary Energy in the People's Republic of China



EIA = Energy International Agency, ERIA = Economic Research Institute for ASEAN and East Asia, ESCAP = Economic and Social Commission for Asia and the Pacific, Mtoe = Million tons of oil equivalent, WEO = World Energy Outlook.

Source: WEO (2008), ESCAP (2008), EIA (2008), ERIA (2008).

The PRC is expected to remain heavily dependent on coal. Estimates for coal's share in the primary energy mix by 2030 vary from 55% (ERIA 2008) to 63% (WEO 2008). The demand for oil is projected to grow at an annual rate of 3.4% (ERIA 2008), while demand for natural gas grows 9.1% annually (ERIA 2008). Statistics published by WEO indicate that the fastest-growing sector for providing primary energy will be renewable energy (excluding biomass), which will grow at a rate of 10.4% (WEO 2008) but still contribute only 1% by 2030. Next will be the nuclear sector (7.3% per year) and gas (5.8%).

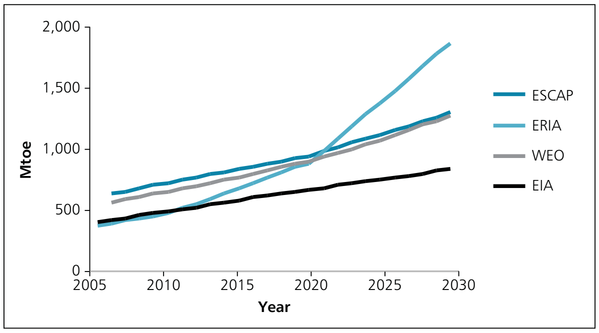
WEO and ERIA both project a 2.8% rate of increase in final energy consumption. They estimate that industry will use 44% and transportation, 27%.

18 IEA 2008.

19 ESCAP 2008.

20 Economic Research Institute for ASEAN and East Asia, Indonesia.

Figure 2.26: Range of Projections of Demand for Primary Energy in India



EIA = Energy International Agency, ERIA = Economic Researc Institute for ASEAN and East Asia, ESCAP = Economic and Social Commission for Asia and the Pacific, Mtoe = Million tons of oil equivalent, WEO = World Energy Outlook.

Source: WEO (2008), ESCAP (2008), EIA (2008), ERIA (2008).

According to WEO estimates, transportation's consumption will grow the most (5.3%), with 95% of the energy derived from oil.

Estimates on how much CO_2 emissions will increase vary from 2.4% per year (ERIA) to 3.1% (WEO) and 3.3% (EIA). All the estimates are lower than the 5.3% annual growth in the PRC's emissions in 1990–2005.

India

India's consumption of crude petroleum grew 9.1% per year in 1997–2006, while the electricity consumption grew at a rate of 6.7%. India is projected to be among the fastest-growing economies in the world up to 2030, and energy will be needed to power that growth.

Estimates of demand for primary energy in India in 2030 vary greatly—from 836 Mtoe (EIA 2008) to 1,845 Mtoe (ERIA 2008)—with projected annual growth rates ranging from 2.9% to 6.6%. Despite the wide variation, a number of common themes emerge from the different projections.

Nuclear energy is expected to be among the fastest-growing sources of primary energy, with both ERIA and WEO forecasting a growth rate of more than 9%. Natural gas is also considered significant, with growth predicted at 8.1% (ERIA 2008). And India is expected to tap its hydro-electricity potential with a growth rate of 6.7% (ERIA 2008). As commercial sources of energy are accessible to a greater proportion of India's population, the share of biomass and waste in primary energy mix is projected to decline from 28% in 2006 to 15% in 2030.

The WEO model for India assumes that the population grows at a rate of 1.1% while GDP grows at 6.4%. ERIA expects a similar increase in the population—1.2%—but assumes that GDP growth is considerably higher at 8%.

Projections for the increase in power generated vary widely from a compound annual growth rate of 4.2% (WEO 2008) to 7.5% (ERIA 2008). India is expected to use a variety of sources of energy, shifting from coal, which provided 81% of power generated in 2006. WEO projects growth rates of 9% for nuclear power, 12% for biomass and waste, and 10.8% for other renewable energy, up to 2030.

Among end users, energy consumption is expected to grow the fastest—6.3%—in the transport sector, with oil providing 93% of the energy. Oil is expected to stay dominant overall, supplying 37% of total energy in 2030. Electricity capacity is expected to grow 5.3% annually, with solar in the lead growing 25.7% and achieving 6 GW installed capacity by 2030 (WEO 2008).

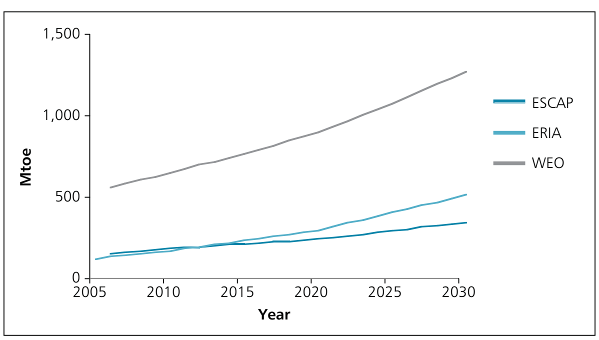
Indonesia

Consumption of crude petroleum grew at a compound annual growth rate of 1.7% in 1997–2004. In 1997–2006, consumption of electricity grew 5.9%. Indonesia is naturally endowed with large and diverse energy reserves. However, it is expected that these reserves will prove to be insufficient to satisfy the country's growing demand.

Estimates of demand for primary energy in 2030 vary widely, from 273 Mtoe (WEO 2008) to 520 Mtoe (ERIA 2008) (Figure 2.27). These numbers represent compound annual growth rates from 1.8% to 5.8%. Hydropower and geothermal energy are forecast to increase the fastest, with WEO predicting 4.2% growth.

ERIA assumes a GDP growth rate of 6.5% and population growth of 1.1%. WEO assumes slower growth in both: 0.8% for population and 4.1% for GDP.

Figure 2.27: Range of Projections for Demand for Primary Energy in Indonesia



ERIA = Economic Research Institute for ASEAN and East Asia; ESCAP = Economic and Social Commission for Asia and the Pacific; IEEJ = Institute of Energy Economic, Japan; Mtoe = Million tons of oil equvalent; WEO = World Energy Outlook.

Source: WEO (2008), ESCAP (2008), ERIA (2008).

Among the end users, energy consumption is expected to grow the fastest in the transport sector, at a rate of 7.3% (ERIA 2008). On an aggregate level, the rate of growth of electricity will be the highest at 4.8% (WEO 2008). Oil is expected to remain dominant in the transport sector, providing 97% of the energy in 2030, while coal holds the lead in industry (though its share is seen dropping from 38% in 2006 to 34% by 2030).

WEO forecasts power generation capacity increasing at a rate of 4.1% in 2006–2030, with the fastest-growing sectors being biomass and waste (17.8%) and wind (15%).

Predictions of carbon emissions differ. WEO projects an emissions growth rate of 2.2% to 565 Mt-CO_2 in 2030. ERIA, which assumes faster growth in demand for energy, projects 5.8% growth in CO_2 emissions to 1,466 Mt-CO_2.

Conclusions

The DAP region faces an uphill challenge in the energy sector, despite being well endowed with fossil, as well as non-fossil, energy resources. Access to commercial energy and electricity remains rather low, and a large part of the population still depends on biomass for fuel. This is further complicated by the following:

- The energy demand in the region is increasing rapidly. Countries, such as the PRC and India, account for the largest increase, but the energy demands of smaller countries, where consumption is currently low, are also rapidly rising.
- The region is highly dependent on fossil fuels, and this dependence is likely to persist and even become stronger.

- The production and consumption of most fuels in the region are increasing. However, consumption is increasing much faster, leading to a growing gap.
- The region is a net energy importer, and this import dependence is expected to increase.
- The demand for coal is primarily fueled by the power sector, and the demand for crude oil is increasing sharply because of transportation growth.
- The power sector in the region suffers from inefficiencies, such as high transmission and distribution losses.
- The region has tremendous potential for non-fossil energy, particularly biomass, solar, wind, hydro, and nuclear. Energy from these fuels is expected to increase at the fastest rate; however, since their share in the fuel mix is currently small, coal will still be dominant in 2030.
- Energy-related emissions of GHGs are expected to grow as the region's demand for energy increases.

Energy security concerns are not restricted to the growing demand–supply gap and the rising import dependence but have a larger social dimension. This will be discussed in the next chapter.

CHAPTER 3
Challenges to energy security

Given the developmental stage and the demography of developing Asia and the Pacific (DAP), an increase in energy consumption is inevitable. Sustained economic growth in the region, which is much needed, is expected to fuel this energy demand further. This brings the question of energy security to the fore for policy makers.

Energy security has been a concern since the first oil shock in 1973. Today, the concept has broadened from a focus on oil to encompass not only secured supplies of all energy resources, fossil fuel and renewables, but also related concepts, such as affordability of energy, access to all, sustainable development, geopolitics, and demand-side management. It is an important aspect of national economic security and has direct impact on national security, sustainable development, and social stability of a country and the region.

The key aspect of energy security is sustained supply of energy at affordable prices. The World Energy Assessment defines energy security simply as "the continuous availability of energy in varied forms in sufficient quantities at reasonable prices (UNDP 2004)." This definition is limited in the sense that energy supply is independent of its impact on the environment and the economy. The Asia Pacific Energy Research Centre defines energy security as "the ability of an economy to guarantee the availability of energy resource supply in a sustainable manner, with the energy price being at a level that will not adversely affect the economic performance of the economy" (APERC 2007). This broader definition is more relevant in the context of Asia and the Pacific. It links energy security to two related fields: economy and environment. It is because of these linkages that energy security has moved up on the international agenda.

Socioeconomic profile of the region

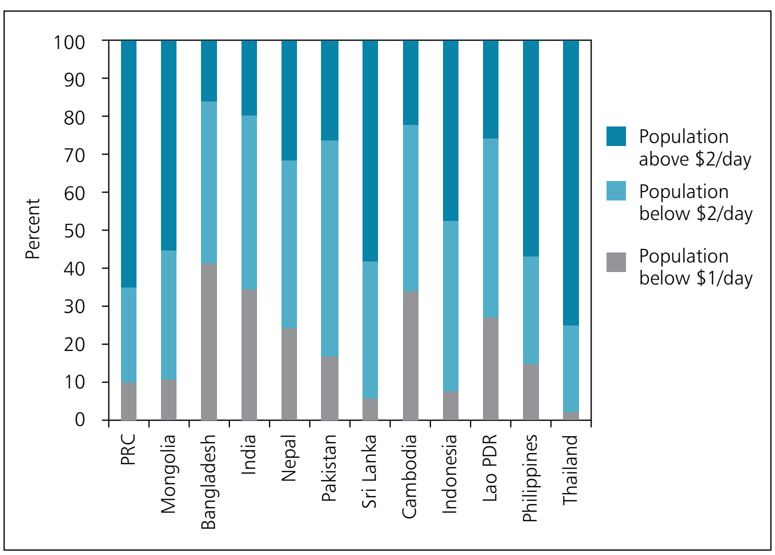
The DAP region has wide variations in terms of population, gross domestic product (GDP) and income levels, urbanization, per capita energy consumption levels, and other characteristics.

Income level

Home to the two most populous countries in the world, the PRC and India, the DAP region accounts for more than half of the world's population (54%) and is witnessing increased urbanization across all countries. Countries, such as Singapore, Republic of Korea, and select island states in the Pacific region, have urbanization levels higher than 70%. On the other hand, countries in the South Asian region, Cambodia, the Lao People's Democratic Republic (PDR), and most Pacific DMCs still have about 70% or more of their populations living in rural areas. But in the past decade, these countries have witnessed a steady increase in the urbanization levels that has placed a greater stress on already constrained energy resources.

With an aggregate GDP of $18 trillion, the region contributes 40% of the world's GDP.[21] Though the GDP levels in region have been growing, a large part of the population is still below the international definition of poverty line—population with an income less than $1 per day and population earning less than $2 per day (Figure 3.1). A majority of countries in the region for which data are available have more than 30% of their population living with incomes less than $2 per day.

Figure 3.1: Populations Below International Poverty Lines in Asia, 2003



PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic.

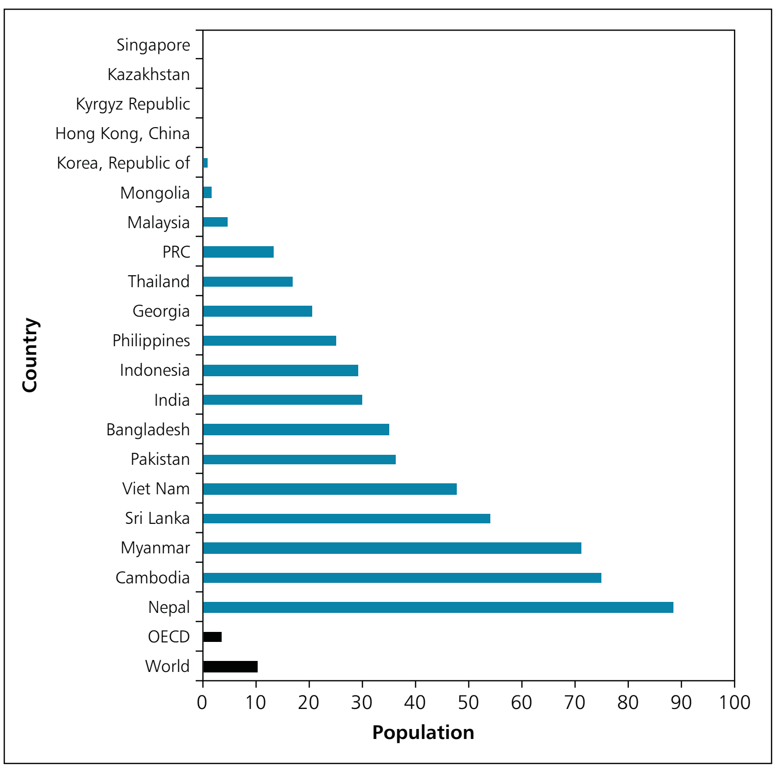
Source: UNDP (2007).

[21] These are 2005 figures. *Human Development Report 2007/08.*

Low income levels restrict the options for energy, and so the poor depend heavily on traditional sources (Figure 3.2). Nepal illustrates the strong correlation between high levels of poverty and a large dependence on traditional fuels driven by (i) a lack of availability of modern fuels and (ii) the fact that traditional sources of energy are free of direct costs. Most countries of the DAP region depend on traditional sources more than the world average, with associated consequences on other developmental indicators.

The burning of traditional energy forms is inefficient, causes indoor air pollution and, according to the World Health Organization, is responsible for 1.6 million deaths each year in the world's poorest countries, with greater impacts on women.[22] The dependence on traditional resources

Figure 3.2: Share of Traditional Sources of Energy in Total Energy Consumption, 2005 (%)



OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

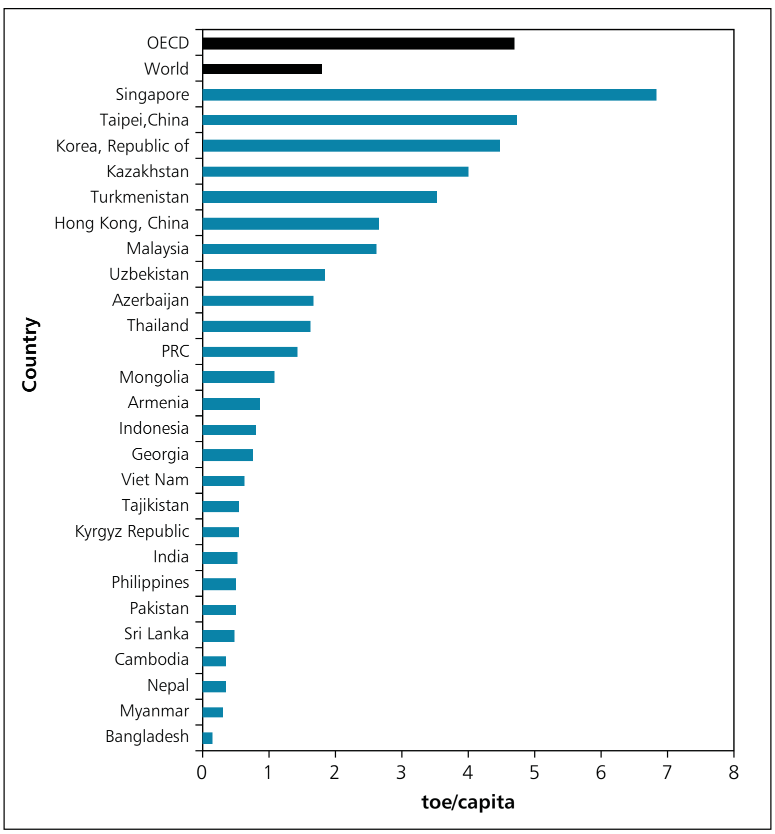
Source: UNDP (2007).

[22] Smoke in the Kitchen: Health Impacts of Indoor Air Pollution in Developing Countries. UNDP. 8 February 2005.

has other effects on gender inequality as the responsibility of fuelwood collection falls on the women and girls in the family. Hours are spent in this process, often at the cost of the education of the female child. Thus, the use of traditional fuel is closely linked to lack of development, as well as poverty.

With such high levels of poverty and dependence on traditional fuels, it is not surprising that the per capita energy consumption across countries is low (Figure 3.3). Only a few countries of the DAP region have a per capita energy consumption level higher than the world average, with only a few countries being comparable to the OECD average.

Figure 3.3: Energy Use Per Capita, 2006
(toe)



OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China, toe = tons of oil equivalent.

Source: Key World Energy Statistics 2008, IEA.

This region is home to nearly 60% of the world population without access to electricity.[23]

Undoubtedly, the energy consumption of the region must increase to fuel economic growth and development. Countries that are lower in per capita energy consumption usually have low adult literacy rates, lower life expectancies, and a low education index.[24] Those three variables can be consolidated into one number known as the "human development index."[25]

The region does have substantial scope for improving its energy intensity (Figure 3.4).

Energy intensity levels are representative of the energy efficiency levels of the country. Most of the countries in the region have energy intensities greater than the world average, highlighting a potential for the region to bring in efficiency in its current energy consumption pattern. However, if one considers energy intensity in purchasing power parity (PPP) terms, the energy intensity of the region is lower than that of the world average. Energy intensity is a function of a number of factors, such as economy structure, energy usage pattern, labor intensity, energy mix, etc. In PPP terms, the DAP region may have a better performance in energy intensity average, but it may worsen in the future especially since currently, a large part of the population in the region does not have access to energy and these economies are more labor intensive as compared to their OECD counterparts.

The largely low per capita energy consumption is also reflected in low per capita carbon dioxide emission levels, especially for the major consumers of energy in aggregate terms (Figure 3.5). Emissions from the developing countries have increased in the past decade, but they are below the world average and much below the OECD average.

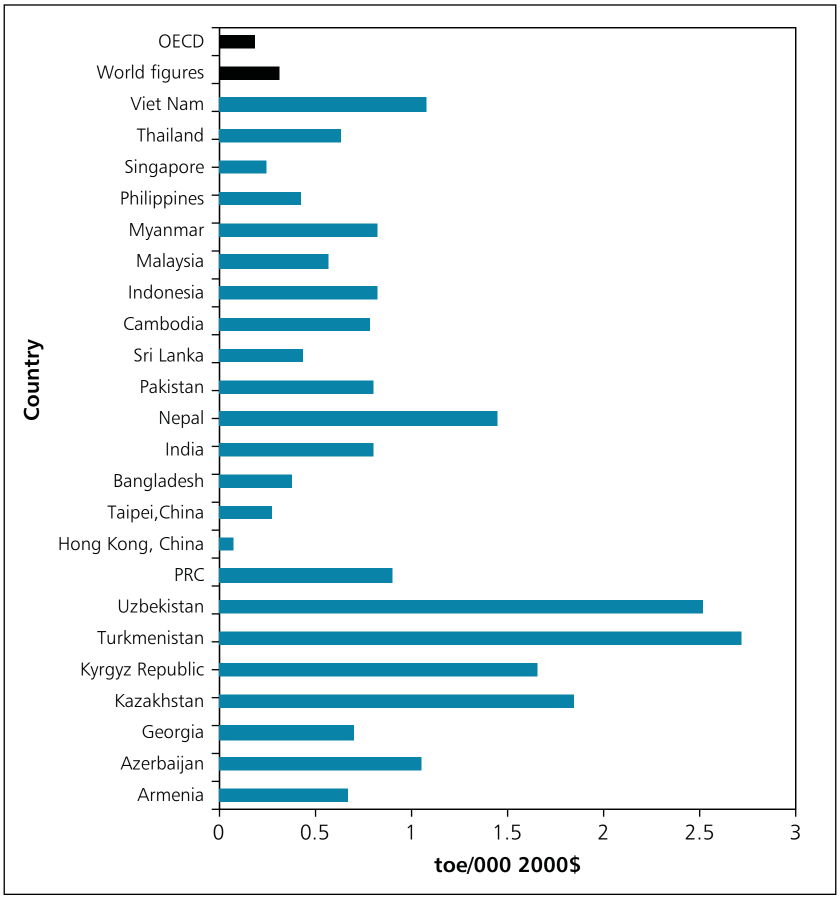
Figure 3.6 plots the human development index and per capita electricity use in Asia and the Pacific in 1995 and 2002 and highlights a close correlation between the two. However, this relationship is not linear. A small increase in electricity use can be matched with a much higher increase in the index, if the energy use is put in the desired sectors and areas. A case in point is the PRC, where a small increase in energy consumption has led to a much higher rise in the index. Similar movement occurred in the 10 countries with the lowest human development scores: Bangladesh, Bhutan, Cambodia, India, Lao PDR, Mongolia, Myanmar, Nepal, Pakistan, and Viet Nam. These countries make up almost 50% of the region's population, accounting for a disproportionately large share of

[23] Human Development Report 2007/08. It has been reported that 1.6 billion people in the world lack access to electricity, 45% of whom are in South Asia and 14% of whom are in East Asia.

[24] *Human Development Report 2007/08.*

[25] The human development index is a summary measure of human development. It measures the average achievement in the country in three basic dimensions of human development: (i) a long and healthy life, as measured by life expectancy at birth; (ii) knowledge, as measured by adult literacy rate (with two-thirds weight) and the combined primary, secondary, and tertiary gross enrollment number (with one-third weight); and (iii) a decent standard of living, as measured by GDP per capita in purchasing power parity terms in US dollars.

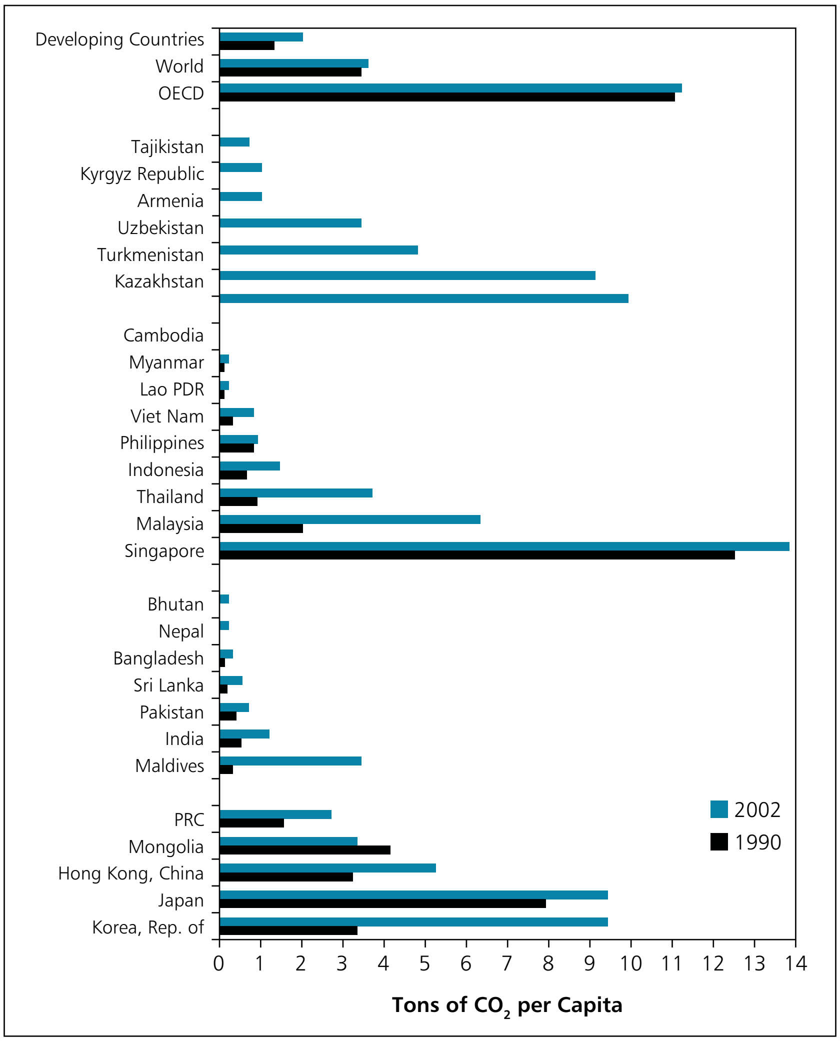
Figure 3.4: Energy Intensity of Asia and the Pacific



OECD = Organisation for Economic Co-Operation and Development, PRC = People's Republic of China, toe = tons of oil equivalent.

Source: Key World Energy Statistics (2008), International Energy Agency (2008).

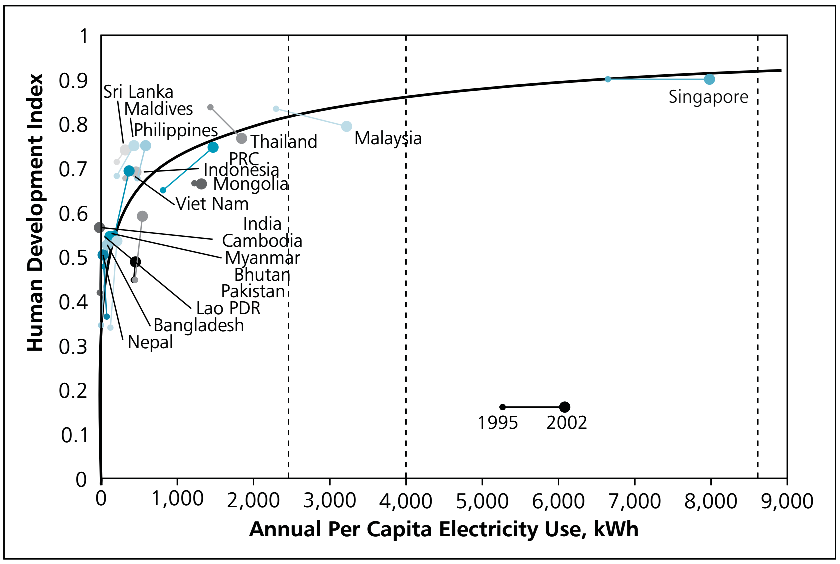
Figure 3.5: Per Capita Carbon Dioxide Emissions in Asia, 1980 and 2002



CO_2 = carbon dioxide, OECD = Organisation for Economic Co-operation and Development, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: UNDP (2005 and 2006).

Figure 3.6: Human Development Index and Electricity Use in Asia and the Pacific, 1995 and 2002



OECD = Organisation for Economic Co-operation and Development, kwh = kilowatt-hour, Lao PDR = Lao People's Democratic Republic.

Source: UNDP (2006).

the poor with a per capita electricity consumption of only 479 kWh.[26]

The human development index of most of the countries in the region is between 0.35 and 0.75 (on a scale of zero to 1), and all countries (except Singapore) are far below the development threshold of 4,000 kWh electricity per capita. Thus, what is seen is that the region has high levels of poverty, both income and energy. Alleviation of both these poverty levels is the combined challenge being faced by the region. Given the interplay between income and energy poverty, improvement in one is expected to boast the second.

Energy security concerns for Asia and the Pacific

Countries in the DAP vary in resource endowments, energy consumption levels, and technology capabilities, but their energy security concerns cut across these variations. A cooperative and collective approach would not only address energy security but also would lead to economic and environmental benefits for the entire region.

The following are the key energy security concerns that the region faces:

- lack of energy access,
- lack of diversification of energy resources,

[26] This per capita electricity consumption level is much lower than the world average of 2,659 kWh in 2002.

- high dependence on traditional fuel,
- increasing gap between energy demand and supply,
- overdependence on imported energy, and
- lack of adequate energy infrastructure.

Lack of energy access

The first and foremost energy security concern for the region is the lack of energy access itself. Energy access is the cornerstone of ensuring energy security. Energy access here means providing modern sources of energy to the population and moving people away from the inefficient uses of traditional sources of energy. Access to modern energy enables the alleviation of poverty, creates new opportunities for livelihoods, and promotes health by improving air quality.

A key aspect of energy access is the provisioning of electricity to households. In the DAP region, access to electricity varies widely. Only a few countries have 100% access, and in other countries the access levels are abysmally low. The electrification rate in Myanmar, for example, is only 11% (Table 3.1). The electrification levels are much lower in the rural areas.

In the Pacific DMCs, household electrification levels vary from 10% to 100% but average an estimated 30% (Table 3.2).[27]

A specific concern of the DAP region is the geographic dispersion of the island states, within individual countries and between countries, which is one of the major constraints to improving access to electricity. With a fragile environment that is also fast deteriorating in and around populated areas, there is difficulty in providing basic services to the people adequately, especially the rural majority, while trying to cause the least damage to the environment.

Table 3.1: Current Electrification Rate in Selected Southeast Asian Countries

Country	Electrification Rate (%)
Cambodia	20.1
Lao PDR	20
Myanmar	11
Thailand	99
Viet Nam	84

Lao PDR = Lao People's Democratic Republic.

Source: For Lao PDR, Myanmar, Thailand, and Viet Nam: UNDP (2008).

For Cambodia: *World Energy Outlook 2006*. International Energy Agency.

Unlike other subregions in Asia and the Pacific, where some countries are 100% electrified, electrification levels in South Asia range from low to medium (Table 3.3).

Energy access is not limited to the physical access to electricity. The quality of power is also important, especially for countries that have been able to provide some access to a large majority of the population. Quality includes such issues as voltage and the length and frequency of electricity outages. In most of the region, especially South Asia and the Pacific DMCs, quality of supply is an energy security concern.

[27] www.forumsec.org.fj/pages.cfm/economic-growth/energy/ (accessed on 31 March 2009).

Table 3.2: Electrification in the Developing Pacific, from 1990s

Country	Households Electrified
Cook Islands	1994: 35%; 2004: 99%
Federated States of Micronesia	1993: 30%; 2000: 54%
Fiji Islands	1994: 50%; 1996: 67%
Kiribati	1993: 29%; N/A
Marshall Islands	1994: 50%; 1996: 67%
Nauru	1994: N/A; 2003: nearly 100%
Palau	1994: N/A; 2003: >95%
Papua New Guinea	1994: 22%; 2003: <10%
Samoa	1994: 90%; 2001: 91%
Solomon Islands	1994: 15%; 1999: 16%
Timor-Leste	1998: 20%; 2003: 21%
Tonga	1994: N/A; 2004: 90%
Vanuatu	1994: N/A; 1999: 19% (61% of urban households)

N/A = not available.

Source: PIREP Report on Regional Overview (2004); Power Sector Master Plan for Timor-Leste, Asian Development Bank (2003); www.adb.org/Documents/News/1996/nr1996150.asp (accessed on 15.04.2009).

Table 3.3: Access to Electricity in South Asia

Country	Share of Household With Electricity Access (%)
Afghanistan	20
Bangladesh	42
Bhutan	40
India	56
Maldives	N/A
Nepal	25
Pakistan	60
Sri Lanka	78

N/A = not available.

Source: ADB SAARC Regional Energy Trade Study; Census of India 2001; ADB website; and Srivastava L., Misra N. 2007. Promoting Regional Energy Co-operation in South Asia. *Energy Policy.* 35: 3360–3368.

Lack of diversification of primary energy fuel mix

A number of countries in the region have a heavy dependence on a single energy resource to meet a bulk of their energy demands. The two biggest energy consumers, the PRC and India, are dominated by coal, which meets more than 50% of their total primary energy demand. For the region as a whole, fossil fuels dominate. In the ASEAN countries—Malaysia, Philippines, Indonesia, Singapore, Viet Nam, select countries in South Asia—Afghanistan, Maldives, Sri Lanka, and a majority of the Pacific DMCs, oil meets a lion's share of the energy demand. Indonesia and Malaysia have domestic hydrocarbon reserves to meet this demand, but the other countries are dependent upon imports.

Lack of diversification limits the flexibility to meet demand, and dependence on either imports or domestic reserves raises security concerns. Though dependence on domestic resources is a desired position for a country, however, given that most of these countries are dependent on domestic fossil fuel reserves, which are finite resources, in the long term energy security concerns are expected to arise. For instance, India, primarily a coal-based economy, has seen over the years an increase in the amount of non-coking coal imported.

High dependence on traditional sources of energy

A related concern for the region is the high dependence on traditional sources of energy. Some countries in the region are more than 50% dependent upon traditional fuels and use them inefficiently. The region is well endowed with biomass resources, and biomass will continue to meet a majority of the energy demand, especially in the rural areas. But what is needed is a shift to more efficient ways of using biomass.

Increasing gap between supply and demand

The top concern for the region's energy security is the widening gap between supply and demand. The region is not able to meet its energy demands through domestic resources, and the problem is getting worse.

To narrow the gap, the region is turning to imports. It is a net importer of crude oil (including petroleum products), with an aggregate import of 818 million tons in 2007. In the same year, it imported 148 billion cubic meters of natural gas.[28] Coal imports have also increased sharply in two of the major energy consumers of the region, the PRC and India.

At the subregional level, South Asia imports most of its fuel; oil is brought in to meet demand. Countries, such as Bangladesh and India, have a natural gas shortage, and Pakistan is expected to face one as well.

All countries in the region have shortages of electricity due to inadequate capacity and insufficient fuel. Deficits for electricity to meet the peak demand of the already electrified households in the respective countries range from about 28% in Bangladesh to about 9% in Nepal.

Shortage of energy has an adverse impact on industrial and economic output. The industry and household sectors are both key energy consumers, and a disruption in energy supply has far-reaching effects.

28 *BP Statistical Review 2008.*

Overdependence on imported energy

Dependence on imported energy has direct implications for energy security, and when the imported energy forms a lion's share of the total primary energy, the risks are heightened. The DAP has an energy deficit as a region, and only select countries within it show a positive energy balance.

Oil is one energy resource that most of the countries in the region import. The level of import dependence highlights the magnitude of concern as well as the vulnerability of the region (Table 3.4).

Singapore is primarily a hydrocarbon-driven economy, with 76% of its electricity generation from natural gas and is 100% dependent on imported natural gas. It also imports all of its crude oil but has surplus refining capacity and hence is a net petroleum product exporter. Smaller nations, such as the Pacific DMCs (except Papua New Guinea, Fiji Islands, and Samoa, where dependence on diesel is in the range of 39% to 51%), Bhutan, Nepal, the Lao PDR, Cambodia, and Maldives, are primarily oil-based economies and are 100% dependent on petroleum imports. This increases the energy security vulnerabilities of these smaller countries considerably—much more as compared to the other countries in the region—as they have limited negotiating power in the international market, and are mostly price takers.

Vulnerabilities linked to energy import dependence are aggravated by the volatility of energy prices. This has far-reaching implications for the financial ability of a country to meet its energy demand and for economic growth, especially in the smaller countries. Another concern is instability in the Middle East. The bulk of the oil imported to the region is from the Middle East, and any disruption of supply would have a substantial impact.

Lack of adequate energy infrastructure

A common concern across the region is the lack of adequate infrastructure for transporting energy from the supply centers to where it is needed. Countries at times cannot get access even to their own domestic resources because they do not have the infrastructure. A well-developed infrastructure

Table 3.4: Oil Import Dependence in the Region

Country	Oil Import Dependence, %
India	75
Indonesia	22
Pacific island states	Ranges from 30 to 100
People's Republic of China	57
Singapore	100
Thailand	65

Source: Compiled from various regional overviews.

is indispensable for development of the energy sector. In India, for example, the natural gas sector is stymied by the absence of a transmission and distribution network. In case of electricity, the country has been unable to harness its hydropower potential in the northeast because of inadequate transmission capacity.

A major barrier to developing infrastructure is the lack of sufficient investment. A high level of capital is needed for basic energy infrastructure, just as it is needed for the initial stages of developing renewable energy resources. This highlights the need for governments to develop policy and regulatory frameworks for encouraging investments.

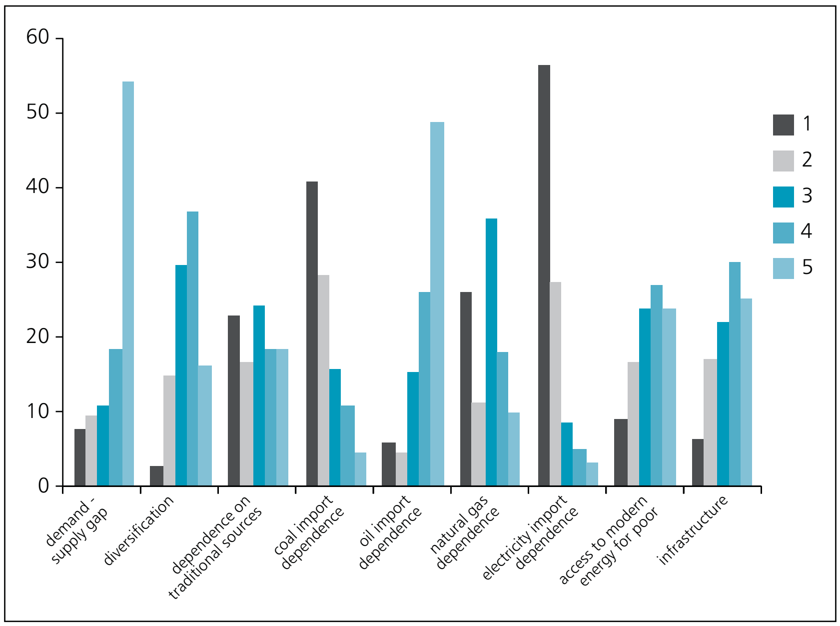
The capabilities of countries in Asia and the Pacific to invest in energy infrastructure and renewable energy development are limited, especially for countries with low GDP levels, such as Cambodia, the Lao PDR, and Myanmar. Investment in energy infrastructure includes investment in physical infrastructure, new technologies, and generation facilities. Based on the estimation of the ASEAN Center for Energy (ACE), ASEAN countries (excluding Myanmar) will need $18.65 billion in the next 10 years to use renewable energy for either 5% of renewable energy potential in the country or for reaching the national target (Akhmad Nidlom 2008). Bangladesh will need $5 billion–$6 billion over the next 10 years for power–sector development. The projects proposed in Bhutan's power system master plan will require an investment of $3.36 billion over 20 years, from 2003 to 2022. According to IEA, India will need $680 billion to meet its generating capacity, transmission, and distribution needs from now to 2030. Nepal's investment need for generation and transmission for the next 10 years is estimated at $1.22 billion (Srivastava and Misra 2007).

To find and channel such substantial sums of money is one of the biggest challenges faced by the countries in the region. Here, the role of national governments becomes paramount in building policies and institutional frameworks that create incentives for investors (both public and private) to invest in the energy sector. Another funding option, especially for the smaller countries, is aid from various multilateral and bilateral sources. The Pacific DMCs, for example, depend heavily on international financial aid for many of their developmental needs. Several organizations, such as ADB, the World Bank Group, the European Commission, and the Renewable Energy & Energy Efficiency Partnership, lend large sums of money for energy projects.

Key energy security concerns: expert survey results

More than 70% of the respondents cited as highly serious issues the widening gap between energy supply and demand and the dependence on imported oil (Figure 3.7). This highlights the peculiar developmental challenge facing many of the DMCs in the region. While the bigger economies, such as the PRC and India, which are relatively more industrialized, require more energy to sustain high growth rates, the smaller and less industrialized economies need to achieve higher total energy consumption to achieve a minimum level of industrialization that is necessary to address high levels of poverty. The inability to meet these requirements domestically necessitates the import of energy, largely oil, making the import-dependent countries vulnerable to international energy price fluctuations and supply disruptions. And oil is expected to remain one of the major sources of energy in 2025–2030 (Figure 3.7).

Figure 3.7: Key Energy Security Concerns in Asia and Pacific Countries
(1 is lowest and 5 is highest)



Source: Survey results.

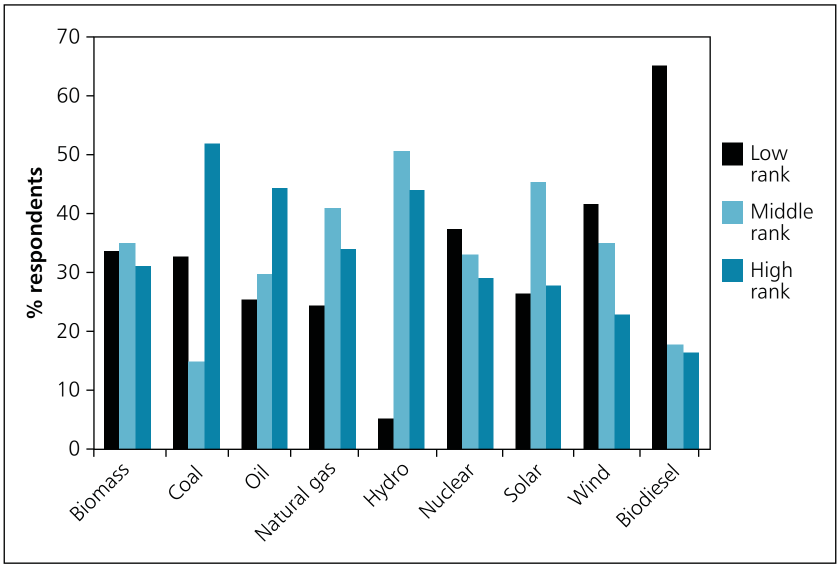
The region's increasing dependence on imports leads to another key energy security concern—the lack of diversification of fuels—with nearly 50% of the respondents rating it high on the scale.

Although the region depends heavily on traditional fuels (biomass), access to modern energy forms did not rate very high on the priority list. Indeed, there seemed to be a high level of acceptance of biomass in the energy mix, perhaps driven by recognition of the existing shortage of fuel, as well as the potentially significant role for bio-energy in a country's energy security strategy.

The two least crucial concerns were import dependence on coal and import dependence on electricity. The region has substantial coal reserves, and most of the demand is met internally or imported from countries within the region. Similarly, since the volume of electricity imports is not significant, electricity import dependence is not a big concern for energy security.

The evolution of the fuel mix over the years seems to have a significant bearing upon the way countries address energy security. The respondents predicted that the high dependence on fossil fuels, coal in particular, would continue at least until 2025–2030 (Figure 3.8). Hydropower is the second most common source of power generation in the region and was ranked high as well. The long-term share of biomass was predicted as low or medium by 67%. Fewer than 30% of the respondents expected nuclear power to rank high, perhaps

Figure 3.8: Expected Energy Mix, 2025–2030



Source: Survey results.

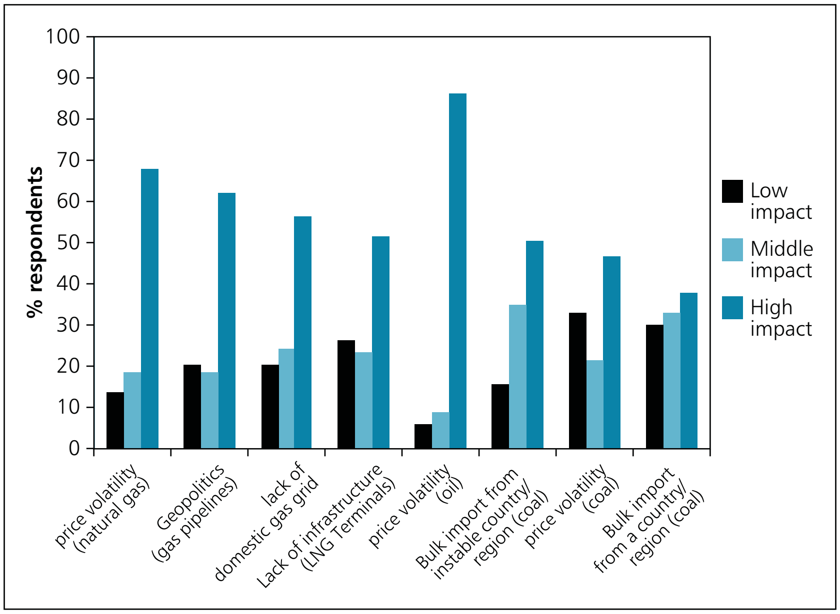
because of oft-cited safety issues, along with the high cost and technological expertise needed for operation of the nuclear power plants.

Renewable energy sources, particularly wind and solar, have not gained the confidence of the experts consulted. Solar has been widely recognized to have tremendous potential in the region, but its high capital cost could be a barrier. Intermittency could be a concern for wind-based energy, and the fuel versus food debate, along with the uncertainties about second-generation biofuel technologies, may have led to some pessimism on the role of biodiesel in the future energy mix.

Given that fossil fuels are expected to dominate future energy supply scenarios and many countries import them, it is of vital importance to ensure that stable and secured import options are available.

Consequently, import-related risks become key concerns for energy security. In this context, volatility of international prices was considered of high importance in the case of both crude oil (85% of respondents) and natural gas (68%) (Figure 3.9). Another crucial factor related to crude oil imports is the lack of diversification in suppliers. This is especially relevant as a large chunk of the crude oil imported in the region comes from West Asia, and any disruption in the region or along the supply routes can interrupt the flow of energy. In case of imported natural gas, another identified risk relates to the geopolitics of the region which, according to 61% of the respondents, has a high impact. This is particularly significant in the case of imports through pipelines, which are mostly trans-national. Other high risks associated with natural gas imports are related to insufficient domestic infrastructure—lack of a well-developed natural gas grid and

Figure 3.9: Perceived Risks Related to Import of Energy



LNG = liquefied natural gas.

Source: Survey results.

terminals for LNG. The natural gas sector is at a nascent stage of development in most countries.

There is much less consensus about the risks related to coal imports. In case of price volatility, 45% of the respondents considered it to be a high-impact risk, versus 32% who called it low impact. As to the risk of importing in bulk from a single supplier, 30% predicted a low impact, versus 38% for a high impact. These results are quite different from those for oil, perhaps partly because imported coal's share in total consumption is lower and because the countries from which coal is imported (Indonesia, South Africa, Australia) are comparatively more stable than the countries that export oil to the region.

The survey makes it clear that the growing energy shortages in the region and the consequent increase in energy import dependency are major concerns for the key decision makers. It is also clear that the preoccupation with fossil fuels remains strong and confidence in alternatives is weak. At the same time, there is a growing nervousness about price volatility and the adequacy of transmission and distribution networks. Given that combination, there is an opportunity for alternative renewable energy forms.

Conclusions

The DAP region faces a number of energy security challenges. Primary among these is ensuring access to modern energy for the entire population. This is crucial for sustained development. Given the role energy provisioning has in alleviating poverty, it is much desired to have the region's energy consumption increase.

While meeting the increased energy demand, it is imperative that the economies in the region adopt modern and cleaner sources of energy. The current commercial energy mix is dominated by fossil fuels, and this dominance is expected to continue. It is essential to minimize the harmful effects on the environment, especially in terms of additional GHG emissions, by adopting energy-efficient technologies. Climate change is closely linked to energy security, and they need to be addressed together.

Increasing the use of renewable energy resources and promoting energy efficiency are two broad interventions that have such a dual purpose. A number of policy and regulatory instruments are available to policy makers for promoting renewable energy and energy efficiency. The subsequent chapter discusses some of these interventions that have been implemented in the region.

CHAPTER 4

Responses to energy security challenges

The countries of developing Asia and the Pacific (DAP) are grappling with a range of energy security concerns. The different dimensions to energy security—external (geopolitical), internal (operations and investment), and temporal (short and long term)—necessitate a multidimensional policy approach to protect the region against energy system disruptions.

In broad terms, the responses to address energy security concerns can be grouped into two categories: one that aims at ensuring uninterrupted fossil fuel supply and the other that directs energy infrastructure toward a more efficient and diversified energy system based on promotion of renewable energy and energy efficiency. The second of these categories aligns well with the responses needed for addressing the climate change problem. However, the specific policies and programs to implement this strategy, and their success rates, vary across countries depending upon energy resource endowments, as well as technological and institutional capabilities.

Fossil fuel–driven response

The region's addiction to fossil energy is reflected in a preoccupation with securing these fuels despite the widely held conviction that their consumption must be reduced to avoid the catastrophic impacts of climate change.

Building strategic reserves

Given their high dependence on imported oil and their vulnerability to supply disruptions, select countries in the DAP region have been actively pursuing the creation of strategic stockpiles. The People's Republic of China (PRC) has already four strategic reserves of 800 million barrel capacity operational and is now planning to construct eight more.[29] These are government-controlled strategic reserve complemented by mandated commercial reserves. In India, the development of a strategic crude oil reserve has begun and is expected to be pegged at a relatively modest 40 million barrels. The Republic of Korea has a reported reserve of 43 million barrels. Among the Association of Southeast Asian Nations (ASEAN), Thailand recently increased its strategic reserve from 60 days to 70 days of consumption. Singapore has an estimated storage capacity of 32 million barrels of crude oil, with an additional 65 million barrels of oil products. The Philippines has begun plans to build a national petroleum strategic reserve of 30 million barrels by 2010.

However, at best, this approach can protect against import supply or price disruptions ranging from a few days to a few months.

Equity investment abroad

Another approach is having an equity stake in energy assets (coal mines, oil and gas fields, uranium mines, etc.) in a foreign country. Often, the driver for assets abroad is said to be commercial in nature, but equity investment abroad may also lead to diversification of supply sources and provide an entry point to the country to build strategic relations with the host country.

Between 1995 and 2006, Chinese National Oil Companies invested $27 billion in oil equity abroad to address energy security concerns (Paik et al. 2007). The Indian company OVL has been acquiring equity assets abroad, and in 2005–2006 acquired nine oil and gas assets in seven countries and increased its oil and gas reserves from 198 million Mtoe in the previous year to 206 million Mtoe.[30] Acquisition of equity abroad is not restricted to the oil and gas sector. A similar trend has been observed in the coal sector, and more recently, there has been talk of acquiring uranium mines.

Critics, who doubt that these investments will stabilize supplies, believe that this approach, at best, can be viewed as a price-hedging measure.

Exploration for fossil fuels

Many countries in the region that have significant fossil fuel endowments have focused on finding new reserves and increasing domestic production. Indonesia, for example, is pushing for more exploration for fossil fuels. India, to improve exploration of its sedimentary basins and increase domestic availability of crude oil and gas, launched the New Exploration Licensing Policy in 1997, providing a level playing field to all the players for award of exploration acreages. The response from

29 peakenergy.blogspot.com/.../china-to-construct-8-strategic-oil.html

30 OVL, a wholly owned subsidiary of the Oil and Natural Gas Corporation (ONGC) Limited, has been designated as the Indian nodal agency for acquiring oil and gas equity abroad for enhancing India's oil security (www.ongcvidesh.com/corp_profile.asp). Reserve data are from the OVL Annual Report 2005–2006.

both public and private sector companies has been encouraging.

It is important to note that such policies have been implemented only by countries with fossil fuel endowments or the ability to invest in strategic reserves and equity abroad. Smaller nations, particularly the Pacific DMCs, have to rely on other countries, within or outside the region, for a substantial part of their energy needs.

Reducing dependence on fossil fuels

Dwindling fossil fuel reserves and the volatility in international prices make reducing dependence on those fuels a sensible strategy. Renewable energy and energy efficiency are, thus, emerging as increasingly significant components of energy security strategy. Renewable sources provide an alternative and cleaner source of power, and improved efficiency means that not as much energy is needed. A strategy combining the two can reduce fossil fuel requirements substantially.

Promotion of renewable energy

The region's countries are promoting renewable energy down three main pathways that are mutually reinforcing: rural electrification, diversification of the energy mix, and reducing dependence on imported oil.

Rural Electrification

One challenge that rural electrification programs face is the high cost of conventional grid electricity supply due to hefty investment requirements, as well as associated transmission and distribution losses. Also, in some cases, it is physically impossible to extend the grid. In these situations, providing electricity through distributed generation based on renewable energy has been preferred.

Countries with explicit mandates for renewable energy for rural electrification include Bangladesh, Cambodia, PRC, Fiji Islands, India, Indonesia, the Lao PDR, Nepal, Philippines, Sri Lanka, Thailand, and Viet Nam. The particular source or technology promoted depends on the natural resource available. Indonesia, for example, allocated $75 million, in 2006, for rural electrification using micro-hydro, wind, and solar PV power, channeled through local governments. Sri Lanka set a target of providing electricity to 85% of the population by directly subsidizing rural solar home systems.

More than 110,000 households are solar-powered. Thailand electrified 200,000 off-grid households with solar home systems during 2003–2006, essentially completing 100% electrification nationwide. Nepal completed a rural electrification program for some 20,000 households with 170 micro-hydropower projects (REN21 2008). In Cambodia, the National Policy for Rural Electrification emphasizes the use of renewable energy (Sat Samy and Touch Sovanna 2005). The Philippines targets full rural village electrification by 2009, including renewable energy explicitly in that strategy. The Lao PDR Government's Power Sector Policy promotes renewable energy as a way to maintain and expand electricity for rural areas, increasing energy sufficiency and security and creating environmental sustainability, with a focus on hydro and solar power for homes. The Fiji Islands has set an ambitious target of 100% renewable energy, propelled by its poor fossil fuel endowments and the technological potential of renewable energy production to meet its energy needs.[31]

[31] *Renewables 2007 Global Status Report*.

Nepal, which is richly endowed in biomass, has a Biogas Support Program under which the Government of Nepal provides a 75% subsidy to family-scale biogas plants. Under the program, 60 private biogas companies have increased their technical and market capabilities, 100 microcredit organizations have provided loans, quality standards have been adopted, and a permanent market facilitation organization has been created. The program has greatly impacted households: a decline in workload for women and girls (3 hours per day per household), annual savings of kerosene (25 liters per household), and annual savings of fuelwood and agricultural waste (3 tons per household).

Diversification of the energy mix

Diversification of the energy mix is high on the energy security agenda of many countries. For instance, Indonesia's renewable energy program, particularly the biofuels effort (Box 4.1), is driven by its need to diversify its fuels as the consumption and price of oil go up. Under its 2006 Presidential Regulation No. 5, the country aims to diversify its energy from the current mix—oil 42%, coal 35%, gas 21%, and renewable energy 2%—to a more balanced combination of oil 20%, coal 33%, gas 30%, and renewable energy 17% by 2025.

India is using renewable energy to provide decentralized power generation to enhance access to electricity in rural and urban areas. By 2032, the country hopes to have 15% of its power capacity based on renewable energy, 10% of oil use substituted by biofuels and synthetic fuels, and enhanced use of solar hot water. The potential for renewable energy in the country, particularly of solar energy, provides confidence that these targets can be met. The potential to reduce greenhouse gas (GHG) emissions has also propelled India to focus on solar energy under its National Action Plan on Climate Change.

The PRC is taking a similar approach. In January 2006, the PRC enacted its Renewable Energy Law to boost renewable energy capacity to 15% by 2020 and committed to invest $180 billion in renewable energy over this period. Its Action Plan on Climate Change gives prominence to renewable energy. The government provides various incentives, such as subsidies for renewable-energy prices and lower tax rates. The economically feasible hydropower potential is about 40,000 megawatts (MW), compared with 17,000 MW that have been developed. Wind power potential is 25,000 MW on-shore and 75,000 MW off-shore, but the total installed capacity was only 1,200 MW in 2008. Biomass energy is widely used in the rural areas of the PRC in the form of biogas digesters and for cooking purposes, although data are not easily available. Biomass use is encouraged by the government. In the renewable energy planning, installed capacity of biomass power generation is targeted to reach 5,500 MW by 2010 and 30,000 MW by 2020—almost 10 times as much as it is today.

Thailand's efforts are geared toward achieving diversification mainly through increasing private investments in energy supply sectors (Box 4.2). Viet Nam, under its strategy of National Energy Development, aims to diversify into renewable energy resources, utilize them in remote areas, and increase the share of renewable energy to about 3% of total commercial primary energy in 2010, 5% by 2020, and 11% by 2050.[32] Malaysia has

[32] Presentation on Country Report: Energy and Climate Change in Viet Nam, Workshop on Energy and Climate Change (organized by ADB), 26–27 March 2009.

set a renewable energy target of 10% of the total electricity generation mix by 2010 as a part of its New Five-Fuel Diversification Strategy, adopted in 2001. Before this plan, in a similar effort to diversify the energy mix, the country had a Four Fuel Strategy that aimed to replace oil with natural gas. Oil consumption for power generation in Malaysia has come down as a result—from more than 80% in 1983 to 2% in 2008.[33]

Only the major energy-consuming countries of the region have an explicitly stated strategy of using renewable energy for diversification. The promotion of renewable energy in most of the countries, not including India and the PRC, is primarily to address energy security; cutting harmful emissions is a side benefit.

Reducing oil import dependency

The transport sector consumes the lion's share of the region's petroleum supply. It is increasingly recognized that the future growth of the sector should focus on reducing dependence on fossil energy. Countries worldwide have turned to biofuels as an alternative; in the DAP region, countries, such as Indonesia and Malaysia, have taken the lead. Bio-ethanol and biodiesel are two biofuels being used across the region. Thailand provides incentives to consumers and producers for the manufacture and purchase of biofuels. In September 2005, the government relaxed import duties for relevant machinery and granted corporate tax exemptions for new investments, which are to last for 8 years. Other incentives for ethanol include an excise tax waiver for ethanol blended into gasoline.

The Philippines has set a target of introducing B1 and E10 by 2010.[34] India's draft national policy on biofuels has a target of 20% blending for biodiesel and bio-ethanol by 2017. Blends of 10% bio-ethanol have been mandatory in select states since October 2008. Indonesia is a key player in the field of biofuels in the region (Box 4.1).

Measures to promote renewable energy

Governments across the region have taken a number of steps to promote renewable energy technologies. These include setting national renewable energy targets; renewable portfolio standards; introduction of feed-in tariffs (FITs); and fiscal measures, such as direct capital investment subsidies or rebates, tax incentives and credits, sales tax and value-added tax (VAT) exemptions, direct production payments or tax credits (i.e., per KWh), green certificates, net metering, and direct public investment or financing. Table 4.1 sums up the various policies that have been adopted by select member countries to encourage renewable energy technologies.

The most common steps taken are setting renewable energy targets, establishing FITs, and creating renewable purchase obligations (RPOs). The role of public investment in supporting renewable energy is also significant. Setting targets is popular as a way to demonstrate the country's support for renewable energy (UNESCAP 2008). Table 4.2 summarizes some of the major national targets.

FITs and RPOs are legislative interventions. The tariffs, targeted at the demand side, are to

[33] A brief presentation on The Electricity Malaysia Supply Industry. Available: www.iea.org/Textbase/work/2008/bangkok/malaysia.pdf (accessed on 4 July 2009).

[34] B1 is diesel with 1% biodiesel blending. E10 is a 10% ethanol, 90% gasoline mix.

Box 4.1: Biofuel Program in Indonesia

Biofuel development in Indonesia is a part of Energy Diversification Policy 1981 (amended in 1987, 1999, 1998, and 2003), which aims at reducing high dependence on oil. However, the development of renewable energy resources remains low, primarily because of the heavily subsidized domestic energy prices. The latest biofuels push started when the country went from being a net oil exporter to a net oil importer in 2004. Increasing world oil prices, along with growing concerns about climate change, have further encouraged this effort. In January 2006, the Government of Indonesia issued a framework policy for biofuel development in the form of a Presidential Instructions No.1 and No.10. The umbrella of the instructions is the National Energy Policy issued in the previous year, which aims to achieve at least 5% share of biofuels in the national energy mix by 2025 (from practically zero by 2005).

The focus of Indonesian biofuel policy is on the use of biodiesel and bio-ethanol in the transport sector, bio-kerosene to replace liquid cooking fuel (kerosene), and pure plant oil to replace fuels used in industry and power generation. The biofuel obligation in transportation is a mere 1% for 2009 but is to increase to 15% by 2025. Development of palm oil and *Jatropha curcas* for biodiesel and cassava and sugarcane for bio-ethanol is being pursued. Indonesia and Malaysia are the two leading producers of palm oil in the world (accounting for more than 85% of world supply). Indonesia produced 18 million tons of crude palm oil in 2008, of which 13 million tons were exported. However, to avoid conflict with the food sector, palm oil is being used only temporarily until alternatives are established. Pertamina, a state oil company, is responsible for blending petroleum with biofuels (5%) and is subsidized by the government to ensure that the retail price of the blended fuel does not exceed the retail price of petroleum diesel and gasoline. However, at the current low petroleum prices, this subsidy is not adequate.

Following the presidential instruction, various ministries and regional governments have developed biofuel programs targeting research and pilot demonstration plants for the promotion and commercialization of biofuels. The National Team of Bio-fuel Development has so far established 123 energy–self-sufficient villages. The regional governments are providing financial assistance to encourage farmers to plant jatropha. In 2008, the total area of jatropha plantation reached 150,000 hectares. The Indonesia Bio-fuel Blueprint estimates that the biofuel program needs 3 million hectares by 2015, compared with the 6 million hectares already established in palm oil plantations.

The industry response to the biofuel policy has been very positive. There are 470 stations (up from about 50 in 2006) selling diesel with 5% blending of biofuels (B-5 fuel) and 60 stations selling E-5 fuel (with 5% blending of ethanol). At least six private companies are producing biodiesel in Indonesia with total production capacity of 2.1 million tons per year, and at least four domestic bio-ethanol producers in the country with total production capacity of 190,000 kilo liters per year. The biofuel producers are responding not only to the domestic market (the government push to biofuel) but also to the international market. Besides large private companies involved in biofuel production, several small and medium-sized enterprises are entering the biofuel industry, especially biodiesel equipment manufacturing, capitalizing on the funding available from government demonstration projects.

The public response has also been encouraging, even though the consumption of biofuel has grown slowly.

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Box 4.1: continued

Currently, about 950,000 kilo liters (kl) of biodiesel blend and 135,000 kl of bio-ethanol blend are consumed annually. This compares with consumption of petroleum diesel (28 million kl) and gasoline (17 million kl). The number of biofuel outlets is still limited, and there is no economic incentive to use biofuels. The environmental benefits of using biofuels do not seem to be playing a part in consumers' fuel choices.

Lessons: The rapid biofuel development in Indonesia is a result of a comprehensive approach helped by the international oil price situation. Unlike previous government policies (which were part of policies for renewable energy in general), the current biofuel policy specifically addresses biofuels and clearly requires specific ministries to take action concerning biofuel development while being supported by follow-up regulations and government programs. The major response to the biofuel policy has come from the producers, with only marginal enthusiasm from consumers, especially in the transport sector. The retail price of the blended fuel is equal to the price of petroleum. The major challenge for biofuels at present is the low petroleum fuel price (since late-2008). To maintain the momentum of biofuel development, the government issued a regulation that makes biofuel use mandatory in transportation, industry, and power generation. This has helped secure a domestic market for the biofuel industry.

Source: ASEAN Regional Overview.

Table 4.1: Renewable Energy Promotion Policies

Country	Feed-in Tariffs	Renewable Portfolio Standards	Capital Subsidies, Grants, or Rebates	Investment or Other Tax Credits	Sales Tax, Energy Tax, Excise Tax, or Value-Added Tax Reduction	Energy Production Payments or Tax Credits	Net Metering	Public Investment, Loans, or Financing	Public Competitive Bidding
Cambodia			X						
People's Republic of China	X		X	X	X			X	X
India	(*)	(*)	X	X	X	X	(*)	X	X
Indonesia	X								
Philippines			X	X	X			X	
Sri Lanka	X								
Thailand	X		X				X	X	

(*) Some states/provinces within these countries have state/province-level policies, but there is no national-level policy. Only enacted policies are included in the table. However, for some policies shown, implementing regulations may not yet be developed or effective leading to lack of implementation or impacts.

Source: Adapted from REN21. 2008. *Renewables 2007 Global Status Report*. Paris: REN21 Secretariat and Washington: Worldwatch Institute.

Table 4.2: National Targets for Increasing Usage of Renewable Energy Resources

Country	Target
Bangladesh	5% of demand met by clean energy by 2010 and 10% by 2020[a]
People's Republic of China	10% of electric power capacity and 5% of primary energy by 2010; 15% of primary energy by 2020[b]
Fiji Islands	Fiji Electricity Authority to become a renewable energy utility by 2013
India	10% of added electric power capacity during the period 2003–2012; full use of co-generation in the sugar industry;15% of power capacity; 10% of oil consumption
Indonesia	More than 5% biofuels; more than 10% other new and renewable energy by 2010[c]
Japan	1.35% of total electricity by 2010; 3% of total energy consumption by 2010
Republic of Korea	5% of total primary energy by 2011
Malaysia	Add 350-MW renewable energy generation capacity by 2010[d]
Pakistan	5% of power generation by 2030
Philippines	100% increase in renewable energy power capacity by 2011
Singapore	50,000-M^2 solar thermal systems by 2012
Sri Lanka	7.5% of grid electricity using renewable energy by 2010; 10% by 2015
Thailand	8% of total primary energy by 2011
Viet Nam	2% of total primary energy by 2010 and 3% by 2020

[a] National energy policy, August 2005.

[b] Long and Mid-Term Renewable Energy Plan, State Council. www.ccchina.gov.cn/WebSite/CCChina/ UpFile/2007/20079583745145.pdf

[c] Presidential Regulation No. 5/2006 on National Energy Policy, January 2006.

[d] Malaysia, Energy Commission. Ninth Malaysian Plan on Energy (available online at www.st.gov.my/images/stories/upload/Chapter19_ Energy4.pdf).

Source: ESCAP (2008).

Box 4.2: Small Power Producer and Very Small Power Producer Scheme, Thailand

The Small Power Producer Scheme was introduced in 1992 to promote private-sector participation in renewable energy–based electricity generation. Each facility is allowed to sell excess power to the Electricity Generating Authority of Thailand at a price determined from the agency's avoided cost. The size of each producer was limited to 60 megawatts (MW), which was subsequently increased to 90 MW.

The scheme has had a success in increasing private participation, but its progress has been gradual. In 1997, after an economic crisis led to an excess capacity in the power system, the scheme was temporarily suspended. It resumed in 2004, but remained ineffective until 2006. The small producers faced problems from electric utilities in connecting to the grid despite the relatively clear interconnection requirements. Except for bagasse, rice husk, and woodchips, there was little use of other types of renewable energy because of the unattractive purchase price, costly interconnection requirements, and technological risk. To reduce some of these costs, the government in 2001 introduced the Very Small Power Producers Scheme, allowing producers of less than 1 MW to sell to the grid.

In 2007, a number of changes were introduced in the criteria for qualifying, the calculation of the avoided cost, and the interconnection requirements, as a result of which a substantial increase has been seen in the number of applications for setting up small co-generation facilities and renewable energy projects. An incentive in terms of an additional tariff was given to small and very small producers. This additional premium was termed as the "adder." It was determined through a competitive bidding system, which resulted in the approval of 14 projects with average "adder" of 0.18 baht per kilowatt-hour. The power agency's avoided cost calculation principles were changed from the cost of avoiding a gas-fired combined cycle plant to avoided cost of imported coal-based power generation. The Very Small Power Producer program was amended to include co-generation facilities and sale from a facility of up to 10 MW and sale of 10–90 MW included under the Small Power Producer program. Financial incentives through soft loans and investment subsidies were expanded in amount and coverage for selected types of renewable energy projects.

As of April 2008, there were 61 small power producer projects supplying 2,286 MW of electricity to the grid, with a total generating capacity of 3,877 MW. Among these, 26 were co-generation projects using fossil fuel, mainly natural gas, with total sales of 1,670 MW. The remaining 615 MW are supplied from 35 nonconventional energy projects and projects using mixtures of fossil fuels and nonconventional energy, mostly bagasse, rice husks, and woodchips. There are also 100 very small power producer projects supplying 215 MW to the power system, with total installed capacity of 540 MW. Here again, most of these projects are bagasse, rice husk, and other biomass. By the end of June 2008, 442 very small producers submitted their applications to sell 1,858 MW of power into the grid. These include producers already commissioned before the new regulation, and projects reclassified from the small power program. However, there are about 300 new projects with total sales of about 1,500 MW as the original projects are fairly small with total sales of only about 200 MW.

The program, however, faces some barriers as well. Adequate availability of biomass at a reasonable

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Box 4.2: continued

price is a major concern for the projects using biomass as fuel. In addition, the lack of public acceptance of the incinerator technology because of the foul smell of waste and its health impacts also creates a hurdle for biomass projects. Procedural complexities involved in approval for projects, along with the complex process of Clean Development Mechanism approval, increase the transaction costs. Compared with their high investment costs, the premium on energy from solar and wind projects is still considered to be inadequate for ensuring their financial viability. The lack of locally developed commercial technologies and the high cost of imported technologies render the available financial support and incentives inadequate for viability.

Source: Regional Overview for the ASEAN region.

encourage private investors by making renewable energy more attractive. The purchase obligations, aimed at the supply side, support a minimum percentage of electricity generation from renewable energy sources. Chapter 7 discusses them in detail.

India was one of the first countries in the region to establish FITs. In early 2006, it announced a new tariff policy to promote renewable power generation, including quotas, preferential tariffs, and guidelines for pricing "non-firm" power. Pakistan has initiated limited tariffs for wind power development, waived import duties for wind turbines, and is considering a broader renewable energy promotion law. In Singapore, guaranteed prices have been given to energy recovered from biomass in municipal waste. The electricity generated by this municipal waste is fed into the electricity grid. Indonesia has introduced FITs for small-scale (1–10 MW) renewable energy plants owned by the private sector.[35] Thailand also has been able to channel private investment into renewable energy through the introduction of FITs. Consequently, the number of "very small power producers" using biomass and other renewable energy resources has increased remarkably. The reclassification of "very small" (from less than 1 MW capacity to less than 10 MW capacity for the purpose of using the tariffs) has contributed to the success, along with the technical assistance and advice provided to the small and medium-sized enterprises and the country's political stability.

RPOs are either in the form of umbrella targets covering all technologies or specify different targets for different technologies. In India, the Electricity Act 2003 lays down the legislative framework for introduction of RPOs. The law empowers the state electricity regulators (state-level independent electricity regulators) to promote renewable energy and specify to the distribution licensee a percentage of the total electricity consumption to be purchased from renewable energy sources. Currently, different states in India are in the process of issuing tariff orders for renewable-energy-based electricity generation and specifying shares for power from renewable energy in accordance with the provisions of the Electricity Act 2003 (Appendix 3.1).

[35] ASEAN Regional Overview.

Apart from FITs and RPOs, many countries have enacted laws to promote renewable energy. For instance, the Renewable Energy Law (2006) of the PRC aims to boost renewable energy capacity to 15% by 2020 and outlines a commitment to invest $180 billion in renewable energy over this period. The law also requires grid operators to purchase energy from renewable energy producers and offer financial incentives to foster renewable energy development, including discounted lending and a range of tax breaks. The electricity grid in the country is obligated to purchase all the electricity generated by approved renewable energy facilities located in its service area at a price set by the National Development and Reform Commission, a regulatory department of the State Council. The law includes other details related to the purchase and use of solar photovoltaic, solar water heating, and renewable energy fuels and also specific penalties for noncompliance (Liming 2009).

In most countries in the region, legislative measures to promote renewable energy are part of broader legislation covering other sources of energy. A list of legislative measures, along with their salient features, is provided in Appendix 3.2.

The most innovative initiative to promote renewable energy—one that can be emulated considering the growing urbanization and need for housing—is the introduction of net metering at the consumer level. With net metering, the consumer is able to supply excess electricity generated at his level into the grid and, in return, either earns revenue for it or has his net consumption reduced. In India, this has been tried for the first time in the residential township of New Town in Kolkata, West Bengal. This residential colony also has another key feature—all the houses and common facilities in the residential are "green" (Box 4.3).

The countries in the region have taken many steps to promote energy efficiency. Most efforts have been aimed at more efficient use of energy because consumption is growing or needs to grow quickly for the countries to meet their development objectives. The underlying concern is continued dependence on fossil fuels, the supply of which is dwindling.

Measures to promote energy efficiency

Among the measures adopted to promote energy efficiency, the most common are efficiency standards for various sectors, energy conservation laws, energy efficiency promotional programs (including an awareness), and financial support and incentives to promote private sector participation in research and development, as well as deployment of energy-efficient technologies. This multipronged, multistakeholder approach bodes well for the success of energy efficiency interventions.

Energy Conservation Laws

Many countries have opted for legislative action, laying the institutional structure for undertaking energy efficiency initiatives and facilitating the establishment of standards and labeling. In India, the Energy Conservation Act 2001 mandates the setting up of the Bureau of Energy Efficiency for spearheading the efficiency efforts (Box 4.4).[36] The much-appreciated energy efficiency program of the PRC is also backed by legislative provisions (Box 4.6).

[36] The Government of India set up the Bureau of Energy Efficiency on 1 March 2002. Its mission is to assist in developing policies and strategies with a thrust on self-regulation and market principles, within the overall framework of the Energy Conservation Act 2001, with the primary objective of reducing the energy intensity of the Indian economy. www.bee-india.nic.in

Box 4.3: Solar Housing Complex (Rabirashmi Abasan) in Kolkata, India

The West Bengal Renewable Energy Development Agency, with partial support from the Ministry of New and Renewable Energy, the Government of India, and state agencies, constructed India's first solar housing complex in the New Town area of Kolkata city in the eastern state of West Bengal, composed of 25 bungalows, a community hall, and a swimming pool. The key principles of green building design, such as site planning, energy and water efficiency, use of appropriate materials, and good indoor environmental quality, have been integrated in these houses. The complex, a unique model in India, has been developed on the concept of "zero use of conventional electricity."

It is designed for maximum use of solar energy (solar street lights; solar photovoltaic [SPV]-operated garden lights, name plates, and signage; solar chimney; solar water heaters; grid-connected rooftop SPV), higher energy efficiency through light-emitting diodes/compact fluorescent lamp lighting, energy-efficient electric appliances, gravity-based sewerage system to reduce sewerage pumping energy, maximum access to solar and wind to individual houses to reduce heat island effect, and high water efficiency through better groundwater storage through pervious paving and hydro-pneumatic water supply system with 40% less energy consumption. Each bungalow has a building-integrated SPV on the rooftop, made up of an SPV panel with a capacity of 2 kilowatts with grid connectivity, metering, and stand-alone facility for 4 hours' operation. Household gadgets and electric installations can run on solar power during the day. After sunset, with the generation dwindling, the system automatically switches to conventional electricity. The SPV system also has a built-in power back-up system, which stores about 3 kilowatts of power. So, in case of an emergency at night, one can switch to the back-up to use stored power. Each house also has an evacuated tube collectors solar water heater of 130 lpd capacity. The small water tank in the solar heater has a thermal insulation that provides round-the-clock hot water supply. The complex also has a swimming pool heated by solar energy and battery-operated vehicles for intra-site transportation.

The houses are priced between $86,000 and $90,000 for a built-up space of 1,760 square feet and an open area of 860 square feet. The land area for each house is 2,150 square feet. Each owner has rights to the land and generates his or her own power for domestic use, as well as for feeding the grid. With net metering, the users export electricity to the grid and thus consume less and save money. The renewable energy agency is in charge of general maintenance for the first year, and each installation—such as the heater, inverter, and solar lights—comes with a 5-year guarantee.

Implementation and policy. This is the first building-integrated solar SPV project in India using the net metering system of transferring power to the grid. It was implemented under the policy guidelines of the West Bengal Electricity Regulatory Commission and used a public–private partnership model. The house owners and the government contributed to the funding for the township; the homeowners paid 50% of the price of the house in advance.

Lessons. The solar housing complex is a pilot township. One of the biggest hindrances to up-scaling it is the lack of incentives for developers to undertake the initial investment. There is also a need

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Box 4.3: continued

for more research and development on integration of renewable energy for multistory residential apartments. Favorable financial mechanisms (such as a 1% interest rate subsidy and capital subsidy) are needed, along with simple procedures to access them. And to promote renewable-energy-based electricity generation, subsidies in the existing price of electricity need to be corrected. Introduction of net metering contributed to the success of this model. Here the role of the regulatory bodies in promoting such housing schemes becomes paramount.

Source: Discussions with residents of the complex and the architecture firm.

Box 4.4: Energy Conservation Act, 2001 of India

India introduced the Energy Conservation Act, 2001 in October 2001 for promoting energy efficiency in all sectors. The law gives the government (both central and state) power to enact regulations; establish energy standards for buildings, equipment, and industrial processes; and classify any group of energy users as "designated consumers" and any type equipment or appliances as "specified." It will be mandatory for designated consumers and specified equipment manufacturers to comply with the energy standards announced by the government. The government can also require these entities to undergo periodic energy audits carried out by certified inspectors. The law enables the government to make mandatory the display of energy labels (providing energy consumption information) on specified equipment. It also calls for a Central Energy Conservation Fund, which would pay for implementing the law, as well as for information dissemination, training, and steps to encourage the preferential use of energy-efficient equipment and appliances. The law called for the creation of the Bureau of Energy Efficiency to provide direction for national energy conservation activities and to coordinate with various stakeholders on the efficient use of energy.

The enactment of such legislative measures indicates the urgency governments feel about saving energy to ensure energy security. Theoretically, energy conservation make wasting energy punishable and make governments responsible for taking all possible steps to support energy efficiency. Practically, however, the success of these interventions depends upon the abilities of different government departments and ministries, as well as industry and consumers, to make appropriate choices (about policy and institutional tools, investment, technology, and consumption), along with availability of financial resources necessary to implement these choices. This probably explains why countries, such as the PRC and India, have much more ambitious and comprehensive policies and programs than smaller countries. And most of the initiatives in the Pacific DMCs are supported by developed countries (Box 4.5).

Box 4.5: Energy Policy Making in the Pacific Developing Member Countries

For a long time not many countries among the Pacific developing member countries (DMCs) had policies, mechanisms, or institutions that work toward increasing energy access. Regional agencies (the Council of Regional Organizations of the Pacific and the Pacific Island Forum Secretariat) have actively promoted the concept of national energy policies for about 20 years, and today, the majority of the Pacific DMCs have formally adopted national energy policies. A decade ago, several countries (including Tuvalu and Kiribati) accepted a generic energy policy that was developed externally, but they essentially ignored its application. The Pacific Islands Energy Policy and Strategic Action Planning project, supported by the Secretariat of the Pacific Applied Geoscience Commission, the United Nations Development Programme, and the Government of Denmark, has shifted the focus from a generic policy to working with countries on policies specifically designed to fit their needs. As a result of this assistance, national energy policies have been prepared and endorsed at the Cabinet level in Tuvalu, Fiji Islands, Samoa, Marshall Islands, Vanuatu, and Solomon Islands.

The following issues are relevant to the preparation of national energy policies and strategies in Pacific DMCs:

- Policy development is a genuinely sovereign activity in which where international and regional agencies can only assist. There is clear tension between country ownership and the role a regional and external project can play.
- Development of effective national policies requires strong institutions and government commitment, which is not always in place. Government energy administrations have inadequate resource and little power to influence policies. In most Pacific DMCs, energy policy decisions, such as pricing, petroleum procurement, power system expansion planning, and allocation of internal or donor budgets, are still undertaken by other entities (such as power utilities and international oil companies), and often, energy offices are not even consulted.
- Energy markets are changing rapidly, and policies risk being outdated.
- Pacific DMCs are mostly consensual societies where inclusiveness and consultation are highly valued, however time-consuming the process may be.
- A multitude of activities in the area of energy overlap in the Pacific DMCs, raising the risk of conflicting or inconsistent advice. Objectives and approaches of different regional, international, and bilateral organizations are not fully compatible or well matched.

Source: Pacific Island States Regional Overview.

Efficiency standards and labeling

An effective way to encourage energy efficiency is by setting standards and labeling manufactured products. This route, which could be based on either mandatory or voluntary standards, sets clear, quantifiable, and verifiable requirements on the producers to adopt more efficient production processes. Among the most comprehensive and successful programs for efficiency standards and labeling is Japan’s Top Runner Program (Chapter 7).

The Philippines introduced mandatory standards for air conditioners, and year average efficiency increased by 25% within a year (ESCAP 2008).

Box 4.6: The People's Republic of China's Energy Efficiency Program

The People's Republic of China places a great emphasis on energy conservation and energy efficiency, along with integrating environmental priorities into energy policy. This policy intends to maintain domestic primary energy resources as the main source supply while enhancing the role of the domestic market. It also emphasizes diversification of energy sources by increasing the use of hydroelectricity, renewable and nuclear energy, and natural gas in order to reduce its reliance on coal. The National Development and Reform Commission launched the Medium and Long-Term Energy Conservation Plan in 2004. Since then, the government has instituted a wide variety of measures to implement the plan.

The overriding goal is to reduce energy intensity by 20% between 2005 and 2010 and continue this decline at the same rate until 2020. The plan identifies projects that should yield significant savings, such as retrofitting industrial boilers and substituting for oil in certain sectors. It also recognizes the need to formulate a more coherent approach to transportation policy and to enforce standards in the construction industry. Many of these targets, objectives, and policies are also part of the Five-Year Plan for Energy Development and the China National Climate Change Program, both published in 2007.

Most important is that the plan recognizes the need for structural changes in the economy, along with adequate economic incentives to encourage energy-efficient behavior. Accordingly, the Energy Conservation Law of 1997 was revised in 2007 to put a great emphasis on the performance of the government and require public institutions to manage their own energy use more effectively and set an example for the rest of the country. The legal liability and penalties were also increased. These initiatives have been backed up by a significant boost in financial support. Investment in energy efficiency by the central government was set to rise to $3.12 billion in 2007, which is significantly higher than the previous year's investment.

Beginning in 2005, the government brought together experts and scholars to compose a plan for implementing 10 key energy-saving projects during the 11th Five-Year Plan Period (2006–2010). It was estimated that implementing these projects would save 0.24 billion tons of standard coal equivalent (excluding petroleum substitutes). This would achieve 40% of the goal for reducing energy consumption per unit GDP at the same period and play an important role in realizing the goal of reducing the emission of the main pollutants (Appendix 3.3).

As far as the effectiveness of these interventions is concerned, in 2006, total energy demand rose by 8%, somewhat below the 10% rise of the previous year and well below the levels of 15% seen in 2003 and 2004. The overall energy intensity rose by 0.8% in the first half of 2006, then fell 1.23% as the new policies began to be implemented. Privately owned heavy industries noted a better performance than state-owned industries. For instance, efficiency improvements have been the greatest in provinces with private-sector steelmakers, such as Hebei and Jiangsu, rather than those with large state-owned steelmakers, such as Hubei, Beijing, and Shanghai. During 2007, the decline in energy intensity for the whole country was reportedly 3.27%. In the first half of 2008, the decline was reportedly 2.88%.

The primary reason behind the potential success of the program is the government's decision to focus its efforts on those sectors that can yield the greatest short-term impact, such as heavy industry, and on applying those instruments that are likely to be most effective, in this case, old fashioned command-and-control using targets and penalties.

Source: Andrews-Speed, Philip. 2009. 'China's Ongoing Energy Efficiency Drive: Origins, Progress and Prospects'. *Energy Policy*. Vol. 37. pp. 1331–1344.

India's Bureau of Energy Efficiency launched a comprehensive efficiency labeling program for home appliances in 2006, borrowing the concept of star ratings from other countries. At present, star ratings have been developed for transformers, pump sets, household refrigerators (frost-free and direct cooling), room air conditioners, and fluorescent tube lights, based on their energy performance, with the active involvement of all stakeholders. The success of this program is encouraging as the number of efficient products available in the market has increased significantly. For instance, the number of refrigerators labeled with four stars (of a maximum of five) rose from 194 models in December 2007 to 308 models in June 2008. The number of three-star air conditioners increased from 19 models to 51 models.[37]

Energy efficiency policies and programs

Unlike standards and labeling, which target sectors, countries have also opted for economy-wide interventions in the form of policies and programs. The most important aspect of this route is setting economy-wide targets for reducing energy intensity. For instance, Singapore's energy efficiency program aims at a 25% improvement in carbon intensity [38] between 1990 and 2012, along with an expected reduction up to 190,000 tons of carbon dioxide emissions by 2012. Perhaps the most ambitious programs are developed by the PRC, setting a target of reducing energy intensity by 20% between 2005 and 2010 (Box 4.6).

A common feature of these policies and programs is the effort to establish clearly the roles of the public sector and the private sector in achieving the targets. This leads to incentives and financial support measures. For instance, Thailand has a pilot project giving tax breaks to owners of energy-efficient buildings and factories. The owners can claim tax benefits of up to $0.06 million for 100% of the energy saved by their energy-efficiency investment. Thailand also gives cost-based tax incentives whereby companies investing in energy-efficiency improvements (first $1.47 million) can apply for a 25% tax break for 5 years.

Thailand has also introduced a revolving fund program for making loans to energy-efficiency and renewable energy projects at a fixed low interest (less than 4%) for up to 7 years with a ceiling of $1.47 million.[39] Eligible investment expenses are the costs of equipment and installation, consultation, costs of civil works, piping, or necessary components for the projects, as well as other associated costs, such as removal of existing equipment, transportation, and taxes. The money comes from an energy service company (ESCO) fund contributed to by 11 commercial banks. Another financing mechanism adopted by Thailand

[37] Presentation by Saurabh Kumar, secretary, Bureau of Energy Efficiency, Ministry of Power, Government of India. Promoting RE and EE: The Government Perspective. February 2009.

[38] Similar to energy intensity. Amount of carbon burned in per unit of economic activity measured in terms of GDP.

[39] Department of Alternative Energy Development and Efficiency by Boonrod Sajjakulnukit (2008). Presentation on Thailand's Experience with Its Energy Conservation Fund and EE Revolving Fund for Asia Clean Energy Forum, Philippines; 3–5 June 2008. Available: www.adb.org/Documents/events/2008/ACEF/Session21-Boonrod.pdf

is the ESCO Venture Capital Fund program.[40] This is a co-investment program (equity investment) between the private sector and investors providing not only financial investment but also other benefits, including equipment leasing, carbon credit trading, technical assistance, and credit guarantee facility. The investment term is for a period of 3–7 years. The money for this program comes from the Energy Conservation Promotion Fund. Examples of the complexities of designing such programs are India's Bachat Lamp Yojna (Box 4.7) and the public–private partnership in the transport sector in the city of Indore (Box 4.8).

Box 4.7: Bachat Lamp Yojna, India

Many initiatives have been undertaken by state governments and electricity distribution companies to replace incandescent bulbs with compact fluorescent lamps (CFLs). They include the Bangalore Electricity Supply Company Electricity Lighting program (2004), the Nashik pilot CFL program of Maharashtra State Electricity Distribution Company Ltd. (2005), and the Efficient Lighting System program by Dakshin Haryana Bijli Vitran Nigam in the Sirsa Circle of Harayana (2007). The first two together resulted in the sale of 8,09,872 CFLs and a peak reduction of 32.70 megawatts (MW)–34.70 MW, along with 49.52 million units (MU)–51.52 MU annual energy savings. Sirsa Circle was the first 100% CFL promotion circle in India. Though a detailed impact in terms of energy savings is not available, the company reported a savings of 9,700 units in one of its feeders (Binola feeder) in 2007 compared with 2006. Learning from these experiences, two new schemes have been recently launched in India: Atal Bijli Bachat Yojna and Bachat Lamp Yojna.

Atal Bijli Bachat

The Atal Bijli Bachat Yojna was launched in November 2008 in the state of Himachal Pradesh for a period of 18 months. Under the scheme, four CFLs, two of 15 watts (W) and two of 20 W, are provided free of cost to about 16 lakh domestic consumers in exchange for four of incandescent bulbs. The power factor of the CFLs distributed is >0.85, and it carries a warranty of 18 months.* The Himachal Pradesh State Electricity Board (the integrated state electricity utility responsible for the implementation of the scheme), gave wide publicity through print media to this program. The state government provided a loan to the utility. As on April 2009, about 86% of the CFLs had been distributed. An energy saving of about 60% in the domestic lighting load is expected, which will translate into an energy saving of about 270 MU per year, or a revenue saving of $18.4 million per year for the utility.

Bachat Lamp Yojna

The Bachat Lamp Yojana is targeted at domestic households where 60-W incandescent bulbs shall be replaced with 11 W–15 W CFLs and 100-W incandescent bulbs shall be replaced with 20 W–25 W CFLs. (Verified replacement is an essential part of monitoring the program.) It targets about 400 million in-use incandescent bulbs to be replaced with CFLs,

continued on next page

[40] UNEP. 2006. Financial Mechanisms for Improving Energy Efficiency in Industry in Asia – A Review of Financial Mechanisms (Draft).

Box 4.7: continued

leading to a reduction of 6,000–10,000 MW of electricity and a reduction of about 24 million tons of CO_2 emissions annually. A maximum of two CFLs will be replaced in each household. Suppliers will provide high-quality CFLs (power factor of 0.85 or more), at a price of 31 cents each. Out of this price, 4 cents per CFL will be used for bringing the fused CFLs to the collection points and 6 cents per CFL for their safe disposal. CFL manufacturers and traders will be responsible for the collection of fused CFLs through buy-back schemes and their disposal. The difference between the actual cost of CFLs and the price at which they will be provided to consumers will be realized through the Clean Development Mechanism (CDM). Smart meters based on Global System for Mobile communications technology have been developed to monitor the electricity savings in each project area as per the approved methodology of the CDM Executive Board. The entire cost of monitoring, including metering, will be borne by the Bureau of Energy Efficiency.

To implement the project, the CFL suppliers and the distribution company have to enter into a tripartite agreement with the Bureau of Energy Efficiency. CFL manufacturers are responsible for providing CFLs to households, collecting and disposing of fused CFLs, securing the initial investment for the cost differential, conducting a pre-project survey to estimate the potential savings, and preparing documentation. The distribution companies are responsible for defining the geographical boundary of the project, preparing the database for the grid-connected residential area, assisting in selection of project sample area, storing replaced incandescent bulbs for independent inspection, and disposal. The Bureau of Energy Efficiency is responsible for coordinating the overall program, monitoring the project areas, disseminating information, and conducting other activities related to the entire CDM process. The first two pilot projects in Vishakapatnam (Andhra Pradesh) and Sonepat and Yamunagar are already under way.

Though this scheme provides a useful framework for recovering the cost through the CDM, implementation would be affected in the near future by the uncertainties surrounding the carbon market. The revenue stream is dependent entirely on the price of carbon credits. The Kyoto mechanism is expected to end in 2012, and any new project initiated under the scheme would require a time lag of 6–9 months before the actual implementation, which decreases the project's viability substantially.

Lessons: A number of pilot schemes in recent years have demonstrated that domestic lighting offers significant potential for energy savings and that replacement of incandescent bulbs with CFLs can lead to a reduction in energy use, as well as peak demand. However, they have failed to convert into large-scale projects, except for Atal Bijli Bachat Yojna. Himachal Pradesh is the only state in the country that has undertaken such large-scale replacement of incandescent bulbs with CFLs.

High initial costs that were considered one major barrier for the penetration of efficient appliances have been addressed very effectively over time. The prices of CFLs offered to the consumers under various schemes have come down drastically. Initial concerns with regard to the power factor and safe disposal of mercury have also been addressed. However, there is a need to ensure timely setup of the mercury recycling plants in the country.

*Load with low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system. In earlier initiatives, CFLs that were distributed had a $>$0.5 power factor.

Source: Bureau of Energy Efficiency document and discussions with distribution companies.

Box 4.8: Public–Private Partnership in Transportation: A Case of Bus Rapid Transit in India

Indore is a fast-growing industrial city in the state of Madhya Pradesh in central India with a population of 1.6 million in 2001. Like any other metropolitan city, Indore faces the challenges of a growing urban population and the resultant increase in transportation demand. To improve mobility, popularize public transit, and reduce dependence on private vehicles, the city started improving its bus services in 2005 and is today cited as a good model.

The project involved road improvements—including creation of a bus corridor—construction of bus stops, purchase of buses, installation of mobile communications systems, and devising of franchise agreements. To bring all this about, three agencies—the Indore Municipal Corporation, Indore Development Authority, and the District Administration—jointly invested in creating a special entity called Indore City Transport Services Ltd. Under the aegis of the new transit entity, these three players structured a public–private partnership model for creating and expanding urban bus services.

The investment was shared between the transit entity, which funded structures, such as bus stops; the private bus operator who bought the vehicles; and providers of services, such as advertising and selling bus passes. Once routes were identified, franchise operators were chosen by competitive bidding. Indore City Transit is now extending the public–private partnership model for operation of 100 luxury taxis, which will be available through a 24-hour call center.

There was no massive survey to estimate the city's overall bus demand. Instead, 18 high-demand routes were chosen based on existing traffic. Once the routes were identified, Indore City Transit tested them and set up bus schedules.

Contracts require every operator to deploy a minimum of two buses on every route. Once they exceed the capacity in terms of passenger kilometers, the number must increase. If the established operator refuses to add buses, someone else is given the opportunity. Deployment is, thus, clearly linked with the demand for service on defined routes. This approach enabled faster implementation of bus service with a shorter planning period.

The new system currently runs 22 routes. As a result of the improved service, operators of tempos and minibuses have been marginalized. They have started operating as feeders for the buses. Indore City Transit is looking at ways to extend its services to less profitable routes by

- planning the systematic integration of the tempo and minibus operators into the system as feeders to the bus service and
- exploring the option of cross-subsidizing service on less commercially attractive routes by working out a negative premium mechanism, with Indore City Transit paying the operator to run the service.

Conclusion

The public–private partnership devised and implemented in Indore is a good model for urban bus system operations. Commitment and involvement of city authorities, agreements with the private sector, performance measurement standards, and usage of modern technologies are all components of enhanced transportation services.

Source: MoUD and WSA (2008).

Incentives and support provisions are essential for promoting energy efficiency. The experts surveyed for this report highly recommended financial incentives that included cheap consumer loans for energy-efficient products, relaxations in loan repayments, tax incentives, exemption from import duties, and rebates on consumption of energy-efficient products. The lack of adequate incentives and financial resources was identified as a major barrier for effective policy intervention by 45%–65% of the respondents.

Creating awareness and moving to a more energy-efficient way of living requires a change in attitude toward consumption patterns and life styles. Probably the most crucial factor that can induce such attitudinal shifts is access to updated information. More than 50% of the respondents in the survey considered lack of awareness and information to be a strong barrier to achieving the policy objectives. Policy makers recognize the problem but are not sure how to remedy it. There are a few exceptions, though. In Malaysia, the Electricity Supply Industry Trust Account provides financial assistance not only for rural electrification, energy efficiency, and renewable energy projects but also for studies that would improve information availability for the energy sector. The fund is in part created through independent power producers and the Malaysian utility Tenaga Nasional Berhad Generation, which contributes 1% of its annual audited revenue to the fund.

In India, the Bureau of Energy Efficiency has undertaken a number of activities to build awareness about energy efficiency. For instance, it conducts exercises for the state-designated agencies on the concepts related to energy efficiency and their role in promoting it. It has also instituted the National Energy Conservation Award, which is given to the best energy-performing industries across different industry subsectors. To encourage different consumers, the bureau provides information on energy conservation efforts undertaken by different industries and case studies online. It has also used the electronic media to launch a campaign on energy conservation.

However, these initiatives take a very narrow approach of promoting energy-efficient technologies and appliances. They do not ask people to think more broadly about a way of living that would be less energy intensive.

Energy pricing and subsides

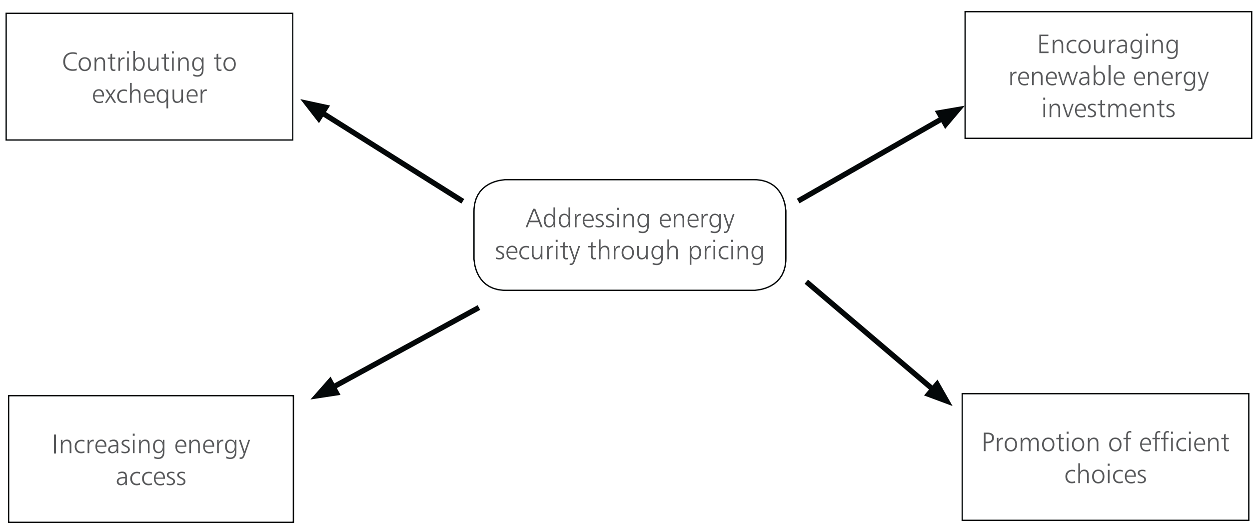
Energy pricing is a strong economic tool available to policy makers and regulators to address energy security (Figure 4.1).

It has an impact on both supply side as well as demand side. If used appropriately, pricing can encourage investments in desired sectors, such as renewable energy, energy-efficient appliance manufacturing, and research and development of new technologies. On the demand side, pricing can encourage a move away from conventional energy resources to renewable energy resources, provide incentives for efficient usage of energy, and shift commuters from personal to public transportation.

The role of energy pricing becomes even more crucial when the dimension of climate change is overlapped with that of energy security.

The impact of pricing in promoting renewable energy and energy efficiency can be manifold; all the measures discussed earlier for promoting renewable energy and energy efficiency are linked

Figure 4.1: Energy Pricing's Role in Addressing Energy Security



to end-use energy price. For instance, introduction of feed-in tariffs (FITs) for promoting renewable energy resources is a pricing method that provides incentives to developers to supply renewable energy to electricity distribution utilities.

In case of energy efficiency, a number of programs have been designed in the region to make the end-use price of efficient appliances compare well with that of inefficient ones. For instance, in India's Bachat Lamp Yojna, incandescent bulbs are being replaced by efficient compact fluorescent lamps (CFLs), and the difference in the price is being funded through a programmatic Clean Development Mechanism (CDM) plan. Fiscal incentives for using energy-efficient appliances have also been provided to consumers so as to shorten the payback on the investments. In Thailand, there is a pilot project that provides tax privileges for energy conservation to owners of energy-efficient buildings and factories.

Historically, however, pricing systems in the region have been skewed toward promoting conventional sources of energy and the inefficient use of energy. In Bangladesh, for example, the energy prices of these resources are so low that consumers have no incentive to choose energy-efficient appliances; it takes too long to recoup the higher purchase price.

In Indonesia, energy price caps and subsidies have been recognized as among the biggest hindrances to adopting energy efficiency and renewable energy. Here, prices for individual consumers are below market levels for electricity and selected petroleum products (kerosene, automotive diesel oil for transport, and gasoline). These subsidies are universal, equally accessible to the poor and the wealthy. They are completely mistargeted, as the families in the top 40% for high incomes benefit from 70% of the subsidies, while the families in the bottom 40% for low income families benefit from only 15% of the subsidies.[41] Indonesia's long-entrenched petroleum and electricity subsidies and price caps have made the country highly vulnerable to global energy price movements. These subsidies and price caps impact investments, efficiency, and diversification in the energy sector.

Poor pricing regimes also affect regional trade prospects. The Kyrgyz Republic, a country with abundant hydropower potential, has an ailing power sector because the cost recovery on regionally traded power is only 50%; thus, the country is not able to generate adequate investments to take the sector forward.

Key to sustainable deployment of renewable energy technology is the removal of subsidies in fossil fuel retail pricing and electricity tariffs, and the establishment of a regulatory framework that will provide incentives and clarity to investors on issues related to the bidding procedure for new projects and the ongoing taxation and renewable energy FITs. The FITs for renewable energy systems should be based on the avoided cost as determined by an independent electricity regulatory body, rather than by the state-owned electricity company.[42]

Countries are making efforts to correct these pricing distortions.

Options and priorities for intervention: survey results

The experts surveyed for this report consider three strategies to have the highest potential for addressing energy security: management of the demand side, including the buildings sector; diversification of the energy supply mix; and a deeper penetration of renewable energy technologies for heating, as well as electricity generation (Figure 4.2). Investments in energy infrastructure and efficiency enhancement of existing power plants are other strategies they recommend.

On introducing biofuels for transportation—identified as the second-most important sector for intervention—the response was split, with equal numbers considering it to have low and high potential. Perhaps this was due to lack of clarity on the financial sustainability of first-generation biofuels and lack of clarity on the commercial availability of second-generation biofuel technologies. Alternative fuels, such as coal to liquid, gas to liquid, and biomass to liquid, in the transport sector received a similar mixed response.

Increasing efficiency in various processes is one of the fastest ways to address energy security. The survey endorsed improvement in existing power plants' efficiency and pursuit of clean coal technologies, given the increasing awareness about climate change.

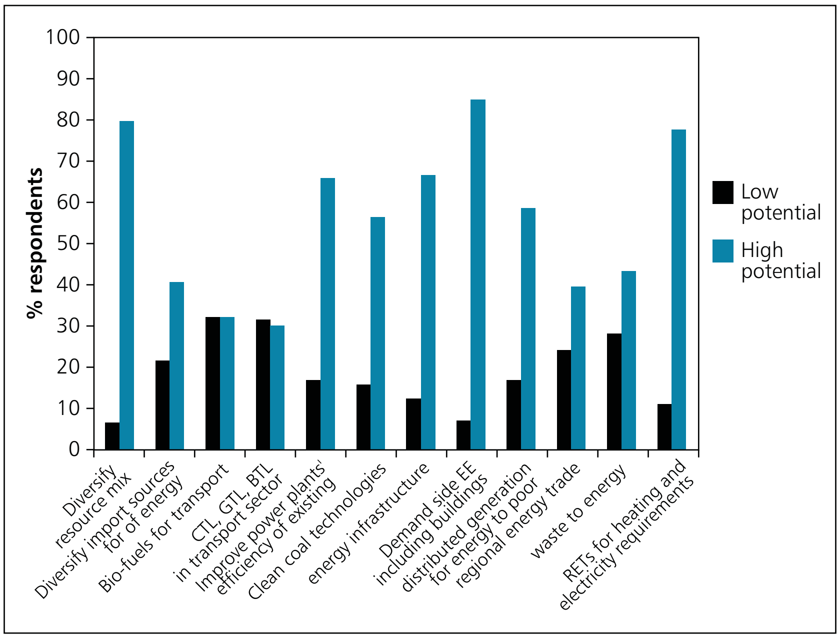
The use of distributed generation has high potential for increasing access to energy, particularly remote and widely dispersed areas, such as island nations, where extending the grid would be very costly.

Regional energy trade in the Asia and Pacific region is limited and primarily bilateral. Efforts are currently under way to encourage regional cooperation—by the Greater Mekong Subregion and the ASEAN, for example. Nearly 40% of the respondents see a high potential for regional energy trade. However,

41 IEA Energy Policies in Indonesia 2008.

42 *SERN Review 2007*; REEEP.

Figure 4.2: Potential Measures to Address Energy Security



BTL = biomass-to-liquid, CTL = coal-to-liquid, EE = energy efficiency, GTL = gas-to-liquid, RET = renewable energy technology.

Source: Expert Survey.

recognizing the region's limited experience and the historical sensitivities, 25% of the respondents think this option has limited potential to meet energy security concerns.

The basic definition of energy security implies diversifying suppliers of energy to lessen the risk of disruption. Fewer than half of the respondents—41%—rated diversification of import sources as a high-potential strategy for mitigating energy security concerns. However, given the region's high dependence on imported crude oil, this may be a good strategy to pursue.

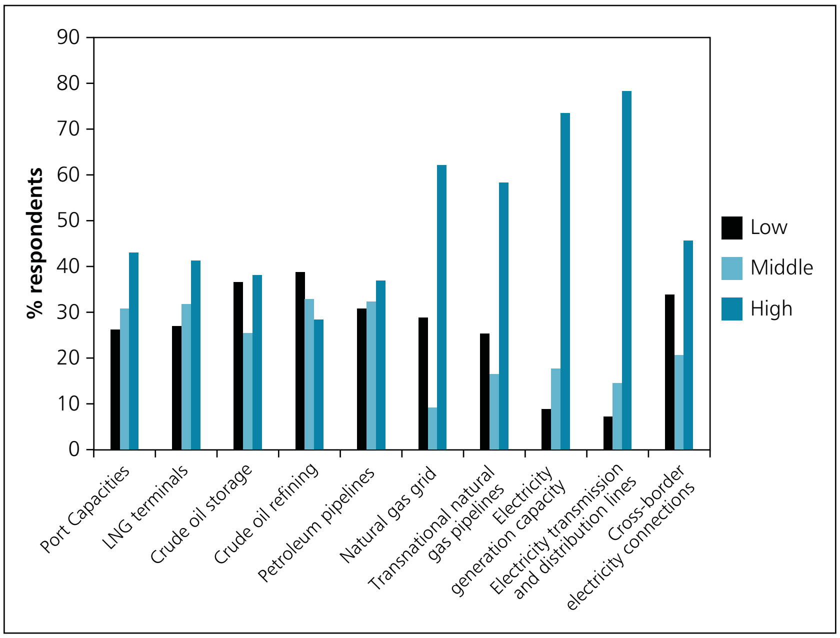
Energy infrastructure is essential for ensuring energy access and in linking demand centers with supply centers. But investments in infrastructure must be prioritized, since some improvements are needed more urgently than others. The survey respondents gave high priority to the electricity sector (Figure 4.3).

Within the electricity sector, 78% of the experts highly recommend investing in the transmission and distribution sector. This would address lack of energy access and the high losses that make those networks inefficient.

According to 70% of the respondents, investments in power generation are also urgently needed. Most of the countries in the region are short of electricity-generating capacity.

In the natural gas sector, another network industry, 62% of the experts consider investments in the grid a top priority. Investments are also urgent

Figure 4.3: Urgency of Investment Requirements



LNG = liquefied natural gas.

Source: Expert Survey.

in transnational pipelines, according to 58% of the experts. By contrast, only 41% of the experts considered investments in LNG terminals as highly desirable, and 26% thought they were a low priority. Pipelines are considered to add to energy security more than LNG because they are backed by long-term take-or-pay contracts, and the risk of diversion is minimal.

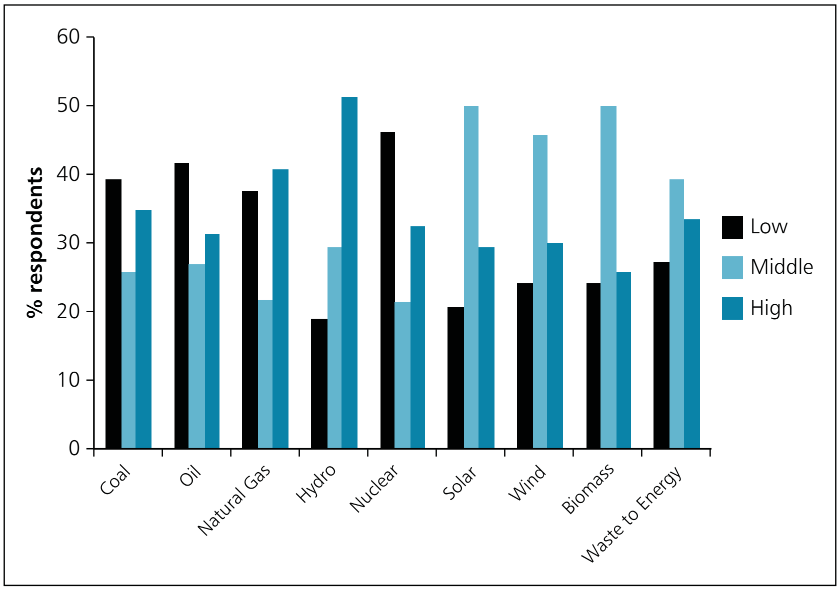
Infrastructure for crude oil was given low priority; possibly it is already well developed in most countries.

Power generation is one of the most energy-intensive industries and one of the biggest contributors to greenhouse gas emissions. Therefore, it is essential to move this sector from fossil fuels to cleaner fuels. Experts were asked their opinion on the principal fuel for power generation in the future (Figure 4.4). More than 51% cited hydropower. Asia and Pacific is well endowed in hydro resources that have not been utilized. It is expected that concerted efforts will be made to harness its potential to the fullest, with opportunity for technical and financial cooperation between countries.

Nearly half of the respondents gave nuclear energy a thumb down, possibly because of safety concerns. Coal and oil also received a lukewarm response.

Among renewable energy resources, solar was slightly ahead, with 80% of the respondents giving it a high or medium likelihood of contributing significantly. Waste to energy got the most votes in the "high" likelihood category, but that was

Figure 4.4: Likelihood of Fuel Choices for Electricity Generation in the Future



Source: Expert Survey.

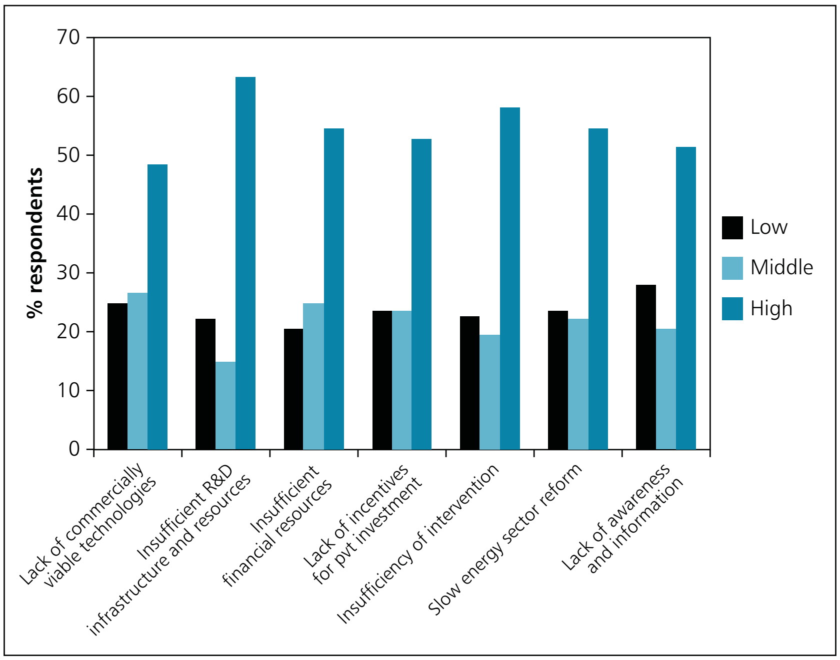
only from 33% of those surveyed. The respondents seem to be positive about the scope of renewable energy technologies in meeting future electricity generation needs but aware that high capital cost, lack of incentives for developers, lack of technology, and lack of financing could impede countries from making use of their full potential.

A number of policies have been introduced in Asia and the Pacific to address concerns about energy security, but in a majority of cases, much more needs to be done to make them effective. The key barriers to success include lack of financial resources, insufficient focus on technology, limited availability of commercially viable technologies, and lack of awareness in general among stakeholders. In the survey, experts were asked to judge the impact of these problems, and almost 50% rated every one of them as a high barrier (Figure 4.5).

One major challenge in designing effective policies to address energy security and climate change is to identify the key sectors where a focused intervention can yield maximum desired results. On this, the opinion of the experts surveyed is overwhelmingly in favor of the industry sector, with more than 60% recognizing it as having a high energy-saving potential. Second in line is transportation, rated high to medium for potential energy savings by more than 70% of respondents. The residential, commercial, and buildings sectors were believed to have a somewhat lower potential. Perhaps this is a structural issue: unorganized end-use sectors are harder to influence than the technologies and production processes in the organized industry and transport sectors (Figure 4.6).

Agriculture was also seen as having low energy-saving potential, probably because the region's

Figure 4.5: Barriers to Implementing Policy on Energy Security



pvt = private, R&D = research and development.

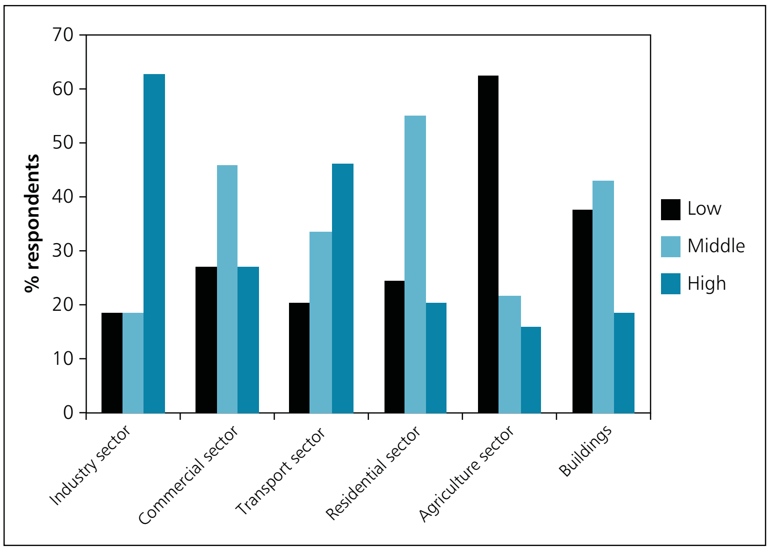
Source: Expert Survey.

agriculture is not yet energy and capital intensive. Considering the importance of agriculture in developing countries, however, this could mean that this sector requires special attention.

In the context of policy interventions for energy security, experts overwhelmingly support promotion of renewable energy technologies on a large scale, as well as end-use energy efficiency, with more than 75% rating them highly effective (Figure 4.7). The interest in dispersed end-use (appliances and practices) is a clear statement of the significance of efficiency in day-to-day activities. Individual strategies for renewable energy (rational energy pricing, building codes, energy sector reforms, and incentives to private sector investment), though important, did not rate as high as the overarching idea of promoting those technologies. This could be seen as a suggestion that no single approach is enough. A multipronged strategy is required, including participation of the private sector. All of these strategies look to the long term, unlike building strategic petroleum reserves, which drew a tepid response.

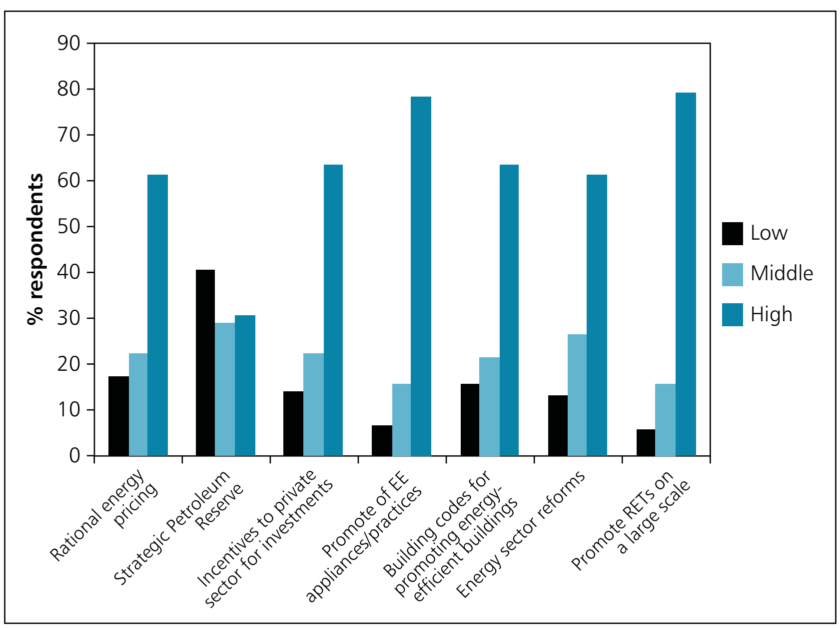
Lack of resources, financing in particular, was identified as a major barrier for effective policy intervention. Thus, the experts surveyed highly recommended all forms of financial incentives to promote renewable energy and energy

Figure 4.6: Energy-Saving Potential by Sector



Source: Expert Survey.

Figure 4.7: Effectiveness of Measures in Addressing Energy Security



EE = energy efficiency, RET = renewable energy technology.

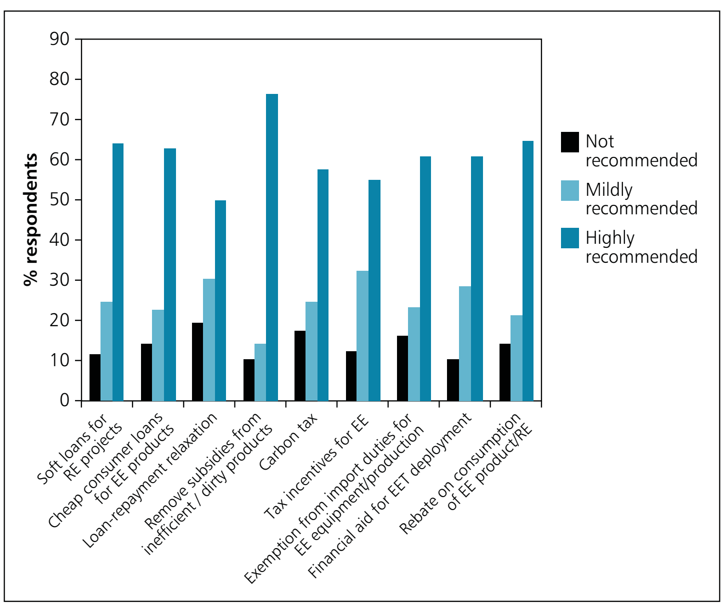
Source: Expert Survey.

efficiency, including soft loans for renewable energy projects, cheap consumer loans for energy efficiency products, relaxations in loan repayments, tax incentives, exemption from import duties, and rebates on consumption of energy efficiency products and electricity produced from renewable energy technologies (Figure 4.8). The biggest majority, however, was for a financial disincentive: the removal of subsidies for inefficient or dirty products. A carbon tax, too, was highly recommended. Clearly, financing is pivotal in shaping the energy sector.

At a more precise level, strict rules are considered to be highly effective in promoting energy efficiency in the economy (Figure 4.9). More than 70% of respondents strongly favor making it mandatory to use the best technologies available and setting up quality standards.

Among the measures to promote renewable energy penetration, making purchase of renewable energy obligatory is considered highly effective by more than 60% of the experts surveyed (Figure 4.10). However, two options clearly favored by most respondents (more than 70%) are concerned with energy pricing. It is evident that realistic pricing of conventional energy which, in effect, would make it more expensive, along with supporting the pricing of renewable energy through appropriate tariff regimes (most prominent is a feed-in tariff), is perceived to be the most effective way to improve

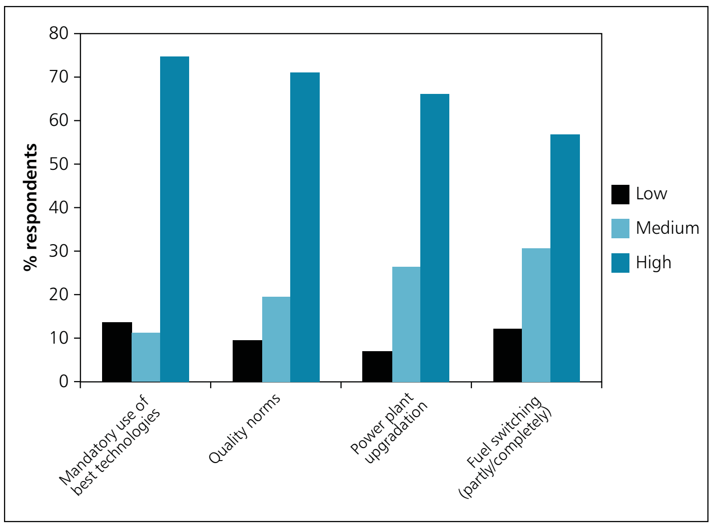
Figure 4.8: Financial Incentives/Disincentives for Energy Efficiency/Renewable Energy Promotion



EE = energy efficiency, EET = Energy Efficiency Technology, RE = renewable energy.

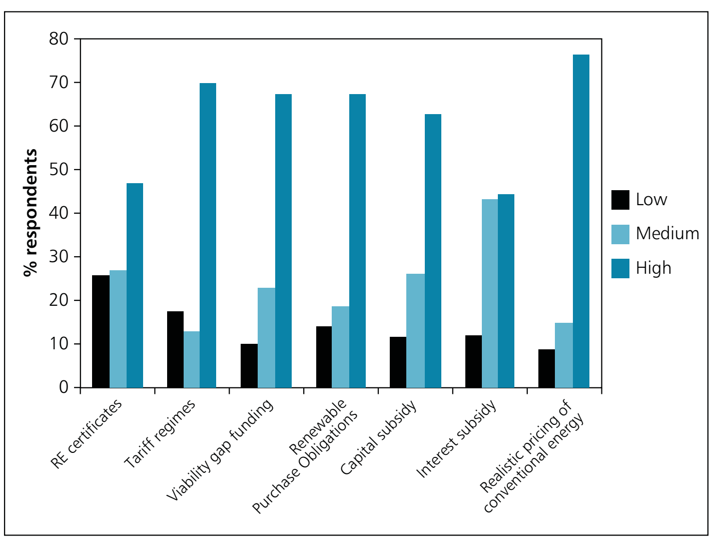
Source: Expert Survey.

Figure 4.9: Effectiveness of Measures to Improve Energy Efficiency



Source: Expert Survey.

Figure 4.10: Effectiveness of Measures to Improve Renewable Energy Penetration



RE = renewable energy.

Source: Expert Survey.

the penetration of renewable energy. Other options that give financial support to renewable energy projects, such as viability gap funding[43] and capital subsidy, also received strong support.

The experts were asked to make recommendations on how to promote technology R&D and technology transfer, and what kind of policies and financial interventions are required for energy security. The role of governments emerged as central. Most of the recommendations require that governments take the lead, not only in providing infrastructure, along with institutional and financial support and demonstration projects, but also in building collaboration and cooperation among academia and research institutes, industry, and state. Building domestic capacity—setting up research infrastructure, training staff, creating markets for new technologies, encouraging the finance sector to support green activities, etc.—and identifying specific technologies to be developed domestically or transferred from abroad are other two important recommendations that should guide the way governments and other agencies assume their responsibilities toward building an energy-secure and environment-friendly region.

It is strongly recommended that the technologies that are imported and are subject to future R&D have local relevance. Clean energy, renewable energy, building design, and end-use energy efficiency are considered as key areas. The technologies perceived to be most relevant are carbon capture and storage, integrated gasification combined cycle (IGCC) and other clean coal technologies, energy efficiency technologies, fuel cell, geothermal, micro-hydro, small wind turbine, and solar.

Tackling the challenges of energy security with sensitivity to climate change issues requires a much greater emphasis on energy efficiency and renewable energy technologies, the experts said, while stressing also the need for diversifying the technology portfolio, as well as the sources of energy. They presented no "silver bullet" solutions but suggested certain avenues:

- The substantial hydropower resources in the region should be explored in an effort toward diversification. Solar, wind, and biomass energy are less attractive than nuclear and waste-to-energy options.
- The barriers to alternative energy are several and fairly uniform across countries. Topping the list is the insufficient R&D infrastructure either to develop or adapt technologies to local contexts and to demonstrate them for purposes of building confidence.
- The industry and transport sectors are the key areas for efficiency-related interventions, followed by the residential and building sectors.
- Fiscal measures that would facilitate more efficiency and greater use of renewable energy include the removal of subsidies on conventional energy forms and a call for more realistic pricing of unconventional energy. Apart from this, it is clear that the countries of the region will have to explore all possible fiscal incentives in a portfolio approach to facilitate a rapid transformation toward a more sustainable energy economy.

[43] Viability gap funding is the funding provided by the government to bridge the investment gap required for infrastructure projects that the private sector is unable to provide.

Conclusions

When setting energy policies, governments face many complex issues, trying to balance concerns about energy supply and demand with social and environmental considerations. Also, the policies are closely interlinked and one intervention affects the other. Therefore, it is widely acknowledged that there is a need to adopt an integrated, multipronged approach to address energy security issues holistically.

On the whole, DMCs have taken many initiatives on both renewable energy and energy efficiency, but there is still a lot of scope for improvement.[44]

One area in need of strengthening is the interagency coordination and a comprehensive approach to policy design. Policy initiatives are rarely comprehensive and typically designed on a sector-by-sector basis. Regionally, forward-looking policies are skewed to select countries. There is also a lack of good data collection and monitoring mechanisms to make sure policies are sound and responsive. A few countries such as India and Sri Lanka have developed integrated energy policies, but the region on the whole has to move away from a piecemeal approach and recognize the linkages in the economic, as well as social, life of countries.

Another key finding is the lack of resources, in institutional capability and in finance, for designing more ambitious responses to energy security concerns and climate change. A number of pilot exercises are being conducted across the region, such as the housing project in Kolkata, India. What is urgently needed is a sufficient scaling up of these initiatives to ensure large-scale impact. Another great barrier to energy efficiency and renewable energy in the region is the domestic energy pricing mechanism in various countries that promotes fossil fuels and provides no incentive to save energy.

The region is still on a learning curve and has a good appetite for learning from inside and outside the region. Yet in emulating international best practices, it needs to ensure that the uniqueness of the region is incorporated into policies. Most of the initiatives in the region have been recently introduced (after 2000, so it is premature to come to definitive conclusions about their impact on energy efficiency or renewable energy).

[44] The PRC has an ambitious plan to move quickly to the adoption of the ultra-supercritical steam cycle and the IGCC for power generation. India has decided to adopt the supercritical steam cycle for its thermal power generation. The Government of India has come out with a special purpose entity for ultramega power projects—4,000 megawatts—and the minimum level of technology to be used for power generation is the supercritical steam cycle.

CHAPTER 5

Technological solutions: clean, renewable energy and energy efficiency

Technology has a significant role to play in the efficient utilization of energy resources. Many existing and emerging technologies can help achieve greater energy security while contributing to a low-carbon future and other environmental goals. Advanced fossil fuel power generation, biomass and bioenergy, wind power, green buildings and appliances, and electricity transmission and distribution technologies are just a few. Each of these is at a different stage of the research, development, demonstration, and deployment cycle and requires the removal of a number of technological, financial, commercial, and regulatory barriers.

A large potential of non-fossil-based energy resources, such as biomass, solar, hydro, and nuclear, is untapped in the region. Technologies for using these are discussed in this chapter. (Appendix 4 provides more data on the global status of renewable energy technologies and the global cost of generation.) The current levels of investments in the mainstreaming of renewable energy technologies are quite low. For instance, energy-related projects received only 4% of total government-funded research and development (UNEP 2008). Such funding is growing at a much slower pace than venture capital directed at renewable energy, which grew 106% over 2006 and 2007.

Clean-coal technologies and energy-efficient technologies in the end-use sectors are also discussed. The applicability and the choice of the technologies will depend on the availability of local resources and other conditions in each country in the region.

Bioenergy: an overview

Biomass—organic materials grown, collected, or harvested for energy use—is a source of renewable hydrocarbons that can be converted to provide energy carriers (heat, electricity, and transport fuels), as well as materials and chemicals. When made from biomass, these conversion products are known as bioenergy, biofuels, biogas, bio-materials, and biochemicals. Developing Asia and the Pacific (DAP) is 50% dependent on biomass energy.

The small-scale use of biomass for cooking and heating in households is widespread in most parts of the world. Some countries, such as Nepal, are dependent on traditional biomass to meet up to 90% of their total energy demand. The efficiency of many stoves and open fireplaces could be improved significantly by introducing better designs. This would reduce the amount of biomass needed to provide the same energy services and reduce air emissions, thereby improving the health of the users by avoiding smoke and carbon-monoxide inhalation. With fewer people living in rural areas and greater uptake of more efficient stoves, small-scale biogas systems, and biomass-based liquid cooking fuels, such as dimethyl ester or ethanol gels, the overall efficiency of small-scale biomass use is expected to increase significantly. The use of existing biomass supplies for modern bioenergy plants to produce process heat, power, and liquid fuels would help some countries meet their sustainable development goals.

Costs

Bioenergy costs are expected to reduce over time with improved technology learning and economies of scale in larger commercial plants. Transportation biofuels could drop in cost from $10 to $31 per gigajoule (GJ) to $7–$12 per GJ. Heat production is expected to remain near today's cost of $4–$19 per GJ over the forecast period.

Policy options

The amount of feedstock available for bioenergy will depend upon a wide range of government and local policies, including those in relation to

- land use and land-use change,
- avoidance of deforestation and protection of conservation areas and biodiversity,
- reclamation of degraded lands,
- crop pricing,
- genetically modified crops,
- soil carbon uptake,
- water use and quality,
- treatment of wastewater and solid waste,
- local air pollution,
- sustainable development goals,
- health improvements,
- support for rural industries,
- transportation, and
- the provision of low-cost energy to stimulate economic growth.

The future uptake of biomass for energy will be determined, at least in part, by the impact such policies have on bioenergy projects. Policies supporting a greater uptake of bioenergy could be offset by others constraining it. For example, the growing demand for biofuels has already led to increased deforestation and the deterioration of wetlands and peat soils, which has actually increased CO_2 emissions (Fargione et al. 2008). It has also led to an upward pressure on food prices.

Biomass logistics

Biomass tends to be bulky, to deteriorate over time, and to be difficult to store and handle. Compared with coal and oil, biomass has a lower energy density (GJ per unit of weight or volume), which makes handling, transport, storage, and combustion more difficult. Supply chain costs can add significantly to delivered biomass costs and can result in the economic failure of bioenergy projects (IEA 2007c). Larger plants can achieve economies of scale, but this can be more than offset by the increased distances from which the required volume of biomass is acquired.

Biomass production costs vary according to the size of the clear-cutting area, distance to the road, optional roadside storage, transport distance, and stumpage fees, but they can be reduced over time with experience. The cost of producing woody biomass has declined by more than 30% in 20 years. The largest influence was the development of new forwarding and chipping technologies, together with improved management of both crop production and logistics.

The main barriers to biomass use include fuel logistics, fuel quality fluctuations (due to variations in rainfall, for example), feedstock price fluctuations, and delivery costs. Technical improvements in harvesting, storage, transporting, fuel preparation, and other measures are still possible for virtually all biomass feedstocks.

The economic potential of biomass is dependent on a wide range of economic, practical, and political variables. It is, therefore, difficult to establish with any degree of confidence the extent to which bioenergy could become a feasible option for climate change mitigation. More work is needed to develop integrated land-use, energy-economy models that could provide a more comprehensive assessment of the prospects for biomass in the sustainable global energy supply mix. Refining the modeling of interactions between land used for bioenergy and land used for food and materials production, and establishing the potential synergies between different land uses more clearly would improve understanding of the prospects for large-scale bioenergy deployment and biomass management in general.

Biomass-based power generation technologies

Biomass-based technologies include those involving primary biomass combustion and those that do not involve direct biomass combustion but may involve conversion to a secondary energy form. Historically, primary biomass combustion has been the main source of energy in Asia and Pacific.

Straight biomass combustion

This is the most commonly used way of converting the chemical energy of biomass into thermal and electrical energy. The advantage of the technology is that it is similar to that of a thermal power project, except for the type of boiler. The cycle used is the conventional Rankine cycle, with biomass being burned in a high-pressure boiler to generate steam and operating a steam turbine with generated steam. The exhaust of the steam turbine can either be fully condensed at low pressure to produce power or used for a heating application when exhausted at medium pressure for process industry.

Biomass gasification

In biomass gasification, biomass undergoes partial combustion to yield a hot, combustible gas. This producer gas may then be either (i) burned in a gas turbine to generate power, and the exhaust gas from the turbine used in a heat recovery boiler to raise steam under pressure to run a steam turbine, i.e., an integrated gasification combined cycle (IGCC); or (ii) run in a modified internal combustion (diesel) engine or reciprocating gas engine, to generate power. Biomass gasification technologies with internal combustion engines are suitable mainly for decentralized electricity generation to cater to the need of a village or a cluster of villages, with capacities in the range of 5–500 kilowatts. On the other hand, gasification technologies with IGCC may be commercially viable at scales of 100 megawatts (MW) if feedstock is sourced from adjacent dedicated energy plantations. The IGCC model of biomass gasification power technologies enables thermal-to-power conversion efficiencies of more than 50%, compared with 35% for power generation from straight combustion.

An alternative method of biomass gasification is generation of "syngas," which involves gasification in a stream of air and steam. The resulting reactions are thermally balanced, being only very slightly exothermic, and the gas contains a higher proportion of hydrogen, enabling ambient temperature storage. Syngas may, thus, be supplied locally as piped gas to homes and industries, as well as being fed to a gas grid supplying combustion fuels (but not gas for chemical processes).

On a small scale, biomass gasification may be promoted for village-level energy supply (for power and cooking or industrial fuel), with feedstock derived largely from agricultural waste (crop and animal residues). The scale of operation for agricultural residue-based supply would necessarily be small, probably less than 1 MW, since transportation of crop residues of low bulk density is costly, and the entire available biomass from a village may not enable surplus generation. However, grid connection may enable both supplying off-peak power to the grid and drawing grid power during the peak.

At larger scales, say up to 100 MW, biomass gasifiers may use feedstock from energy plantations grown on cultivable wasteland or other available lands, such as village commons lands. At such scale, biomass gasifiers may be hybridized with solar thermal systems to ensure continuous power supply. Typically, such generation units would operate as mid-scale independent power producers for the grid.

Technology transfer

Countries, such as the United States, Finland, and United Kingdom, have biomass gasifier capacities up to 100 MW based on circulating fluidized bed, bubbling fluidized bed, and pressurized fluidized bed gasifiers. Transfer of these technologies and, where necessary, adaptive research and development, would enable deployment models involving energy plantations on wastelands or common lands that would not compete with food crops to be operational.

Capacity building needs include support to entrepreneurs for commercial demonstrations of biomass-based distributed generation systems, and using these as training facilities for local entrepreneurs and operation and maintenance personnel. Such demonstrations and skills development would enable accelerated deployment of these technologies.

Biofuels for transportation

To achieve energy security and low-carbon intensity in the transport sector, a shift away from fossil fuels to electricity, hydrogen, and/or biofuels will be necessary.

The production of transport fuel from biomass, in either liquid or gas form, holds the promise of a low net fossil-energy requirement and low life-cycle greenhouse gas (GHG) emissions. However, there are many hurdles still to overcome, and its remains unclear what level of biofuels production can be achieved globally on a sustainable basis. Issues, such as food security resulting from land competition with biofuels and the potential impacts of biofuels on water resources, biodiversity, and other aspects of the environment, are becoming major concerns that could severely limit the role of biofuels if not fully addressed. The successful development of advanced biofuels technologies, using non-food biomass feedstocks, could help overcome most barriers and achieve sustainable, low-CO_2, cost-effective biofuels.

Biofuels can be divided into a number of categories, including by type (liquid and gaseous) and by the feedstock or conversion process used (Table 5.1). Liquid biofuels, such as ethanol and biodiesel, are likely to dominate over gaseous fields, such as methane and hydrogen, for many years because they are more compatible with internal combustion engine vehicles and the infrastructure exists. The conversion process is classified according to whether it uses "first-generation" biofuels (those already under commercial production, based on food-crop feedstocks) or advanced-technology "second-generation" biofuels (mainly ligno-cellulosic feedstocks, such as straw, bagasse, vegetative grasses, and wood). There are also "third-generation" biofuels under development, including oils from algae and other alcohols, such as bio-butanol, but it is assumed that these will make little contribution before 2050.

The characteristics of the different types of biofuels vary substantially. Second-generation technologies hold the promise of high-yielding, low GHG-emitting, and sustainably produced liquid fuels derived from forest and agricultural residues and purpose-grown energy crops. It is likely that commercial production of second-generation biofuels to produce gasoline or diesel substitutes from a range of ligno-cellulosic feedstocks (using either thermo-chemical-based biomass-to-liquids technologies or biochemical-based pathways) will eventually complement and perhaps supersede current first-generation biofuels from grains and oilseed crops.

For light-duty vehicles (cars, small vans, and sport utility vehicles), other propulsion technologies, including electric motors and fuel cells, are likely to compete with the internal combustion engine in the near future. It is possible that the greatest demand for biofuels in the medium-to-long term will come from heavy-goods vehicles, marine vessels, and aviation, where developing new power systems could be more challenging. Second-generation biofuels, in particular "biomass-to-liquids" from biomass gasification and Fischer-Tropsch synthesis, could be important for diesel-fuel-dominated transport modes in the coming decades. The Fischer-Tropsch process is used to produce synfuels from gasified, biomass. Carbonaceous material is gasified, and the gas is processed to make purified syngas (a mixture of carbon monoxide and hydrogen). The Fischer-Tropsch polymerizes syngas into diesel-range hydrocarbons. While biodiesel and bio-ethanol production so far use only parts of a plant, such as the oil, sugar, starch, or cellulose, biomass-to-liquids production uses the whole plant, which is gasified. Biomass-to-liquids diesel could be important for diesel-dominated transport modes in the coming decades, since it is a high-quality fuel and fully substitutable for current aviation fuels.

Evolution to second-generation biofuels

In a situation analogous to the refining of oil to produce multiple, higher-value chemicals and plastics, it is recognized that second-generation biofuels are likely to be produced in conjunction with a series of value-added by-products, including biochemicals and bio-materials and other forms of bioenergy (e.g., electricity and heat). This would allow a more comprehensive "bio-refining" of biomass to serve multiple purposes.

The International Energy Agency (IEA) has developed a set of projections of costs and potential market penetration of the two major second-generation conversion technologies under development (enzymatic hydrolysis of cellulosic materials and gasification/Fischer-Tropsch liquefaction) using a wide variety of biomass materials. The rate at which the cost of production declines will depend on feedstock prices, economies of scale realized from commercial plant development, and the benefits of experience and learning as cumulative production rises.

Table 5.1: A Typology of Liquid Biofuels

Fuel	Feedstock ***	Region where currently mainly produced	GHG reduction impacts vs. petroleum fuel use	Costs	Biofuel yield per hectare of land	Land types
First-Generation ethanol	Grains (wheat, maize)	United States, Europe, PRC	Low-moderate	Moderate-high	Moderate	Croplands
	Sugarcane	Brazil, India, Thailand	High	Low-moderate	High	Croplands
Second-Generation ethanol	Biomass (cellulose)	None used but widely available	High	High	Medium-high	Croplands, pasturelands, forests
First-Generation biodiesel	Oilseeds (rape, soybean)	United States, Europe, Brazil	Moderate	Moderate-high	Low	Croplands
	Palm oil, jatropha	Southeast Asia South Asia	Moderate	Low-moderate	Moderate-high	Coastal lands, forests
Second-Generation biodiesel*	Any biomass (via Fischer-Tropsch**)	None used commercially	High	High	Medium-high	Croplands, pasturelands, forests

PRC = People's Republic of China.

* Also termed biomass-to-liquids.

** Fischer-Tropsch process converts gasified biomass (or coal) to liquid fuels via hydrocarbon chain-building process.

*** A range of other crop feedstocks can also be used, including sugar beet, cassava, jatropha, sunflower oil, and sorghum, as well as purpose-grown vegetative grasses, such as miscanthus and reed canary grass, and short-rotation forest crops, including salix and eucalyptus. These are not listed because they are less dominant.

Source: Energy Technology Perspective (2008).

Current costs range from $0.80 to $1 per liter, and projected long-term "best-case" costs are $0.50–$0.65 per liter. At an optimistic learning rate, both ligno-cellulosic ethanol and biomass-to-liquids biodiesel production costs drop rapidly after 2010 and reach a near-long-run cost level by 2030. At a more pessimistic learning rate, costs come down more slowly and permanently remain about $0.15 per liter gasoline equivalent higher than the optimistic cost curve.

Hydropower

Large-scale hydropower projects, while flexible and eminently dispatchable, can be controversial because they affect water availability downstream, inundate valuable ecosystems, may require relocation of populations, and require large DC direct-current transmission lines. New, less-intrusive low-head turbines are being developed to run on smaller reservoirs. Hydropower usually depends on rainfall in the upstream catchment area.

Small-scale hydropower is normally designed to run of river. This is an environmentally friendly energy conversion option because it does not interfere significantly with river flows. Small hydro is often used in self-standing applications to replace diesel generators or other small-scale power plants, or to provide electricity to rural populations.

Costs

Existing hydropower is one of the cheapest ways of producing electricity. Most plants were built many years ago, and their initial costs have been fully amortized. For new large plants in the Organisation for Economic Co-operation and Development (OECD) countries, capital costs are about $2,400 per kW and generating costs, about $0.03–$0.04 per kWh. In developing countries, investment costs are routinely below $1,000 per kW. Small hydropower generating costs are about $0.02–$0.06 per kWh. Such systems commonly operate without major replacement costs for 50 years or more. The cost of pumped storage systems depends on their configuration and use. They may be up to twice as expensive as an equivalent unpumped hydropower system. Depending on cycling rates, their generating costs may be similar to those of unpumped systems.

Geothermal energy

High-temperature geothermal resources can be used in electricity generation, while lower-temperature geothermal resources can be tapped for a range of direct uses, such as district heating and industrial processing. This section deals only with the use of geothermal heat for electricity generation.

Geothermal power plants can provide extremely reliable base-load capacity 24 hours a day. Deep geothermal heat is produced from the decay of radioactive material. The heat is moved to the surface through conduction and convection.

The international geothermal power capacity grew at a broadly constant rate of about 200 MW per year from 1980 to 2005. Total capacity reached about 10 GW in 2007, generating 56 TWh per year of electricity. Several countries, such as Indonesia, Mexico, New Zealand, Nicaragua, and United States, are now accelerating development.

There are three types of commercial geothermal power plants: dry steam, flash steam, and binary cycle. Dry-steam sites use direct-steam resources at temperatures of about 250°C. Others are generally low temperature, about 100°–150°C. Only five fields of this nature have been discovered in the world to date.

Large-scale geothermal power development is currently limited to tectonically active regions, such as areas near plate boundaries, rifts zones, and mantle plumes or hot spots. These active, high heat-flow areas include countries around the "Ring of Fire" (Indonesia, Philippines, Japan, New Zealand, Central America, and the western coast of the United States) and rift zones (Iceland and East Africa). These areas are likely to be the most promising for large development in the near term. If current efforts to enhance geothermal systems are successful, geothermal potential could lead to an expansion in other regions.

Costs

Exploration, well-drilling, and plant construction make up a large share of the overall costs of geothermal electricity. Drilling costs can account for as much as one third to one half of the cost of a geothermal project. The IEA Geothermal Energy Implementing Agreement, which provides a framework for international collaboration on geothermal issues, is pursuing research into advanced geothermal drilling techniques and investigating aspects of well construction with the aim of reducing costs.

Capital costs are closely related to the characteristics of the local resource system and reservoir, but they typically vary from $1,150 per kW installed capacity for large, high-quality resources to $5,500 per kW for small, low-quality resources.

Generation costs depend on a number of factors but particularly on the temperature of the geothermal fluid. Plants in the United States report current operating costs of $0.015–$0.025 per kWh at the geysers filed in California, or $0.02–$0.05 per kWh for other flash and binary systems, excluding investment costs. New constructions can deliver power at $0.05–$0.08 per kWh, depending on the source; similar costs are reported in Europe, where generation costs are $0.06–$0.11 per kWh for tradition geothermal power plants (liquid or steam water resources).

Solar energy

The solar energy that hits the earth's surface in an hour is about the same as the amount of energy consumed by all human activities in a year (Energy Technology Perspective 2008). Its low energy density and intermittency, however, make it difficult and expensive to exploit on a large scale. Solar energy currently provides less than 1% of the world's total commercial energy.

Solar energy can be harnessed in several ways. Solar heat can be used directly to supply heat to the residential sector and in industrial processes. Overall, heating needs compose more than 40% of global energy dexmand (Philibert 2006). Solar energy can also produce power, either through the concentration of solar rays or through direct conversion to electricity in photovoltaic (PV) cells. It can also be used to produce various fuels, notably hydrogen, and it produces metals from metal oxides.

In terms of regional distribution, PV power is projected to grow very significantly in solar-rich OECD countries (particularly in North America), but also in emerging economies, such as the PRC and India. Concentrated solar power (CSP) is expected to be deployed widely in those regions as well and even more so in the sunbelt regions of Latin America and Africa.

Photovoltaics

PV systems directly convert solar energy into electricity. The basic building block of a PV system is the PV cell, which is a semiconductor device that converts solar energy into direct-current electricity.

PV systems can be grid-connected or stand-alone (off-grid). They can be ground-mounted, as in centralized electricity production facilities, or integrated into buildings. However, the number of grid-connected systems for distributed generation has been increasing exponentially from a few hundred megawatts in 1992 to about 5,500 MW in 2006. A large majority of grid-connected systems are integrated in buildings.

Off-grid PV systems for transmission, water-pumping, and rural electrification constitute up to 10% of the total PV market. Such applications are important in remote areas and are likely to remain so in developing countries.

Crystalline silicon

Today, more than 90% of PV modules are based on wafer-based crystalline silicon. This is expected to remain the main PV technology until at least 2020. It is a well-established and reliable technology that uses the abundant resources of silicon as primary feedstock material. The resource effectiveness and cost efficiency of production can still, however, be substantially improved.

Thin films

Thin films are based on a completely different manufacturing approach. Instead of producing an ingot and then cutting it into wafers, thin films are obtained by depositing extremely thin layers of photosensitive materials on a low-cost backing, such as glass, stainless steel, or plastic.

The main advantages of thin films are their relatively low consumption of raw materials, the high automation and resource efficiency of production, their suitability for building integration, and their better appearance and reduced sensitivity to overheating. The current main drawbacks are lower efficiencies, limited experience of lifetime performance, and (still) small production units.

Third-generation devices and long-term PV technology road map

The long-term PV market will look very different from today's market. All major PV technology road maps forecast that the share of crystalline silicon systems will significantly decline after 2020 in favor of a stronger diffusion of thin films (Hoffmann 2004; NEDO 2004; PVNET 2004; PV-TRAC 2005; Frankl, Menichetti, and Raugei 2008; EUPVPLATF 2007).

All three categories of PV technology mentioned above are expected to coexist in the long term, each one responding to specific application needs and market segments.

Costs and potential for cost reduction

The investment costs of PV systems are still high, although—as these systems do not have moving parts—operating and maintenance costs are much less significant, about 0.5% of capital investment per year. This represents the most important barrier to PV deployment.

PV costs have, in the past, decreased, with a learning rate of 15%–20% (Neij 2007).[45] This resulted in a significant decrease in costs from the early 1990s until 2004. However, since 2004, PV prices have increased, driven by increasing demand for PV (especially in Germany and Japan) and a shortage of purified silicon. Crystalline silicon modules are currently back to 2004 (nominal) prices and are expected to decrease further as new manufacturing plants and silicon-purification facilities come on line.

At present, PV modules account for roughly 60% of total system costs, with mounting structures, inverters, cabling, etc. accounting for the rest. Total PV-system costs were about $6.25 per watt by the end of 2006, although some PV systems were sold at $5.50 per watt in Germany.[46] They were expected to drop to $5–$5.60 per watt in 2008 and to $3.75–$4.40 per watt by 2010.

The increasing penetration of thin film modules in the market will help drive down total PV-system costs. Thin film modules are produced at about $2.25 per watt today (compared with $3.75 per watt for crystalline silicon), and their cost is expected to drop further to $1.50–$1.90 per watt by 2010. A sustained high learning rate until 2050 is justified by the double technology shift expected in PV systems, from current crystalline silicon to thin films to third-generation novel devices. Mass-scale integration in buildings is assumed to significantly reduce costs related to mounting structures.

The cost of the electricity generated from PV modules also depends on the amount of local solar irradiation, the system lifetime, and the discount rate. The expected PV electricity generation costs in 2050, as a function of the number of full-load hours, are expected to be in the range of $0.05–$0.07 per kWh in good irradiation places (above 1,600 kWh/kWp* per year). Electricity produced in PV building-integrated systems is fed directly into the distribution grid. Its generation costs, therefore, compete with electricity retail prices.

Concentrated solar power

CSP uses direct sunlight, concentrating it several times to reach higher energy densities and thus higher temperatures. The heat is used to operate a conventional power cycle, e.g., through a steam turbine or a stirling engine that drives a generator.

The technology has two basic features:

- It is best suited for areas with high direct solar radiation. These areas are widespread but not universal.
- Because it uses a thermal energy intermediate phase, it has the potential to deliver power demand, using stored heat in various forms. Heat storage also offers the potential for continuous solar-only generation. Alternatively, CSP can work in tandem with fuel combustion in a hybrid plant, using the same steam generators, turbines, and generators to produce electricity on a continuous basis.

Expansion of CSP technologies will be limited by the regional availability of good-quality sunlight. A yearly direct insolation of 2,000 kWh/m^2 is often considered a minimum requirement. The

45 A learning rate of 20% means a 20% reduction in cost per each doubling of cumulative installed capacity.

46 All figures are in 2005 dollar rates.

Middle East, North America, South Africa, Australia, south-western United States, parts of South America, and central Asian countries from Turkey to parts of India and the PRC are among the most promising areas. Large engineering and industry groups, notably in Germany (Flabeg, Fichtner, and Schott) and Spain (Abengoa, Accioina, ACS Cobra, and Iberdrola), are now active in these markets.

Concentrated solar power uses conventional technologies and materials (glass, concrete, steel, and standard utility-scale turbines). Production capacity can be rapidly scaled to several hundred megawatts per year using existing industrial technologies.

There are three main types of CSP technologies: troughs, towers, and dishes. The solar flux concentration ratios that are typically obtained are expressed in suns: 30–100 for the trough systems, 500–1,000 for the tower, and 1,000–10,000 for the dish.

Troughs. Parabolic trough-shaped mirror reflectors linearly concentrate sunlight onto receiver tubes, heating a thermal transfer fluid. Fresnel collectors are a less effective but significantly cheaper form of trough in which the absorber is fixed in space above the mirror field, which is made up of segments that focus collectively on a receiver (Mills 2004).

Towers. Numerous heliostats concentrate sunlight onto a central receiver on the top of a tower. This is sometimes coupled with a second concentration step.

Dishes. Parabolic dish-shaped reflectors concentrate sunlight in two dimensions and run a small engine or turbine at the focal point.

Usually based on trough or tower designs, CSP on-grid generation is evolving toward larger installations. In addition, some developers are now proposing large plants made of many dishes. New concepts, such as compact Fresnel linear collectors and multi-tower arrays, may emerge as ways to effectively use available roof surfaces for distributed power generation in sunny cities (Mills 2004).

Costs and potential for cost reduction

Investment costs today for trough plants are in the range in $4–$9 per watt, depending on local construction costs, on the desired yearly electrical output, and on local solar conditions. Capital costs for a 10-MW tower start at $9 per watt but would be lower for a bigger plant. Capital costs for dishes are above $10 per watt but might fall with mass production.

Plants under construction are expected to generate electricity at a cost of $125–$225 per MWh, depending mostly on the location.

There is considerable scope to reduce the cost of all elements of CSP. For example, the performance of trough plants with direct steam generation could be improved by using larger turbines to allow for better conversion rates and smaller mirror surface. Thinner mirrors to prevent dust deposition, storage in concrete and phase-change materials, and the creation of higher temperatures in the solar field are other potential sources of savings (Ferriere 2005). However, this potential will only be reached if there is an active marketplace that can support technology learning.

The United States Department of Energy has recently set the objective of making CSP competitive against carbon-constrained base-load power by 2020. The industry considers that learning and economies of scale could achieve this in the next 10–15 years, provided that global CSP capacities of 5,000 MW are built. Detailed analyses have confirmed that future costs may lie in the range of \$43–\$62 per MWh for trough plants and \$35–\$55 per MWh for tower plants (Sargent & Lundy LLC consulting Group 2003). Cost reduction from current levels would come from increased volume production, plant scale-up, and technological advances. Significant cost reductions could be achieved with technology improvements limited to current demonstrated or tested technologies and the deployment of 2.8 GW trough plants and 2.6 GW tower plants; further reductions would be dependent on more active research and development and the deployment of 4.9 GW trough plants and 8.7 GW tower plants.

Wind

Wind power has been a very successful technology, growing rapidly worldwide. Since 2001, installed capacity has grown by 20%–30% a year. In 2007 alone, \$31 billion worth was added, bringing global capacity to 94 GW. These are predominantly onshore installations.

From the 1970s to the early 1990s, a variety of concepts have been tested. Today's standard is a three-bladed horizontal axis, upwind, and grid-connected wind turbine. The power-generating capacities of the turbines that were available in 1980 were in the range of 50 kW to 100 kW. The largest wind turbines today are units of 5 MW to 6 MW with a rotor diameter of up to 123 meters. Turbines have doubled in size nearly every 5 years, but a slowdown in this rate is expected in the near term, as transport and installation constraints start to limit these continuous increases.

Market overview

Onshore wind power installed costs in 2006 ranged from a low of \$1,224 per kW in Denmark to a high of \$1,707 per kW in Canada. Since 2004, turbine prices, constituting about 75% of project costs, have increased about 20%. Operation and maintenance costs for service, consumables, repair, insurance, administration, and site leasing for new large turbines in 2006 ranged from 2% to 3.5% of capital cost—or from \$13 to \$24 per MWh.

Offshore costs are largely dependent on water depth and the distance from shore. Recent offshore costs in the United Kingdom, where 90 MW of capacity was added in 2006, ranged from \$2,226 to \$2,969 per kW. The costs of offshore foundations, construction, installations, and grid connection are significantly higher than for onshore wind farms. Offshore turbines are typically 20% more expensive, and towers and foundations cost more than 2.5 times the price of an onshore project of similar size.

The United States is leading the market in terms of annual installations, and with more than 16 GW installed, it ranks second largest in the world. India and, more recently, the PRC have also been witnessing impressive growth and now rank fourth and fifth, respectively, in installed capacity.

The global market for wind power has created an international industry with an estimated annual turnover of more than \$31 billion in 2007. It has fostered a substantial manufacturing industry with about 200,000 employees.

Six leading wind turbine manufacturers accounted for about 90% of the global market in 2006. Turbine manufacturing continues to expand in Europe, and new production plants are being opened in India, the PRC, and the United States. Four leading wind turbine companies opened manufacturing facilities in the United States in 2006, including India's Suzlon. There are now 40 turbine manufacturers operating in the PRC market, and one of them, Goldwind, has reached the top 10 in terms of market share worldwide.

Onshore wind power

Today, most of the world's wind power capacity is land-based. The size of onshore wind turbines has increased steadily over the last 25 years. Large turbines can usually deliver electricity at a lower average cost than smaller ones, as the costs of foundations, road building, maintenance, grid connection, and other factors are largely independent of the size of the turbine. Large turbines with tall towers use wind resources more efficiently.

In Spain, the average size installed in 2006 was 1,100 kW, well below that of Germany (1,634 kW) and the United States (1,466 kW). In India, the average size installed in 2006 was approximately 800 kW, significantly below the level of other countries. This difference is mainly because Indian manufacturers only recently began producing megawatt-scale turbines.

Costs

About 75%–80% of wind-power production costs are capital costs. This makes wind power relatively capital-intensive compared with conventional fossil fuel-fired generation technologies, in which 40%–60% of total costs are related to fuel and operation and maintenance.

The capital costs of wind energy projects are dominated by the price of the wind turbine. Three major trends have dominated the cost of onshore wind turbines in recent years:

- Turbines have become larger and taller.
- Efficiency of turbine electricity production has increased steadily.
- Investment cost per kW installed power decreased until 2004.

Table 5.2 shows the cost structure for a medium-sized (850 kW–1,500 kW) onshore wind installation.

Energy output from a wind turbine is proportional to the swept area of the rotor. So are manufacturing costs.

Operation and maintenance

The main components of operation and maintenance costs are maintenance and repair, spare parts, insurance, and administration costs. Over the life of a turbine, these costs can constitute about 20%–25% of the total costs per kWh produced.

Cost of power

The cost of power generated ranges from $.089 to $.135 per kWh at sites with low average wind speeds, to between $.065 and $.094 per kWh at sites with high average wind speeds (give wind speed). At a medium wind site, average costs are estimated to be $.085 per kWh. The quality of the wind resource critically influences production costs.

Offshore wind power

Offshore wind power technology is less mature and currently about 50% more expensive than onshore wind installations. Yet offshore installations produce up to 50% more output than onshore machines because of better wind conditions. New approaches in foundation technology, larger turbines, more efficient and reliable components, and learning from early projects have increased the attractiveness of offshore wind energy in recent years. Offshore wind faces the challenges of technological

Table 5.2: Cost Structure for a Typical Medium-Sized Onshore Wind Installation

	Share to total cost (%)	Typical share of other costs (%)
Turbine (ex works)*	74–82	–
Foundation	1–6	20–25
Electric installation	1–9	10–15
Grid connection	2–9	35–45
Consultancy	1–3	5–10
Land	1–3	5–10
Financial costs	1–5	5–10
Road construction	1–5	5–10

*Ex works means that no balance-of-plant costs, i.e., works, foundation, or grid connection costs, are included. Ex works costs include the turbine as provided by the manufacturer, including the turbine, blades, tower, and transport to the site.

Note: Based on data from Germany, Denmark, Spain, and United Kingdom for 850–1,500 KW turbines.

Source: Lemming et al. 2008.

performance in harsh conditions, a shortage of installation vessels, competition for space with other marine users, environmental impacts, and grid interconnection.

Five countries have offshore wind power capacity. These are Denmark, Ireland, the Netherlands, Sweden, and United Kingdom, with a total of 1,102 MW installed in 2007. Most of this capacity is in relatively shallow water (less than 20 meters deep) and is close to the coast (less than 20 kilometers). Offshore wind farms have used turbines of 2 MW or larger since 2000.

Today, the high cost of offshore developments, difficulties in siting approvals, spatial planning uncertainties, constraints in the manufacturing supply chain, and the scarcity of installation vessels are causing some delays. Nonetheless, several projects in Denmark, Germany, and the United Kingdom are expected to be completed in the near term. The world's largest offshore wind farm, the London Array, received planning approval in December 2006, and the first phase of development was expected in 2009. Situated more than 20 kilometers offshore, with 1,000 MW of capacity, it will be capable of powering one quarter of London households.

Offshore wind power potential is currently untapped in Asia and Pacific.

Coal and natural gas: the generation of electricity

The rising consumption of coal for electricity in the region is increasing the emission of GHGs. Improving the efficiency of power plants could cut emissions and save fuel. Coal demand would drop

21% in the PRC if its power plants were as efficient as the average plant in Japan.

Natural gas is another option for generating electricity. Natural gas combined cycle (NGCC) plants have the lowest CO_2 emissions of all fossil fuel-based technologies, because of the low carbon intensity of natural gas and the high efficiency of the plants.

Power generation using natural gas is competitive with coal at today's prices for natural gas and coal in many regions of the world (for gas, typically $4–$8 per GJ). However, fuel costs in NGCC plants account for 60%–75% of total generation costs, compared with plants powered by renewables, nuclear, or coal, where fuel costs account for between 0% and 40%.

Plant efficiency in the People's Republic of China

Installed power generation capacity in the PRC increased tenfold from 1985 to 2006, reaching 622 GW. Seventy-eight percent of the electricity supply in 2006 was from coal-fired plants, mostly pulverized coal, and coal-fired capacity is expected to hit 1,259 GW by 2030. Most of the plants use a great deal of coal—the equivalent of 100 million tons of coal equivalent a year—more than could be achieved with the best available technologies.

The country is planning to introduce a large number of more efficient plants. The Huaneng Yuhuan power plant in Zhejiang province is the world's largest coal-fired ultra-supercritical plant, with a target efficiency of more than 45% higher heating value.

Table 5.3 shows emissions relative to electricity generation in the PRC's coal-fired plants. The coming of many supercritical plants, along with the retirement of older, small-capacity units, is expected to improve average efficiency from 32% in 2005 to 39% in 2030 and should reduce emissions per kWh by 28% in 2030 compared with 2005.

Plant efficiency in India

Power generation is rising rapidly in India, growing 7.1% in 1 year from 154,685 MW in 2005–2006. However, the country still experiences severe power shortages—an overall shortage of 9.9% in 2006–2007. To meet demand, an increase in utility-based generation of 60,000 MW is expected during the 11th Five-Year Plan by 2012. A significant proportion of this new capacity is likely to be coal-based. The overall low efficiency of these power plants in India, despite recent large investments in new capacity and high aggregate technical and commercial transmission and distribution losses, are key concerns. The power sector accounts for more than 50% of GHG emissions from the energy sector.

Coal-based power generation in India currently contributes nearly 57% of the installed capacity at 70,682 MW. The technologies for mitigation of GHGs in the coal-based power sector include supercritical and ultra-supercritical steam cycles and the integrated gasification combined cycle (IGCC).

India has now adopted the supercritical steam cycle for ultramega power plants, which are plants of at least 4,000 MW. The ultra-supercritical steam cycle is still not considered economically viable. An IGCC plant of 300 MW is being planned in Vijayawada.

Boosting efficiency and lowering CO_2

Fuel consumption and CO_2 emissions could be reduced considerably if advanced technologies were

Table 5.3: Coal-Fired Electricity Generation and CO_2 Emissions in the PRC

	1990	2005	2015	2030
Generation, (TWh)	471	1,996	4,326	6,586
Capacity, (GW)	87	368	814	1259
CO_2, (Mt)	589	2,424	4,328	5,997
Emissions (kg of CO_2/kWh)	1.27	1.21	1.00	0.91

CO_2 = carbon dioxide, GW = gigawatt, kWh = kilowatt-hour, Mt = million tons, TWh = terawatt-hour.

Source: IEA, Energy Technology Perspective (2008).

employed for retrofitting existing power plants (Table 5.4).

For a power plant with efficiency of 30%, an increase in efficiency to 45% brings about a 50% decrease in CO_2 emissions.

Efficiency improvements also have the potential to reduce emissions of sulfur dioxide and, in certain cases, nitrous oxides (NO_x). NGCC plants have the lowest CO_2 emissions of all fossil fuel-based technologies because of the low carbon intensity of natural gas and the high efficiency of the plants.

Advanced steam cycles

Supercritical and ultra-supercritical plants are defined by the steam temperatures they generate. Supercritical plants use steam temperatures of 540°C and above, while ultra-supercritical plants use steam at 580° C and above. Supercritical steam cycle technology has been used in OECD countries for several decades. Typically, a switch from supercritical to ultra-supercritical steam conditions would raise efficiency by another 4 percentage points. Overall, the efficiency of ultra-supercritical pressure units could be in the range of 50%–55% by 2020.

Supercritical technology is already used in the region. In the PRC, more than 18 GW of supercritical units were installed in 2006. There are ultra-supercritical plants in operation in Japan, Denmark, and Germany. Ultra-supercritical units operating at temperatures of 700° C and higher are under development. They will need to use nickel-based superalloys for some components. These are already used in gas turbines, but larger components are needed for steam boilers and turbines, and the operating environment is different. International program, such as the European Conference–supported AD700 project and the associated COMTES700 demonstration in Germany, as well national programs, such as COORETEC in Germany, are seeking to develop the necessary materials and components (IEA 2007b).

Because of fuel savings, the total investment cost for ultra-supercritical steam cycle plants can be 12%–15% higher than the cost of a sub-critical steam-cycle and still be competitive. The balance-of-plant cost is 13%–16% lower in an ultra-supercritical plant because of reduced coal handling and reduced flue gas handling. The boiler and steam turbine costs can be as much as 40%–50% higher for an ultra-supercritical plant. Studies in the United States of supercritical coal power plants indicate a relatively low learning rate of 5% for the capital cost.

Integrated gasification combined-cycle

IGCC technology (Maurstad 2005) comprises four basic steps:

- Fuel gas is generated from the partial combustion of solid fuels, such as coal, at pressure in a limited supply of air or oxygen.
- Particulates, sulfur, and nitrogen compounds are removed.
- The clean fuel gas is combusted in a gas turbine generator to produce electricity.
- The residual heat in the hot exhaust gas from the gas turbine is recovered in a heat recovery steam generator—the steam is used to produce additional electricity in a steam turbine generator.

Table 5.4: Performance Summary for Different Fossil Fuel-Fired Plants

Plant Type		PCC	PCC	PCC	PCC	NGCC	IGCC
Fuel		**Hard coal**	**Hard coal**	**Hard coal**	**Hard coal**	**Natural Gas**	**Hard coal**
Steam Cycle		**Sub-critical**	**Typical supercritical**	**Ultra-supercritical (best available)**	**Ultra-supercritical (AD700)**	**Triple pressure reheat**	**Triple pressure reheat**
Steam conditions		180 bar 540°C 540°C	250 bar 560°C 560°C	300 bar 600°C 620°C	350 bar 700°C 700°C	124 bar 566°C 566°C	124 bar 563°C 563°C
Gross output	MW	500	500	500	500	500	500
Auxiliary power	MW	42	42	44	43	11	67
Net output	MW	458	458	456	457	489	433
Gross efficiency	%	43.9	45.9	47.6	49.9	59.3	50.9
Net efficiency	%	40.2	42.0	43.4	45.6	58.1	44.1
CO_2 emitted	t/h	381	364	352	335	170	321
Specific CO_2 emitted	t/MWh net	0.83	0.80	0.77	0.73	0.35	0.74

CO_2 = carbon dioxide, IGCC = integrated gasification combined cycle, MW = megawatt, NGCC = natural gas combined cycle, PCC= pulverized coal combustion.

IGCC systems are among the cleanest and most efficient of the coal technologies. Gasification technologies can process all carbonaceous feedstocks, including coal, petroleum coke, residual oil, biomass, and municipal solid waste. There are 17 (totaling 4,000 MW) IGCC plants operating in the world today—of which five are using coal alone (IEA Clean Coal Center 2007).

The net efficiency of existing coal-fired IGCC plants is about 40%–43% (IEA 2007b). Recent gas turbines would enable this to be improved, and future developments should take efficiencies beyond 50%. The investment cost of IGCC is about 20% higher than that of Pulverized Coal Combustion (PCC). There is, however, more uncertainty in IGCC costs, as there are no recently built coal-fueled IGCC plants and the existing ones were originally constructed as demonstrations. Availabilities have also not yet reached the demonstrated level of operating PCC units. Suppliers have plans to bring capital costs within 10% of that of PCC.

Groups of suppliers have gotten together to develop IGCC plant designs (600 MW) to drive down costs and encourage the market. This is aimed at facilitating planning and decision making for power producers. Examples are those from GE-Bechtel and Siemens with ConocoPhillips. With IGCC now available as a commercial package, more orders could follow as utilities see the cost decreasing and availability improving. Subsidies or incentives may still be necessary to cover the higher cost compared with PCC.

IGCC fits well with carbon capture and storage (CCS), and there are CCS projects planned in several countries, including Canada, Australia, Germany, and the United Kingdom. Further programs are being pursued through the European Commission Hypogen initiative and the Green Gen project in the PRC. Inclusion of CCS will reduce efficiency, but the generation cost may be lower than for CO_2 capture on PCC.

Studies have shown that second-generation IGCC plants will have an investment cost around that of supercritical plants. Second-generation IGCC plants are expected to have lower unit costs than pressurized fluidized bed combustion and supercritical plants. Their competitiveness relative to NGCC plants depends on the evolution in natural gas prices.

CO_2 capture and storage

CCS involves three main steps. These have been used in the chemical processing and oil and gas industries for decades but are not yet incorporated into large-scale power plants:

- CO_2 capture from a large-scale stationary source, such as power plant or other industrial emission processes. This includes gas processing transformation and compression.
- Transportation to an injection sink. Onshore and offshore pipeline, ships, and trucks are the most common options.
- Underground geological injection. This involves injecting CO_2 in a supercritical state via well bores into suitable geological strata, such as deep saline formations, depleted oil and gas reservoirs, and non-mineral coal seams on land or under the sea floor (at depths generally exceeding 700 meters). Other methods, such as storage in ocean waters and mineral carbonation, are still in the research phase and will require a considerable amount of testing and

assessment of environmental risks, especially for ocean storage (IPCC 2005). Most countries, including those in the European Union, exclude storage in ocean waters for environmental reasons.

Turning the gas into storable solids through chemical reaction with rocks would require very large quantities of reactant and enormous storage space for the reaction product.

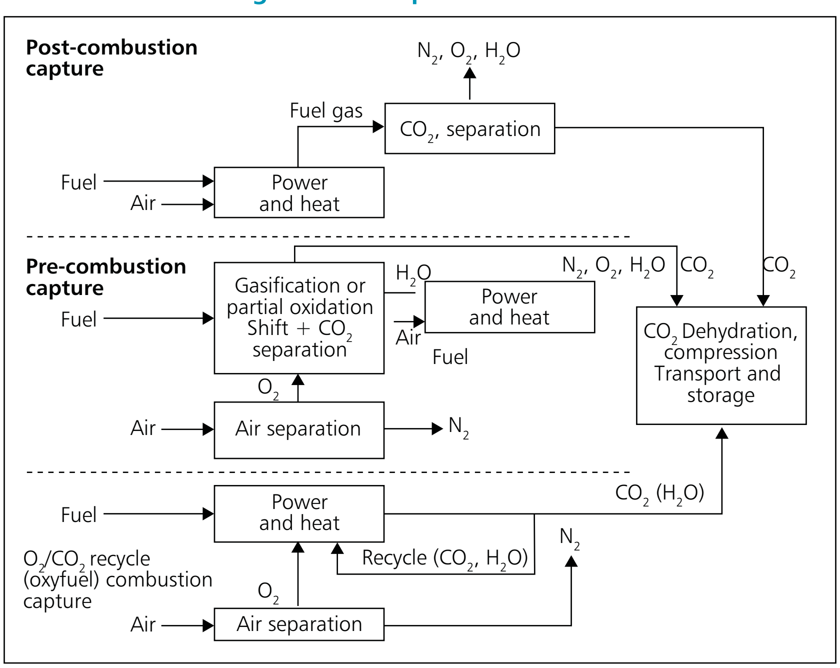
CO_2 capture

Most human CO_2 emissions come from power generation and large-scale industrial processes. The cost of capturing CO_2 from these large-scale emission sources is much less than from distributed sources, such as transport.

There are three main classes of CO_2 capture process. With post-combustion processes, CO_2 is captured at low pressure from flue gas that generally has 2%–25% CO_2 content. The challenge is to recover CO_2 from the flue gas economically. The separated CO_2 gas has to be compressed before transportation.

CO_2 can also be captured pre-combustion in coal- or natural gas-burning plants. Partial oxidation of the fuel with air or oxygen in the gasification process enables the capture of high concentrations of CO_2 (more than 95%) before combustion in the gas turbine. In the oxy-fuel combustion, the combustion takes place in a mixture of oxygen and CO_2. The oxygen is produced by cryogenic distillation of air. The pure oxygen is mixed with recycled CO_2 from the combustion chamber. These capture processes are shown in Figure 5.1.

Figure 5.1: Capture Processes



CO_2 = carbon dioxide, H_2O = water, N_2 = nitrogen gas, O_2 = oxygen gas.

Costs and potential for savings for power plants

The bulk of the costs of CCS projects are associated with CO_2 capture. CCS costs between $40 and $90 per ton of CO_2 emissions removed, depending on the fuel and the technology that the power plant uses. For the most cost-effective technologies, capture costs alone are $25–$50 per ton, with transport and storage costs at about $10. Because CO_2 capture itself uses more energy and leads to the production of more CO_2, the cost per ton of CO_2 emission reduction is higher than the per ton cost of capturing and storing CO_2. The gap between the two narrows, however, as CO_2 capture efficiency increases.

In some circumstances, depending on factors, such as oil prices, extraction economics, and reservoir performance, using CO_2 for enhanced oil recovery can offset part or all of the capture, transportation, and injection costs. By 2030, costs for coal-fired plants could fall below $35 per ton of CO_2 captured, provided that sufficient research and development occurs and that demonstration projects are successful (IEA 2008b).

Using CCS with new power plants fired with natural gas or coal would increase electricity production costs by $0.02–$0.04 per kWh. By 2030, the additional costs could drop to $0.01–$0.03 per kWh (Remme and Bennaceur 2007).

Efficiency and retrofitting

Capturing CO_2 from low-efficiency power plants is not economically viable. The higher the efficiency of electricity generation, the lower the cost increases per kilowatt-hour of electricity. Future PCC systems employing superalloys, high temperature hydrogen gas turbines, and new CO_2 separation technologies should enable power generation efficiencies with CO_2 capture that are comparable with current conventional plants without capture (IEA 2007b).

A case study of a new gas-fired power plant in Karsto, Norway, has compared the costs of an integrated system (where steam was extracted from the power plant) with those of a back-end capture system (with its own steam supply) designed as a retrofit after the power plant had been built. The analysis suggested that the retrofit would reduce efficiency by 3.3% more than the integrated option, at a similar investment cost (IEA 2004a).

As most coal-fired power plants have a long life span, any rapid expansion of CO_2 capture into the power sector would require an investment in retrofitting. New capacity will also be needed to offset the capacity de-rating caused by CO_2 capture.

Capture readiness

Current financial and regulatory frameworks do not make CCS from fossil fuel-fired power plants economically justifiable. The option of making a new plant capture-ready when the appropriate economic conditions are in place is under evaluation, following the recommendations of the 2005 G8 Gleneagles Plan of Action (Mandil 2007). The 2007 IEA Greenhouse Gas R&D Programme's study of capture-ready plants provides conceptual definitions and assesses the economic implications. The three elements under consideration are

- plant space and access requirements for additional equipment needed to capture CO_2,
- a reasonable storage route for CO_2 (including a suitable storage reservoir in the vicinity) and feasible transportation options, and
- an economic analysis of CCS options (IEA GHG 2007a).

Transporting CO_2

Pipeline transport of CO_2 is generally more cost-effective than the alternatives (trucking or sea shipping), especially for distances less than 1,000 kilometers. A network of CO_2 pipelines has been operating in the United States for more than two decades, with a proven track record of safety.

The cost of transportation depends on terrain and pipeline configurations, pressure requirements, distance, and CO_2 volumes. For a 250-kilometer pipeline carrying 10 Mt CO_2 a year, costs range from $1 to $8 per ton of CO_2 onshore and are 40%–70% higher offshore. Pipeline transportation is an established technology, and no significant cost decrease is expected, except in the optimization of the configuration and scheduling of the pipeline network.

Geological storage

Geological storage options include

- deep saline formations
- depleted oil and gas fields. These are expected to be ideal CO_2 sinks, as the formations have generally been well characterized by the oil and gas industry, and they generally have excellent geological seals. But the permanence of storage over longer timescales has yet to be demonstrated.
- enhanced oil recovery. CO_2 has been used for almost three decades to enhance oil recovery. Up to an additional 5%–23% of hydrocarbon recovery can be obtained, depending on CO_2 and oil miscibility and reservoir conditions.
- enhanced gas recovery, through reservoir re-pressurization. Only one commercial project has been implemented (the Gaz de France K12-B project). This technology is still considered speculative, as the additional amount of gas extracted using CO_2 can be very low.
- enhanced coal bed methane recovery.

Other geological potions include basalts, caverns, and mines. But these techniques are generally limited by the available storage volumes, the absence of natural seals, low injectivity, or chemical interactions. Basalt formations have the advantage of being widespread, and these require further research.

Table 5.5 gives a worldwide assessment of capacity by storage type.

Table 5.5: Storage Capacity ($Gt\ CO_2$)

Storage option	Deep saline formations	Oil and gas fields	Coal beds
Lower estimate	1000	600	3
Upper estimate	> 10000	1200	200

Gt CO_2 = gigatons of carbon dioxide.

Source: IPCC (2005).

The largest capacity of CO_2 storage exists in deep saline formations.

Factors that affect storage costs include infrastructure requirements (injection and monitoring wells and retrofitting facilities, especially in offshore environments), the volumes to be injected, injection depth, and hydrocarbon economics. Enhanced oil recovery allows the recovery of 0.1–0.5 ton of additional oil per ton of CO_2 injected. In cases where the enhanced recovery contributes to revenue generation, the cost of CCS can be negative. Estimated storage costs for enhanced oil recovery range from \$35–\$40 per ton of CO_2. Storage in saline aquifers is estimated to cost \$0.50–\$10 per ton of CO_2, and in depleted oil and gas fields, \$1–\$40 per ton of CO_2. Increases in material costs, combined with a lack of resources (drilling rigs and personnel), have contributed to the rise in CCS costs, which more than doubled from 2004 to 2007.

Nuclear energy

Nuclear power generation has the capacity to provide large-scale electricity, virtually CO_2-free. The technology is already proven. It has the potential to play a very significant role in the decarbonization of power generation. Of late, nuclear power generation has become more prominent in both developed and developing countries. The PRC and India are likely to become the dominant users of nuclear power.

Current status of nuclear power generation

In August 2007, there were 438 operating nuclear power plants in 30 countries. They had a total capacity of 372 GW (IAEA database). Thirty-one reactors were under construction in Asia, Russian Federation, Bulgaria, and Ukraine, which will produce an additional 24 GW. Nuclear power supplied 2,700 TWh in 2006, 16% of the world's electricity and 25% of OECD countries' electricity generation. The global operating experience of nuclear power reactors now exceeds 12,000 reactor-years.

Generation I prototype reactors were developed in the 1950s and 1960s. Very few are still operational. A large number of Generation II reactors were built in the 1970s as large commercial power plants, many of which are still operating today, often with licenses for extension, typically to 60 years. In the United States, about 46 reactors have been granted life extensions, the most recent (Nine Mile Point Unit 2) to 2046. Twelve others are in the application process (NEI 2008a). Generation III reactors were developed in the 1990s with a number of evolutionary designs that offered advances in safety and economics. Generation III+ reactors have additional evolutionary and revolutionary aspects to their designs. Generation IV reactors offer the prospect of further enhanced safety and economic advantages, while minimizing waste production and improving proliferation resistance and physical protection.

Nuclear electricity generation depends on the availability of uranium for fuel. In addition, the reprocessing of spent fuel would enable existing supplies to be used more efficiently. The use of fast-breeder reactors, which generate fissile material faster than they consume it, would mean the world has almost unlimited stocks of readily available fuel. Fast-breeder reactors have received significant research funding over several decades, but there has been little commercial incentive to build them because uranium has, until recently, remained relatively inexpensive. These reactors can extract some 50 times more energy per kilogram of uranium than other reactor types.

Thorium can also be used to provide fuel for nuclear power plants, although the thorium fuel-cycle has received little attention because of the availability of uranium. India has shown the most interest in developing the thorium cycle, driven by ample domestic thorium resources and a shortage of domestic uranium. Thorium is thought to be about three times as abundant in the earth's crust as uranium.

The cost of nuclear power

Three main factors contribute to the direct costs of nuclear power: construction costs; operation, maintenance, and fuel costs; and so-called back-end costs, for waste management and decommissioning.

To compare different technologies, a standardized methodology is used that produces a "levelized" cost expressed in currency units per kilowatt-hour (kWh) or megawatt-hour (MWh). This is the ratio of total lifetime cost to total expected output, expressed in terms of current value equivalent (NEA 2005). Levelized cost is equivalent to the average consumer price that exactly repays the investor and operator for the capital, operation and maintenance, fuel, and back-end costs, with a rate of return equal to the discount rate.

Based on data collected from 10 OECD countries, a Nuclear Energy Agency (NEA) study projected a total levelized cost (at 2004 prices) in the range of $30–$50 per MWh in all countries except Japan. In Japan, the total cost is expected to be $69 per MWh. Broadly, investment costs represent 70% of total costs, operations and maintenance 20%, and fuel-cycle costs 10%.

India's nuclear program is based on the promotion of nuclear energy through enhancing nuclear capacity, and the adoption of fast-breeder and thorium-based thermal reactor technology in nuclear power generation would bring significant benefits in terms of energy security and environmental protection, including mitigation of GHGs.

The country has developed the capability to build and operate nuclear power plants, observing international standards of safety. The current installed capacity of nuclear power plants is 3,360 MW, accounting for 2.34% of the total installed capacity of the country. The Nuclear Power Corporation of India Ltd. proposes to increase the installed capacity to 9,935 MW by 2011–2012. Strategies for the future focus on a three-stage nuclear power program for the optimal utilization of available nuclear energy resources. The first stage of 10,000 MW of nuclear power generation is based on pressurized heavy-water reactor technology using indigenous natural uranium resources. The second stage is proposed to be based on fast-breeder reactor technology using plutonium extracted by reprocessing the spent fuel obtained from the first stage. In the third stage, the country's vast thorium resources will be utilized.

Advanced nuclear power systems (fast-breeder reactors and fusion reactors) are being designed with the potential to make significant contributions toward energy demands in an environmentally acceptable manner. The economic efficiency and reliability of nuclear energy in India have been demonstrated by the reactors operating today. The fast-breeder reactors are the inevitable source of energy in the next 50 years.

Transportation

Despite rising oil prices and concerns about the climate, energy use for transportation is increasing around the world. High growth rates are forecast for most travel modes for decades to come. Two main factors influence the sector's emissions: changes in the volume of travel and changes in the efficiency of the mode of transport used. In Asia and the Pacific, precise growth rates are often uncertain, but given the still very low average rates of automobile ownership and high expected gross domestic product growth rates, vehicle travel is expected to increase significantly for many years to come.

Light-duty vehicles

Status and trends

Sales of light-duty vehicle (car, sport-utility vehicle, and small van) have increased dramatically in recent years, particularly in developing countries, such as the PRC and India. Box 5.1 describes a development that may further that trend.

Fuel-economy requirements in Japan and the PRC, expected requirements in the European Union, and recently passed legislation in the United States are all likely to result in substantial improvements in new car fuel use per kilometer, at least through 2015–2020. India is also expected to show strong improvements, in part due to expected strong sales of small cars. Other countries may also improve but at slightly slower rates. After 2020, fuel-economy trends are projected to be nearly flat since, without new policies, any gains from better technology are once again likely to be offset by increases in vehicle size, weight, and power.

Technologically advanced vehicles, such as the hybrid-electric, plug-in hybrids, and fuel cell vehicles, are expected to play a great role in the future, especially in the OECD countries. Together with these power-train shifts, non-engine improvements, such as increased use of lighter materials, improved aerodynamics, and better tires and accessories, are estimated to result in large efficiency gains. Hybrids are assumed to be about 50% more efficient (less energy intensive) than today's average new light-duty vehicles, and conventional (non-hybridized) gasoline vehicles about 30% more efficient, given strong improvements in engine/drive-train technologies. An overall reduction in new light-duty vehicle energy intensity of close to 70% can be achieved.

Non-engine components

Most fuel efficiency improvements in conventional vehicles are expected to derive from technologies and changes to vehicle design that are already commercially available today. Incremental fuel-economy technologies and their estimated costs and benefits are shown in Table 5.6.

Lighter materials, including high-strength steel and aluminum, are assumed to progressively deliver a weight reduction reaching 25% by 2050 at an estimated cost of $1 per vehicle. Taking into account improvement from other technologies, this

Box 5.1: A New Generation of Very Small, Inexpensive Vehicles

A revolution in the types of vehicles available in developing countries appears likely to begin soon, given announcements of plans to offer new models of very small, inexpensive cars in countries, such as the People's Republic of China and India. Manufacturers are pursuing this strategy with the aim of producing vehicles that would be affordable for most families in rapidly developing areas. Such models could cost less than $3,000 and consume as little as 4 liters per 100 kilometers, about half that of an average US car and two-thirds that of the average European or Japanese vehicle on sale today (Tata Motors 2008). Commercial operations have already started, and the vehicles are available in the market since June 2009.

Table 5.6: Potential Boost in Fuel Economy from Engine and Non-Engine Improvements

	Gasoline Vehicle (%)			Diesel Vehicle		
	Conventional	Advanced	Hybrid	Conventional	Advanced	Hybrid
Non-engine improvements	1.5–14	1.5–14	1.5–14	1.5–14	1.5–14	1.5–14
Tires	0.5–4	0.5–4	0.5–4	0.5–4	0.5–4	0.5–4
Improved aerodynamics	0.5–4	0.5–4	0.5–4	0.5–4	0.5–4	0.5–4
Lights	0–2	0–2	0–2	0–2	0–2	0–2
Better appliances	0.5–4	0.5–4	0.5–4	0.5–4	0.5–4	0.5–4
Material substitution (25% lower weight)	10–11	10–11	10–11	10–11	10–11	10–11
Variable valve timing / higher compression ratio						
No throttle		6–8	5–6	7–9	7–9	2–3
Turbocharging		2–3		3–4	3–4	
Direct injection		3–5	1–2	5–7	5–7	7–8
Improved combustion		2–3	2–3		1–2	3–4
Start/stop (lower idling)	0.5–3	0.5–3			0.5–2	
Continuously variable transmission (to replace automatic transmissions)	5–6	5–6		5–6	5–6	
Hybrid system			16–18			15–17
Total improvements compared to base gasoline vehicle	**14–27**	**28–45**	**40–52**	**30–43**	**32–47**	**40–55**
Cost for these improvements (change in vehicle price)	$1,500–$1,800	$2,800–$3,400	$4,000–$5,400	$2,500–$3,400	$3,000–$3,600	$4,200–$5,600

Source: IEA data and analysis.

is estimated to result in an additional reduction in fuel consumption of about 10%.

Power train options

A number of different power trains are in wide commercial use, and more may be commercialized in the future. Each of these power trains can be associated with a range of potential fuel efficiency improvements and corresponding costs. Table 5.6 provides IEA estimates of fuel economy improvement (reductions in fuel use per kilometer) associated with different technologies and their application to different configurations of vehicle (gasoline versus diesel, conventional versus advanced versus hybridized). Here "advanced" refers to vehicles that use advanced engine designs, whereas the non-engine improvements are the same as for "conventional" vehicles.

Virtually all the technologies listed in the table are commercial today, at least in some markets. Their costs are likely to be offset by the fuel savings they offer. This is particularly true in an analysis using social costs and benefits, and therefore taking into account most or all of the fuel used over a vehicle's life. This can represent several times more fuel (and fuel savings) than is typically considered by consumers when choosing among vehicles that have different fuel economies.

Both gasoline and diesel light-duty vehicles could achieve close to 50% reductions in fuel intensity even without hybridization, and more than 50% with hybridization. Today's hybrids contain many other technologies, such as light-weight materials and low-rolling-resistance tires, which could also be applied to non-hybridized vehicles. Therefore, the potential improvements even without hybridization could approach those for hybridized vehicles as incremental technologies are applied over time.

Similarly, gasoline vehicle efficiency could approach that of diesel vehicles over time, as gasoline engines improve and adopt some technologies already present on many diesel vehicles.

It can be seen that advanced gasoline power trains have the potential to approach the efficiency of diesel power trains; both gasoline and diesel advanced power trains could approach the efficiency of hybridized systems.

Vehicle hybridization, involving the addition of an electric motor, a controller, and an energy storage system (typically a battery) to the existing engine/fuel system, has proven to be a commercial success, at least in some market segments, despite relatively high costs. The most notable example, the Toyota Prius, has been joined by many other makes and models of hybridized vehicles in the past few years, and most major manufacturers were expected to offer at least one hybrid model (or one model with hybridization as an option) by 2009 (Passier et al. 2007).

Hybrid vehicles benefit from a much more efficient use of the internal combustion engine, allowing it to operate steadily at near-optimal loads. This is because the motor/battery system handles some of the peak power requirement and because engine power can be diverted to recharging the batteries during periods of low load. Hybrids also benefit from innovations, such as regenerative braking (which recovers energy during braking and returns this to the batteries, turning the engine off when the car is not moving), and from more efficient components, such as continuously variable transmission systems. Some of these components can also be added to vehicles that are not fully hybridized. And like conventional vehicle technologies, hybrid systems can be configured to increase vehicle power rather than only improving fuel economy.

Hybrid power trains, far more than conventional engines, also rely heavily on electronic controls. Full hybrids require a computer to manage the use of the electric motor, the loads on the combustion engine and batteries, engine shutdowns, and the use of regenerative braking and to ensure proper management and maintenance of the batteries. These vehicles demonstrate that improved electronic design can allow a much better use of the technological potential available, and they are paving the way for the much greater use of hybrid technologies and other complementary fuel-saving technologies on non-hybridized, conventional internal combustion engines.

Energy storage

Energy storage is critical to hybridization. Currently, this is provided by batteries. Batteries are being steadily improved, but even the best today—lithium-ion batteries, used in small electronics and beginning to be introduced for larger applications, such as vehicles—suffer from high cost and inadequate performance.

The energy density of today's best batteries, and for the foreseeable future, is much lower than that of conventional fuels. As a result, the more a vehicle relies on batteries for energy storage, the more batteries will be used, the heavier the vehicle will be, and the less space will be available for other purposes. This puts practical limits on the benefits that batteries can offer.

Batteries are also very expensive per unit of energy they produce. Typical commercial nickel-metal hydride batteries used on today's hybrids cost about $1,000 per kWh of storage capacity (ACEEE 2006). For the Prius, this cost amounts to a little more than $1,000 per vehicle. Lithium-ion batteries will offer improved energy and power densities, but their cost per unit of energy appears likely, at least in the very near term, to be as high as today's nickel-metal hydride batteries. For vehicle electrification to become a viable pathway toward eventually carbon-free vehicle travel, battery costs will need to come down by a half to two-thirds, possibly over the next 5–10 years. Batteries must also be able to endure up to 15 years of recharge discharge cycles or else must be replaced during the vehicle's life, perhaps doubling their life-cycle cost.

Plug-in hybrids

Plug-in hybrid vehicles combine the vehicle efficiency advantages of hybridization with the opportunity to travel part time on electricity provided by the grid rather than through the vehicle's internal recharging system. Plug-in hybrids are a potentially important technology for the reduction of oil use and CO_2 emissions by light-duty vehicles, since they offer the opportunity to rely more on the electricity sector, which is less expensive to de-carbonize than other sectors and are expected to be fully decarbonized by 2050.

Battery-motor systems are about three times as efficient as even a hybridized combustion engine system. As a result, even with fairly high future electricity prices, the end-use energy cost to the consumer is likely to be significantly lower with plug-in battery operation than with onboard liquid fuel. This may provide an important incentive for consumers to buy and use plug-in hybrids. Actual cost savings will depend on the relative fuel prices for electricity and liquid fuels in any given location, but 50% savings per kilometer are not unlikely.

The fuel savings from operating a plug-in hybrid on grid electricity must, of course, be weighed against the additional cost of purchasing such a vehicle.

Electric vehicles

Electric vehicles benefit from the removal of the entire internal combustion engine system, the drive train and fuel tank, giving a savings of up to $4,000 per vehicle compared with hybrids. But they require much greater battery capacity than plug-in hybrids and, without a complementary internal combustion engine, they will require a significantly more powerful motor/battery system to provide the peak power that drivers expect.

Pure electric vehicle prospects would no doubt benefit from the success of plug-in hybrids, in part because plug-ins are likely to help bring down the cost of batteries, motors, and control systems.

Fuel cell vehicles

Fuel cell vehicles represent a set of technologies very different from those discussed so far. The power plant, a fuel cell stack, is a highly efficient system for converting hydrogen into electricity. Vehicles would either store onboard or carry a liquid fuel rich in hydrogen (such as ethanol) with a reformer to take hydrogen out of the fuel and feed it into the fuel cell stack.

A wide variety of fuel cell systems and energy storage systems are in development, though at this stage the polymer-electrolyte membrane (fuel cell system with onboard compressed hydrogen storage) appears to be the most viable option.

Fuel cell vehicles need to overcome a number of technical hurdles, and their costs must be brought down significantly. Recent limited production runs of demonstration fuel cell cars have been estimated to cost at least $100,000 per vehicle, with fuel cell buses costing upwards of $1 million. Moving to large-scale production will help bring some costs down, but some component costs appear likely to remain high. For example, a fuel cell stack/controller system is currently estimated to cost at least $500 per kW of power, even in volume production.

For a very efficient fuel cell vehicle requiring 75 kW of power, the resulting fuel cell system cost would be $37,500. Researchers are looking for ways to cut the cost to under $100 per kW, but whether and when they will achieve this is unclear. A key goal is to cut the use of platinum (used as a catalyst) to a small fraction of its use in previous generations of fuel cells. A good deal of progress has recently been made in this area.

In short, the cost of the fuel cell stack system and the energy storage system must each come down by nearly an order of magnitude for fuel cell vehicles to reach a cost-competitive point. A wide range of research programs are focused on different approaches to achieving such targets, but the ultimate form of success, the level of success (and cost reduction), and the timing of such success are very difficult to predict.

Shift to public transit and non-motorized modes

The share of travel by different travel modes can have a large impact on energy use. This is true for passenger and freight travel and for urban and inter-urban traffic.

In any urban area, virtually all travel is accomplished by car, bus, rail, motorized two- or three-wheeled vehicles, bicycles, or walking. These choices have very different characteristics in terms of speed, cost, comfort, and energy use. In Hong Kong, China, for example, more than 80% of trips are made either by public transit (bus, tram, or train) or by non-motorized modes (walking or bicycling). In some US cities such as Houston, only about 5% of trips use these modes; more than 90% of trips are by private light-duty vehicles.

A number of factors influence the modes of passenger transportation chosen. Although population and building density are important among these and are not easy to change, most cities in the developing world have high densities and high shares of efficient modes of transportation and could maintain and even improve that efficiency if they take strong action. Cities that invest heavily in public transportation systems and in maintaining or improving the infrastructure for walking and biking, along with careful spatial planning and other complementary measures, will tend to maintain much higher shares of the most efficient modes than cities that cater more to automobiles by, for example, investing heavily in the expansion of road networks.

Clearly, the dynamics of city growth are complex, and it is not fully clear what circumstances and policies are needed to move a city along one pathway or another. But some elements appear critical: strong urban planning, major investments in public transit and non-motorized transport infrastructure, and policies to discourage car use. These clearly go well beyond technological considerations.

High-speed rail

High-speed rail is typically defined as steel-wheel-on-rail operation with cruise speeds exceeding 200 kilometers (km) per hour. Currently, such systems exist in Europe, Japan and other parts of Asia, and the east coast of the United States. Fast train trips of less than 3 hours can provide a very attractive alternative to air travel, as the journeys to airports and the process of going through check-in and security screening can make the total travel time longer than that.

Though the energy intensity of high-speed rail varies significantly with operating conditions and passenger load factors, recent experience in Europe and Japan shows that the average energy consumption per passenger-kilometer is generally in the range of one-third to one-fifth that of airplanes and cars (ENN 2008, Sierra Club 2001).

A key consideration for high-speed rail construction is the niche it serves. It can be competitive with air travel up to at least 700–800 km. The recent announcement of a new generation of technology (Alstom 2008) promises even greater speeds and applicable distances. However, high-speed rail is not especially advantageous for journeys of less than 200 km, as conventional rail systems achieve nearly the same overall time performance at much lower cost (SDG 2004).

Construction costs vary significantly from country to country because of differences in land costs, labor costs, financing methods, and topography. The costs per kilometer range from $10 million to more than $100 million (SDG 2004). The Channel Tunnel rail link between France and the United Kingdom cost four to six times as much per kilometer as typical construction over flat land.

Many high-speed rail lines are currently proposed and planned around the world. However, their rate of construction is far slower than announced plans would suggest. Europe leads with 2,000 km of high-speed lines in operation and with another 4,000 km planned for construction by 2020 (ENN 2008). The PRC is expected to build 3,000 km of high-speed railways within 15 years. Argentina has recently announced plans to build a 700 km line from Buenos Aires to Cordoba that would be the first high-speed rail in Latin America. Many other countries are planning lines, including Brazil, Morocco, Saudi Arabia, Iran, Israel, Turkey, Portugal, Russian Federation, Malaysia (with Singapore), Pakistan, and Viet Nam.

Truck and rail freight transportation

Surface freight transportation is one of the fastest-growing sectors worldwide and has one of the fastest growth rates in energy uses. In OECD countries, freight's energy use has grown faster than that of passenger transportation. Freight transport volumes are generally closely linked to economic growth, and they have grown most strongly in countries, such as the PRC and India, with high economic growth rates.

Freight truck energy efficiency varies considerably by country, reflecting different truck sizes and freight patterns; in most countries, efficiency improvement has been slowing in recent years.

Recent work in countries, including the United States, suggests that the trend in efficiency improvement has been higher in medium-duty (urban cycle) trucks than in large, long-haul trucks. There may also be a somewhat higher potential for efficiency improvement in urban cycle trucks, given the much better applicability of hybrid systems to these vehicles (Duleep 2007).

Buildings and appliances: an overview

Residential, service sector, and public buildings encompass a wide array of technologies in the building envelope and its insulation, space heating and cooling systems, water heating systems, lighting, appliances and consumer products, and business equipment. Other technologies also play an important role. Intelligent lighting, for example, helps reduce and manage energy loads. Energy consumption in buildings is highly influenced by local climates and cultures and even more so by individual users.

Unlike consumer goods, buildings can last for decades, even centuries. More than half of the existing building stock will still be standing in 2050. Buildings are much more frequently renewed than replaced. A considerable portion of many buildings is changed in time frames much shorter than the lifetime of the building. Lighting systems and numerous appliances, as well as heating, ventilation, and air-conditioning systems, are often changed after 15–20 years.

Many of these technologies are already economical, based on total life-cycle costs. But noneconomic barriers can be significant without the help of well-designed government policies. Several recently developed technologies (including high-performance windows, vacuum-insulated panels, and high-performance reversible heat pumps), when combined with integrated passive solar design, can reduce energy consumption and GHG emissions by 80%. A number of other technologies are under development, such as integrated intelligent building control systems, which could have an increasingly large impact over the next two decades.

Status and trends in the global buildings sector

Energy use in buildings currently accounts for 38% of global total final energy consumption.[47] Of this, 45% is consumed in OECD countries, 9% in countries in Central and east European countries, and about 46% in developing countries.

In developing countries, traditional biomass for heating and cooking accounts for 56% of total energy consumption. Electricity accounts for only 15% and reflects low electrification rates in many developing countries.

Although data on end-use energy consumption is sketchy outside OECD countries, space and water heating are estimated to account for about two-thirds of global energy consumption in buildings, and cooking for 10%–13%. The remaining electricity use is for lighting, cooling, and appliances and electrical equipment. However, there are significant variations among countries: for example, it is estimated that space and water heating in the PRC accounts for about three-quarters of all energy consumed in the buildings sector (Lawrence Berkeley National Laboratory and IEA analysis), while these uses might account for as little as a quarter in Mexico (Sheinbaum, Martinez, and Rodriguez 1996; and IEA analysis).

Technologies and measures to make buildings more energy efficient

The energy efficiency of buildings can be improved in many ways. Some of the most significant, particularly in terms of their contribution to the large reductions in CO_2 emissions, are discussed here.

The building shell, water heating, and systems integration

Envelope

The effectiveness of the building envelope depends on the insulation levels and thermal properties of walls, ceiling, and ground or basement floor. Improvements can reduce heating requirements by a factor of two to four compared with standard practice. This can be achieved at a cost of only a few percent of the total cost of residential buildings and at little or no net incremental cost in service-sector buildings (Demirbilek et al. 2000, Hamada et al. 2003, Hastings 2004). In countries that have mild winters but still require heating (including developing countries), modest amounts of insulation can readily reduce heating requirements by a factor of two or more, as well as substantially reducing indoor summer temperatures (Taylor et at. 2000, Florides et al. 2002, Safarzadeh and Bahadori 2005).

[47] In this chapter, the buildings sector includes the projections for the agriculture, fisheries, and "other non-specified" sectors in the IEA statistics. In 2005, they accounted for 345 Mtoe, or 13% of the buildings sector total.

In many cases, improvements to building envelopes can achieve net cost savings for the owner even in the short term. But typically, investments are needed early, while savings are achieved over a period of years. This creates a need for financing. Retrofitting high-rise residential buildings with energy-efficiency improvements when they are refurbished can yield energy savings of up to 80% and negative life-cycle costs.

Windows

The thermal performance of windows has improved greatly through the use of multiple glazing layers, low-conductivity gases (argon in particular) between glazing layers, low-emissivity coatings as one or more glazing surfaces, and the use of very low-conductivity framing materials, such as extruded fiberglass. Windows are available with heat losses of only 25%–35% that of standard non-coated double-glazed (or 15%–20% of single-glazed) windows. It is important that glazing with low-conductivity gases is well maintained, as a loss of filling can result in performance deterioration of up to 60%.

Glazings that reflect or absorb a large fraction of the incident solar radiation while maximizing the transmission of visible sunlight can reduce solar heat gain by up to 75%, thus reducing the need for cooling.

The cost of glazing and windows, even with these technological improvements, has remained constant or even dropped in real terms (Jakob and Madlener 2004).

The costs of replacing single glazing with more efficient glazing can be very low when windows need replacing (anywhere from about $57–$490 per ton of CO_2 saved) but can otherwise be an expensive option (Shorrock 2005, Ecofys 2005).

Hot water

The efficiency of hot-water systems can be improved in several ways, from installing hot-water cylinder insulation to installing condensing boilers or heat pumps. Solar water-heating systems, depending on the location, could provide as much as 60%–70% of domestic hot-water needs and perhaps up to 50% of the hot-water needs of service-sector buildings (up to 250°C). Solar water-heating systems can cost $1–$2 per watt of capacity, with the cost of energy supplied varying depending on the location and sunshine hours per year.

Systems integration

Buildings are complex systems. All of their components contribute to overall energy demand. These components need to be considered together as an integrated package. The interaction between them is often only partially understood at the design stage. Researchers, designers, and architects are trying to find ways to more systematically integrate the individual components to reduce energy consumption. Building-energy simulations can model the change in internal environmental conditions as the use of the building changes. A growing number of tools are available.

An example of effective technology integration is a “zero-energy” building. Zero-energy buildings consume energy, but their energy demand is balanced, on average, by the energy they produce. Another concept is zero-carbon buildings, where the net CO_2 emissions from the building are zero over a year. Minimizing the cost of these buildings requires an integrated systems approach. The challenge is significant in service sector buildings where complex designs, operational parameters, and user behavior combine in ways that are not always foreseeable.

Demand-side management

Demand-side management tools can play an important role in reducing CO_2 emissions from peak electricity generation where supply-side options are expensive. It influences the amount or pattern of energy use—for example, reducing demand during peak periods when energy-supply systems are constrained. Peak-demand management does not necessarily decrease total energy consumption. But it can reduce the need for investments in networks or power plants, particularly peak-load plants. Better management of the demand side will depend heavily on the development and deployment of smart grids, smart appliances, and advanced metering.

Cooling systems: air conditioning

Air-conditioning systems cool, ventilate, humidify, and de-humidify buildings. The efficiency of the air conditioners available on the market varies substantially. The least-efficient portable air conditioner currently available has an energy efficiency ratio of less than 1.5 watts cooling output per watts power input, compared with the most efficient split-room air conditioners, which can achieve a ratio of more than 6.5. There is room to improve even on this—for example, through using variable-speed drive compressors, improving heat transfer at the heat exchangers, optimizing the refrigerant, utilizing more efficient compressors, and optimizing controls.

New standards in effect in 2006 in the United States call for an improvement of 30% over the previous standard introduced in 1992. Japan's Top Runner Program has set far higher performance requirements than those in place in other OECD countries. Most air conditioners are driven by heat pumps. The efficiency of this technology has improved significantly in recent years. For example, the coefficient of performance of heat-pump air conditioners increased from about 4.3 in 1997 to about 6.6 in 2006, while some reach 9.0.

Developments to use solar power for cooling purposes are under way. Evaporative coolers also work well in hot, dry climates. These units cool the outdoor air by evaporation and blow it inside the building. Evaporative coolers cost about half as much to install as central air conditioners and use about a quarter as much energy.

In climates that are both hot and cold (seasonally or at different times of the day), reversible heat pumps can provide both heating and cooling needs. The efficiency of these systems depends both on the unit's coefficient of performance and on the building and the integration of the system into it. Recovery of ventilated hot or cold air can also help improve efficiency.

Costs

Well-designed passive solar homes can minimize or eliminate the need for air conditioning. Good "non-passive" building design should, in any case, be able to significantly reduce the need for air conditioning in many climatic conditions.

But where air conditioning is deemed necessary, more efficient systems offer the potential for significant energy savings at low cost. More efficient systems, although initially more expensive, can have lower life-cycle costs. However, there is a wide range in terms of costs, from a negative cost of energy saved in the case of replacement systems up to $0.03 per kWh. Programmable thermostat controls can save energy and money. Shifting to an energy-star rated air-conditioning unit can result in saving money (Seeline Group 2005).

In India today, room air-conditioner electricity consumption could be cut by about 10%–11% (for -$14 to -$65 per ton of CO_2 saved) to about 30% (for $120 to $170 per ton of CO_2 saved). This latter cost range could fall to between $50 and $100 per ton of CO_2 by 2030 (McNeil et al. 2005 and IEA analysis). In the PRC, split system heat-pump air-conditioning systems could potentially reduce air-conditioner electricity consumption by 27% at a cost of -$20 per ton of CO_2 saved (Fridley et al. 2001 and IEA analysis). In the service sector, higher-efficiency refrigeration units can often achieve significant savings in energy and money (McKinsey 2007b).

Barriers

The tightening of energy efficiency standards for new buildings and major refurbishments would help encourage the introduction of more-efficient cooling technologies, although care needs to be taken to ensure that tighter thermal envelopes do not raise cooling needs. New building codes could ensure, for example, that more efficient air conditioners were installed. If such steps were taken, they should be supported by the training and certification of more installers to ensure that this does not become a bottleneck. The development of better cooling and ventilation controls, accompanied by measures to promote their deployment, could also have a significant impact.

Appliances

The demand for large and small appliances, often with new functions, is rapidly boosting electricity consumption in both the residential and service sectors. While traditional large appliances are still responsible for most household electricity use, electronic home entertainment and information and communications equipment now account for more than 20% of residential electricity consumed in most countries. The rapid technology penetration offers opportunities to roll out more efficient appliances, but this effect has been overwhelmed by the increased uptake of new devices.

In general, most established household appliances, such as residential refrigerators, have become more energy efficient in recent years. However, in these and many other appliances, the impact of efficiency gains has been diminished by an increase in the size of products, as well as their proliferation. This is most clearly seen in home entertainment, where a rapid switch from cathode-ray tube televisions to more efficient liquid crystal display screens in recent years has not resulted in energy savings, because the switch has been accompanied by an expansion in average screen sizes and an increase in viewing hours and the number of televisions per household.

Costs

In developed countries, energy efficiency policies for major appliances have achieved efficiency gains of 10%–60% in most major economies in recent years. At the same time, occurred real consumer prices have fallen 10%–45% (IEA 2007a). This has been due to a combination of factors, including the availability of low-cost electronic control technologies, improved materials, and reduced manufacturing costs. Experience and economies of scale have also contributed.

Despite recent gains, most regional and national studies conclude that the technical potential exists for 30%–60% of further energy efficiency improvements in appliances (Wuppertal Institute

2005, Sachs et al 2004). Estimates of the cost-effective potential suggest that at least 25% savings can be achieved. International studies have also demonstrated that the potential savings from appliances in developing and transitional countries are greater than in developed countries, because of their ability to leapfrog to more efficient technologies (IEA 2006c,WEC 2006 and 2007).

The European Commission's eco-design directive looked at a range of appliances and found that some amount of energy could be saved at zero cost. Moving to best available technologies would initially be very expensive, but the cost would drop as the technologies spread, perhaps even to the point of saving money. And the bulk of the savings potential for appliances could be achieved without major technological development (McKinsey 2007b).

Barriers

Despite the achievements to date, which have been largely policy led, further deployment of energy-efficient appliances faces many barriers. In most developed countries, low energy costs and rising affluence mean that the overall running cost of appliances is a small proportion of household incomes. And it is an expenditure that remains largely hidden.

While energy labels have become widespread for major appliances, there is very little available public information on the running costs and savings potential of smaller appliances. In addition, labels do not usually specify the highest efficiency potential. As a result, few consumers have the ability to make informed decisions about relative life-cycle costs. Such information could provide a market pull for new, more efficient appliances. For example, consumers are largely unaware of the consumption of current TV technologies; and there is little market incentive for the commercialization of liquid crystal display televisions with back-light modulation or organic light-emitting diodes technologies that could reduce consumption by 50%.

The lack of appropriate protocols for appliances connected to digital networks is a major barrier to energy efficiency, since connected devices may not utilize automatically low-power modes when not in use. This will become increasingly important, yet also harder to rectify, as more appliances are connected into networks.

Lighting

Lighting entails GHG emissions of 1,900 Mt of CO_2 per year—equivalent to 70% of the emissions from the world's light passenger vehicles.

New, efficient lighting systems that will reduce emissions often cost the same or less than existing systems over a lifetime. Many lighting solutions are so cost-effective that it makes sense to prematurely retire old systems. Not all forms of lighting can substitute for any other, but large gains can be achieved by trading out lower-efficiency components even within the same technology.

A number of already fully commercialized technologies could significantly reduce lighting demand. They include incandescent, fluorescent, and high-intensity discharge lightbulbs; the ballasts and transformers that drive them; the luminaries in which they are housed; and the controls that operate them. Day-lighting and daylight sensors are also important alternatives. A market shift from inefficient incandescent lightbulbs to compact fluorescents would cut world lighting electricity demand by 18%. If end users were to install only efficient lightbulbs, ballasts, and controls, global lighting electricity demand in 2030 would be almost unchanged from 2005 and could actually be lower (IEA 2006a). This could be achieved while cutting the global average cost $161 per ton of CO_2 saved, but it would require strong policy action.

In the service sector, the use of high-efficiency ballasts, slimmer fluorescent tubes with efficient phosphors, and high-quality luminaries produces savings that are just as impressive. For street and industrial lighting, there are great savings to be had from discontinuing the use of mercury vapor lamps and low-efficiency ballasts in favor of higher-efficiency alternatives.

Incandescent, tungsten halogen, and high-pressure mercury lighting are considered mature technologies with little room for increased luminous efficiency, whereas semiconductor (as in light-emitting diode) and metal halide lamps offer high potential for further improvements. In the near term, however, the greatest gains are to be had from substituting new, high-quality compact fluorescent lamps for inefficient standard incandescent lamps, from phasing out mercury vapor lamps, and from using higher-efficiency ballasts and linear fluorescent lamps.

Heat Pumps

Heat pumps include a wide range of products that transform low-temperature heat from sources, such as air, water, soil, or bedrock, into higher-temperature heat that can be used for heating. Heat pumps can also be reversed and function as space coolers. Most heat pumps operate on a vapor-compression cycle and are driven by an electric motor. Some heat pumps use the absorption principle, with gas or waste heat as the driving energy. This means that heat, rather than mechanical energy, is supplied to drive the cycle. Absorption heat pumps for space air conditioning can be gas-fired, while industrial installations are usually driven by high-pressure steam or waste heat. Heat pumps are most suitable for use in cooling, space heating, water heating, and industrial heat. This section focuses on their heating applications.

Energy savings and costs

Electric heat pumps typically use about 20%–50% of the electricity used by electric resistance heaters for space and water heating. They can reduce primary energy consumption for heating by as much as 50% compared with fossil fuel-fired boilers. Ground-source heat pumps are more efficient than air-sourced systems in cold conditions, but they have higher initial capital costs. According to the United States Environmental Protection Agency, ground-source heat pumps can reduce energy consumption up to 44% compared with an air-source heat pump.

Heat pumps are considerably more expensive than boilers, although running costs are much lower. While a typical condensing gas boiler may cost $1,500, a heat pump will cost about $5,000. The gas boiler would use about 50 gigajoules of gas per year, while the heat pump would use 15 gigajoules of electricity per year. Replacing a gas boiler with a heat pump would result in a reduction in CO_2 emissions of 2.8 tons per year (provided the electricity was CO_2- free) at a lifetime cost of about $160 per ton of CO_2 saved. In the service sector, the CO_2 abatement cost of heat pumps for space heating is about $200 per ton of CO_2 saved. For large service-sector buildings, ground-source heat pump systems are likely to be economic and end up saving money if they provide space and water heating, as well as cooling in summer (Sachs 2004).

Heat pumps represent expensive CO_2 abatement options for space or water heating in developing countries. For example, in the PRC, the average gas heater to provide hot water has a storage tank of 8–10 liters and a capital cost of $100. However, high-efficiency reversible heat pumps for cooling and space heating are potentially an important abatement option in the PRC and other developing countries or regions with moderate heating loads and significant cooling loads over summer.

Solar thermal heating

The world's installed capacity of solar thermal systems for water heating increased significantly each year from 1999 to 2006 (REN 21 2006), with more than 15 gigawatts of net new capacity (16%) added in 2006. The PRC had the greatest increase in 2005 and is by far the largest market, with about 60% of the world's total capacity (Philibert 2006, REN 21 2006).

Technology status

There are two types of solar thermal heating systems: passive and active. Passive systems use windows directed mainly toward the sun, whereas active systems are relatively complicated (with collectors, heat storage, and controls) and most commonly require a backup system. In active heating systems, water or another heat transfer fluid is circulated through a duct and heated by solar radiation on the collector panel. The amount of heat energy captured per square meter of collector surface area varies with design and location but typically ranges from 300 $kWh/m^2/yr$ to 800 $kWh/m^2/yr$. Some designs use a heat transfer fluid that when warmed flows to a storage tank or a heat pump, where the heat is then transferred to water that can be used as hot water or for space heating.

Promising new designs include "combi-systems" that combine water and space heating. This extends the operation period and thus improves profitability. Active solar space and water heating systems usually need a backup system that uses electricity, bioenergy, or fossil fuels. These backups add to overall system costs (IEA 2006b). New technology integrates a solar-assisted heating system with a heating pump, resulting in ultra-high efficiencies of 125%–145% compared with a condensing boiler at about 107% (Daniels and Farla 2006).

Solar hot-water heating has strongly negative or modest abatement costs where good insolation levels occur and cheap evacuated tube systems are available and appropriate. In Hong Kong, China, solar hot-water system that replaces gas-fired systems could save CO_2 at a negative cost of about -$850 per ton of CO_2 (Li and Yang 2008). In cold climates requiring freeze protection, abatement costs can be high. In the United Kingdom, for example, the abatement cost could be more than $1,000 per ton of CO_2 (Shorrock et al. 2005).

Barriers

Solar water heaters are a mature technology and are readily available in many countries. Where support policies are in place to encourage use by building owners, especially if the payback period is longer than 5 years, they are making good progress into the market. Barriers include the high cost of systems for cold-climate countries, which have to include freeze protection, and the lack of low-cost heat storage and backup systems that can match solar heat supply to demand loads. In developing countries, even simple systems manufactured locally with a cost of only $400 represent a significant barrier to their uptake at present.

Passive houses and zero-energy buildings

The efficiency of individual parts of a building and the components of its systems for heating, ventilating, and air conditioning play an important role in the efficiency of its energy use. But the overall design and the way these individual parts interact are also important. There is increasing interest in buildings that have extremely low energy consumption and CO_2 emission profiles, such as passive houses, zero-energy buildings, and zero-carbon buildings. Often, these are developed as integrated designs, where particular attention is paid to efficiency through all phases of design and construction. Indeed, this is necessary if the additional investment cost of these buildings is to be affordable.

Potential energy savings and costs

The potential for energy savings through passive buildings will depend on the overall demand for new buildings. These vary substantially in different IEA countries and in developing countries. Demand can even vary for different types of buildings or for different regions or states within an individual country. The cost of zero-energy or zero-carbon buildings will depend heavily on developments in solar photovoltaic energy.

The additional investment cost for passive houses is typically in the range of 6%–8%, but can be more. Over a 30-year economic life before refurbishment, the typical costs for a new, passive building will, in most regions with significant heating loads, be lower than the costs for a traditionally designed building.

Barriers

There are many barriers to the construction of passive, zero-energy, and zero-carbon buildings. As with many energy-efficient technologies, initial costs are high, and building owners may perceive that the long-term benefits are uncertain if the additional investment is not reflected in resale values. Little information is available to decision makers about the benefits and potential of these buildings.

Some aspects of passive buildings need specially designed products or particular construction or installation skills that are not economically justifiable in small runs or for businesses building only a small number of passive houses.

Industry: an overview[48]

The industry sector is relatively efficient, compared with the other sectors. However, improving energy efficiency has an important part to play in reducing industrial emissions. In energy-intensive industries, such as chemicals, paper, steel, and cement manufacturing, cost-effective efficiency gains in the order of 10%–20% are already possible using commercially available technologies. The energy

[48] Energy Technology Perspectives: in support of the G8 plan of action, 2008, International Energy Agency.

intensity of most industrial processes is at least 50% higher than the theoretical minimum determined by the basic laws of thermodynamics. Energy efficiency tends to be lower in regions with low energy prices. Crosscutting technologies for motor and steam systems would yield efficiency improvements in all industries, with typical energy savings in the range of 15%–30%. The payback period can be as short as 2 years, and in the best cases, the financial savings over the operating life of improved systems can run as high as 30%–50%. In those processes where efficiency is close to the practical maximum, innovations in materials and processes would enable even further gains.

Many relatively new technologies, such as smelt reduction, near net-shape casting of steel, new separation membranes, black liquor gasification, and advanced co-generation, are currently being developed, demonstrated, and adopted in the industry sector. Some completely new process designs and processing techniques are also on the horizon, although these are unlikely to be commercially available in the next 10–15 years.

CO_2 capture and storage is an emerging option for industry. This technology is most suited for large sources of off-gases with high CO_2 concentrations, such as blast furnaces (iron and steel), cement kilns (nonmetallic minerals), ammonia plants (chemicals and petrochemicals), and black liquor boilers or gasifiers (pulp and paper).

Industrial energy use and CO_2 emissions profile

Industry accounted for nearly one-third of total global energy use in 2005, including conversion losses from electricity and heat supply.

The approximately 1,000 million tons (Mt) of wood and biomass feedstock used by industry, equivalent to 380 million tons of oil equivalent (Mtoe)–430 Mtoe of biomass, is not accounted for in these figures.

Most industrial energy use is for raw materials production. This accounts for 68% of total final industrial energy use, with the chemical and petrochemical industry alone accounting for 29% and the iron and steel industry, 20%.

Industrial energy intensity (energy use per unit of industrial output, measured in physical tonnage or added-value terms) has improved substantially in most sectors over the past three decades across all manufacturing subsectors and all regions. Increases in levels of activity, however, mean that energy use and CO_2 emissions have increased worldwide. Industrial final energy use increased 65% between 1971 and 2005, an average annual growth of 1.5%. But growth rates are not uniform. For example, in the chemical and petrochemical subsector, energy and feedstock use has doubled, while energy use for iron and steel production has been relatively flat despite strong growth in global production.

The PRC accounts for about 80% of the growth in industrial production over the last 25 years and for a similar share in industrial energy demand growth for materials production. Today, the PRC is the largest producer of commodities, such as aluminum, ammonia, cement, and iron and steel. The energy efficiency of production in the PRC is, on average, lower than that in OECD countries and, being largely coal-based, is also more carbon intensive. That said, the averages hide big differences over the range of plants. New plants tend to be more efficient than old ones, and many new plants are located in developing countries. As a consequence, the PRC has some of the most efficient steel- and paper-making plants in the world. The most efficient aluminum smelters can be found in Africa, while India has a high share of very efficient cement kilns (IEA 2007b).

Iron and steel

The iron and steel sector is the second-largest industrial consumer of energy and the largest emitter of CO_2. In 2005, it accounted for 20% of world industrial energy use and 30% of energy and process CO_2 emissions. The four largest producers (the PRC, the European Union, Japan, and the United States) accounted for 67% of the CO_2 emissions.

Processing overview

Steel is produced via a dozen or so processing steps, which are carried out in various configurations, depending on product mixes, available raw materials, energy supply, and investment capital. There are three principal modern processing routes:

- the scrap/electric arc furnace method, based on scrap for the iron input;
- the direct reduced iron method, based on iron ore and often scrap for the iron input; and
- the blast furnace and basic oxygen furnace method, based on 70%–100% iron ore, with the remainder scrap, for the iron input.[49]

Over the past several decades, electric arc furnace production has grown, and basic oxygen furnace has held steady. The latter is still the most widely used process, largely because of local limitations on scrap availability. Electric arc furnace production is much higher in the United States and Europe, where more scrap is available, than elsewhere. This difference should gradually disappear as other economies mature. Direct reduced iron/electric arc furnace production is widespread in the Middle East, South America, India, and Mexico. Most direct reduced iron production is based on cheap, stranded natural gas (except in India, where it is largely coal-based).

The scrap/electric arc route is much less energy-intensive (4 gigajoule [GJ] per ton–6 GJper ton) than the blast/basic oxygen route (13 GJ per ton–14 GJ per ton).[50] This is because there is no need to reduce iron ore to iron, which cuts out the need for the ore preparation, coke-making, and iron-making steps.[51] Significant energy savings can be made by switching to the scrap/electric arc furnace.

[49] A fourth processing route, the open hearth route, has an iron input profile similar to that of basic oxygen furnace. However, it is considered outdated technology and is used for only 3% of current production. Direct reduced iron can be economically substituted for scrap in places where scrap is in short supply and there are cheap sources of fossil fuels (e.g., stranded gas supplies).

[50] An electric-arc furnace uses about 1.6 GJ of electricity per ton of steel for 100% scrap feedstock and somewhat more with increasing direct reduced iron inputs. In actual operation, however, its energy use is somewhat higher. To be truly comparable with the blast/basic oxygen furnace process, the electricity should be expressed in primary energy terms. With electricity generation efficiency ranging from 35% to more than 50%, electric arc's primary energy use is in the range of 4 GJ–6 GJ per ton of liquid steel.

[51] More scrap can be added in the basic oxygen furnace, which reduces the energy use for this route. However, this implies less scrap recycling in the electric arc furnace, so the CO_2 benefit is limited for the iron and steel industry as a whole.

There are considerable differences in the energy efficiency of primary steel production among countries and even between individual plants. These differences can be explained by factors, such as economies of scale, the level of waste energy recovery, the quality of iron ore, operations know-how, and quality control.

This suggests a potential for emissions reductions of 50%–95%, excluding any reductions that might be achieved through CO_2 capture from blast furnaces. However, the overall potential of scrap/electric arc is limited by scrap availability. Using gas-based direct reduced iron also yields some, more limited, emissions reductions.

Energy efficiency: best available technology

Important emissions reductions could be achieved if the best available technologies for steelmaking were applied worldwide. The total reduction potential is 340 Mt CO_2 per year. The PRC accounts for nearly half of this potential because of its high share of total world production. In terms of reduction per unit of steel produced, however, a number of other countries have higher potentials. The average global potential is 0.30 ton of CO_2 per ton of steel produced.

Numerous gas streams from the various steel-making processes contain energy in the form of heat, pressure, or combustible content. Recovering and using the energy content of these streams reduces overall energy needs and upstream CO_2 emissions (e.g., in the power sector). The relevant technologies are widely applied in some countries, but virtually nonexistent in others. The total potential from the wider application of these technologies is about 100 Mt CO_2 reductions per year worldwide.

Each processing step adds inefficiency to the overall steel-making process, as energy and materials are lost. Reducing the number of steps, or the amount of material processed in any step, improves efficiency.

The industry has been trying to develop alternative production processes that minimize the number of coal and ore processing steps. These include

- injecting pulverized coal as a substitute for coke into the blast furnace;
- new reactor designs that can use coal instead of coke (such as the COREX process); and
- still newer reactor designs that can use coal and ore fines (such as FINEX and cyclone converter furnaces).

Coal injection is already a widely applied technology. It is financially attractive because it reduces the need for coke production. It also results in substantial energy savings, as one energy unit of coke is replaced by one energy unit of coal. Trials have shown that coal injection can replace up to half the coke now used in blast furnaces. Assuming that coal and coke have the same energy content, that half of all coke is replaced by injected coal, and that the energy used in coke production is 2 GJ per ton–4 GJ per ton coke, the potential for coal savings would amount to 12 Mtoe per year, equivalent to 50 Mt of CO_2.

Nonmetallic minerals: an overview

The nonmetallic sector, producing cement, bricks, glass, ceramics, and other building materials, is the third largest industrial consumer of energy and second largest industrial emitter of CO_2. In 2005, it accounted for 10% of world industrial energy use and 27% of energy and process CO_2 emissions. The four largest producers (the PRC, India, the European Union, and the United States) accounted for 75% of these CO_2 emissions.

In the production of nonmetallic minerals, cement accounts for 83% of total energy use and 94% of CO_2 emissions.

Cement

Global cement production grew from 594 Mt in 1970 to 2,310 Mt in 2005, with the vast majority of the growth occurring in developing countries, especially the PRC.

In 2005, developing countries produced 1,649 Mt of cement (72% of the world output). Developed countries produced 563 Mt (24%) and transition economies 98 Mt.

Processing overview

Energy represents 20%–40% of the total cost of cement production. The production of cement clinker from limestone and chalk by heating limestone to temperatures above 950˚C is the main energy-consuming process. Portland cement, the most widely used cement type, contains 95% cement clinker. Large amounts of electricity are used to grind the raw materials and finished cement.

The clinker-making process also emits CO_2 as a by-product during the calcinations of limestone. These process emissions are unrelated to energy use and account for about 3.5% of emissions worldwide and for 57% of the total CO_2 emissions from cement production. Emissions from limestone calcinations cannot be reduced through energy efficiency measures or fuel substitution, but they can be diminished through production of blended cement and raw material selection.

Energy efficiency: best available technology

Making technical improvements in cement-making could cut CO_2 emissions by about 290 Mt annually. If clinker substitutes are included, the potential reduction rises to 450 Mt CO_2. This shows the importance of fuel and feedstock switching in this sector.

The PRC accounts for more than half of this potential because of its large production volume and its low energy efficiency. In terms of savings per ton of cement, a number of countries are similar to the PRC, and the Russian Federation has an ever-higher potential. The world average potential is 0.18 t CO_2 per ton cement.

Kiln type

Different cement-producing technologies show widely different energy efficiencies. In industrial countries, large-scale rotary kilns are used. In developing countries (including the PRC, the largest world producer of cement) markedly less-efficient, small-scale shaft (vertical) kilns are still widely used. However, the situation in the PRC is changing rapidly with active government policies to phase out shaft kilns.

The energy efficiency of rotary kilns can be increased significantly by increasing the number of preheaters: an increase from 4 to 6 cyclone pre-heaters cuts fuel use about 10%. In the past few decades, pre-calcination technology has also been introduced as an energy-saving measure.

The predominant production process for Portland cement clinker is the dry process. It is gradually replacing the less-efficient wet process, which requires more drying.

The trend toward using dry kilns that incorporate pre-calcining and six-step preheaters is likely to continue with no need for government support. Today's state-of-the-art dry-rotary kilns use approximately 2.9 GJ–3.0 GJ of energy per ton of clinker, while a wet kiln uses 5.9 GJ–6.8 GJ per ton.

Grinding

Grinding also uses large amounts of electricity. Current state-of-the-art technologies, using roller presses and high-efficiency classifiers, are much more efficient than earlier ones. Yet the energy efficiency of grinding is typically only 5%–10%, with the remainder converted into heat. Grinding is one key to producing high-strength cements and cements with high fly-ash content, which reduces energy use and CO_2 emissions.

Potential of new processes

Rotary-kiln technology is approaching the limits of its energy efficiency potential. New fluid-bed technologies have been tested, but research has been abandoned. Power generation from low-temperature residual heat has been applied at some kilns that are equipped with preheaters and clinker heat recovery. This requires special power-generation cycles. The potential for power generation for such kilns is about 20 kWh per ton of clinker, but it is expensive.

Better grinding technologies and additives can lead to products, such as high-strength cement, that result in a substantial reduction of cement use. High-strength materials are already used in skyscrapers. But they are more costly than conventional cement, and their application requires special knowledge.

Fuel and feedstock substitution

Another way to reduce emissions is to substitute fossil fuels with waste or biomass. Cement kilns are well suited for waste combustion because of their high process temperature and because the clinker product and limestone feedstock act as gas-cleaning agents. Used tires, wood, plastic, chemicals, and other types of waste are co-combusted in cement kilns in large quantities. Plants in Belgium, France, Germany, the Netherlands, and Switzerland have reached average substitution rates of 35% to more than 70%. Some individual plants have even achieved 100% substitution using appropriate waste materials. However, very high substitution rates can be accomplished only if a tailored pretreatment and surveillance system is in place. Municipal solid waste, for example, needs to be pretreated to obtain homogeneous calorific values and feed characteristics.

The cement industry in the United States burns 53 million used tires per year, which is 41% of all tires that are burned and is equivalent to 15 petajoule (PJ). About 50 million tires, or 20% of the total, are still used as landfill. Another potential source of energy is carpets: the equivalent of about 100 PJ per year is dumped in landfills, but these could instead be burned in cement kilns. Although these alternative materials are widely used, their use is controversial, as cement kilns are not subject to the same tight emission controls as waste-incineration installations.

According to IEA statistics, the cement industry in OECD countries used 1.6 Mtoe of combustible renewables and waste in 2005, half of it industrial waste and half wood waste. This equals less than 2% of total fuel use in this sector. From a technical perspective, the use of alternative fuels could be raised from 24 Mtoe to 48 Mtoe, although there would be differences among regions due to the varying availability of such fuels. This would yield CO_2 reductions in the range of 100 Mt–200 Mt a year.

Clinker substitutes and blended cements

Yet another way to reduce energy and process emissions in cement production is to blend cements with increased proportions of alternative (non-clinker) feedstocks, such as volcanic ash, granulated blast-furnace slag from iron production, or fly ash from coal-fired power generation.

The use of such blended cements varies widely from country to country. It is high in continental Europe but low in the United States and the United Kingdom. In the United States and the PRC, other clinker substitutes are added directly at the concrete-making stage. Blended cements offer a major opportunity for energy conservation and emission reductions, but their use would, in many cases, require revisions to construction standards, codes, and practices.

In total, the savings potential for blended cements amounts to between 300 and 450 Mt CO_2 by 2050. The main approaches to this are to use

- Blast-furnace slag that has been cooled with water rather than air. About half of all blast-furnace slag is already used for cement-making in which the slag is water-cooled and where transport distances and costs are acceptable. If all blast-furnace slag were used, this would yield a CO_2 reduction of approximately 100 Mt.
- Fly ash from coal-fired power plants. But the carbon content of fly ash can affect the concrete setting time, which determines the quality of the cement. To be used as clinker substitute, high-carbon fly ash must be upgraded. Technologies for this are just emerging. Special grinding methods are also being studied as a way to increase the reaction rate of fly ash, allowing the fly ash content of cement to increase to 70% compared with a maximum of 30% today. The PRC and India have the potential to significantly increase the use of fly ash. If 50% of all fly ash that currently goes to landfill could be used, this would yield a CO_2 reduction of approximately 75 Mt.
- Steel slag. The CemStar process, which uses a 15% charge of air-cooled steel slag pebbles in the rotary-kiln feedstock mix, has been developed and successfully applied in the United States, resulting in a CO_2 reduction of approximately 0.47 t/t steel lag added. In the PRC, there are about 30 steel slag cement plants with a combined annual output of 4.8 Mt. However, steel slag quality varies and it is difficult to process, which limits its use. If the total worldwide steel slag resource of 100 Mt–200 Mt per year (basic oxygen furnace and electric arc furnace) was used this way, the CO_2 reduction potential would be from 50 Mt to 100 Mt per year. Further analysis is needed on the viability of this option.

Other materials that could be used to a greater extent as clinker substitutes include volcanic ash, ground limestone, and broken glass. Such approaches could alleviate clinker substitute availability problems and possibly pave the way to a 50% reduction of energy use and CO_2 emissions.

In the long term, new cement types that do not use limestone as primary resources may be developed. These new types are called synthetic pozzolans. The technological feasibility, economics, and energy effects of such alternative cements remain speculative.

Pulp and paper

The pulp and paper sector is the fourth largest industrial consumer of energy and emitter of CO_2. In 2005, it accounted for 6% of world industrial energy use and 3% of energy and process CO_2 emissions. The four largest paper producers (the European Union, the United States, the PRC, and Japan) accounted for 80% of the CO_2 emissions.

The pulp and paper industry also produces energy as a by-product and already generates about 50% of its own energy needs from biomass residues. This means that the CO_2 intensity of the industry is relatively low, and the CO_2 reduction potentials are correspondingly limited. But greater efficiency would, nonetheless, free up scarce bioenergy resources that could be used to replace fossil fuels elsewhere.

Processing overview

Energy use in the pulp and paper industry is divided among a number of different pulp production processes and paper production. The need for large amounts of steam makes combined heat and power an attractive technology. Most modern paper mills have their own combined units. Chemical pulp mills produce large amounts of black liquor, which is used to generate electricity but with relatively low conversion efficiencies. New technologies that promise higher conversion efficiency could have important energy benefits, particularly in terms of electricity production and, possibly, biofuels.

In theory, pulp and paper could be produced without CO_2 emissions. To do so, all wastepaper would need to be used for energy recovery. But from the viewpoint of the energy and resource system as a whole, it would make more sense to recycle as much paper as possible and to use the wood surplus to produce biofuels or electricity.

Much of the past improvement in energy efficiency has resulted from increased heat recovery where the recovered steam is used to dry the pulp and paper. More than 90% of the electricity used in mechanical pulping is transformed into heat. The main source of further energy efficiency gains is heat recovery. Integrated mechanical and chemical recycled pulp and paper mills provide the best solution for improving efficiency and minimizing CO_2 emissions, because pulp drying can be avoided and the excess energy from the chemical pulp mill can be used efficiently in papermaking. The energy efficiency of integrated pulp and paper mills is 10%–50% better, depending on the grade of paper produced, than stand-alone mills.

Almost half of all paper is produced from wastepaper. Recycling plants tend to be smaller and more dispersed than primary paper production facilities, and their energy needs for papermaking are higher. But the energy that would have gone into pulp making is saved. This saving far exceeds the additional energy they use. In many developed countries, more paper is recycled than produced.

Energy efficiency: best available technology

The European Commission has produced a widely recognized reference on paper and pulp energy use, the key findings of which are reproduced in Table 5.7.

IEA analysis shows that the energy intensity of heat use compared with best available technology varies from a remaining improvement potential of 35% for Canada to surpassing that technology by 43% for Japan.[52] For electricity, the improvement potential varied from 32% for the United Kingdom to 3% better than the best available technology for Germany.

Canada and the United States are among the countries with the most energy-intensive pulp and paper industries in the world. Their pulp and paper mills perhaps use the oldest technology on average. Both are rich in wood resources. The United States is the largest chemical pulp producer, and Canada is the largest mechanical producer.

Table 5.7: Energy Used by Best Available Technology for Paper and Pulp

	Heat (GJ/t)	Electricity (GJ/t)
Mechanical pulping		7.5
Chemical pulping	12.25	2.08
Wastepaper pulp	0.20	0.50
De-inked wastepaper pulp	1.00	2.00
Coated papers	5.25	2.34
Folding boxboard	5.13	2.88
Household and sanitary paper	5.13	3.60
Newsprint	3.78	2.16
Printing and writing paper	5.25	1.80
Wrapping and packaging paper and board	4.32	1.80
Paper and paperboard not elsewhere specified	4.88	2.88

GJ/t = gigajoule per ton of.

Source: European Commission (2001), Finnish Forestry Industries Federation (2002).

[52] The fact that energy efficiency index in Japan, Sweden, and Finland falls well above the "best available technology" results indicates either exaggerated savings or problems of data consistency and comparability across countries. Different reporting methodologies, system boundaries, problems related to combined heat and power accounting, high recovered paper use rates, and a high level of integrated mills (in the case of Japan) could explain the unexpectedly high energy efficiency index of these countries.

Potential of new processes

Current pulp and paper facilities in many OECD countries are nearing the end of their operating lives and will need to be replaced over the next 10–15 years. This presents an excellent opportunity for new technology deployment to have an impact on energy savings in the medium term. The most promising energy-saving technologies in the industry are likely to come from black-liquor gasification and bio-refinery concepts, advanced paper-drying technologies, and increased paper recycling.

Black-liquor gasification and bio-refinery concepts

The paper industry produces black liquor as a by-product, which is normally burned in a recovery boiler. Given the high water content of black liquor, the efficiency of existing recovery boilers is limited. Electricity production is also limited because the recovery boilers produce steam at low pressures for safety reasons.

Gasification offers opportunities to increase the efficiency of black liquor recovery by conversion to syngas, which can be used in gas-turbine power generation. Teams from the United States, Sweden, and Finland are collaborating in the development of the technology. The internal rate of return of an investment in such power generation has been estimated at 16%–17%, if the electricity can be sold at $0.04/kWh. Further research is needed to increase the reliability of the gasifier. The use of a gasifier with a gas turbine has not yet been demonstrated, and the total capital costs of a black liquor gasification-combined cycle system are estimated to be 60%–90% higher than those for a standard boiler system. In addition to the energy efficiency benefit, gasification makes it possible to enhance pulping by modifying conventional pulping liquors.

Alternatively, the syngas can be used as a feedback to produce chemicals—in effect, turning the paper mill into a bio-refinery. In Europe, policies aimed at increasing the share of biofuels in transportation have sparked interest in using black liquor gasifiers to produce dimethyl ester as replacement for diesel fuel.

Black liquor production is projected to grow to 79 Mtoe by 2025. Based on the performance of a typical kraft plant in the southeastern United States, a pulp plant will be able to produce and sell 220 kWh–335 kWh of excess electricity per ton of pulp. If the overall electric efficiency was raised by 10% and the steam efficiency remained the same, 79 Mtoe of black liquor per year would yield an additional 8 Mtoe of electricity annually. The savings in terms of primary energy would be in the range of 12 Mtoe–19 Mtoe, depending on whether a gas-or coal-fired power plant was displaced.

Advanced paper-drying technologies

In paper production, energy is needed to dry process fibers. Technical changes that might reduce energy use in the paper industry by 30% or more have been identified in various countries, with cost-effective potentials of at least 15%–20%.

New process designs focus on more efficient water-removal techniques—for example, by combining new forming technologies with increased pressing and thermal drying. In the long term, the need to use water can be reevaluated, and other ways of managing the fiber orientation process for optimal paper quality, such as the use of supercritical CO_2 and nanotechnology, may be possible.

Paper drying consumes about 25%–30% of the total energy used in the pulp and paper industry. Assuming that energy efficiency improvements of

20%–30% are possible in this production stage, overall energy savings are estimated at 17 Mtoe.

Increased paper recycling

Paper recycling is another important potential contributor to energy savings. Paper recycling rates are already high in many countries, varying between 30% in the Russian Federation to 64% in the PRC. But increased recycling of paper is feasible. The recovery rate in most non-OECD countries is 15%–30% lower than in OECD countries, although the rate at which wastepaper is actually recycled in developing countries is higher than the recovery rate suggests large amounts of wastepaper are imported from OECD countries. Between 10 GJ and 20 GJ can be saved per ton of paper recycled, depending on the type of pulp and the efficiency of the pulp production it replaces. The net effect on CO_2 emissions is less clear, as some pulp mills use biomass, while recycling mills may use fossil fuels. However, biomass that is not used for paper production could potentially be used for dedicated power generation, with potentially higher power production rates than municipal solid waste incineration would generate.

Nonferrous metals: aluminum

The nonferrous metals sector produces aluminum, copper, and a number of other materials, such as zinc, lead, and cadmium. It is the fifth largest industrial consumer of energy and emitter of CO_2. In 2005, it accounted for 3% of world industrial energy use and 2% of energy and process CO_2 emissions. Among these, aluminum is the most energy intensive.

The main primary producers of aluminum are located in the PRC, North America, Latin America, Western Europe, Russian Federation, and Australia. The aluminum industry is the single largest industrial consumer of electricity in Australia, accounting for about 13% of total final electricity consumption. The industry is of similar importance in other countries and regions with low-cost electricity, such as Norway, Iceland, Canada, Russian Federation, and the Middle East. In recent years, several new smelters have been built in Africa. New smelter projects are being developed in the Middle East on the basis of access to lower-cost electricity.

Most growth in recent years has been in the PRC, a trend expected to continue in the immediate future. The PRC's production was expected to double between 2005 and 2008, from 7 Mt to 14 Mt. The rapid growth is driven by low investment cost for smelters, about a third of those in Western countries, offset by higher energy costs. PRC consumption was about 13 kilograms (kg) per capita in 2007, compared with 20 kg–35 kg per capita in OECD countries.

Processing overview

Aluminum production can be split into primary aluminum production and recycling. Primary production is about 20 times as energy intensive as recycling and represents the bulk of energy consumption. With world alumina production at 60 Mt, total energy use was 16 Mtoe in 2005.

Energy efficiency: best available technology

Primary aluminum is produced in three distinct steps: bauxite (ore) mining, alumina refining, and aluminum smelting. Most of the energy consumed in alumina refineries is in the form of steam. The calcining (drying) of the alumina also requires large amounts of high heat. Because of their high demand for steam, modern plants use combined heat and power systems. The average energy consumption of Australian refineries is 11.8 GJ per ton of alumina produced. The global average was 12.0 GJ per ton in 2006, with a regional range from 11.2 GJ per ton to 14.5 GJ per ton (Table 5.8).[53] This could be reduced to about 9.5 GJ per ton through better heat integration and improved combined heat and power systems. The production of 1 kg of aluminum requires about 2 kg of alumina.

The main energy use in aluminum production is for the electrochemical conversion of alumina into aluminum in the Hall-Heroult process. The worst plants consume about 20% more than the most energy-efficient plants. This can be attributed to different cell types and to the size of the smelters, which is generally related to the age of the plant.

Table 5.8: Regional Average Energy Use of Metallurgical Alumina Production, 2006

	GJ/t Alumina
Africa and South Asia	14.5
North America	11.9
Latin America	11.2
East Asia and Oceania	11.8
Europe	13.1
Weighted average	12.0

GJ/t = gigajoule per ton of.

Source: World Aluminium (2007a).

Modern prebake Hall-Heroult smelters use about 50 GJ–55 GJ of electricity per ton of product. Older configurations (Søderbergs) may use up to 60 GJ per ton of aluminum. The theoretical minimum energy use is about 20 GJ per ton. About 18 GJ of pitch and petroleum coke (petcoke) is needed per ton of aluminum for production of anodes. Another 7.4 GJ of energy is consumed per ton of aluminum for other uses in the smelters. Multiplied by the aluminum production volume, this represents another 19 Mtoe of industrial energy use.

The industry plans to retrofit or replace existing smelters in order to reduce electricity consumption to 14,500 kWh per ton (52.2 GJ) in the short term and then as low as 13,500 kWh per ton as new smelters are built and older ones are retired. New world-class plants achieve 13,000 kWh per ton.

Table 5.9: Regional Average Electricity Use of Primary Aluminum Production, 2006

	kWh/t aluminum
Africa	14,622
North America	15,452
Latin America	15,030
Asia	15,103
Europe	15,387
Oceania	14,854
Weighted average	15,194

kWh/t = kilowatt-hour per ton of.

Source: World Aluminium (2007b).

53 These figures do not include the energy consumption figures for Chinese alumina production in the PRC, where the energy required for alumina production from the domestic bauxite (which accounts for over half of production) is more than double the International Aluminium Institute reported level.

Potential of new technologies

Technologies under development, such as drained cells (drained cathodes) and inert anodes, offer the promise of further smelter efficiencies.

Inert anodes could end CO_2 emissions stemming from the use of carbon anodes and also eliminate emissions of perfluorocarbons (a category of powerful greenhouse gases) from the electrolysis process. Electricity consumption could also be reduced by some 10%–20% compared with today's advanced smelters. The technology is, however, suited only for new smelters because the cell design has to be changed fundamentally. The ultimate technical feasibility of inert anodes is not yet proven, despite 25 years of research. More fundamental research on materials will be needed, and anode wear-rates of less than 5 millimeters per year will have to be attained.

Smart grid and mini-grid

Smart grid basically involves the digitization and modernization of the entire grid infrastructure. Smart grid denotes a grid network that distributes power more efficiently, controls peak loads, and helps people measure and control demand in real time with domestic smart meters and related software.

A smart mini-grid is a mini-grid that delivers electricity from suppliers to consumers using digital technology. It optimizes the flow of current through digital gradations of distribution grids. Smart mini-grid could be defined as the application of digital information technology to optimize electrical power generation and delivery and, ultimately, its end-use within the domain of the mini-grid. In the smart mini-grid model, at every instance, the load and the distributed generation resources (like wind and solar) are optimally managed and distributed through advanced controls and interfaces.

Hence, smart mini-grid is an integrated energy system that consists of (i) variable loads that are connected to the distribution grid; (ii) a diverse range of small, local generators based on distributed energy resources, with or without a storage system; and (iii) control and power conditioning systems. The distributed energy resources can meet the local energy requirement or feed power to the conventional grid. The smart controllers can disconnect or reconnect the distributed energy resources to the conventional grid with minimal disruptions.

This technology has opened the door for coordination and integration of the main grid with a large number of small power producers using alternate energy sources, such as biomass, biogas, wind, solar, and fuel cells. This technology is of great relevance to the Asia and Pacific region as it will help increase the penetration of renewable energy power sources in the grid.

Mini-grid programs

Several projects investigating the smart mini-grid model are briefly described below.

Australia's Smart Mini-Grid Demonstration The Commonwealth Scientific and Industrial Research Organization is Australia's national science agency and one of the largest and most diverse research agencies in the world. It has developed a renewable-based smart mini-grid demonstration facility in New Castle, Australia. This facility has 90 kW of solar photovoltaic generation (three different technologies and many different orientations), 150 kW of gas-fired micro-turbine generation from three different generators, 60 kW of wind turbine generation, and extensive monitoring and control systems.

The agency is developing the intelligent unit for a distributed generation system, which not only controls on-site energy assets to suit power utilities but also allows consumers to control and choose their power supply.

The European Union's Micro-Grids Research
At the international level, two major research efforts have been devoted exclusively to micro-grids/smart mini-grids, within the European Union's 5th Framework Programme (1998–2002). The research consortium, led by the National Technical University of Athens, included 14 partners from seven European Union countries, including utilities from France, Greece, and Portugal, manufacturers, and research institutions.

The major activities of the project were to

- Study the operation of mini-grids to increase penetration of renewable while reducing carbon emissions;
- Study the operation of micro-grids in parallel with the grid and islanded, as may follow faults;
- Define and develop control strategies to ensure efficient, reliable, and economic operation and management of micro-grids; and
- Simulate and demonstrate micro-grid operation on laboratory scales.

Japan's Micro-Grid Field Tests
The New Energy and Industrial Technology Development Organization, the research funding and management agency of Japan's Ministry of Economy, Trade, and Industry, started three demonstrations under its Regional Power Grid with Renewable Energy Resources Project in 2003. These field tests focus on the integration of new energy sources into a local distribution network. Proposed micro-grid projects in Aomori, Aichi, and Kyoto prefectures qualified for the program, and all have a significant renewable energy component.

India's distributed-generation smart mini-grid project
As part of the Asia Pacific Partnership on Clean Development and Climate's program to accelerate deployment of smart mini-grids, models appropriate for Indian conditions will be developed. The objective is to demonstrate how smarter control of distributed-energy sources combined with intelligent management of loads can improve the efficiency and reliability of the overall mini-grid system. The Energy and Resources Institute and the Solar Energy Center will lead the work on simulation, design, and demonstration of smart mini-grid models in collaboration with the Commonwealth Scientific and Industrial Research Organization. The scope of work includes (i) mini-grid aggregation; (ii) load profiling, categorization, and forecasting; (iii) design and simulation of the smart mini-grid model, applicable to Indian sites and conditions; (iv) development and demonstration of the smart mini-grid model; and (v) performance assessment, monitoring, and analysis of the model. The project started in April 2009 and is likely to be completed in 2012.

Advantages of the smart mini-grid

The smart mini-grid offers major advantages:

1. It increases reliability, efficiency, and safety of the power mini-grid and prevents outages. It lowers carbon emissions and lowers electricity bills.
2. It allows distributed power generation to be coupled with the main grids and provides a two-way power flow (to import or export of power, depending upon the requirements).
3. It reduces peak demand and energy consumption by providing real-time assessment of power consumption.

4. It reduces distribution losses.
5. It offers potential cost savings to the utility from remote and automated controls and elimination of unnecessary field trips of utility staff.
6. It increases gross domestic product by creating more new jobs related to the renewable energy industry, such as manufacturing solar panels and wind turbines.

Conclusions

Adoption of low-carbon technologies, such as clean coal, renewable energy, waste to energy, nuclear energy, biomass gasification, and biofuels, is not uniform across developing Asia and the Pacific (DAP). High capital cost is the main barrier. The region lacks any significant research and development (R&D) in clean energy, although work is being done in the commercialization of the technologies.

Select countries have acquired new technologies through international cooperation or, in some cases, through purchase. The small islands are totally dependent on the developed countries and on some of the region's larger nations.

Indonesia, Thailand, and Viet Nam think they will need to adopt the integrated gasification combined cycle and carbon capture and storage (CCS) because they will be dependent on fossil fuels for at least the next three decades. The PRC is already experimenting with CCS technologies and is planning to set up a full-scale CCS power plant with assistance from the United Kingdom.

The use of the combined cycle with carbon capture holds more promise for Viet Nam than for Thailand. Viet Nam has its own coal reserves and is currently a net exporter of coal. At present, CCS has been introduced in Viet Nam through a Clean Development Mechanism (CDM) project, but it still has to get clearance from the CDM executive board. Indonesia is considering the use of CCS as it has huge natural gas reserves with high concentrations of CO_2. The gas is unfit for commercial applications unless the CO_2 concentrations are brought down sufficiently to make the energy level valuable.

Availability of financing (discussed in Chapter 6) is one of the key issues in technology transfer and innovation. Lack of funding, especially for technologies in the pre-commercialization stage, will kill innovation and deployment. Financing can ensure that key technologies are carried through the testing phase and absorbed globally. International cooperation is vital.

As most investments in the new energy infrastructure are locked in for 40–50 years, it is important that fast-growing countries in the Asia and Pacific region, who will be installing a significant infrastructure, also deploy state-of-the-art cleaner and energy-efficient technologies. Most of the technology R&D occurs in the OECD countries. Collaboration between OECD and the developing countries would help not only to promote the uptake of cleaner technologies but also to speed up deployment, as manufacturing costs are generally lower in Asian countries. This would also provide opportunities to build a national industry from the low-carbon energy technologies, which would justify the higher deployment costs.

Addressing the issue of intellectual property rights by protecting the suppliers of the technology will ensure that business-based technology transfer takes place much more easily. This will also speed up the commercialization of new technologies. International collaboration will ensure that the benefits of technology learning are shared among the participating countries, which will help bring down the costs.

Technology will play a key role in addressing energy security and climate change. Innovations in technology are the key ingredient for economic efficiency and sustainability. However, to reap the benefits of new technologies, the DAP countries must build strength in several arenas: local capacity in technology R&D, as well as policy making, accurate assessment of which technologies are needed, cooperation regionally and internationally, and creativity in supporting the spread of energy-efficient technologies. The responsibility of clean technology deployment and commercialization lies with both the developing and the developed countries.

CHAPTER 6

Financing: status, performance, and challenges

An aggressive deployment of energy-efficient and clean energy technologies is crucial for mitigating energy security concerns, as well as climate change. However, putting the energy sector on a more efficient and cleaner trajectory faces many challenges pertaining to technology, financial resources, market structure, regulatory and policy environment, human resources, and entrepreneurship. These challenges are particularly daunting in developing countries. Of these, financing is the most significant obstacle: without adequate financial resources, other barriers cannot be overcome.

Various studies have estimated the cost of revamping the energy sector to reduce greenhouse gases (GHGs) (the mitigation scenario). They have concluded that investing in infrastructure that deploys energy-efficient and renewable energy technologies would end up costing less than continuing to invest in older technologies. That is because the new systems would cut energy demand and the cost of operations.

For instance, according to the United Nations Framework Convention on Climate Change (UNFCCC 2007), global investment in energy supply infrastructure under the mitigation scenario is projected to reach $695 billion by 2030—$67 billion (9%) less than under the reference scenario. The power sector saves $7 billion, and capital expenditures for fossil fuel drop $59 billion.

The potential savings apply regionally as well as globally. The International Energy Agency (IEA 2007a) estimates that to meet growing demand, $20 trillion will be needed for energy supplies globally from 2006 to 2030, more than half of which will be in developing countries ($3.7 trillion in the People's Republic of China [PRC] and $1.2 trillion in India). For developing Asia and the Pacific (DAP), expansion and modernization under the baseline scenario would cost $9 trillion, compared with $8.3 trillion under the sustainable energy scenario (UNESCAP 2008).

The up-front costs for deploying the new technologies are high, which means the developers must have access to financing from commercial banks.

New investments in sustainable energy have risen worldwide, reaching $148.4 billion in 2007, but they remain concentrated in developed countries (UNEP 2008). Most of this investment is private investment in renewable energy (Table 6.1). Investment in energy efficiency in developing countries is miniscule compared with total renewable energy and energy efficiency investment globally in 2005.

However, the share of total new investments (venture capital/private equity, public markets, and asset finance) going to developing countries

Table 6.1: Energy Investments and Funding Sources, 2005
($ millions)

	Renewable Energy			Energy Efficiency			
	Source	OECD	Developing	OECD	Developing	Total	% Total
Total investment Debt							
Private sector	NEF	9,089	656	41	6	9,791	33
Multilateral	CRS	–	386	–	–	386	1
Total debt		9,089	1,041	41	6	10,177	–
Equity							
Total equity (private sector)	NEF	14,107	2,906	1,342	96	17,451	63
Grants							
Multilateral (GEF)	GEF		42		30	71	0
Bilateral	CRS		601		–	601	2
Total grants			642		30	672	–
Total investment		23,196	4, 590	1,383	132	29,300	
Private investment		23,196	3,562	1,383	102	28,242	96
Multilateral/bilateral		–	1028	–	30	1058	4

– = no data, CRS = creditor reporting system, GEF= Global Environment Facility, NEF = New Energy Finance, OECD = Organisation for Economic Co-operation and Development.

Source: UNFCCC (2007).

increased from 12% in 2004 to 22% in 2007, with the PRC and Brazil accounting for 17% (UNEP 2008). In actual terms, developing countries attracted $26 billion of new investment in 2007—14 times that in 2004. In asset finance, however, there has been a distinct shift from the Organisation for Economic Co-operation and Development (OECD) to the large emerging economies, with Brazil, the PRC, and India accounting for 20% ($13.6 billion) in 2006–2007, compared with 10% in 2004–2005. Asset finance flowing to other non-OECD countries remained roughly constant at 5%–6% (UNEP 2008).

For the DAP region, this makes clear that the absolute levels of investment are very small in comparison with the world, particularly in energy efficiency, and that the increase in investment is largely concentrated in the PRC and India, leaving other countries far behind. Moreover, much developing country financing, other than in developing Asia, comes through a combination of official development assistance and loans from the World Bank and regional development banks. Overall, the region attracts limited private sector investment. And local financial institutions in developing countries are reluctant to get involved with energy efficiency and renewable energy projects because of perceived credit risks, in terms of the end-user customer and energy services companies, and the technical risks of the projects. This further deepens the dependence on international loans and grants.[54]

Financial institutions have a crucial role to play in helping countries transform their energy sector, just as they have fostered structural change in other aspects of the economy. In the absence of adequate financial institutions and mechanisms, the risks associated with new technologies keep the investors at bay. Consequently, investment goals remain unachieved and energy markets remain locked in and dominated by well-entrenched companies and institutions (UNEP 2008).

Existing sources of finance and financial instruments

The existing sources of finance can largely be categorized into three categories: (i) grants and loans from the public sector (governments, bilateral financing, and multilateral financial institutions, such as ADB and the World Bank); (ii) carbon financing from the public, as well as the private sector, through the carbon market; and (iii) voluntary actions by the private sector, including foreign direct investment and private banks. The flow of finance can come as grants, concessional (soft) loans, equity financing, technical assistance, and other measures (Table 6.2).

In recent years, carbon markets—particularly the clean development mechanism (CDM) (allowing an industrialized country to get emissions-reduction credit by financing a developing country's project)—have been impressive in promoting private investment in sustainable development.

Multilateral organizations

The role of multilateral organizations is very important for developing countries, where banks and private investors often wait for signals from the international financial community—the World Bank, ADB, and others—before getting involved in

[54] www.adb.org/Media/Articles/2003/3830_Regional_Renewable_Energy/

Table 6.2: Options for Financing Energy Efficiency and Renewable Energy Projects

	Market-Based Loans	Soft Loans	Grants	Equity Investments	Guarantees	Technical Assistance	Risk Mitigation Measures
Multilateral development banks	X	X	X	X	X	X	X
Multilateral/ bilateral aid		X	X			X	X
Funds/foundations	X	X	X	X			X
Green investments				X			
National development funds	X	X			X	X	X
Commercial banks	X						
Venture capital funds	X			X			

large projects. By providing assistance to specific activities, which also include the enabling regulatory and policy environment, these multilateral organizations also encourage certain activities in a given sector.

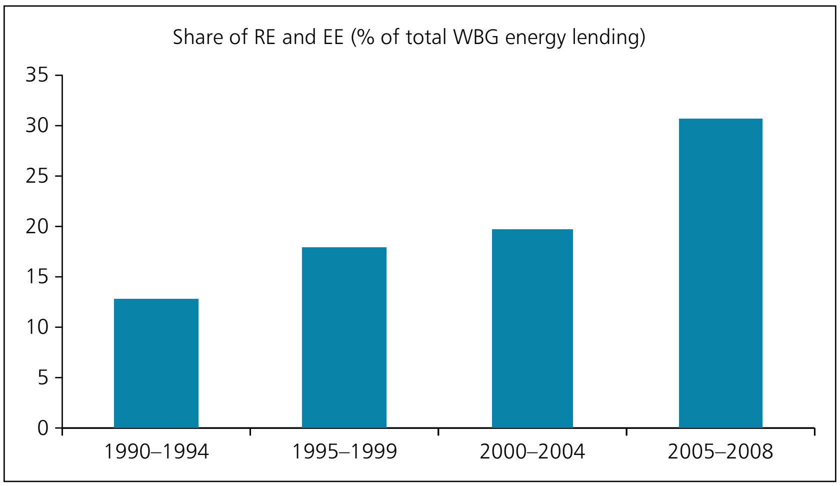
World Bank Group

The World Bank Group comprises the International Bank for Reconstruction and Development, the International Development Association, and the International Finance Corporation. The bank provides loans to developing countries at more favorable terms (such as 15–20 year repayment periods, with grace periods of 3–5 years during which no interest is charged) than commercial lending organizations. The development association supports the reduction of poverty worldwide through loans; guarantees; and nonlending services, including analytical, policy, and advisory services. The finance corporation provides loans, equity financing, and quasi equity to private-sector projects in developing countries. It also offers financial risk management products and intermediary financing.

The share of renewable energy and energy efficiency in the World Bank Group's total energy lending increased from 13% in 1990–1994 to 31% in 2005–2008 (Figure 6.1). It provided $2.7 billion to 95 projects in fiscal 2008 (an 87% increase over 2007): $1 billion for hydropower over 10 megawatts, $1.2 billion for energy efficiency, and $476 million for "new" renewable energy projects (World Bank 2009). Twenty percent of the support was aimed at increasing rural access to energy (Figure 6.2).

The rise in support for renewable energy and energy efficiency projects comes from new programs, such as the Clean Energy for Development Investment Framework. This includes a Carbon Finance Unit, which manages a $2 billion portfolio of trust funds through which governments and companies in industrialized countries can purchase credit for

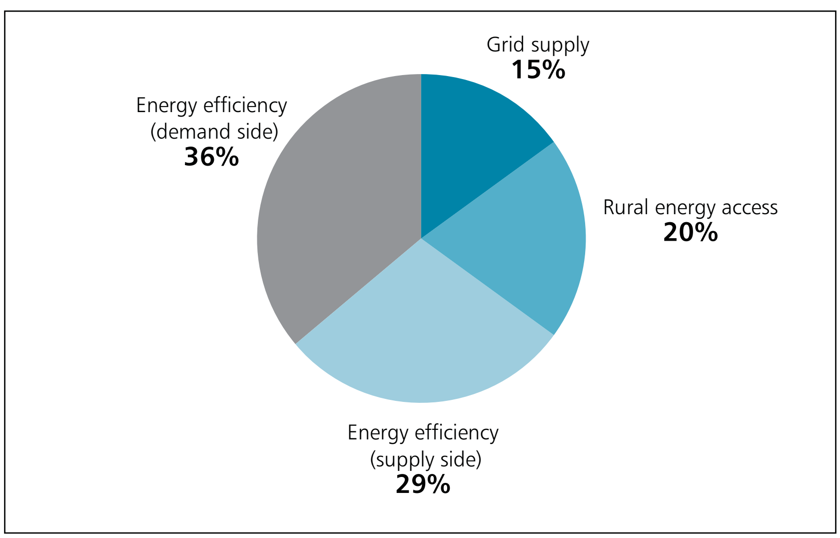
Figure 6.1: WBG Lending to Renewable Energy and Energy Efficiency as Percent of Total WBG Lending



EE = energy efficiency, RE = renewable energy, WBG = World Bank Group.

Source: World Bank (2009).

Figure 6.2: WBG-Supported Projects (Renewable Energy and Energy Efficiency), Fiscal Year 2008



WBG = World Bank Group.

Source: World Bank (2009).

cuts in GHG emissions by supporting projects in developing countries. These projects range from the destruction of industrial gases to the capture of methane in landfills; improved energy efficiency in steel production; bagasse co-generation; renewable energy (wind, geothermal, and hydropower); and land-use change and forestation. Having different funds allows investments by sector, with the goal of larger-scale and more efficient reduction of carbon emissions and greater revenues than occurred with a project-by-project approach. By 2006, almost 430 million Mt CO_2 had been contracted from 60 projects (World Bank 2006). The World Bank also launched two climate investment funds in July 2008—the Clean Technology Fund and the Strategic Climate Fund.[55]

However, the World Bank Group continues lending to coal, oil, and gas projects, which almost doubled from $1.58 billion in 2007 to $3.06 billion in 2008, while lending for new renewable—wind, solar, biomass, geothermal, and small hydropower projects—increased only marginally from $421 million (Redman 2008). Further, in 2007, less than 10% of the bank's carbon finance was allocated to solar, wind, geothermal, biomass, and mini-hydropower.[56]

A large part of the lending takes the form of specific investment loans (Figure 6.3). Other instruments include technical assistance loans, development policy lending, structural adjustment loans, adaptable program loans, and emergency recovery loans.

In the Asia and Pacific region, the World Bank Group provided $30 billion for 314 energy-related projects during 1996–2009, about 3% of it in the form of grants (Table 6.3). Half of the total financial support went to India and the PRC; 35% went to Bangladesh, Indonesia, Pakistan, Philippines, and Viet Nam.

Of the 99 energy efficiency projects supported by the World Bank Group in the DAP during 1996–2009, the PRC had 30%, followed by India (12%), Viet Nam (9%), Armenia (7%), and Sri Lanka (5%) (Figure 6.4). In terms of financing for the projects, the PRC received 38% of the total $8.4 billion, followed by India (22%), Viet Nam (14%), Thailand (7%), and Bangladesh (6%) (Figure 6.4). Thus, five countries took in 87% of the financial support.

Global Environment Facility

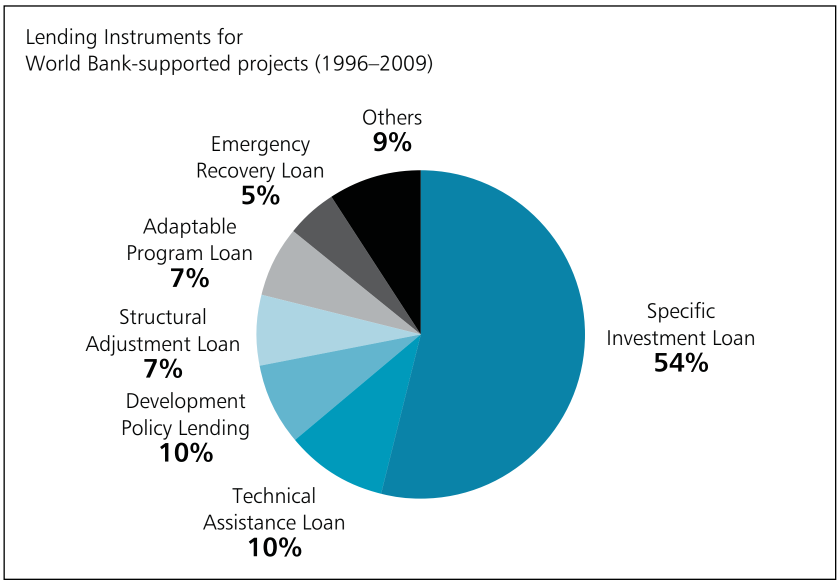
The Global Environment Facility was established in 1991 to provide grants and concessional funding to cover the additional costs associated with transforming a project with national benefits into one with global environmental benefits. So far, it has distributed $2.3 billion in grants to 595 projects related to climate change area, 28% of which are in the DAP region and received 41% of the grant money (Table 6.4).

The grants for renewable energy projects in the region are smaller than those for energy efficiency projects. It may be inferred here that the overall poor performance of developing countries in

[55] www.foe.org/media-center/press-release/world-bank-climate-initiative-comes-under-fire

[56] www.foe.org/new-report-world-bank-missing-its-renewable-energy-targets-climate-change-meeting-start-london

Figure 6.3: Lending Instruments for World Bank Support of Energy Projects 1996–2009 [Total 1,028 projects worldwide]



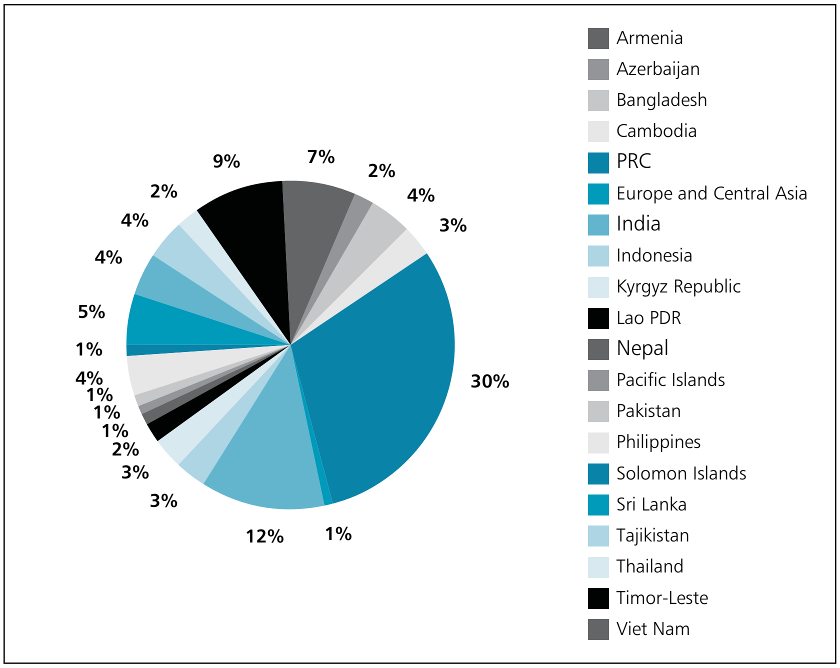
Source: http://web.worldbank.org/projects/templates/JspToExcel.jsp?category=simsearch&query=Energy&sortorder=DESC&sortby=BOARDSORTDATE&sitegroup=EXTERNAL&theSitePK=40941&status=ALL

renewable energy investments is a reflection of lesser grant aid for renewable energy projects. Another program with weak support is reducing the long-term cost of technologies for low GHG emissions. Only 5% of the grant money for this category was allocated to the DAP.

Performance evaluations of the organization suggest that there is a continuing need, particularly among least-developed countries and small island developing states, to strengthen the capacity for coordination of environmental activities at the country level, the stakeholder involvement in global environmental programs, and the capacity of those countries to develop and implement projects (Global Environment Facility 2007). Overall funding is concentrated on financing full-sized projects ($1 million and higher). Under climate change, during 1991–2007, the amount allocated to enabling activities was only 6% of total allocations.

Among all the climate change projects in the region supported by the Global Environment Facility during 1991–2007, the PRC and India accounted for 29% of the projects, 54% of the grant money given to countries in Asia and the Pacific, and 60% of total cofinancing generated. There was a big gap between the PRC and India in terms of grant received and cofinancing, however, with the PRC receiving 43% of total grant and cofinancing, compared with 17% and

Figure 6.4: Distribution of World Bank Energy Efficiency Projects in Asia and the Pacific



Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: http://web.worldbank.org/external/projects/main?pagePK=218616&piPK=217470&theSitePK=40941&menuPK=224076&category=simsearch&sortby=PRODLINETEXT&sortorder=ASC&query=energy%20efficiency&status=ALL

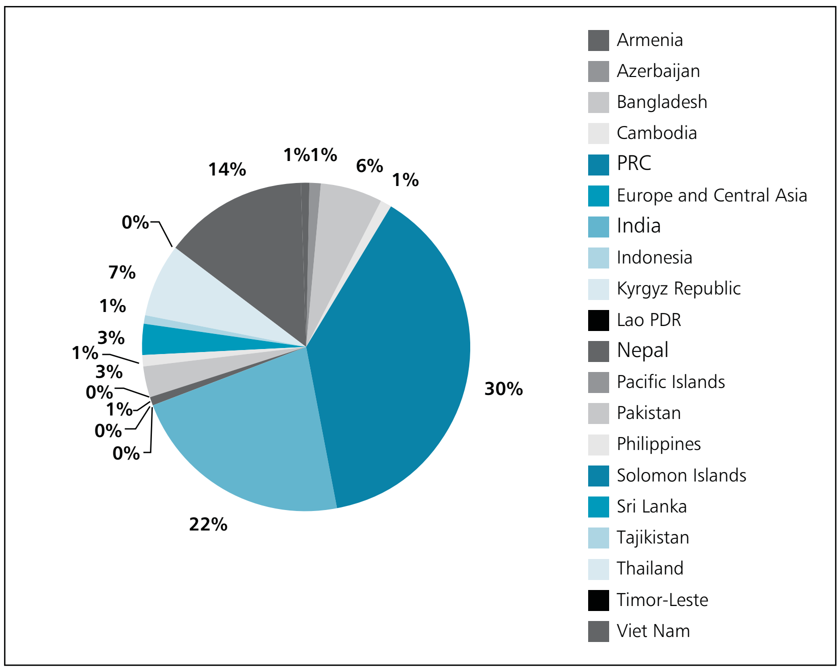
16% for India. The grant/cofinancing ratio has been much better for the PRC (1:8.6) than for India (1:7.9).[57] (For the organization's overall financing activity, the grant/cofinancing/grant ratio has been 1:4.33.)

Between 2006 and 2010, the PRC is expected to receive $150 million for climate change projects, while India takes in $75 million. To date, the PRC has been granted $360 million as direct grants and $3.2 billion as cofinancing for 26 projects under the climate change portfolio. India has received $130 million as direct grants and $876 million as cofinancing (Zhang 2007). Thus, more than 20% of total funding under climate change has gone to India and the PRC, with the PRC's share more than double that of India's. A further distribution of climate change grants by the Global Environment Facility to India and PRC is given in Table 6.6.

Over the years, projects supported by the Global Environment Facility have attracted additional

[57] http://projectdatabase.thegef.org/ (accessed on 7 May 2009).

Figure 6.5: Distribution of World Bank Financing for Energy Efficiency Projects in Asia and the Pacific



Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: http://web.worldbank.org/projects/templates/JspToExcel.jsp?category=simsearch&query=Energy&sortorder=DESC&sortby=BOARDSORTDATE&sitegroup=EXTERNAL&theSitePK=40941&status=ALL

Table 6.3: World Bank Lending to Energy Projects in Asia and Pacific Countries by Instrument Type, 1996–2009 ($ million)

Country	Number of Projects by Instrument Type			Project Cost and Funding		
	Development Policy Lending	Investment	Total	Project Cost	Total Funding	Grant
Total	56	258	314	72,434	30,416	994
India	4	34	38	24,588	8,849	120
People's Republic of China		48	48	20,845	6,304	370
Pakistan	7	6	13	3,767	2,685	0
Bangladesh	8	10	18	4,209	2,583	17

continued on next page

Table 6.3: continued

Country	Number of Projects by Instrument Type			Project Cost and Funding		
	Development Policy Lending	Investment	Total	Project Cost	Total Funding	Grant
Viet Nam	1	16	17	3,742	2,484	22
Indonesia	3	13	16	3,268	1,807	44
Philippines	3	13	16	2,191	1,123	32
Azerbaijan	2	14	16	1,409	829	37
Afghanistan	1	17	18	1,009	783	111
Kazakhstan	1	5	6	854	627	0
Thailand		3	3	1,083	545	3
Georgia	9	9	18	638	426	123
Armenia	5	8	13	423	366	8
Nepal		5	5	467	245	11
Mongolia	1	10	11	235	166	7
Lao People's Democratic Republic	5	7	12	2,862	164	4
Tajikistan	2	9	11	155	116	0
Cambodia		5	5	157	109	6
Kyrgyz Republic	1	8	9	218	108	1
Fiji Islands		1	1	88	34	0
Papua New Guinea		3	3	50	32	1
Maldives		1	1	14	13	0
Bhutan	1		1	12	12	0
Solomon Islands		1	1	5	4	0
Timor-Leste	2	6	8	68	3	55
East Asia and Pacific		1	1	2	0	1
Europe and Central Asia		2	2	15	0	11
Pacific Islands		1	1	58	0	9
Palau		1	1	0	0	0

Source: World Bank Project Templates. http://web.worldbank.org/projects/templates/JspToExcel.jsp?category=simsearch&query=Energy&sortorder=DESC&sortby=BOARDSORTDATE&sitegroup=EXTERNAL&theSitePK=40941&status=ALL

Table 6.4: Projects under Climate Change Area of Global Environment Facility

Operation Program	Projects		Grant ($ million)		Cofinancing ($ million)	
	Total	Asia-Pacific	Total	Asia-Pacific	Total	Asia-Pacific
Removing Barriers to Energy Conservation and Efficiency	113	52	710.33	440.10	4,721.93	3,474.13
Promoting Adoption of Renewable Energy by Removing Barriers and Reducing Costs	130	38	779.18	309.39	6,000.32	2,916.85
Reducing Long-Term Cost of Low GHG-Emitting Energy Technologies	17	4	231.59	13.58	492.23	36.37
Environmentally Sustainable Transport	23	7	165.84	64.82	2,140.47	1,151.87
Enabling Activity	288	65	201.16	41.60	39.83	11.61
Short-Term Measures	24		119.50	40.59	393.20	149.59
Total	595	166	2208	910	13,788	7740
% of Total		27.89		41.22		56.14

GHG = greenhouse gas.

Source: http://projectdatabase.thegef.org/ (accessed on 7 May 2009).

financing from other sources, particularly for the PRC and India. This implies that increased support in the region can create a favorable atmosphere for financing renewable energy and energy efficiency projects—but that there is a bias for areas of fast economic growth. Other countries need additional help to achieve higher growth that will then attract financing.

Other multilateral organizations

While the support by the World Bank Group and the Global Environment Fund is, in principle, available to all, it is concentrated in a few countries. Other multilateral organizations have specific programs targeting a set of countries in the region.

Asian Development Bank

ADB has initiated targeted programs to promote energy efficiency and renewable energy. The Energy Efficiency Initiative was initially focused on India, Indonesia, the PRC, Pakistan, and the Philippines, with an objective to catalyze $240 billion in investments in energy efficiency and renewable energy over 10 years. To help finance the initiative, ADB has developed special financing tools—the Clean Energy Financing Partnership Facility and the Climate Change Fund. Through the fund, the initiative is being expanded to involve more countries, such as like Afghanistan, Bangladesh, Cambodia, the Lao People's Democratic Republic, Mongolia, and Uzbekistan.

Table 6.5: The GEF Portfolio Project Types (Allocations in %)

Project	1991–2007			2006–2007		
	Enabling Activities[a]	Medium-Sized Projects[b]	Full-Sized projects[c]	Enabling Activities[a]	Medium-Sized Projects[b]	Full-Sized Projects[c]
Biodiversity	4	7	90	–	6	94
Climate Change	6	2	91	–	2	98
International Waters	–	2	98	–	2	98
Land Degradation	–	4	96	–	1	99
Multifocal Area	3	3	94	1	1	98
Ozone Depletion	–	3	97	–	–	100
Persistent Organic Pollutants	26	3	71	6	4	90

[a] Typically up to $450,000.

[b] Up to $1 million; projects are accessible to nongovernment organizations.

[c] $1 million and higher.

Source: Global Environment Facility (GEF) 2007. Investing in our Planet: GEF Annual Report 2006–07. GEF.

Table 6.6: Global Environment Facility Grants under Climate Change for the PRC and India

Category	India			PRC (direct grant)		
	Projects	Grant ($ million)	% of Climate Change Grant	Projects	Grant ($ million)	% of Climate Change Grant
Energy Efficiency	4	63	48	13	200	56
Renewable Energy	5	49	38	5	98	27
Transport	1	1	1	3	33	9
Short-Term Response Measures	1	9	7	2	22	6
Enabling Activities	3	7	6	3	7	2

PRC = People's Republic of China.

Source: http://projectdatabase.thegef.org/ (accessed on 7 May 2009).

Table 6.7: ADB's Clean Energy Investments

Year	2003	2004	2005	2006	2007	2008
Total Approved energy loans ($ million)	1,263	1,431	1,685	1,812	1,801	3,223
Clean Energy Component ($ million)	226	381	637	834	668	1,703
Percentage of the total loans approved for clean energy	17.89	26.62	37.80	46.02	37.00	52.99

Source: ADB (2009a).

Similarly, the Renewable Energy and Efficiency Program for the Pacific is an ADB technical assistance project funded by Denmark for East Timor and the Pacific developing member countries (DMCs) with a budget of $0.6 million. It aims at developing a demand-driven and private sector-based market for renewable energy and energy efficiency in the Fiji Islands and Samoa, targeting the rural and remote communities. It is also supposed to develop action plans for policy and legal frameworks specific to renewable energies and energy efficiency, along with financing mechanisms focused on private-sector companies and end users.

Other ADB programs to promote energy efficiency and renewable energy in the region, in general, include

- the Climate Change Program to mobilize concessional resources, catalyzing private capital and maximizing market mechanisms for advancing energy efficiency and use of low-carbon energy sources, enabling sustainable transport policies, and applying efficient systems.
- the Clean Energy and Environment Program, which includes various financing structures, such as like risk-sharing mechanisms, subordinated contingent loans, and grants to promote clean technologies, prepayments for carbon credits through the ADB Carbon Market Initiative and the Asia Pacific Carbon Fund, and carbon delivery guarantees. Through the Carbon Market Initiative, ADB provided up-front financing and technical support for more than 40 mitigation projects (ADB 2008). The Asia Pacific Carbon Fund ($80 million–$200 million) secures 25%–50% of future carbon credits generated by CDM projects and fills a critical financing gap with up-front payment using at a discount rate. It targets projects involving methane capture and utilization, industrial technology, supply-side efficiency (e.g., upgrade of generation equipment), and renewable energy (biomass, small to mid-scale run-of-the-river hydropower, wind power, and geothermal). Under carbon delivery guarantees, the clean energy projects eligible for support under the CDM can receive additional finance from the pre-sale of some or all carbon credits generated. This could be in the form of prepayments from the carbon fund or other carbon credit

funds or buyers who are willing to pay in advance under emission reduction purchase agreements or in the form of carbon finance.

Despite the proactive approach of ADB, the value of ADB's energy loans has not increased much, except in 2008. However, the share of clean energy investments increased substantially from less than 20% in 2003 to more than 50% in 2008 (Table 6.7). It has also been observed that ADB is good at supporting large public-sector infrastructure projects that need long-term, hard-currency financing, rather than smaller clean energy projects that need carefully structured short- to medium-term support.[58]

European Union programs

The European Union has funded a number of projects in the Pacific DMCs, including photovoltaic systems in Kiribati, Tonga, Papua New Guinea, Fiji Islands, and Tuvalu. It is also running a €11.4 million (or $16.30 million) regional development, project for five Pacific DMCs—namely, Niue, Marshall Islands, Federated States of Micronesia, Palau, and Nauru—to promote renewable energy deployment, along with enhancing vital role of local companies. Most funds are for purchasing renewable energy equipment.

Another program is the Global Energy Efficiency and Renewable Energy Fund to provide risk capital through private investment for energy efficiency and renewable energy projects and accelerate the transfer, development, use, and enforcement of environmentally sound technologies in developing countries and economies in transition.[59] The project is a public–private partnership, offering risk sharing and co-funding opportunities for commercial investors and public investors. It targets an overall investment amount of €150 million (€) or $214.54 million, €80 million ($114.41 million) of which will be funded by the European Community budget. The project gives priority to investment in a group of 79 African, Caribbean, and Pacific developing countries that have policies on energy efficiency and renewable energy that are conducive to private-sector engagement. It supports a broad mix of energy efficiency and renewable energy projects and technologies, such as small hydropower, biomass, and on-shore wind farms. It will invest in private equity funds that specialize in providing equity finance—financing in return for shareholdings—to small and medium-sized regional projects and enterprises.

The European Bank for Reconstruction and Development launched the Sustainable Energy Initiative, in May 2006, to address the specific needs of the energy transition in countries from central Europe to central Asia with a focus on energy efficiency. The objective is to scale up sustainable energy investments to €1.5 billion ($2.145 billion) between 2006 and 2008 (more than double the level of the previous period), strengthen capacity to mainstream energy efficiency objectives, and establish broad partnerships with donors to mobilize grant. By the end of November 2007, the total investment volume by the bank had reached 92% of the 3-year target. Total project value reached about €7 billion ($10,01 billion).

[58] www.un.org/esa/sustdev/csd15/lc/usaid_adb.pdf

[59] www.eif.org/about/geeref.htm

The European Bank for Reconstruction and Development and the European Investment Bank have established a public–private fund—the Multilateral Carbon Credit Fund—of €165 million ($235.99 million) dedicated to countries from Central Europe to Central Asia.[60] By joining the fund, private and public companies, as well as the banks' shareholder countries, can purchase carbon credits from emission reduction projects financed by the banks to meet their mandatory or voluntary GHG emission reduction targets. Countries can also participate in green investment schemes. This is an innovative way to facilitate government-to-government trade in carbon credits, whereby the selling country uses the revenue from the sale of carbon credits to support investments in climate-friendly projects. By selling carbon credits to carbon funds, the investor increases the financial return on a project. For example, renewable energy projects (e.g., wind, hydro, and biomass) are able to boost their internal rate of return by 1%–7%. There are also projects, such as landfill gas collection and flaring projects at large waste management sites, that can be financed almost completely from sales of carbon credits. The countries from which fund can purchase carbon credits include Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Macedonia, Moldova, Mongolia, Montenegro, Poland, Romania, the Russian Federation, Serbia, Slovak Republic, Slovenia, Tajikistan, Turkey, Turkmenistan, Ukraine, and Uzbekistan.

Bilateral aid

In addition to providing funding through their own national funds, the major developed nations also coordinate their development financing through the Development Assistance Committee. The goal is to increase the effectiveness of the sustainable development work of OECD member nations. Bilateral financing is generally open only to the national governments of developing countries. It is a significant source of investment in developing countries, but it falls short of what is required. The official development assistance (ODA), for instance, has generally contributed only $5.4 billion per year to energy projects (UNESCAP 2008). The investment component of assistance amounts to between 1% and 7% of total investment in new physical assets in developing country regions (UNEP 2008).

National public institutions

In many DAP countries, public institutions find it difficult to raise the necessary funds, while in all but a few countries, the private sector is unwilling to invest in larger projects (UNESCAP 2008).

One instrument that is gaining popularity is the special purpose vehicle for project financing. This is a legal entity created when a sponsor transfers assets to it to carry out a specific purpose. The rules governing it are set in advance and built into its activities. It is a form of securitization, which offers higher-quality assets to investors by insulating them from the risk of bankruptcy either of the sponsor or the originator. The India Infrastructure Finance Company Ltd. was set up in 2006 as a special purpose vehicle to finance infrastructure projects on a long-term basis. This could be broadened to assist all countries in the region.

Local financial institutions, such as banks and private players, can offer financing through

[60] www.ebrd.com/country/sector/energyef/carbon/mccf/index.htm

leasing and term loans—following well-defined, due diligence processes for evaluating loan and investment proposals. This is not happening much at present, partly for lack of information about the potential of infrastructure investment but also for lack of resources. In the DAP region, infrastructure financing will depend, to a large extent, on financial institutions. The PRC Development Bank, for example, is primarily responsible for raising funds for large infrastructure projects and is one of three policy banks in the PRC.[61] Countries, such as the PRC and India, can also use the stock and bond markets, though these are usually fairly small: the value of listed shares divided by the gross dometic product is between 30% and 40% of that in OECD countries. Countries with more developed finance sectors can provide better access to equity, bonds, and borrowing.

Private finance

In recent years, a number of specialized private equity funds that concentrate on infrastructure development have emerged. These offer investors a range of options with different risk profiles and investment objectives. As a result, investing in infrastructure development is no longer limited to large, institutional players with abundant cash and long-term investment horizons. If the financial markets in the DAP region develop, private finance could play a major role in infrastructure financing.

Cofinancing for renewable energy projects and enterprises can come from the commercial banking sector and venture capital. This could be from local banks in each country, which would require reassurance to enter the market. Venture capitalists invest and fully participate in early-stage technology companies. They demand a large equity stake, and they expect returns in the order of 50%–60%.

Barriers to financing energy efficiency and renewable energy

The key to the growth of the clean energy industry is the attraction of sufficient investment to satisfy the demand for project funding at all stages of development. Given some barriers to clean energy investment, there is a need to develop schemes tailored to encouraging the flow of capital to clean energy projects. Governments have a range of policy options. However, in the DAP region, regional policy makers need basic training on the design of incentives, the relative merits of the different measures, and the most effective methods of implementation, and governments need to commit funds to these schemes.

Lack of seed money to support start-up businesses is one of the key barriers that slow the spread of energy efficiency and renewable energy. Projects also require working and growth capital which, in developing countries, especially for the small and mid-range entrepreneurs, are often very difficult to access from traditional commercial sources.

Currently, even though there are many mechanisms in place, energy efficiency and renewable energy projects find it difficult to get institutional financial support. The high risk[62] associated with investing in the early stages of an industry's development

[61] Policy banks are banks in the PRC established under the Policy Banks Law 1994.

[62] An estimated $9 billion of risk capital is needed for renewable energy generation in developing countries by 2010. European Commission. The Global Energy Efficiency and Renewable Energy Fund (GEEREF): Key elements of the European Commission initiative. Available: www.geeref.com/background/ (accessed in May 2009).

makes financial institutions shy away from projects, such as wind farms, if the cost of preparing and administering the first few loans is too high. Most financiers have a "strong tendency to let others go first—to 'do what they've always done'—and finance another thermal power station powered by fossil fuels, rather than something new like a wind farm" (UNEP 2008). This shyness of financial institutions blocks them from creating new financial products that can help develop the energy-efficient and renewable energy technology sector. The risks and market development costs prompt banks that do participate to compensate with higher interest rates and more restrictive lending conditions that hinder the development of sound projects.

For institutional financing, particularly from multilateral sources, such as the Global Environment Facility and the Clean Investment Fund, the experts surveyed said the major barrier to financing was the lack of detailed knowledge about the procedures, along with bureaucratic hurdles and complicated rules. The experts were also of the opinion that institutions fail to target the conventional small-scale sector, where the potential for energy efficiency enhancement is huge. Other constraints are inadequate government leadership, the cost of financing, and the small size of loans or other financial assistance made available.

The region, on the whole, lacks early-stage investment from the private sector. Traditionally, this investment comes from venture capital and private equity funding, although high-net-worth individuals can also fill this role. Development finance institutions are well-placed to provide a matching service using measures, such as cofinancing, loans, or direct equity co-investment, to take direct involvement in a project. They can set up programs specifically designed to address problem funding areas, an example being the Seed Capital Assistance Facility set up by ADB and the United Nations Environment Programme (UNEP), which will provide seed capital to renewable energy and energy efficiency projects in the DAP region. To be successful, these sources of financing must be matched with developers.

Barriers specific to energy efficiency

Despite the numerous advantages offered by investments in energy efficiency, a significant potential remains untapped—perhaps 20%–35% in the DAP region. The small size of projects, their difficulty in being bundled, and their perceived high risks have discouraged commercial banks and investors who, lacking the technical understanding of energy efficiency projects, tend to see them as too much effort for too little profit. The majority of the need is for very small loans to cover higher up-front costs than those of less energy-efficient technologies in appliances; windows; and heat, ventilation and cooling systems. The high up-front cost can discourage a sizable portion of the population from adopting energy-efficient appliances.

Policies can be used to overcome barriers to investments in energy efficiency (IEA 2008a). They include the following:

1. Public–private partnerships for energy efficiency most commonly appear in the form of preferential rate loans, wherein the government subsidizes the private sector so that financial institutions can offer customers reduced rates. For, example, through its Gernelle de l'Environment, France has most recently renewed its commitment of offering 0% interest rate loan for home retrofitting energy efficiency projects up to €30,000 ($42,653). The case of the German KfW is another successful example. KfW, which was created with the funding of the

Box 6.1: Case Study: ReEx Capital Asia

In 2006, the development finance arm of German KfW Bank seed-funded ReEx Capital Asia, an investment banking boutique based in Singapore, specializing in the Asian clean energy sector. ReEx Capital Asia's main business is capital-raising: originating investment opportunities, structuring deals, and raising funds (debt/equity) for renewable energy infrastructure, biofuel production facilities, energy efficiency projects, and companies that provide green energy products or services.

The lack of transparency and the still immature nature of the green energy market make it difficult for entrepreneurs and financiers to find each other. ReEx Capital Asia aims at filling this gap by connecting capital with clean energy investment opportunities. ReEx helps companies and project developers raise money through matchmaking with commercial banks, corporate investors, clean energy private equity funds, and carbon funds.

Today, ReEx Capital Asia has 25 investment opportunities in its pipeline, and several are undergoing due diligence by partnering investors or lenders. ReEx Capital Asia has had the advantage of having a strong advisory board with individuals from major institutions, giving the company credibility from its inception. ReEx has not only received financial support but has also benefited from the marketing activities of the KfW Bank's financing arm, known as the Renewable Energy and Energy Efficiency Partnership, which has promoted ReEx services.

The willingness of national governments, bilateral agencies, or financial institutions to support the establishment of ReEx-type operations on a risk-shared or grant basis may be a key to its replication. Basing the operation in Singapore has provided an established and well-regarded business environment that has seen increasing government support for the clean energy industry.

Source: Renewable Energy Regional Policy Analysis Report Washington International Renewable Energy Conference 2008; Renewable Energy and Energy Efficiency Partnership, February 2008.

post-World War II rescue package known as the Marshall Plan, contributed to the retrofitting of close to a million dwellings from 1996 to 2004, through the provision of preferential rate loans. The KfW mechanism has proven very effective at overcoming financial barriers and creating energy efficiency.

2. Risk-sharing mechanisms are critical to successful public–private collaboration. The Flat-35 developed in Japan rightly illustrates the principle of risk-sharing agreements wherein the government guarantees a fixed interest rate in its loans to financial institutions which, in turn, provide a fixed and reduced rate of interest to their customers in exchange for an energy consumption reduction certificate. Initiated in 2003, this scheme led to the refurbishment of more than 100,000 dwellings in 3 years.
3. Staff training is another core element of successful policy packages. Overcoming the information failure within financial institutions and building expertise on energy efficiency are key to the sustainability of any measures to trigger increased energy efficiency.

ESCOs in promotion of energy efficiency

An energy service company (ESCO) is a market-oriented mechanism to improve energy efficiency. ESCOs have been in operation in the United States, Canada, and the Republic of Korea for several years. In the Asia and Pacific region, they are in nascent stage and face barriers in markets, financing, and institutions.

ESCOs are private or public companies that can provide technical, commercial, and financial services. They take the project performance risk, arrange financing and, depending on the agreement reached with client, may take customer credit risk also. This is done through performance contracting. Two of the most commonly used models are

1. sharing–saving contracts, in which the ESCO finances the project either from its own fund or by borrowing from a third party (in this case, the ESCO assumes performance, as well as credit risk);
2. guaranteed savings contract, in which the customer finances the project by borrowing funds from a third party. Finance is usually arranged by the ESCO, but the contract for the loan is between the bank and customer. The ESCO takes only performance risk by guaranteeing the savings.

Barriers to ESCOs in developing countries

ESCOs in developing countries face most of the barriers that energy efficiency projects have come across, plus the additional hurdle of being unfamiliar to clients and financing institutions. Further, the obstacles may vary from one developing country to another, depending on the stage of development, the role of markets and competition in the economy, and institutional and regulatory practices.[63]

Market barriers. Creation of a market for ESCOs can be hampered for the following reasons:

- Scarcity of capital. This leads to competing alternatives for the scarce capital—capacity expansion versus energy efficiency. In developing countries, expansion of capacity usually wins.
- Preference for modernization. In developing countries, companies prefer to carry out low-cost or no-cost options only. Since manufacturing processes in many countries are outdated, companies would rather modernize than carry out energy efficiency projects.
- Modest size. A large potential for energy efficiency projects lies with small and medium-sized enterprises but they lack access to capital, and their projects are too small for commercial banks.
- In some countries, market development for energy efficiency improvement in electrical equipment is hindered by poor policies and practices, such as very low prices of electricity, poor bill collection, and poor quality of supply (requiring robust, rather than efficient, equipment).

Institutional barriers include the following:

- ESCO business requires performance contracting, a concept unfamiliar to service

[63] *Financing Energy Efficiency, Lessons from Brazil, China, India and Beyond*. World Bank, 2008.

providers and buyers. In the public sector, procurement practices are centered on assets rather than services. Therefore, procedures and practices may need to be modified.
- In the case of utility involvement in projects involving utility customers, new institutional arrangements, practices, and legal provisions may be required, such as collection of payment with utility bills. Utilities may not be willing to participate in such arrangements.
- Many developing countries have a weak legal and contract enforcement framework. Where it exists, it is too slow to cater to the needs of the contracts.

Financial barriers relate to the fact that the ESCO industry, being unfamiliar, is subjected to procedures not suitable for its unique nature:

- A large number of energy efficiency projects are small, not suitable for project financing (in which the financing institution analyzes the project's ability to pay). The transaction costs are too high for project financing on small projects.
- Most financial institutions lack appraisal ability when it comes to an energy efficiency project. Their focus is mostly on cash flow rather than the savings that energy efficiency projects offer.
- In most cases, financial institutions in developing countries prefer to lend based on balance sheet financing. It means that either the ESCO or its client should have a strong balance sheet. Since the ESCO industry is still in its initial stages in developing countries, this has been a major barrier to the growth of the industry.
- Because of a lack of credit history, ESCOs are treated as a high credit risk. This leads to high collateral requirements, which ESCOs are unable to provide.
- In many cases, lenders are either risk-averse or have very low risk-taking capacity. They also lack the capability to carry out a risk analysis and factor it into their lending practices.

Removing barriers to energy efficiency financing

The measures needed to remove the barriers can be integrated into a few actions.

Development of a market for energy efficiency projects. This is one of the most important tasks for a successful program. It may need the following:

- Government support may be crucial in the initial. This may include opening up government facilities for ESCO projects and setting up demonstration projects to build confidence among stakeholders.
- For small and medium-sized enterprises that may lack access to information on energy efficiency measures and financing, special efforts, such as setting up an information clearinghouse, energy efficiency database, or projects database, may be required.
- Reforms in energy pricing may be crucial if prices are distorted. Energy pricing should be transparent and sound. Measures that encourage people to pay the economic costs for the energy (such as proper metering and bill collection in case of electricity) are important.

Development of the local financing market. Financing from local financial institutions needs to be unlocked. This may require some or all of the following:

- Development of a specialized energy efficiency financing window in the appropriate financial institutions, such as commercial banks. This may require upgrading the skill of the staff to appraise energy efficiency projects. Specialized methods for appraisal that are based on a savings model rather than cash flow may be required. This can be standardized for small projects to keep transaction costs low. In cases where projects are still too small, a mechanism to aggregate the projects (such as a super ESCO) could be applied. For big projects, special financing deals may have to be structured that consider saving streams and performance contracting as important components in assessment. Thus, special financial products may have to be designed, keeping in view the unique features of the specific energy efficiency projects.
- A measure similar to the energy efficiency window is establishment of specialized energy efficiency funds. The funds can be supported by governments, multilateral agencies, and donors in this area. The funds can develop requisite expertise to appraise the projects and finance the project or enhance the credit through cofinancing.
- In some cases, financial institutions may require guarantees before they are comfortable with energy efficiency financing. In that case, a guarantee fund may have to be created. Development of an insurance product for ESCO projects is a mechanism similar to the guarantee. However, insurance companies may themselves need to develop expertise to develop such a product. Transactions costs may be quite high unless a sizable insurance market can develop.

Development of ESCOs and institutions. The ability of ESCOS to design performance contract suitable to specific projects is key to their market expansion. Similarly, monitoring, verification, and reporting procedures may have to be developed for different types of projects. A database of model contracts and such procedures, accessible to all the ESCOs, is important for this. It could be created and made available by an ESCO association. In some cases, collaboration with international ESCOs can be useful. Government support in institution building is also crucial.

A reliable and enforceable contract system needs proper laws in place. Enforcement tends to be slow in many developing countries, and this can discourage participation by international ESCOs. An appropriate arbitration procedure may have to be established if the existing legal system is inadequate.

Financing challenges in commercialization

Moving from publicly funded demonstration to commercial viability is often the most difficult phase for many technologies, resulting in what Murphy and Edwards (2003) have called a "Valley of Death." It is at this point, where investment costs can be very high and where risks also remain significant, that projects can easily fail. Frequently, neither the public nor the private sector considers it their duty to finance commercialization. This is where neither "technology-push" force nor "market-pull" force has sufficient strength to bring the innovation across the desert. The halt in funding is particularly problematic for technologies with long lead times and a need for considerable applied research and testing between invention and commercialization, as is the case for many energy technologies (Norberg-Bohm 2002).

Navigating the "Valley of Death": successful technology transfer

Policy tools to close the gap include both economic incentives (such as tax credits, production subsidies, or guaranteed procurements) and support in the form of better access to information. Spin-off companies formed from public–private research consortia are often an important means of technology transfer and commercialization. To support technology incubators and entrepreneur start-ups and spin-offs, governments can offer funding for technology transfer or establish specialized technology transfer centers. This is a phase where governments need to begin incorporating market-pull policy measures. On the market side, governments can stimulate the incorporation of clean-energy centers and/or environment-specific venture capital into the current capital market by reducing regulatory barriers and providing fiscal incentives.

Governments can also help create demand for new technologies by putting in place regulatory requirements (for example, building standards) that progressively challenge the supply side to respond to new demands.

Analysis of international market mechanisms

Performance of the Clean Development Mechanism

The CDM under the Kyoto Protocol was established to (ii) provide flexibility to Annex I countries in meeting their emission reduction targets at a lower marginal cost by investing in non-Annex I countries and (ii) to promote sustainable development in non-Annex I countries by facilitating flow of technology and finance from developed countries to developing countries. This section focuses on the analysis of financial assistance that the CDM has so far provided to developing countries. A brief discussion on technology transfer is also included. The assumption made here is that all the projects in the CDM pipeline would not have been conceived in their present form in the absence of revenues from certified emission reduction (CER). This includes the instances of technology transfer in these CDM projects. It is also taken for granted that all the projects are in line with the objective of sustainable development.

As of 1 December 2008, 1,243 projects have been registered under CDM, and 2,694 are at validation stage. A total of 4,359 projects were put before the CDM executive board for approval (Table 6.8). With regard to their emission reduction potential, the majority of the projects were small or midsize. The share of projects below 25 kiloton (kt) CO_2/yr capacity was 29%, while 67.5% were of 25–500 ktCO_2/yr capacity (Table 6.9).

Taking all countries together, hydro, biomass, and biogas have attracted more projects than any other

Table 6.8: CDM Projects by Status (as of 1 December 2008)

Status of CDM projects	Number
At validation	2,694
Request for registration	136
Request for review	70
Correction requested	101
Under review	8
Total in the process of registration	315
Withdrawn	23
Rejected by executive board	84
Registered, no credits issued	815
Registered, credits issued	428
Total registered	1,243
Total number of projects (includes rejected and withdrawn)	4,359

CDM = clean development mechanism.

Source: www.cd4cdm.com (accessed in February 2009).

Table 6.9: CDM Projects by Emission Reduction Capacity (as of 1 December 2008)

Size of project in $ktCO_2$/yr	Number of projects	Number of projects (%)
0–5	184	4.2
5–10	276	6.3
10–25	809	18.6
25–60	1,012	23.2
60–100	850	19.5
100–500	1,082	24.8
500–1,000	77	1.8
1,000–5,000	61	1.4
5,000–10,000	5	0.1
> 10,000	3	0.1

CDM = clean development mechanism, $ktCO_2$/yr = kiloton of carbon dioxide per year.

Source: www.cd4cdm.com (accessed in February 2009).

category (Table 6.10). Hydro tops the list with 1,120 projects in the pipeline, biomass has 645, and biogas 497. Within hydropower, the run-of-the-river type account for about 68% projects. In the biomass category, bagasse power (175 projects) and agricultural residues (312 projects) are dominant, followed by forest-based activities (72 projects). It is evident that the activities involving advanced technologies—gasification of biomass and bio-diesel—have not taken off yet despite high expectations.

Among the DAP countries, CDM activity is heavily concentrated in India and the PRC (Table 6.11). Of 809 registered projects as of 1 December 2008, India accounted for 371 projects and the PRC 317, a total of more than 85% of the projects. The numbers were similar at the validation stage. In terms of emission reduction potential, however, the PRC is way ahead of India. The PRC claims more than 60% of the emission reduction credits until 2012; India's share is a little above 20%. The Republic of Korea is an exceptional case in terms of emission reduction per project: despite having only 19 that are registered, it claims 94,148 kilo certified emission reductions.

In terms of installed power-generating capacity in the CDM projects in the pipeline in Asia and Pacific countries, the activities are again heavily concentrated in India and the PRC (Table 6.12). Of total installed capacity of 60,042 megawatts (MW), the PRC accounts for 41,191 MW, and India's contribution is 14,411 MW.

In terms of sectors, hydropower accounts for almost 50% (29,524 MW), followed by wind power (32%) and biomass energy (12%). Solar power, which is considered to have the largest potential among the renewable energy options, is almost absent in the CDM activities.

CDM has been influential in promoting renewable energy, with almost 50% of projects in the pipeline involving renewable energy activities. However, the distribution of these projects shows that those subtypes involving advanced technologies (biomass gasification, biodiesel, and solar) have not taken off yet. This is indicative of the limitations of the CDM in promoting technology transfer within the renewable energy sector.

Table 6.10: CDM Projects by Subtypes (as of 1 December 2008)

		Number of Projects			
Type	**Subtypes Used in CDM Projects**	**At Validation**	**Request Registration**	**Registered**	**Total**
Biomass	Bagasse power	97	2	76	175
	Palm-oil solid waste	30	2	16	48
	Agricultural residues	190	7	115	312
	Black liquor	4	1	6	11
	Irrigation	1	0	0	1
	Forest-based	54	1	17	72
	Industrial waste	4	0	1	5
	Gasification of biomass	13	0	1	14
	Biodiesel	7	0	0	7
Biogas	Biogas flaring	109	5	114	228
	Biogas power	191	8	70	269
Hydro	Run of river	486	77	194	757
	Existing dam	33	2	30	65
	New dam	197	53	48	298
Solar	Solar photovoltaic	10	4	2	16
	Solar thermal electric	2	0	0	2
	Solar water heating	2	0	0	2
	Solar cooking	4	0	2	6

CDM = clean development mechanism.

Source: www.cd4cdm.com (accessed in February 2009).

Table 6.11: CDM Projects by Status in DAP Countries (as of 1 December 2008)

	At Validation		Request Registration		Registered	
	Number	2012 kCERs	Number	2012 kCERs	Number	2012 kCERs
Asia and the Pacific	2,159	991,485	287	240,345	809	1,049,759
Bangladesh	2	348	0	0	2	1,116
Bhutan	2	16,078	0	0	1	4
Cambodia	2	500	1	32	2	509
PRC	1,038	641,795	213	213,231	317	679,280
Fiji Islands	0	0	0	0	1	164
India	719	214,229	48	14,349	371	217,213
Indonesia	75	23,785	4	2,852	17	15,189
Lao PDR	0	0	0	0	1	19
Malaysia	106	46,957	4	3,397	35	16,061
Mongolia	1	724	0	0	3	385
Nepal	1	162	0	0	2	697
Pakistan	11	9,341	0	0	1	4,935
Papua New Guinea	0	0	0	0	1	1,836
Philippines	54	6,161	3	3,896	20	3,743
Singapore	4	1,671	1	66	0	0
Korea, Republic of	29	5,823	6	562	19	94,148
Sri Lanka	14	1,930	0	0	4	924
Thailand	61	15,575	4	841	10	6,601
Viet Nam	40	6,407	3	1,121	2	6,933

PRC = People’s Republic of China, kCERs = kilo certified emission reductions, Lao PDR = Lao People’s Democratic Republic.

Source: www.cd4cdm.com (accessed in February 2009).

Table 6.12: MW Installed in All CDM Projects in Pipeline in Asia and Pacific Countries (as of 1 December 2008)

Region/ Country for CDM Projects (No. of projects)	Biogas	Biomass Energy	Coal Bed/ Mine Methane	Energy Efficiency	Geo-thermal	Hydro	Landfill Gas	Solar	Tidal	Wind	Total
Asia and the Pacific	348	7,605	893	0	329	29,524	537	98	254	20,453	60,042
Bhutan						1,134					1,134
PRC	62	1,632	893			22,827	331	41		15,406	41,191
India	61	5,333				4,393	43			4,581	14,411
Indonesia	19	104			201	222	10				694
Malaysia	12	226				16	15				270
Philippines	7	52			60	44	24			73	259
Korea, Republic of		2			12	32	101	56	254	314	772
Thailand	97	189					3				288
Viet Nam	15					430	7			30	483

CDM = clean development mechanism, MW = megawatt, PRC = People's Republic of China.

Source: www.cd4cdm.com (accessed in February 2009).

Energy efficiency projects in CDM

In terms of promoting energy efficiency, the performance of the CDM has not been very satisfactory. Of the total projects registered, only 11.75% belong to the energy efficiency category. Similarly, only 16% of those at the validation stage are for energy efficiency and 17.5% of those requesting registration. The share of emission reduction credits generated by energy efficiency is even smaller (Table 6.13). Activity is heavily concentrated in "own generation" or captive power generation, followed by industry.

In the DAP region, this performance is even more skewed, with India, the PRC, and Indonesia accounting for all the energy efficiency projects. End-use energy efficiency projects are marginal, with most of the activity concentrated in Indian industry. On the supply side, the PRC leads with 236 projects in the pipeline, compared with India's 121. The transport sector is almost absent despite a high potential for energy efficiency improvement.

Table 6.13: Energy Efficiency Projects in CDM at Different Stages (as of 1 December 2008)

	At Validation		Request Registration		Registered	
Type	Number	2012 kCERs	Number	2012 kCERs	Number	2012 kCERs
Energy efficiency households	10	3,505	1	178	3	253
Energy efficiency industry	124	23,393	5	198	47	9,562
Energy efficiency service	7	540	1	39	2	93
Energy efficiency own generation	257	164,785	48	36,468	80	77,559
Energy efficiency supply side	34	28,050	0	0	14	3,635
Energy efficiency total	432	220,273	55	36,882	146	91,102
% of Total CDM projects	16.04	18.02	17.46	14.18	11.75	6.59

CDM = clean development mechanism, kCER = kilo certified emission reduction.

End-use energy efficiency and CDM

Various studies have emphasized the significant contribution that energy efficiency, particularly end-use energy efficiency, can make toward mitigating climate change, as well as improving energy security.[64] The share of energy efficiency projects in CDM projects, however, does not give any indication that these findings are being acted upon. As of 1 May 2009, there are only 58 registered end-use efficiency projects (household, service, and industry), representing 3.6 % of all registered CDM projects and an even smaller share of cumulative emission reduction credits until 2012 (less than 1%). This is primarily due to their small size. Overall, the amount of CERs issued for end-use efficiency is very small compared with the vast savings potential. The cumulative CERs expected to be issued through 2012 from these projects is about 10 million CERs, compared with IEA's estimate of annual saving of about 8.2 gigatons (Gt) CO_2 by 2030 if its 25 energy efficiency policy recommendations are achieved.[65]

Compared with other countries, there has been greater CDM activity in India's industry sector, both in end-use efficiency and in waste heat power generation, even though these are predominantly small industrial efficiency projects with annual emission reductions of less than 30 kCERs. For instance, of the 10 key energy-saving programs under the national climate change program of the PRC, which is the second largest country in terms of registered CDM projects, only one program, waste heat and gas recovery and utilization, is related to CDM. Further, the CDM activities in the PRC and India have had very little impact on the areas, such as coal-power generation, energy-intensive industry, buildings, and transportation.[66]

Barriers

Many reasons have been identified by various researchers as to why end-use energy efficiency projects are not being developed under the CDM. Some concern the very design of the CDM; others are outside its realm.

The design of CDM

The most important factor is the requirement to demonstrate additionality (Table 6.14). It is difficult to determine the baseline for end-use efficiency projects. It has also been argued that many of them would fail a classical investment analysis. Another aspect is the lack of a viable methodology to support the wide array of project types. Existing methodologies have only a narrow applicability. All told, it is clear from recent comments to the CDM executive board that the public finds the registration of energy efficiency projects overly difficult.[67]

At a larger level, the problem with the Kyoto Protocol and Bali Road Map is that the approach has been climate-centric, with an emphasis on climate commitments, carbon markets, and technology, rather than concentrating on how best to mainstream climate-friendly choices into development planning to maximize co-benefits and transition toward a sustainable society. For instance, the discussions under the Ad Hoc Working Group

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[64] IEA 2007; Koakutus and Watanabe 2006.

[65] Niederberger 2008.

[66] Footnote 66.

[67] http://cdm.unfccc.int/public_inputs/2008/cers_rev/index.html

Table 6.14: Project Type-Reason for Rejection of Registration (as of 1 April 2009)

	Bio-mass	Hydro power	Waste Gas/Heat Utilization	Wind Power	Energy Efficiency	Biogas	Methane Recovery and Utilization	Cement	Fuel Switch	TOTAL
Baseline and Monitoring Methodology	16	2	9	0	13	3	3	1	4	51
Investment Analysis	5	9	11	6	0	0	2	0	1	34
Barrier Analysis	5	4	1	7	2	0	0	18	2	39
Common Practice Analysis	3	0	1	0	0	0	0	2	0	6
Other Reasons	0	1	2	0	3	0	0	0	2	8

Source: Institute for Global Environmental Strategies (2008).

on Further Commitments for Annex I parties under Kyoto are not considering energy efficiency to be one of the primary "means to reach emission reduction targets and ways to enhance their effectiveness and contribution to sustainable development."

Similarly, the related discussion of reforming the CDM refers to energy efficiency only as a possible "co-benefit" for CDM project activities, rather than including reforms to facilitate end-use energy efficiency projects. Overcoming the CDM barriers to end-use efficiency was not included in the list of 26 possible reforms in FCCC/KP/AWG/2008/L.12 despite widespread recognition of the problem, including by the executive board.[68]

On the whole, climate change negotiations have not yet conceptualized the necessary building blocks for promoting energy efficiency as a key instrument for climate change mitigation in developing countries. So far, most energy efficiency actions have focused on promoting end-use practices through various public and private sector instruments as national initiatives, including demand-side policies, standards and regulations, financial incentives, and the establishment of an energy efficiency market. Because of barriers arising from the nature of energy end-uses and their derived market failures, however, energy efficiency interventions have not been widely adopted or effectively enforced.

Regulatory environment

End-use energy efficiency projects face many hurdles. Getting over them requires well-designed and well-implemented policies within a well-supported regulatory environment. Resources for these have generally been undersupplied, even in more developed economies. Even where there is a favorable regulatory environment, local governments, on whom the enforcement burden often falls, have a limited workforce and little expertise to undertake all the tasks stipulated by law, including local enforcement, supervision, and inspection. These tasks require large numbers of professionals with sufficient knowledge of energy efficiency and experience in various engineering fields. This knowledge and experience is drastically lacking among the least-developed countries. Besides, promotion of energy efficiency faces the inert attitude of various firms and individuals, particularly those who look for short-term ways to minimize expense. Behavioral inertia in choice making is also a big block to promoting energy efficiency. Evidently, these barriers cannot be removed through the CDM. For instance, the transport sector, which has immense potential for end-use efficiency improvement, finds almost no projects under CDM, primarily because of high transaction costs including—economic, social, and political costs, which cannot be compensated for by the revenues accruing through emission reduction credits.

Low carbon price

One of the key reasons identified for the disappointing performance of CDM is the low price of carbon in terms of low levels of cap-and-trade and the absence of adequate carbon taxes. It is argued that a more stringent cap-and-trade regime would make it more expensive to go for carbon-intensive activities, which would automatically boost energy efficiency and renewable energy technologies. Similarly, higher taxes on carbon-

[68] Niederberger 2008.

intensive processes would encourage people to go for more efficient and cleaner technological options.

Financial barriers

At the initial stage, installing energy-efficient equipment, buildings, and appliances requires more money. The additional investment is compensated for by the energy savings, and yet users are hesitant because of lack of information on the relative efficiency of products and services, lack of information on the cost effectiveness of energy-efficient choices, and constraints in initial funding.

Limited technological expertise

The developing countries lack technological capacity for designing and manufacturing energy-efficient products, as well as for deploying the technologies and practices in the marketplace. Technological asymmetry is also more prevalent in developing countries. For instance, small and mid-sized companies generally have less access to energy efficiency technologies than their publicly owned counterparts and large private or multinational companies.

Dispersed nature of the end user

Many financial, technical, and informational barriers for energy efficiency improvement come from its dispersed nature. The widespread geographical locations, multiplicity of small end users, and differing technological and knowledge levels of end users make the management of activities difficult and costly. Command-and-control government policies work best in large and aggregated energy consumers; they find it difficult to reach the dispersed consumers effectively.

Technology transfer and CDM

One objective of the CDM was to promote technology transfer from developed countries to developing countries by providing additional financing through carbon. Various surveys of stakeholders have suggested that the CDM has failed to deliver enough technology transfer (IGES 2006). On the other hand, studies of the design documents of CDM projects have concluded the opposite—that CDM, has indeed, promoted technology transfer. For instance, Seres (2008) concludes that 39% of the projects have technology transfer components and that these projects covered 64% of total emission reduction under CDM projects.

The credibility of these studies is questionable, as they have counted, as instances of technology transfer, components that are more accurately considered as knowledge sharing. Such sharing is concentrated in the wind, hydropower, and landfill gas recovery sectors (de Coninck et al. 2007, Table 6.15).

These studies have some deeper insights, however, into the CDM's performance in the context of technology. They conclude:

- Unilateral projects are less likely to involve technology transfer.
- Technology transfer is more likely with larger projects.
- The bilateral projects with a foreign partner are more likely to have technology transfer.
- Frequency of technology transfer claims is high for least-developed countries although the number of projects is small.
- Large developing countries, such as Brazil, PRC, India, and South Africa, dominate the

Table 6.15: Instances of Technology Transfer in CDM Projects

Technology	Number of Projects	Transfer from Outside Country	Country Origin of Technology
Biogas	6	0	PRC, India
Biomass	10	0	India
Energy efficiency	1	0	South Africa
Fuel Switching	1	1	Germany, United States
HFC-23 (hydroflorocarbon or R-23 a refrigerant)	3	2	Germany, Japan, United Kingdom
Hydropower	22	12	PRC, Australia, France, India, Japan, Panama, Brazil, Peru, Spain, Sri Lanka, Switzerland, United States
Landfill gas	10	8	Belgium, the Netherlands, Japan, France, Brazil, United States
Methane capture	3	0	Chile
Nitrous oxide destruction	2	2	France
Wind energy	5	4	Spain, Denmark
Total	63	29	

CDM = clean development mechanism, PRC = People's Republic of China.

Source: De Coninck et al. 2007.

totals by sharing 72% of the projects (Seres 2008).

- A host country can influence the extent of technology transfer involved in its CDM project by including the provision for technology transfer in its approval criteria.
- India has the smallest share of technology transfer (14%), but there is upward movement in domestically available technology. The low rate is due to the fact that most projects are small and unilateral.
- Japan, Germany, United States, France, and United Kingdom are the main origins of transferred equipment and knowledge.
- Brazil; the PRC; India; Republic of Korea; and Taipei,China are the source of 94% of equipment transfers and 74% of knowledge transfers from non-Annex I sources.

Financing and financial institutions: expert survey results

None of the experts surveyed thought that a single approach would solve the financial problems of spreading clean and efficient energy technology. The most common measure recommended, however, is to provide seed capital, along with tax and price incentives, for the private sector to undertake research and development and to make cleaner technology choices. Other recommendations include cheap long-term green loans with softer repayment conditions, targeted subsidies, special funds for renewable energy, viability gap funding, venture capital, and development of supportive financial markets. Despite assigning a prominent role to government, most of the experts considered it crucial to get private enterprise on board.

International financial institutions have a big role to play in the region, where many countries lack financial resources. The experts want those institutions to create a long-term vision for building local capacities while enabling financing. They strongly recommend a clear list of do's and don'ts for financing, along with simplifying and clarifying the process of approval and disbursement.

The experts lean on financial institutions, more than governments, to raise awareness of energy security and environmental concerns. Increased awareness within the institutions might be reflected in their lending policies, which would eventually encourage industry and consumers to opt for cleaner choices. Making financing conditional can help determine the path of development that an economy takes, particularly one that is yet to embark on an industrialization trajectory.

Another crucial recommendation is to build regional collaboration in technology, financing, and policy interventions. Again, financing is the key. International institutions are advised to support collaborative research between private players and nations (through the provision of funds), the diffusion of new and advanced technologies, and the construction of networks of information and experience.

Perceptions of CDM

The survey results suggest that the overall perception of CDM's performance is not very positive. A majority of the respondents rated performance as average on various indicators, including the promotion of renewable energy, energy efficiency, fuel switching, diffusion of clean technologies, private-sector participation, and emissions reduction. A significant number found performance unsatisfactory for many indicators, particularly promoting end-use energy efficiency, knowledge sharing, diffusion of clean technologies, innovation, and adaptation fund (as well as addressing poverty) (Figure 6.6).

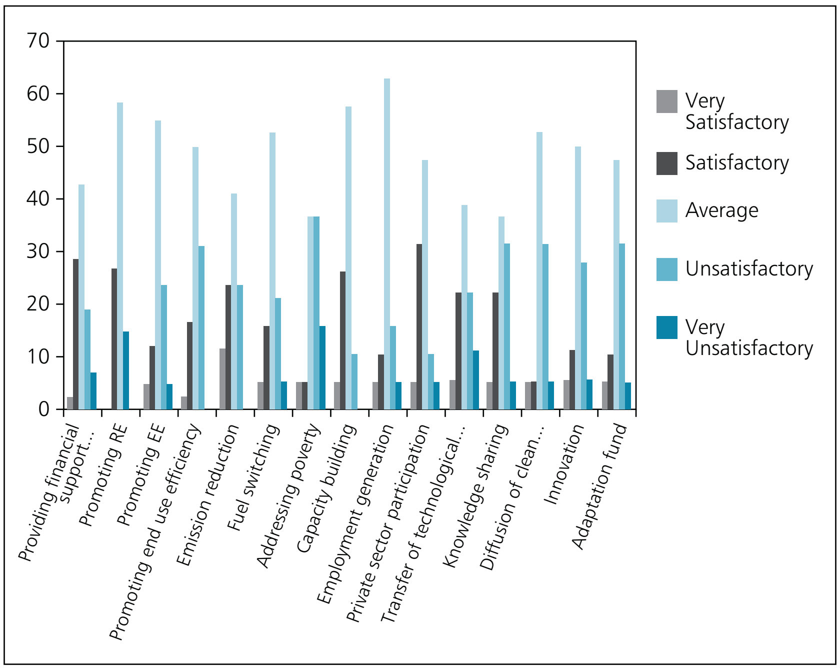
Asked to rate the barriers to CDM's potential benefits, the experts picked lack of awareness in the business community as the worst. Inadequate financing, complexity of the approval process, and low carbon prices were also considered serious problems (Figure 6.7).

Conclusions

Many initiatives have been launched in the past 10 years to make financing for renewable energy and energy efficiency projects more available in the region. However, compared with investments in OECD countries, investments in DMCs in the DAP region are miniscule. The situation is particularly dismal in the energy efficiency sector. Moreover, the increased investments are largely concentrated in the PRC and India, leaving other countries behind.

Countries in the region are dependent upon official development assistance and loans from multilateral financial organizations for financing their energy efficiency and renewable energy projects. The contribution of private investment is very small.

Figure 6.6: Assessment of CDM Performance



CDM = clean development mechanism, EE = energy efficiency, RE = renewable energy.

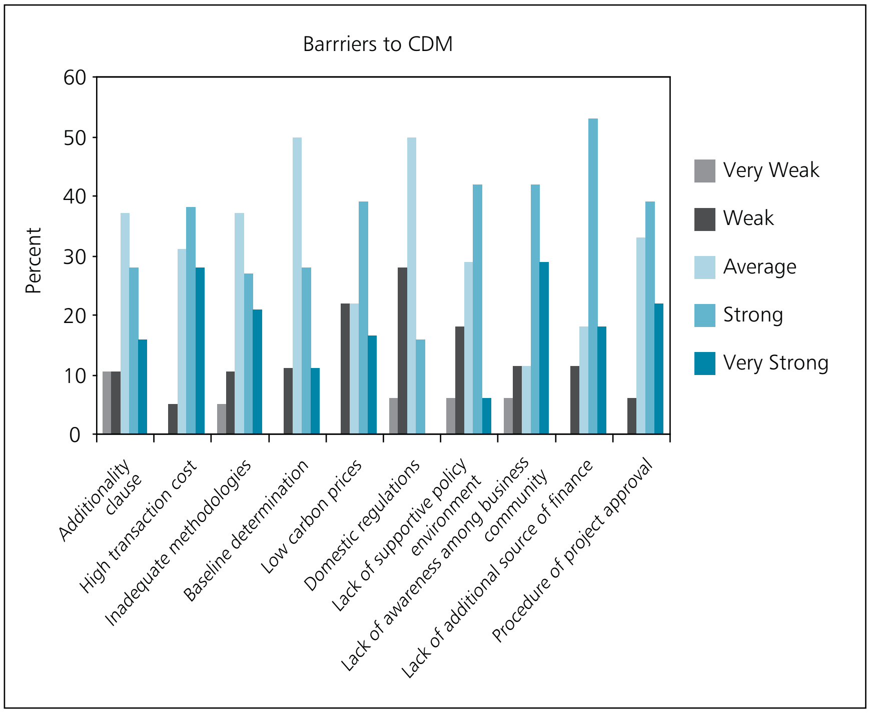
Source: Expert survey.

Support from multilateral institutions helps to leverage other financing only in those DMCs that already have a fairly developed finance sector and relatively high levels of economic activity. Thus, the least-developed economies are highly marginalized in terms of access to and availability of finance. The access to finance from multilateral organizations is further restricted by lack of knowledge among the project developers, along with the complex, long, and highly bureaucratic procedures. Moreover, the funds available under various financial institutions are completely inadequate to the region's requirements.

Local financial institutions in developing countries are reluctant to get involved with energy efficiency and renewable energy projects because of perceptions of credit risk and technical risks of the projects, which further deepens their dependence on international loans and grants. While the credit lines provided to domestic banks by multilateral organizations have shown encouraging results, the scale of availability of such credit lines is inadequate.

For financing of energy efficiency projects where split incentives are involved, interventions, such as incentive structures, risk mitigation methods, and preferential rate loan scheme, can be adopted after taking into consideration the relevant international experience. Another option is to promote energy service companies.

Figure 6.7: Barriers to Clean Development Mechanism



Source: Expert survey.

Promotion of renewable energy will require special policy interventions, such as feed-in tariffs and renewable purchase obligations, which are discussed under the best practices chapter.

The market-based CDMs, offering incentives for new investments in renewable energy and energy efficiency, may be the best way to ensure an increased private investment. However, they excite the private sector only in countries that have already achieved a fair degree of economic development. The analysis of CDM also suggests that such mechanisms should be designed with flexibility or specific provisions so that desired activities do not get marginalized, which is the case with end-use energy efficiency in CDM.

From the DAP region's, point of view, the flow of finance from the developed world, be it through market-based mechanisms or through international financial institutions in the form of grants or soft loans, is of paramount importance. It is needed not only to leverage private investment but also to produce conducive economic levels of development for countries to develop the institutions and dynamism that will attract more international as well as domestic financing, private as well as public. Therefore, there is a need to introduce innovations in the financial mechanisms and to have a stable carbon price to facilitate the commercialization of low-carbon technologies. Innovative financing can also be based on the stimulus packages that the governments have announced to revive their economies.

CHAPTER 7

International best practices in renewable energy and energy efficiency

Having identified several opportunities for developing Asia and the Pacific (DAP) to move to an energy-secure, low-carbon development pathway, it is useful to examine the experiences in other countries that have implemented similar options. The starting points in these countries may be different, but the examples include instances where technologies and policies innovated in the developed world have been successfully deployed in a developing country, with appropriate modifications.

International best practices in renewable energy

Renewable purchase obligations

Increased use of renewable energy is one of several promising methods for reducing emissions of local, regional, and global air pollutants, including greenhouse gas (GHG) emissions associated with fossil fuel-based electricity production. Among the options for encouraging renewable electricity generation, the renewable energy purchase obligation (RPO) has become especially popular.[69] The RPO policy requires that consumers of electricity purchase a certain minimum percentage of their electricity consumption in the form of electricity from renewable energy sources. The obligation may be imposed on any member of the electricity sector—

[69] Also known as renewable portfolio standard or renewable purchase specifications.

consumers, distributors, suppliers, or generators. Very often, it is the electricity supplier who has the responsibility of arranging for renewable electricity, and the minimum percentage that must be purchased is fixed in advance by the local regulator (often the government). The RPO is a relatively new mechanism, and success or failure depends on how it is designed in each country or state.

Development of the RPO policy

The United Kingdom and Italy were among the first to introduce RPO laws within the past decade. Soon, with the success of the policy becoming obvious, several other countries (including Belgium, United States, Japan, Australia, Germany, and Sweden) followed suit. The obligation is typically imposed on consumption, often through supply or distribution companies, but is, in at least one case (Italy), being applied to electricity producers. There is usually a penalty for noncompliance to pressure the parties to meet their quota. To simplify the verification of compliance and to provide flexibility in achieving it, systems often use some form of certification and tracking scheme. Several countries use what are called renewable energy certificates (RECs). These are quantified as the renewable attributes of the electricity (one REC for every megawatt-hour [MWh] of renewable electricity generated) that was produced from renewable energy sources. Thus, the cost of renewable electricity was divided into two: the cost of electricity (as if it were conventional electricity) and the cost of renewable attributes, all together quantified and bundled into an REC. RECs allowed even those consumers with little or no physical access to renewable electricity to be able to promote renewable electricity generation by buying RECs from a distant renewable generator. Thus, trade of RECs began on a large scale, with the certificates getting a new name as tradable RECs.

Trade of RECs occurs in the United States between individual states and in the European Union between certain member states. Plans are under way to harmonize the European Union trade of RECs under a single trading platform.[70] Today, in most countries, these certificates can be traded, banked, and consumed like any other commodity. Selling them separately from the associated electricity can provide useful compliance flexibility. For example, smaller suppliers or suppliers in transmission-constrained areas may not be equipped to handle the delivery of intermittent wind generation, in which case the purchase of certificates (and not the associated electricity) may be the least costly compliance option. These trading systems can also simplify the regulators' role in verifying compliance with the obligation system.

RPO design aspects

The RPO system obligates the supplier (or producer or consumer) to pay for a minimum percentage of power from renewable energy. This is usually done by purchasing RECs equivalent to his obligation (in MWh). The supplier can obtain these from a producer of renewable energy or from another supplier who has a surplus of RECs. These certificates then need to be submitted to the monitoring agency (usually a government body) to demonstrate compliance to the RPO policy. RECs are usually issued as electronic certificate and tracked.

[70] RECS International is an association of market players trading in RECs throughout Europe. It is in dialogue with national and European governments regarding a harmonized pan-European certificate system that enables cross-border trade.

The RPO is intended to create a predictable market for renewable electricity that maximizes the benefits of renewable generation while minimizing costs through the use of market mechanisms. Though the RPO may be designed in different ways (as with any energy policy instrument), certain fundamental principles must be incorporated if the RPO is to function effectively at low cost and with maximum impact:[71]

The purchase obligations should drive development of new renewable generation: The primary purpose of the RPO in the long term should be to increase the share of renewable electricity flowing through the grid. RPO quota levels should be carefully set to meet this objective. In particular, purchase requirements must be high enough to require new renewable generation development. As evidence from experience in the United States, where this criterion is not met, the RPO is unlikely to provide substantial public benefits.

Resource eligibility decisions should be made with care: Policy makers need to determine ahead of time which renewable generating resources should be eligible to produce electricity to meet the RPO levels of utilities. Where resource eligibility is overly broad and eligible supply exceeds RPO-derived renewable energy demand, the system will be ineffectual. In general, eligibility should be restricted to those renewable technologies that provide substantial public benefits and that would not be developed at this time without public support.

Purchase obligations should be durable and increase gradually with time: To maximize the impact of the RPO, reduce its costs, and ensure predictable, dependable growth in renewable generation, quota levels must be in effect for the long term and should increase in a predictable fashion. Short-duration and politically unstable policies will create substantial volatility in the cost of compliance and will not provide a favorable market for renewable development. Purchase obligations that do not increase in a predictable and gradual fashion may create damaging "boom and bust" cycles in renewable energy development.

To ensure a durable RPO, two effective options can be used: The policy can end 10 years after the last increase in the percentage purchase obligation, or the purchase obligation can be made indefinite without a sunset. To ensure predictability, purchase obligations should increase regularly (annually or biannually) and should not increase dramatically from one year to the next.

Strong and effective enforcement: Without an effective penalty for noncompliance, electric utilities, retailers, generators, and developers will have little incentive to meet their renewable energy obligations. A good penalty system meet three important criteria: First, penalties must be sizable enough to ensure compliance with the RPO. An automatic financial penalty of several times the incremental cost of RPO compliance has been used effectively in the United States for both RPO and environmental credit trading policies. Second, electric utilities, generators, or developers should be required to "make up" any renewable energy purchase shortfall in 1 year with renewable energy purchases in the following year. Such a principle will assure renewable generators that a market exists for their output and will not allow perpetual non-

[71] Designing a Renewables Portfolio Standard: principles, design option and implications for China, Jan Hamrin, Ryan Wiser, Seth Baruch; Centre for Resource Solutions; www.resource-solutions.org/pub_pdfs/IntPolicy-Final_RPS_Options.pdf (accessed on 10.03.2009.)

compliance by electric utilities and retailers. Third, penalties should ideally be imposed automatically and without excessive discretion to ensure that all utilities, generators, or developers are treated equally and to assure renewable generators and the financial community that a market will exist for their output.

The most positive feature of the RPO is the market-based standard (or quota) for renewable energy supply. Policy makers set the quota (which is usually a percentage of the total electricity supply)—typically, a renewable energy purchase requirement applied to retail electricity suppliers or electricity generators. The market (via trade of RECs) then determines the most effective, least costly way of meeting the quota.

Lessons learned

Experience with RPOs worldwide has been mixed and that designing an RPO policy is complex and requires great care.

A very important lesson is the need for policy stability and long-term contracting. Where RPO-driven demand for renewable energy exceeds supply, and short-term trade in the certificates dominates over long-term contracting, the system appears to be a costly and unstable way to pursue renewable energy objectives. Quotas specified in the RPO policies should be set for a long term.

Other pitfalls include poorly balanced supply and demand, selective application of the purchase requirement (creating an inequitable atmosphere among market players), poorly defined and unstable rules for resource eligibility and the eligibility of out-of-state generators, rigid verification mechanisms, and inadequate compliance flexibility (not allowing banking of RECs, for example).

On the positive side, an effective RPO usually has

- strong political support and regulatory commitment that are expected to continue over the duration of the policy;
- clear and well-thought-out renewable energy eligibility rules;
- predictable, long-term renewable energy targets that ensure new renewable energy supply;
- standards that are achievable given existing challenges;
- credible and automatic enforcement;
- electricity suppliers who are credit-worthy and are in a position to enter into long-term contracts;
- a fair distribution of costs and benefits;
- market efficiency (well-designed obligation markets should lead to competition and, therefore, an efficient allocation of resources in support of renewable energy); and
- stakeholder support.

The popularity of RPO policies has grown, leading to promotion of electricity from renewable energy sources. In the United States, 26 policies now cover 46% of the nation’s electrical load (Wiser and Barbose 2008), and the importance of these programs is expected to increase. Comparative experience from countries that have and have not achieved substantial renewable generation growth highlights the importance of careful policy design.

Within Asia and the Pacific, few countries have RPO laws in place. In India, the Electricity Act of June 2003 mandated that a certain percentage of electricity consumption come from renewable energy sources (EA 2003). Following this, several state electricity regulatory commissions ordered all utilities within their areas to get a minimum share of electricity from renewable energy plants.[72] Utilities could set up their own renewable energy plants or purchase power from other independent renewable energy plants. In spite of setting low targets, several states have faced difficulties in ensuring compliance with the RPO by all utilities in their area. The reasons range from inadequate renewable energy generation within the area to difficulty in getting grid capacity for interstate sale of the renewable energy power.[73] In Japan, on the other hand, an RPO law that was put into place in April 2003 created an innovative way for utilities to meet their quotas. It allows one utility to take over the renewable energy obligation of another. This could facilitate a faster uptake of renewable energy into an entire country's electricity consumption. However, it is still unclear whether the Japanese option will evolve into a market that allows true linkage between customers, or if it will lead to future trading and "takeover" price surges (or vice versa).[74] The PRC has also been developing an RPO law, but it is expected to require that power generators, not utilities, meet the quotas. It considers utility mandates "too complicated and costly for implementing in PRC" (Baker & McKenzie, REGA, CREIA, CRED 2007).

Countries with existing RPO programs are likely to continue to adapt their designs to better suit their economic settings. and minimize the mismatches that we see now. Some of this may occur through scheduled reviews of existing RPO policies, while other changes may be ordered by legislation. An emerging challenge will be to make modifications without unduly destabilizing investments made earlier for renewable energy infrastructure.

Feed-in tariffs

Feed-in tariffs (FITs) can be considered a "pricing law," under which producers of renewable energy are paid a set rate for their electricity, usually differentiated according to the technology used and size of the installation. FIT policies set a guaranteed price at which power producers can sell renewable power into the electric power network. Some policies provide a fixed tariff; others provide fixed premiums added to market or cost-related tariffs. One of the most important aspects of a FIT design is the determination of the tariff level and the duration of support. One possibility is to set the tariff level based on the electricity generation costs from renewable energy sources. Alternatively, the support level of renewable electricity can be based on the external costs avoided by electricity generation using renewable energy sources.

In the FIT system, the rates have to be scientifically calculated to ensure profitable operation of the plant. The period for which that rate is received is also set in the law and should cover a large portion of the life of the installation. The FIT presupposes

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72 Utility is any entity that is involved in the business of supplying electricity to a group of consumers by metering and billing the amount of consumed electricity. A utility may have its own power plants or may purchase power from other plants.

73 Because of the fluctuating nature of renewable energy power, the local utilities find it quite difficult to schedule it.

74 http://eneken.ieej.or.jp/en/data/pdf/205.pdf (accessed on 6 March 2009.)

that all renewable energy grid-connected installations have priority access to the grid.

Development of feed-in law

Feed-in laws are still largely a European and North American phenomenon. As of 2007, more than 46 countries, states, and provinces had implemented feed-in policies (REN 21 2007). The first one was created in the United States and dramatically stimulated the wind industry in some states, especially California. The Public Utility Regulatory Policies Act, a US federal law, was enacted in 1978 with the intention of encouraging energy-efficient and environmentally friendly commercial energy production. Germany followed suit by issuing a relatively simple, one-page bill for assisting producers of electricity from small hydro stations. With large-scale interest and acceptance of the bill, it went on to become the Electricity Feed-in Law of 1990. A key purpose of the law was to create a level playing field for renewable energy by setting tariffs that took account of the external costs of conventional power generation. The German legislation was a good starting point for a fair price of electricity from renewable energy. The minimum reimbursement per kilowatt-hour for electricity from solar and wind energy amounted to at least 90% of the average price electricity providers charged the end consumer. This, however, allowed profitable business only at very good locations for wind power operators. Inland wind plants and especially photovoltaic plants could not be operated profitably under the conditions established within the feed-in law. As a result, many cities and parishes introduced additional reimbursements to allow an economically viable operation as an incentive for investments.

Spain implemented a very effective feed-in law, one that helped it become one of the world's top manufacturers of renewable energy technologies. Its success in developing renewable energy sources was not solely due to this single piece of legislation, but because of reciprocated actions by the necessary agencies that responded intelligently by exploiting available energy resources and responding to Spain's growing energy requirements.

Feed-in design

The two basic issues addressed when developing a FIT system are how grid operators are to accept electricity supplied by renewable energy producers, and at what price. The market price must be supplemented with a premium that reflects the social and ecological benefits of renewable energy, provides an adequate investment return from its generating installations, and increases investment security for renewable energy projects.

Countries handle these issues and other design questions in different ways. Table 7.1 lists the main features that have been used to develop FIT policies in different countries. These design elements are briefly discussed.

Purchase obligations. Purchase obligations are mandatory purchases of electricity from renewable energy sources, required of the electricity grid operators, energy supply companies, or electricity consumers. Most European Union member states have some kind of purchase obligation within their FIT, but there are exceptions. For instance, there may be no purchase obligation for electricity offered on the spot market (in Slovenia), or a purchase obligation may be there only to the extent of electricity network losses (in Estonia).

Stepped tariff. Most European countries apply differentiated tariffs for different renewable energy

Table 7.1: FIT Design in Different Countries in the European Union for 2007

Country	Purchase Obligation	Stepped Tariff	Tariff Degression	Premium Option	Equal Burden-Sharing	Forecast Obligation
Austria	X	X	–	–	X[a]	–
Cyprus	X	X	–	–	X	–
Czech Republic	X (for fixed tariff)	X	–	X	X	–
Denmark	X	X	–	X (wind)	X[a]	–
Estonia	X	–	–	X (new draft)	X	X (new draft)
France	X	X	X (wind)	–	X	–
Germany	X	X	X	–	X[a]	–
Greece	X	X	–	–	X	–
Hungary	X	–	–	–	X	–
Ireland	X	X	–	–	X	–
Italy	X	X	X (PV)	–	X	–
Lithuania	X	–	–	–	X	–
Luxembourg	X	X	–	–	X	–
The Netherlands	X	X	–	–	X[b]	–
Portugal	X	X	–	–	X	–
Slovakia	X (for grid losses)	X	–	–	X	–
Slovenia	X (for grid losses)	X	–	X	X	X
Spain	X (for grid losses)	X	–	X	X	X

FIT = feed-in tariff, PV = photovoltaic.

[a] Austria, Denmark, and Germany apply an equal burden sharing with advantages for electricity-intensive industries.

[b] In the Netherlands, each electricity consumer contributes the same amount of money to support renewable energy-sourced electricity, regardless of the amount of electricity consumed.

Source: Mendonca (2007), Klein et al (2006).

technologies because of their varying generation costs. However, generation costs may differ even within the same technology, depending on the scale of the installation and site conditions. Stepped tariffs are differing rates paid within each technology type. These can be designed based on plant location, plant size, or fuel. Almost all European Union countries applying FITs use different levels of remuneration according to the size of the plant and/or the nature of the fuel (for biomass and biogas plants). Table 7.2 lists the advantages and disadvantages of the stepped tariff.

Tariff degression. The German FIT policy contains a degressive element, which means lowering the payments each year to new installations. Here is an example of the reasoning behind degression: The development of wind turbines with capacity above 1 MW has meant higher expenses for the turbine producers. Furthermore, steel prices have been increasing in recent years. But global demand for wind turbines has grown in recent years, and technical improvements and more efficient solutions led to a decrease in the specific generation costs. This rate of degression can be reflected accurately in the tariff structure. Table 7.3 gives the pros and cons of using tariff degression.

Premium option. Tariff systems for paying renewable energy power producers are generally of two types: an overall remuneration (known as the fixed tariff) or an additional payment over and above the market price of the electricity (known as the premium tariff). In the fixed tariff system, producers receive a fixed price irrespective of what the market price of electricity is. In the premium tariff option, more flexibility exists with respect to assignment of grid costs, making it more efficient. Table 7.4 lists the advantages and disadvantages of the premium option.

Table 7.2: Advantages and Disadvantages of the Stepped Tariff

Advantages	Disadvantages
Differences in power generation costs due to plant size or fuel type can be taken into account.	The system can lead to high administrative complexity (e.g., for defining a reference turbine, as in Germany).
Local conditions can be considered and reflected in the tariff level.	
Not only the sites with most favorable conditions can be exploited.	Many different tariff levels within the same technology may lead to less transparency and uncertainty for the investors.
Risk of over-compensating very efficient plants is minimized.	
Producer profit is kept on a moderate level at favorable sites. Therefore, the burden on electricity consumers is lower.	If the tariffs for plants with a low capacity are significantly higher than for larger plants, it could be economically feasible to construct two small plants instead of a large one, even though larger plants might be more efficient. This decreases the overall efficiency of the system.
Higher electricity generation costs, for example, due to deeper water or large distance to the coastline (for offshore wind turbines) can be taken into account.	

Source: Mendonca (2007), Klein et al (2006).

Table 7.3: Advantages and Disadvantages of a Tariff Degression in the FIT Design

Advantages	Disadvantages
Investment security Transparency Incentives to build a plant early in time, because the level of remuneration is decreasing along with the plant prices	If the degression rate is set for many years, the system is not very flexible in the case of varying technology prices due to structural changes (e.g., increased prices of steel or silicon).
Incentive for technological improvement Lower burden on electricity consumers	It is difficult to set an appropriate degression rate because of difficulties in predicting technological learning, which is related partly to the cumulative amount of installed capacity.

FIT = feed-in tariff.

Source: Mendonca (2007), Klein et al (2006).

Table 7.4: Advantages and Disadvantages of the Premium Option

Advantages	Disadvantages
More market oriented and less distortion	No purchase guarantee, therefore less investment security
More demand oriented	Most likely higher costs for electricity consumers, especially if the market price rises
Provides an incentive to feed electricity into the grid	Operators of wind and solar power plants can hardly influence the time of electricity generation and, therefore, are not able to take advantage of feeding electricity into the grid at peak demand.

Source: Mendonca (2007), Klein et al (2006).

Burden sharing. In countries where the electricity from new renewable energy plants contributes significantly to the total electricity consumption, the distribution of the costs emerging from the support of renewable energy is a crucial aspect of the FIT design. In most European Union countries, these costs are distributed equally among all electricity consumers by including them in the power price. However, distinct consumer groups are affected in different ways by the increased power price due to renewable sources of electricity generation. Especially for electricity-intensive industry sectors, the power costs may represent a significant part of their expenses, thus influencing their international competitiveness. To keep the burden for electricity-intensive industries at a moderate level, some European countries have implemented a burden-sharing mechanism depending on the consumer type. This mechanism involves consumers paying a calculated amount to the government. Typically, electricity-intensive consumers pay less than other groups. For example, in Austria, electricity-intensive industries pay 78% of this burden-sharing "tariff," whereas households are obliged to pay 111% (Klein et al 2006).

In order to determine which industry sectors are affected most by increased power prices due to renewable energy electricity generation, the following indicators can be applied:

1. total amount of electricity consumption of a company;
2. annual costs of electricity consumption in relation to other parameters, such as the revenues, the total costs, or the gross value added of a company; and
3. voltage level of the grid connection (usually a connection to a high-voltage grid implies that a consumer uses a high amount of electricity).

Burden sharing among all electricity consumers in Europe and other regions of the world could be considered for solving the problem of international competitiveness. But for this, without proper coordination of the support systems for renewable energy, a single country could end up paying very high tariffs to the producers, even when the costs are distributed among all electricity-consuming countries in that region.

Forecast obligation. For some types of renewable energy sources, the amount of electricity generated depends on external conditions, such as solar radiation, wind speed, or the level of water in a river. An integration of the electricity from these sources into the power grids is much easier if the amount of electricity that is generated can be forecast. The amount of water in a river is predictable, and changes are rather slow. Therefore, the amount of electricity from hydropower plants can be forecast. The integration of electricity from photovoltaic plants does not have great influence on the electricity grid, because the share of photovoltaic electricity is still very small. This is different for wind power, as the wind conditions tend to change very fast, and the share of electricity from wind energy is significant in some areas. As a result, in some countries, such as Spain, operators of renewable energy-based electricity plants are obliged to predict the amount of electricity they plan to feed into the grid.

Lessons learned

In Asia and the Pacific, countries that are known for FIT policies are India, Sri Lanka, Thailand, Republic of Korea, Philippines, and Indonesia. In 2009, Japan announced its plans for a FIT for solar photovoltaic-based electricity.[75] Japan aims to make utilities pay for surplus solar-power electricity that households produce. As a result, utility firms will have to strengthen their grid networks and install efficient batteries to absorb fluctuating amounts of electricity from solar power and also pay for the solar electricity. The PRC has no FIT, and experts in the field disagree on how likely the government

[75] Reuters, February 2009; www.reuters.com/article/environmentNews/idUSTRE51N29E20090224 (accessed on 04.06.2009.)

is to institute one. For the moment, the policy preference is on several different kinds of financial support from the government (Campillo and Foster 2008).

How FITs would affect Asia and Pacific would depend on their design. And designers of a FIT policy might want to consider further a few aspects of such systems, analyzed here based on the experiences of European countries and observations from the general literature.

Investment certainty

The core argument for using FITs is that they offer a high level of investment certainty to independent producers of renewable electricity by guaranteeing a fixed price for each kilowatt-hour of power fed into the grid over a certain period. However, this certainty may apply more to the short or medium term, as in the long run, fixed FITs may be unsustainable either because of high cost or because they are not compatible with a competitive market and a system of harmonized, renewable energy policies that already exist in a country.

Effectiveness

FITs have been very effective in promoting wind power in countries, such as Germany, Denmark, or Spain. Their effectiveness, however, depends largely on the particular level of the tariffs set, as well as on other factors, such as the production costs involved; the existence of other promotion schemes; administrative procedures; natural conditions; or other specific characteristics at the local, regional, or national level. Apart from wind power, FITs seem to have been far less effective in encouraging other forms of renewable electricity.

Efficiency

A major criticism with regard to FITs is that they have failed to be efficient—compared with other promotion schemes; they have generally failed to drive down prices for renewable electricity. This is because FITs are generally fixed by a regulatory authority that usually lacks adequate, up-to-date information regarding the production costs of renewable electricity from a variety of different sources and technologies, especially over a certain period. Therefore, it is very hard to fix the "right" price and to differentiate it adequately over time or by different types of renewable energy sources and technologies. Besides, as a system of feed-in payments is not based on direct competition, either among renewable power producers or between these producers and nonrenewable electricity generators, the incentive for innovations will, by definition, be less pronounced than under schemes based on competition.

Market compatibility and competition

Because FITs conflict with free competition, they are not compatible with a single, liberalized electricity market like the one in Europe. This can cause three problems.

First, FITs do not mesh with competitive pricing between generators of green electricity, which may result in less efficiency in renewable power production. Second, a national system of FITs that is eligible to domestic generators of green electricity only and excludes imports of renewable electricity may result in discrimination of domestic versus foreign producers and free international trade among member states. On the other hand, nondiscrimination of producers and free international trade may lead to major imports of green electricity and major outflows of financial resources, which may be unacceptable for a country offering relatively high FITs. Third, grid utilities that are located in areas with a large potential of renewable energy sources will likely be offered more green electricity and will, therefore, have to pay more premium tariffs. In a liberalized electricity market, this puts these utilities at a competitive disadvantage relative to utilities in areas with low renewable energy potentials. Some kind of compensation mechanism could be designed to avoid this problem, as was introduced in Germany in April 2000. Such a national mechanism, however, would complicate the administrative demands of a FIT system, while it would not solve similar problems at the international level.

Administrative demands

A major advantage of a system of FITs is that its administrative demands are, in principle, low and simple. The one-page text of the Electricity Feed Law used to be one of the shortest and simplest laws implemented in Germany during the 1990s. However, both the administrative demands and the informational needs of a FIT system will rise rapidly if (i) a compensation mechanism covering all grid utilities is introduced, (ii) the system is extended from the national to the international level, and (iii) the system becomes more fine-tuned and complicated to meet the efficiency conditions discussed above.

Several countries have already introduced feed-in laws. The increasingly widespread popularity of feed-in laws indicates the growing acceptance of this legislation as an effective tool to promote renewable energy. FITs are an efficient instrument to promote renewable electricity if certain basic principles are incorporated in the design (Sijm 2002):

1. The cost curve of the technology concerned is flat and predictable with high probability.
2. The FITs decrease over time in line with the expected learning curve of the investment costs.
3. The time period over which a producer receives a guaranteed price is limited.
4. FITs should be lower if actual output of renewable electricity is higher.

Although these principles are theoretically sound, in practice they may be hard to meet (especially the first principle). For several renewable energy technologies, reliable knowledge on the exact shape of the cost curve (particularly in a dynamic sense) is often scarce. Moreover, available evidence suggests that the static cost curve of renewable energy is usually steeply rising (i.e., costs rise significantly when output increases), whereas the dynamic cost curve is generally declining (costs decline substantially over time). Therefore, it may be hard to determine the FITs over time in line with the expected learning curve of a certain renewable technology. Moreover, decrease in FITs should not be so fast that it prevents an efficient outcome with regard to the actual output of renewable electricity. Nevertheless, carefully following these principles may optimize the tariffs' efficiency.

Overall, a system of premium FITs has been an effective instrument to promote the generation of renewable electricity, notably to ensure a low-level market take-off of wind power at the national level. In the longer term, however, such a system may become hard to sustain as it may suffer from some major drawbacks, especially when the generation of green electricity accounts for a significant share in total power production. These disadvantages refer particularly to the fact that a system of fixed premium prices tends to be costly, inefficient, distortive of competitive pricing and, hence, incompatible with the creation of a single, liberalized electricity market. In the long run, the best way to encourage renewable electricity within a free market is probably either to internalize the external costs and disadvantages of nonrenewable energy sources (e.g., by means of taxation) or to introduce market-conform instruments, such as a well-functioning system of tradable green certificates (where the price of these certificates accounts for the social and environmental benefits of renewable energy compared with nonrenewable energy). However, it may take quite some time before either one of these “best means” (or a combination of both) will be achieved. In the meantime, FITs can and will be justified in several countries as the best alternative to encourage the generation of a certain amount of green electricity, notably when this amount is still small.

International best practices in energy efficiency

Energy efficiency is one of the key policy areas to achieve energy security and reduce GHGs. Many countries have introduced a range of tools to encourage energy efficiency, including financial instruments, mandatory minimum efficiency levels, and voluntary programs. Improving energy efficiency requires a combination of policies, regulations, standards, programs, and partnerships, the nature of which depends upon the targeted sector or activity for efficient use of energy. The success of the Top Runner program in Japan offers an insightful example of such a combination of policies (Box 7.1). Following are some of the practices that have proven helpful in promoting, and designing better interventions to enhance energy efficiency in different sectors.

Careful monitoring

Close monitoring and evaluation of energy efficiency trends are prerequisites for a successful energy efficiency policy. Developing disaggregated energy indicators can be an important tool for this. Many countries already employ energy indicators to follow end-use developments in different sectors of the economy. For instance, in 2001, the Government of Japan carried out a comprehensive analysis of factors influencing the increase in energy consumption and the effect of energy efficiency measures, such as the Top Runner program. It was found that two-thirds of the increase in fuel consumption and related CO_2 emissions in the transport sector could be attributed to increased mileage and the remainder to reduced on-the-road fuel efficiency. Such an analysis enabled Japan to specify the areas where further efforts would be needed to improve energy efficiency in transportation.

Voluntary agreements with industry

Voluntary agreements with industries are widespread in many countries to improve energy efficiency and reduce GHG emissions. This policy tool has been preferred over regulations because of its flexibility and relatively light-handed approach. The Netherlands, in 1999, established the Energy Efficiency Benchmarking Covenants for industries using at least 0.5 peta joules of energy per year. The covenants followed the successful experience of the Long-Term Agreements on Energy Efficiency, which had improved the energy efficiency of participating companies by 22.3% between 1990 and 2000, surpassing the target of 20%. Under the benchmarking covenants, participating companies pledge to be among the top 10% of the most energy-efficient installations worldwide as soon as possible but no later than

Box 7.1: Top Runner Program

Japan's Top Runner program is a regulatory scheme focusing on continuous improvement of energy efficiency on the end-use side. The program was incorporated as an element of the Energy Conservation Law in 1998. The impetus was twofold: to meet the commitment on emissions reduction in the Kyoto Protocol of 1997 and to break up stagnation in industry-led progress that had followed two decades of improvement from 1970 to 1990. (Japan is a net importer of energy and was addressing energy security concerns.) The primary purpose of the program is to push manufacturers and importers of energy-consuming equipment to accomplish and implement technological improvements and increased end-use energy efficiency of marketed goods.

The program introduces product-specific energy performance requirements for household and office appliances in repeated cycles, where the end-use energy performance of the best technology available on the market at the time of revision is adopted as standard for that particular product category. Later on it included vehicles as well. The obligation of compliance with Top Runner regulations rests with manufacturers and importers. Exact standard levels, however, along with target years for all manufacturers to achieve those standards, are agreed on through consultation with all stakeholders. A product covered by the Top Runner program meets three conditions: (i) the appliance/product is sold mainly in the domestic market, (ii) it requires a relatively large amount of energy for its usage, and (iii) potential for energy efficiency improvement exists. The program, at present, covers 21 products, and these products cover about 80% of residential energy consumption. During the standard-setting process, categories are often divided into subcategories, primarily for technical reasons. The target year set for each product allows for technological improvement, taking the product development cycle into consideration. The target year is usually set for 4–8 years into the future.

The most import aspect of the program is the flexibility it provides for manufacturers and importers in terms of choice and timing of actions to be taken in order to comply with Top Runner standards. Once standards are agreed upon, the regulator takes no official action until target years are reached. The flexibility comes with a twofold legal obligation, though. The manufacturers and importers are required to provide public information about the end-use energy performance of each product model, and they have to ascertain that by the target year, the weighted average energy performance of all the listed products they sell in a year meets or exceeds the target standard of the product subcategory concerned. The obligation with respect to weighted average energy performance is not applicable if the annual sales are less than a certain number, but information about each product's performance has to be provided. Informal interim evaluation, however, can be performed. For instance, in the case of computers, the targets were achieved before the original target year. The informal interim evaluation then led to a formal revision of standards to be initiated ahead of time. The industry was initially surprised by the concept, but the long tradition in Japan of close strategic cooperation between industry and the government made its success possible.

Another factor contributing to the program's success is availability of a set of complementary instruments promoting sales and penetration of products with higher energy efficiency. For instance, Green Taxation for Automobiles was introduced in 2004 to promote the introduction of more fuel-efficient cars. Cars that achieve 120% of the fuel economy standard are given a 50% reduction of the local car tax; the reduction is 25% reduction for achieving 110% of the standard. For electric cars, compressed natural gas (CNG) cars, and methanol cars get a 50% tax cut. Vehicle excise tax (local tax) is also reduced by approximately $3,000; $1,500; and by 2.7%, respectively. Hybrid vehicles get a reduction of 2.7% deduction for

continued on next page

Box 7.1: continued

buses/trucks and 2.2% for passenger cars. Other supporting instruments include backing for research and development, energy performance labeling (e.g., the Energy Star label and Tokyo's energy rating label), an e-shop commendation scheme, product awards (for energy efficiency along with resource efficiency, innovativeness, and safety), the Green Procurement Law of 2001 (requiring public procurement of only those products that meet the Top Runner standards), and a program for informed consumer affirmation (requiring car retailers to obtain signatures from all customers, whereby they affirm that before purchasing a vehicle they have received information about its energy performance and rating).

It is estimated that during 1998–2006, the Top Runner program cut energy use 10% in the residential sector and 5% in passenger transportation. By 2030, these figures are expected to reach 30% for residential and 26% for transportation. Reasons for this success include manufacturers' participation in setting targets, along with a long tradition of collaboration between industry and regulators in Japan; the iterative, flexible, dynamic, and adaptive design of the program; a set of supportive policy instruments; the advantage for best performers during the compliance period; domination of domestic actors in the regulated markets; the competitive advantage due to energy efficiency; and the high value assigned to name-and-shame sanctions in Japan (one of the most common penalties for noncompliance, along with financial penalties). The implementation of program is also made possible by the fact that markets in Japan are well documented through updated product catalogues, published twice yearly.

The program, however, is also criticized on certain grounds. The most common is that it encourages only incremental technical improvements and provides no incentives for innovations. Considering that there are many examples of premature and extensive overcompliance, it is argued that if standard-setting procedures do not account properly for the potential for technological development (which may already be achieved but remain untapped), the program may become suboptimal.

Source: Nordqvist, Joakim (2006). *Evaluation of Japan's Top Runner Program*. Within the Framework of the AID-EE project under the Energy Intelligence for Europe program.

2012. In exchange for their participation, the government agreed not to impose additional energy efficiency or CO_2 reduction measures on them. Participating companies also benefited from simplified environmental permit procedures, fiscal incentives, and technical assistance. The companies are required to develop an energy efficiency plan, which is subject to review every 4 years, along with a redefining of the world energy efficiency leader in the related sector.

Similarly, the United Kingdom's Climate Change Agreements requires participating energy-intensive industries to set stringent targets to reduce energy consumption or emissions. In return for agreeing to and meeting these targets, these sectors are entitled to an 80% reduction in the climate change levy. The sector performance is tested against the sector target adjusted for exits and entrants; carbon trading under the emissions trading scheme, where applicable; and product mix and/or throughput. If the sector fails to meet the target, the individual facilities in the sector are not eligible for the levy discount for the next 2-year period.

For small and medium-sized companies, which fall outside such voluntary agreements, Finland has nine energy conservation agreements, which cover not only industry and energy companies but also municipalities; the property and buildings sector; transportation (truck, buses, and vans); and housing properties. These agreements cover more than 55% of Finland's total energy consumption, which is wider than coverage rates in other countries.

In Belgium, companies, which are covered under European Union-Emission Trading System (EU-ETS) and also implement energy saving more rapidly than required, are rewarded and given the option of selling the excess emissions allowances. Increasing economic support for energy investments by companies participating in the covenants is also under consideration. If implemented, support would be linked to emissions reductions resulting from new energy investments. The Wallonia region of Belgium also relies on voluntary agreements with industry to increase energy efficiency. It has signed voluntary agreements with 117 energy-intensive firms, covering more than 90% of Wallonia's industrial energy consumption, or 47% of its total energy consumption. These voluntary agreements include individual action plans for each firm and require firms to provide annual information. In return, the firms are granted subsidies for energy accountancy and audits, no additional regulatory regional obligations on energy efficiency, CO_2 tax exemptions (should CO_2 taxes be implemented in the future), realistic CO_2 quota allocations under the EU-ETS, and exemptions from green certificate requirements.

Strict regulations and standards in the transport sector

The transport sector is among the top energy-consuming sectors. Furthermore, given its high dependence on oil with a limited potential for substitution, this sector is very vulnerable to oil supply disruption. Curbing the growth of energy demand in the transport sector is more challenging than in other sectors, given the large number of players involved. Accordingly, enhanced energy efficiency policies in the transport sector have been recommended for almost all countries from the viewpoint of energy security and climate change mitigation.

The introduction of regulations and efficiency standards is the most common and successful practice. For instance, in the field of fuel efficiency, Japan has expanded its Top Runner program, based on the Energy Conservation Law, to set the most stringent mandatory fuel efficiency standards on vehicles, where the standards are higher than the best performance in each vehicle size category. Under this program, car manufacturers are obliged to improve fuel efficiency by 23% (for gasoline vehicles) and 15% (for diesel vehicles) between 1995 and 2010. Japan has also amended the Energy Conservation Law recently to introduce new regulations on large-scale freight industry (cargo and passengers) and cargo owners. The new regulations oblige large-scale freight industries and cargo owners to formulate energy conservation plans and report the amount of energy consumption every year, and promote the use of public transportation.

Economic instruments, such as taxes and charges, are also instrumental in managing transportation demand. The United Kingdom significantly reformed the company car tax to improve energy efficiency in the transport sector. Previously, employees who had a company car available for private use were liable to pay income tax on this "benefit in kind". Company car tax is currently based on the "list price" of the car and annual business mileage. Company car drivers who do less than 2,500 business miles a year are taxed at 35% of the list price of the vehicle, while those doing more business miles pay less tax: 25% of the list price for over 18,000 miles and 15% of the list price for 2,500–18,000 miles. Since April 2002, cleaner, more fuel-efficient cars are rewarded by linking the tax charge to the car's exhaust emissions, in particular its CO_2 emissions. In 2008–2009, the cars emitting 120 g CO_2 per kilometer (km) were charged with 10% of their list price as company car tax. The Government of the United Kingdom expects this reform to have multiple impacts on annual CO_2 emissions reduction (0.15–0.25 Mt of carbon in 2004, 0.4 MtC in 2010), fuel type (increased diesel sales), business mileage reduction (300–400 million miles in 2002–2003), and car sales reduction. Similarly, Switzerland has been levying a fee on heavy-duty vehicles since 2001. The fee is calculated on distance, weight, and emissions standards. Two-thirds of this revenue is used to finance rail infrastructure, including two trans-Alpine tunnels, to promote a shift away from cars. This fee has curbed road freight mileage by 8% since its introduction, after years of uninterrupted growth.

Building codes in the residential/commercial sector

Another sector that has received attention for reducing energy demand is residential and commercial buildings. In this sector, building codes have been identified as the most effective measure to improve energy efficiency. Denmark has been progressively tightening the code for new buildings, setting limits on electricity consumption for ventilation, and enforcing low-temperature heating systems, each in several stages since 1977. The most recent revision, introduced in 2005, proposed to reduce net heating demand from 70 kWh/m^2 to 45 kWh/m^2. Using additional policies, such as prevention of energy waste in households and stipulations on insulation and tighter-sealing doors and windows, Denmark lowered its heating bill by 20% between 1975 and 2001, even though 30% more heated floor space was built in that period.[76]

The European Union, in 2002, approved the Energy Performance of Buildings Directive, requiring each member state to develop minimum efficiency standards for new buildings, energy performance rating schemes, mandatory energy equipment performance inspections, and energy performance certification to reduce energy use in new and existing buildings. Germany's new Energy Conservation Ordinance in 2002 integrated the thermal insulation and the heat insulation ordinances within an integrated methodology, as required by the directive. To complement this effort, new analytical standards are being developed which, for the first time, are likely to result in a common basis for calculating building energy performance across Europe.

The energy use of domestic appliances and equipment represents a significant share of energy demand in the residential/commercial sector. Large efficiency improvements through minimum energy performance regulation are technically feasible and highly cost-effective.

[76] www.ambbeograd.um.dk/en/menu/InfoDenmark/EnergyEnvironmentandClimate/TheDanishExperience/ (accessed on 4 July 2009).

White certificates

Some countries are introducing new, market-based instruments, such as white certificates, which gas and electricity distributors are required to obtain either by saving energy themselves or purchasing energy-efficiency certificates. In 2002, the United Kingdom introduced the Energy Efficiency Commitment, which is to remain in place until 2011. Gas and electricity suppliers (with at least 15,000 residential customers) were obliged to meet a combined energy saving target of 130 terawatt-hours (TWh) by 2008. The trade in energy efficiency certificates is performed by means of bilateral contracts based on saved TWh instead of "liquid" trade by means of white certificates. Trading occurs in the final stage of each target period to reconcile suppliers' performance with their targets.

In Italy, energy efficiency certificates are issued by the market operator (once it has been certified that a defined amount of energy savings will be attained by a project). The Authority for Electric Energy and Gas has issued energy-saving targets for 2005–2009 for electricity and gas distributors; guidelines for the preparation, execution, and evaluation of the projects; and criteria for issuing energy efficiency certificates. The authority will evaluate energy savings based on three different methods according to the type of project. About 100 projects have been submitted for evaluation.

France's Energy Law of 2005 requires suppliers to reduce energy consumption by 34 TWh (for electricity suppliers), 10.5 TWh (gas), 1.5 TWh (heating oil), and 7.5 TWh (fuel oil) from 2006 to 2008. These obligations are to be met either by certificates or paying a penalty. All measures initiated by an obliged energy supplier or an eligible consumer in the building, industry, and transport sectors can receive white certificates based on their contribution to additional saving. To avoid duplication, installations subject to CO_2 quota obligations will be excluded from the white certificate obligations. This could be an effective tool to capture energy-saving potential in sectors not covered under the European Union trading system, such as building owners, companies, and communities.

Best practices in urban planning

In recent years, cities have attracted increasing attention for their energy use. There are many national and international programs focusing on sustainable cities, including the International Council for Local Environmental Initiatives, C40 Large Cities Climate Leadership Group, OECD's Urban Development Program, Joint UN–Habitat–UNEP Sustainable Cities Program, Urban Environmental Management Project (of the Institute for Global Environment Strategies), Sierra Club's Energy Efficiency Solutions for Cool Cities Campaign, and European Green Cities Network. The reasons for this increased attention are that (i) energy consumption in cities is significant; (ii) city authorities are significant energy users and influence city energy use indirectly; and (iii) city authorities play an important role in implementing national energy efficiency policies. Following is a list of city-level interventions that are replicable and economical:[77]

[77] Itron 2008; Nigel Jollands, Stephen Kenihan, and Wayne Wescott 2008; and www3.iclei.org/egpis/citylist.htm

- City of Enschede, the Netherlands: Oikos, a suburban sustainable development of 600 houses in the east of the Netherlands, by the German border
- Cork City, Ireland: The Clean Technology Centre
- Frankfurt am Main, Germany: An energy saving concept in a large city
- Graz, Austria: Heating upgrades (consumer-oriented model)
- Greece: Action plan "ENERGY 2001"(to conserve energy and promote renewable energy in the built environment)
- Rochefort, France: City life charter "Target Nature, Energy-Environment"
- Sheffield, United Kingdom: Housing Plus (to improve domestic energy efficiency and residents' health)
- Adelaide, Australia: Light-emitting diode traffic signals at 107 intersections
- Berkeley, California, United States: Energy conservation ordinance requiring retrofitting houses prior to new occupancy
- Berlin, Germany: School buildings offered for energy performance contracts
- Graz, Austria: Green Light Graz I (replacing old street lamps)
- Gwalior, India: Street lighting
- Riga, Latvia: Indoor lighting at Latvian Academy of Sport Education
- Stockholm, Sweden: Light-emitting diode traffic signals at 530 traffic control points
- Sydney, Australia: Library lighting and air-conditioning retrofit.

Evidently, all these examples focus on different aspects of urban life. Nonetheless, what is common across these examples is the approach and implementation process of particular energy efficiency improvement projects. The factors that were instrumental in the success of these projects are listed below.

- Local authorities took the initiative.
- They targeted buildings and transportation.
- They started with public buildings and services.
- Regulations and standards, where applicable, played an important role.
- An awareness campaign was an integral part of these projects, particularly those covering privately owned buildings and vehicles.
- Local authorities partnered with regional/national authorities, as well as industry.
- In cases where public financing was unavailable or insufficient, private firms were asked to make the initial investment. In return, they were guaranteed exemptions from various taxes and levies, along with guaranteed higher returns on their investment over a certain number of years. In cases where consumers were to pay a higher price in future, local authorities subsidized services for those who lacked the resources.
- In the planning phase, a multidisciplinary team of experts was involved, particularly when designing buildings, so that all resources could be utilized optimally rather than focusing on energy requirements only.

The two most important aspects of these examples, particularly the large-scale projects, were that they combined many approaches—regulations, programs, partnerships, awareness campaigns, and financial incentives including subsidies—that they targeted public facilities first.

A similar case is found in the experience of the countries of southeast and Eastern Europe, the Caucasus, and Central Asia in promoting sustainable consumption and production in the industry sector.[78] Many forces there can combine to push companies to address environmental management:

- environmental laws and regulations, and their enforcement;
- economic instruments that provide incentives;
- the potential to decrease operating costs;
- perceived need to have environmental certification (to increase sales and profits or to gain market share and new clients;
- in the case of goods and services in a supply chain (including exports), the buyer's requirements with respect to environmental aspects;
- availability of financing for environmentally sound technologies or for better production technology;
- opportunity to improve a company's environmental image, with possible gains in new clients;
- need for cleaner materials and technology to remain competitive;
- opportunity to replace obsolete technology when repairs are needed or when a company is relocating; and
- pressure from consumers, news media, environmental groups, citizens, or employees to decrease pollution.

All these factors were dependent upon and influenced by the awareness campaigns and services provided by the cleaner production centers in these countries.

Conclusions

Strong political support and regulatory commitment over a considerable length of time is critical for the success of any program to promote renewable energy and energy efficiency. The key role of government, however, is not that of direct intervention and substitution for the private sector. Rather, the government bodies provide a launching pad for greater private participation. If adequate incentives and initial support are provided, along with sufficiently robust regulations that are monitored and enforced, the private sector does not hesitate to take action as a constructive partner.

Public awareness of environmental issues and energy conservation is also important for success, as it makes the consumer more willing to pay, particularly in the case of energy efficiency. The financing mechanisms used to promote renewable energy and energy efficiency should encourage the participation of private players and the common citizen. This reduces dependence on government funding, which is of vital importance for countries in the region where governments cannot pay for such programs. However, in cases where the private sector also lacks financial capabilities, undertaking such programs is not easy without external funding and expertise.

[78] EEA. 2007. *Sustainable consumption and production in South East Europe and Eastern Europe, Caucasus and Central Asia*. EEA report no. 3/2007. UNEP & EEA.

CHAPTER 8

The role of regional trade in energy security and clean development

Though countries of Asia and the Pacific (DAP) have wide variations in socioeconomic parameters, energy resource endowments, and energy consumption patterns, they face similar energy security challenges. Moreover, the region is in need of financial support and technology cooperation to address these concerns. Notwithstanding the above, countries in the region would also need to be mindful of the environmental impacts, so that they can move toward sustainable development. There is ample opportunity for countries in the region to reap the benefits of complementing and learning from one another, as most of them are in different stages of development. A trade and cooperation arrangement would be beneficial for all the countries for the following reasons (Kumar 2008):

- ***Existence of common factor endowments.*** Asia and the Pacific has an abundance of cheap labor but lacks enterprise as well as capital. Countries on the lower level of the learning curve can gain from the experience of those on a higher level.
- ***Common solutions to cope with inadequately developed infrastructure.*** The developing countries' technological solutions have evolved in an environment of relatively poorer infrastructure and, hence, may be more appropriate than those in industrialized countries—for instance, telecommunication switching technologies not requiring air-conditioning or vehicles with more rugged suspensions to work in poor road conditions.

- ***Similar geo-climatic conditions.*** The expertise of these countries may be more attuned to similar geo-climatic conditions (for example, tropical rather than temperate climate) than those in the industrialized countries.
- ***Similar and smaller markets than in a developed region.*** Technologies and expertise available in these countries are likely to be scaled down to levels more appropriate to the size of markets in the Asia and Pacific region compared with mass production skills in industrialized countries.

Energy trade potential

The region as a whole is a net importer of energy (36% of world imports compared with 35% of world exports).[79] There is considerable energy trade among the countries in the region, but trade is restricted within select subregions. The following factors provide strong reasons to undertake regional energy trade:[80]

- There are mismatches between energy demand and energy resource endowments. Indonesia, Malaysia, and Bhutan are energy-surplus countries, whereas most of the other countries have energy deficits, thus creating an opportunity for trade.
- Relatively smaller economies in the region have energy resources far in excess of their energy demand (Malaysia, Indonesia, Brunei Darussalam, and Central Asian countries). In the remaining countries (India, the People's Republic of China (PRC), Singapore, Thailand, Pakistan, Bangladesh, and Sri Lanka) energy demand is far outstripping domestic supply. The gap will become wider unless domestic supplies are supplemented by imports.
- Reliance on energy trade for meeting a part of the domestic demand can enhance national energy security by diversifying energy forms and supply sources and lowering the cost of energy supply.
- For countries heavily dependent upon fossil fuels, energy trade in renewable energy resources and regional cooperation can help curtail fossil demand, thus helping meet environmental imperatives of the countries.
- Carbon emissions are increasing, and Himalayan glacial resources are shrinking. The management of regional water resources and the use of other primary energy sources have to be optimized for the benefit of the region as a whole, and trade enables such optimization.
- Trade could reduce system development costs and enable lower-cost supply. Nepal, for example, could dramatically reduce its cost of power supply (compared with its attempt to meet its demand by the expensive all-hydro generation option) by optimizing its power system with the sale of hydropower to, and import of thermal power from, India.

There are definite benefits of regional energy trade. First, the countries can complement one

79 UNESCAP 2006.

80 Potential and Prospects for Regional Energy Trade in the South Asia Region, World Bank; Energy Sector Management Assistance Program (ESMAP) and South Asia Regional Cooperation Program, August 2008.

another in primary energy endowments, resource development costs, and demand functions. Second, countries exporting energy will benefit from larger markets being available and, thus, can enjoy economies of scale and scope. Third, in importing countries, optimization of the fuel mix will lead to reduced costs, improved energy security, and better response to environmental concerns. The countries will also benefit from increased supply and better access to energy resources.

In sum, regional energy trade can be a "win-win" situation for both the importing and exporting countries in Asia and Pacific, with reduced costs on both sides, better investment opportunities for the private sector, and substantial potential for financial gains to all.

Current trade and cooperation arrangements

Southeast Asia and the People's Republic of China

Countries of Asia and the Pacific have made numerous attempts at regional economic cooperation since the 1970s. These initiatives include subregional efforts by the Association of Southeast Asian Nations (ASEAN), South Asian Association for Regional Cooperation (SAARC), and Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) to form free-trade agreements and further deepen economic integration and comprehensive partnership arrangements between individual countries, as well as between countries and groups like ASEAN. Each of the ongoing schemes of regional cooperation, such as the ASEAN+1 dialogue partnerships, involves considerable mutual cooperation among member countries.

In the context of energy security, however, the cooperation has taken a different form as governments are individually seeking and taking measures to ensure a steady supply of energy resources to sustain their economic growth. For instance, in 2004, the PRC and Uzbekistan signed a cooperation agreement in the oil and gas sector. In 2006, the PRC Oil and Gas Exploration and Development Corporation and Uzbekgneftegaz, an Uzbek national holding, signed an agreement on joint prospecting and exploration of oil and gas deposits in Uzbekistan. Turkmenistan has recently agreed to sell the PRC its natural gas and to build a pipeline to deliver it.

The PRC exports electricity to Southeast Asia. In 1993, the Yunnan Electric Power Group of the PRC began discussing with the Electricity Generation Authority of Thailand the development of hydropower projects in Yunnan and the sale of electricity to the authority. In 1998, the PRC and Thailand signed a memorandum of understanding on a power purchase agreement. The PRC also exports electricity to Viet Nam.

In the Southeast Asian subregion, three electricity interconnections facilitate trade between Thailand and Malaysia, Malaysia and Singapore, and Thailand and the Lao People's Democratic Republic. The electricity trade in Southeast Asia is expected to increase with the implementation of the ASEAN Power Grid under the ADB-sponsored Greater Mekong Subregion program on ASEAN energy cooperation and power interconnection.

Nonetheless, there is a growing recognition among Asian governments that the region needs an energy cooperation network. Various proposals have been suggested to promote energy cooperation among Asian countries, including the Asian Energy Community; the Inter-Asia Oil and

Gas Transportation System; the Sustainable and Flexible Energy System; Asian Energy Partnership; the Pan-Asia Continental Oil Bridge involving the Middle East, Central Asia, the Russian Federation, Republic of Korea, and Japan; ASEAN-SCO Energy Partnership; and others (Len 2007).

The Asia Pacific Economic Cooperation (APEC) has focused on clean energy through its Energy Working Group, which was launched in 1990 to maximize the energy sector's contribution to the region's economic and social well-being while mitigating the environmental effects of energy supply and use. Another subgroup under APEC, the Expert Group on Energy Efficiency and Conservation (EGEE&C), has been promoting areas of harmonization and energy efficiency of traded products, including appliances and electrical equipment. One important program of this expert group is the Energy Standards Information System, which is a Web-based database of technical information and standards on energy-using equipment in 55 countries worldwide. The expert group currently has several regional projects under way focusing on sharing information and improving the energy efficiency of products and effectiveness of policies in the region.

Energy cooperation is featured within the ASEAN network in the form of the ASEAN Plan of Action for Energy Cooperation 1999–2004. The Plan comprises six programs to promote energy cooperation in the region (ASEAN Centre for Energy 2004):

1. **ASEAN Power Grid** (to facilitate the ASEAN Interconnection Master Plan and the establishment of a policy framework for the electricity networks in the grid)
2. **Trans-ASEAN Gas Pipeline** (to facilitate the Trans-ASEAN Gas Pipeline Infrastructure Project to ensure greater economic value and security of gas supply)
3. **Coal** (to cooperatively promote sustainable development and utilization of coal while addressing environmental issues)
4. **Energy Efficiency and Conservation** (to strengthen cooperation in energy efficiency and conservation through building institutional capacity and increasing private-sector involvement, including enhancing public awareness and expanding markets for energy-efficient products)
5. **Renewable Energy** (to institute and maintain sustainable development using renewable energy and its technologies)
6. **Regional Energy Policy and Planning** (to enhance national and regional energy policy analysis and planning toward sustainable development)

These programs address various areas of cooperation, including knowledge sharing, energy markets, and technology. ASEAN has implemented several tasks under the action plan.[81]

Regarding programs with other regions and countries, the ASEAN Centre for Energy participates

[81] Meeting Report on Sixth Meeting of the ASEAN Regional Energy Policy and Planning Subsector Network (REPP-SNN), Bangkok, 20–21 September 2007; Available at www.aseanenergy.org/download/reports/energy_organisastion/repp-ssn/6th%20REPP-SSN.pdf

in a number of cooperative efforts on energy efficiency, renewable energy, and energy security in the ASEAN region (Table 8.1).

Central Asia

The five Central Asian countries—Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan—are involved in electricity trade through the Electricity Pool of Central Asia. The United States Agency for International Development and ADB have been involved in strengthening power trade among these countries and in rehabilitating and improving the operation of the electricity pool. Turkmenistan, Uzbekistan, and Tajikistan also export electricity to South and Southwest Asia, particularly to Afghanistan. In addition, Tajikistan has signed a Memorandum of Understanding with Pakistan for the export of 100 megawatts (MW) of hydropower. ADB and other multilateral organizations, including the World Bank, are helping these countries increase trading opportunities between the two subregions.

In 2005, the CAREC Members Electricity Regulators Forum (CMERF) was established with assistance from ADB and the Public Private Infrastructure Advisory Facility (PPIAF) to support regional cooperation and integration in the energy sector under the Central Asia Regional Economic Cooperation (CAREC) program. The objective is to help its members improve power-sector regulation and support reforms in that sector. Better regulation will be vital for attracting private investment to the power sectors of the region. The forum members of CMERF comprise the electricity or other energy regulators from Azerbaijan, the PRC, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, and Uzbekistan.

South Asia

Regional energy trade among South Asian countries is limited to electricity and some commercial arrangements for the supply of petroleum products among only a few countries. The trade is primarily bilateral; there is no multilateral energy trade.

Electricity trade

India and Nepal

India has been assisting Nepal in the development of its hydropower potential since the 1950s. The power exchange between the countries began in 1971 with exchange of about 5 MW of power. By 2006–2007, the exchange of power had grown to about 400 MW to meet the requirement of remote areas on the border.

A Power Trade Agreement between Nepal and India was signed in 1996. Under the agreement, which is valid for 50 years, both countries adopted a policy of economic liberalization to promote participation of the private sector in their development. Main provisions are as follows:

- Any party (government or semi-government agency or a private enterprise) in India and Nepal may enter into an agreement for power trade between the two countries.
- The parties entering into such an agreement for power trade may determine the terms and conditions, including the quantum and parameters of supply, the point of delivery, and price of supply of electrical power to be traded between them.
- The parties entering into such an agreement shall be offered necessary assistance by the respective governments, according

Table 8.1: Key Programs of ASEAN with Other Regions

Project	Partner	Detail

EC–ASEAN COGEN Programs* (completed)	European Union	• Three phases from 1991 to 2004
		  • Phase 1: 1991 and 1994, technically focused on identification phase for what was to become Phase 2
		  • Phase 2: 1995–1998, a demonstration phase combining technical and business expertise. The purpose is to demonstrate that proven European technologies are available to support biomass-based co-generation in ASEAN countries and to enhance the European Union–ASEAN economic cooperation. Sixteen full-scale demonstration projects using proven biomass-based technologies.
		  • Phase 3: 2002–2004, promoting and creating business opportunities for the use of co-generation to generate power and heat using biomass, coal, or gas. It was achieved through partnerships between ASEAN industries and power producers and European equipment suppliers.

EC–ASEAN Energy Facility** (completed)	European Union	• Period 2002–2005
		• Objectives
		  • Increasing the security of energy supply of ASEAN countries and indirectly of Europe,
		  • Increasing the economic exchanges between European Union and ASEAN countries,
		  • Improving the environment at the local and global levels,
		  • Facilitating the implementation of the ASEAN Plan of Action for Energy Co-operation 2004–2009.
		• Four key facilities responding to the objectives
		  • Increasing market awareness (workshops, high-level meetings, study tours, exchanges of personnel)
		  • Adapting institutional frameworks (master plans, strategic studies, policy formulation, secondment of experts in ASEAN, staff placement in European Union, training)
		  • Conducting feasibility studies (covering costs for provision of expertise, travel, and documentation)
		  • Implementing demonstration projects (covering for contribution to equipment cost, training of operations and maintenance staff, independent monitoring)
		• Five concerned subsectors to work with
		  • Electricity, focusing on the interconnection of the electricity grids (the ASEAN Power Grid), the reduction of generation losses, and the modernization of distribution companies

continued on next page

Table 8.1: continued

Project	Partner	Detail
		• Natural gas, with emphasis on gas transmission, the Trans-ASEAN Gas Pipeline, and distribution • Clean coal technology • Energy efficiency • Renewable energy
ASEAN–AUSTRALIA Development of Regional Competency Standards for Training in Renewable Energy*** (completed)	Australia	• Period 2004–2006 • This project sought to develop and implement regionally applicable and mutually recognized competency standards related to training in renewable energy, drawing on the Institute for Sustainable Power's international experience with developing similar accreditation standards and knowledge of international renewable energy training requirements. In particular, the project sought to establish the mechanism for developing competency standards within the ASEAN region and auditing regional training institutions and trainers.
ASEAN–AUSTRALIA Development of Regional Competency Standards for Training in Renewable Energy Phase II**** (completed)	Australia	• Period 2007 • The follow-on project to the Development of Regional Competency Standards for Training in Renewable Energy Project undertaken between 2004 and 2006. The project worked with representatives from ASEAN member country energy departments, the renewable energy industry, and training institutes from the 10 ASEAN countries to prioritize renewable energy training requirements for the region and develop task analyses detailing competencies and skills that practitioners need to design and install such technologies.

ASEAN–Japan Promotion on Energy Efficiency and Conservation for ASEAN Countries (PROMEEC) (ongoing)	Japan	• Promote energy efficiency and conservation in three areas
		  • Building, industry, and energy management
		• Key activities
		  • Building and industry: (i) energy audit and on-the-job local workshops, (ii) development of in-house database and technology directory, and (iii) award system for energy-efficient best-practices buildings
		  • Energy management: (i) building "ASEAN Energy Management System," (ii) award system for best practices in energy management, (iii) preparation of energy management tools, such as a handbook

continued on next page

Table 8.1: continued

Project	Partner	Detail

ASEAN + 3 Energy Security Systems (ongoing)	People's Republic of China, Japan, and Republic of Korea	• Enhancing energy security communication by communication system and database
		• Energy communication systems
		  • Chat and bulletin board
		• Database
		  • Oil price database and ASEAN energy database – production and utilization of energy in ASEAN countries

ASEAN = Association of Southeast Asian Nations.

Source: * EC-ASEAN COGEN Programmes,[82]** EC-ASEAN Energy Facility,[83]***ACE,[84] ****ACE,[85] *****ACE.[86]

to their laws and regulations, to conduct surveys, including field investigations, and for construction, installation, operations, and maintenance of facilities required for generation and transmission of power in both countries.

The power exchange between the two countries is made possible by interconnections at voltages of 11 kilovolts (kV), 33 kV, and 132 kV at 22 interconnection points. The three significant transmission lines are

- 132 kV Gandak (Nepal) to Ram Nagar (India) line, which is used for power export from Nepal to Bihar in India;
- 132kV Duhabi (Nepal) to Kataiya (India) line, which is used for power export to Nepal from Bihar grid, whenever Nepal needs more power in the eastern region; and
- 132 kV Mahendra Nagar (Nepal) to Tanakpur (India) line, which was constructed for Nepal's power usage under the Tanakpur agreement.

Discussions are on going to augment transmission interconnection capacity between the two countries.

Bhutan and India

Cooperation in the hydropower sector between India and Bhutan dates back to 1961, when the first Indo–Bhutan agreement was signed on the Jaldhaka Hydroelectric Project. The Government of India has been assisting in development of mini hydro electric infrastructure for the electrification of district headquarters since 1967. An agreement on trade and commerce was signed in 1972 and

82 EC-ASEAN COGEN Programmes Website. www.cogen3.net/index.html

83 EC-ASEAN Energy Facility Website. http://aseanenergy.org/eaef/

84 ASEAN Website. www.aseansec.org/aadcp/download/project/rps/026%20brief%20summary%20web%20feb%2008.pdf

85 ASEAN Website. www.aseansec.org/aadcp/download/project/rps/026%20brief%20summary%20web%20feb%2008.pdf

86 ASEAN Centre for Energy, ACE by Dr. Weerawat Chantahakome and team (2008), Presentation on Progress Report on ASEAN + 3 Energy Communication System and Oil Price Data for the 5th ASEAN + 3 Energy Security Forum and 7th SOME + 3 Energy Policy Governing Group Meeting, Malaysia, 29 January 2008, Available: www.aseanenergy.org/download/papers/2007/ASEAN+3%20Energy%20Communication%20System%20and%20Oil%20.pdf

extended until 2005 and beyond. The two countries realized that cooperation in the hydropower sector would improve their economic growth, welfare, and energy security. Thus, India has assisted Bhutan in the development of hydropower, and Bhutan has seen rapid socioeconomic development. However, Bhutan's need for electricity is still modest, so it exports power to India to meet the growing demand there.

India assisted Bhutan in the development of three hydropower projects: the 336 MW Chukha, 60 MW Kurichhu, and 1,020 MW Tala hydro electric plants. The power exchange between the two countries has been steadily increasing from just 414 million units in 2002–2003 to nearly 4,893 million units in 2007–2008.[87]

Based on the successful cooperation in the past, India and Bhutan signed an agreement, in 2006, for cooperation in hydropower. Both countries agreed to facilitate development and construction of hydropower projects and associated transmission systems, as well as trade in electricity, through both public and private participation. India agreed to a minimum import of 5,000 MW electricity from Bhutan by 2020. One important feature of the agreement is that the two countries will be cooperating to develop projects under the clean development mechanism of the Kyoto Protocol, using India's carbon emission baseline.

Oil trade

Regional trade in the oil sector refers to commercial arrangements among oil companies in the countries. Lanka IOCL Limited, a fully owned subsidiary of the Indian Public Sector Enterprise Indian Oil Corporation, has set up retail outlets in Sri Lanka to supply petroleum products there. The company is also importing petroleum products from India for these outlets. Cross-border trade in petroleum products is also undertaken between India (Indian Oil Corporation) and Nepal (Nepal Oil Corporation). Nepal imports its petroleum products exclusively from India.

Room for more

Existing regional trade and cooperation arrangements are clearly limited in number and scope, leaving room for expansion:

1. There is no energy trade or cooperation at the Asia-Pacific level.
2. Among the subregions, there is little multilateral trade.
3. The ASEAN region has had a number of initiatives to strengthen regional cooperation. The Asia and Pacific region can learn from these and possibly replicate them.
4. Regional trade and cooperation in the fields of renewable energy resources and energy efficiency now occur only in some ASEAN initiatives. Given the potential of renewable energy resources in the Asia and Pacific region, especially biomass, efforts should be made to promote cooperation in these two fields.

Asia Pacific Partnership on Clean Development and Climate

One initiative that needs mention is the Asia Pacific Partnership on Clean Development and Climate. Though there are only three countries from ADB

[87] Until December 2007.

developing member countries (DMCs) in the partnership, it has been able to initiate some on-the-ground projects and facilitate capacity building in the region.

It is a collaborative effort of seven developed and developing nations—Australia, Canada, PRC, India, Japan, Republic of Korea, and United States—aimed at partnership in addressing challenges of climate change, energy security, and air pollution in a way that encourages economic development and reduces poverty. The member countries account for about half of the world's population and more than half of the world economy and energy use.

Eight task forces have been set up to look at various aspects of energy use. These are

- Aluminum Task Force
- Building and Appliances Task Force
- Cement Task Force
- Cleaner Fossil Energy Task Force
- Coal Mining Task Force
- Power Generation and Transmission Task Force
- Renewable Energy and Distributed Generation Task Force
- Steel Task Force

Under each task force, projects have been undertaken through a public–private partnership that includes members from the industry and research institutes. Projects include application of best practices, capacity building, technology-based research, and demonstration and deployment.

Barriers to regional energy trade and cooperation

Regional trade in Asia and Pacific has developed in a skewed, constrained manner. The barriers hindering it are grounded in politics, economics, and infrastructure.

Political and security problems, including territorial disputes

A number of countries in the region have been experiencing political instability for several years. Countries in the South Asian subregion (Afghanistan, Pakistan, Sri Lanka, and Nepal), Myanmar, Thailand, and Indonesia, for instance, have faced recent political crises. Central Asia itself has only recently recovered from the economic decline and political instabilities that followed the dissolution of the Soviet Union toward the end of the 1980s.This has had an impact on regional trade because the risk of investing in politically unstable countries is much higher. There are also territorial issues, which have diminished trust and hindered regional energy trade.

Lack of transregional energy infrastructure

Lack of energy infrastructure is a serious problem within countries of the region, threatening their energy security. But it is also a problem between countries. There is little infrastructure to carry the different forms of energy across borders. The lack of connectivity between countries prevents the region from developing regional energy trade.

Among other barriers related to setting up of new energy infrastructure in the region, substantial investment requirements for building transregional energy infrastructure are most critical. Another dimension related to lack of trans-energy infrastructure is security of the infrastructure especially if the transit country is a troubled state. And there are right-of-way issues that need to be sorted out.

Energy is a high-investment, high-risk sector to begin with, and the risks grow much bigger when the investment is made in more than one country. One way of mitigating the risk is to set up a strong regional institutional and regulatory framework for promoting regional energy trade. The second step would be to harmonize policies and regulations so as to provide a transparent and predictable governance structure, thus addressing policy risks.

The region's financial institutions are at a nascent stage compared with European or American counterparts. This can stifle investment in the region and, thus, hinder regional energy trade.

Incongruent pricing

Energy pricing can be an effective policy tool to influence choices. However, the energy pricing mechanism in the region is weak. Different countries give priority—and subsidies—to different sources of energy. More congruent pricing would assist in developing regional energy trade.

Conclusions

Regional cooperation is an effective strategy that Asia and the Pacific could use to meet both energy security and climate change concerns. There has been some progress on this, but it needs more attention. It is a "win-win" approach for all stakeholders that merits special effort.

Given the geographic expanse of the region, regional trade may take time to develop. But a methodical, phased-in plan can build the framework for it.

The first and foremost area for regional cooperation is knowledge sharing and regional data collection in order to create a robust database that can be used to identify economically sound regional trade options.

Second, the region needs to set broad framework conditions for regional energy trade. Trade will occur only if the economics of it is favorable.

Third, the region should set up training programs in relevant areas of the energy sector, such as energy efficiency and renewable energy technologies. Lack of basic capacity in terms of human expertise is a major barrier to energy efficiency progress.

Fourth, governments need to work together to address institutional, regulatory, and policy issues. Simultaneously, technical issues (especially those related to electricity grids and natural gas grids) need to be sorted out.

Fifth, in the long term, it is envisaged that with technological innovations, trade of energy among all countries of the region will be possible. Until then, the region should focus on strengthening the existing bilateral trade agreements. It can then move steadily toward subregional trade and finally graduate to regional trade.

Sixth, the region needs to strengthen the existing physical infrastructure, such as regional electricity transmission lines and natural gas pipelines. The governments of countries in the Asia and Pacific region can look at the financing options discussed in Chapter 6.

CHAPTER 9

The way ahead

Countries in developing Asia and the Pacific (DAP) that are already grappling with high levels of poverty and a growing concern with energy access and security now face the challenges posed by climate change in the form of urgent adaptation measures and a growing pressure to help with the mitigation efforts of the developed world.

The Fourth Assessment report of the Inter-governmental Panel on Climate Change estimated a window of opportunity open until 2015 for reversing the upward trend of greenhouse gas (GHG) emissions. At the same time, it concluded that no matter how successful the mitigation efforts, the world is going to experience a certain amount of climate change. Although the developing countries maintain that—on the principles of historical and "common but differentiated" responsibilities—the responsibility for mitigation and for the costs of adaptation rests with the developed world, the developing countries, through their commitments under the United Nations Framework Convention on Climate Change (UNFCCC), have to "take climate change considerations into account, to the extent feasible, in their relevant…policies and actions.

The two sets of intervention measures that have been discussed as ways to enhance energy security—improving energy efficiency and increasing the spread of clean and renewable energy technologies—also can fulfill the pledges made under the climate change convention. There are serious challenges, but the potential for convergence is strong.

Challenges

The DAP region faces high levels of poverty, in both income and energy. The region holds more than half (54%) of the world's population, and about 50% of the region's people have incomes of less than $2 a day. The current per capita energy consumption levels of many of the countries are among the lowest in the world, and most of the population is dependent on traditional sources of energy, especially biomass. This dual poverty poses a complex challenge for sustainable development and for energy security. Given the role energy access has in alleviating poverty, an increase in energy consumption is highly desired, although that—without a dramatic shift in practices— will enormously increase greenhouse gas (GHG) emissions as the region is heavily dependent on fossil fuels.

The countries of this region also have energy security concerns due to rapidly increasing demand. Countries, such as the People's Republic of China (PRC) and India, have the largest incremental energy demand. The smaller countries, where consumption is currently very low, are also experiencing a rise in demand. Access to fossil fuel-based technologies and their cost effectiveness has pushed the region into high dependence on them, which is likely to persist in the short and medium term. The production of fossil fuels has been increasing but has not kept pace with demand, leading to a rise in trade that has made the region a net importer of fossil fuels. The DAP region's self-sufficiency in coal decreased from 100% in 1999 to 67% in 2006. The number also dropped for oil (from 62% to 55%) and natural gas (from 125% to 115%). The demand for coal is primarily fueled by the power sector; the demand for crude oil is increasing sharply because of a modernizing transport sector.

Lack of energy infrastructure is one major hindrance in ensuring energy access to all and in closing the gap between the supply of energy and the demand for it. The existing infrastructure is extremely inefficient, which is highlighted by high losses during transmission and distribution. Since most energy demand centers within a country are not near the source of supply, it becomes imperative to have an adequate transmission and distribution network of the primary and secondary energy sources. This calls for a huge investment in the energy infrastructure. However, the contribution of private investment in the region is limited, and the governments' financial resources are scarce.

The way energy is priced in the region hinders the development of energy efficiency and renewable energy. Domestic energy pricing mechanisms favor the use of fossil fuels; the incentives for renewable energy and energy efficiency are inadequate.

Though the energy intensity of the region is low, intensities of select sectors are high. The energy savings potential of the industry, transport and buildings sectors is estimated to be more than 45%. Energy-efficient and emissions-reducing technologies are needed at affordable prices, but most countries in the region lack the capacity and financial resources to develop and deploy them.

Lack of financing also affects policy; resources are needed to design and implement more ambitious responses to energy security and climate change concerns. The region has a plethora of policy initiatives to address energy security, but these are rarely comprehensive and typically designed on a sector-by-sector basis. Forward-looking policy making is confined to a few select countries, highlighting the region's shortage of expertise in policy design. This is exacerbated by a lack of good data and monitoring mechanisms.

Lack of adequate financing is a central theme in many of these challenges. While the region is largely dependent on multilateral financial organizations, the support available from these institutions is concentrated in large economies. Financing is further restricted by complex and cumbersome procedures, which are normally beyond the reach of small entrepreneurs. The local financial institutions are averse to the credit risk of the end-user customer and energy services companies and the technical risks of the projects.

Market-based tools, such as the clean development mechanism (CDM), have been established to encourage private investment in clean and renewable energy in developing countries. However, in the absence of a minimum level of economic activity, they are not effective at attracting investors.

Advantages: endowments and shared experience

There is immense scope for aligning the responses to energy security concerns with the responses to climate change, and the DAP region is advantageously placed to bring that convergence about. It is endowed with substantial quantities of non-fossil energy resources that, properly harnessed, will provide energy security while avoiding ever-escalating growth in the emitting of GHGs that affect the earth's climate.

The region has tremendous potential for non-fossil energy, particularly from biomass, solar, hydro, and nuclear. However, this possibility has yet to be realized. The penetration of renewable energy has just begun in the PRC and India and, in other countries, the potential is yet to be harnessed. The region has more than 290 gigawatts of hydropower still untapped, and 27% of the global uranium is largely unexploited.

There is an advantage to the region's nascent stage of development; it means that a sustainable energy sector and the overall economy of the region can grow together in a purposeful way. Much of the needed investment in infrastructure has yet to built, so it can be built with energy security and energy efficiency in mind from the ground up, instead of requiring massive retrofitting.

Many of the DAP countries have already taken steps toward sustainable energy. Most of these include the promotion and deployment of renewable energy technologies and energy-efficient technologies supported by regulatory measures and policy incentives, such as energy efficiency labeling and feed-in tarriffs (FITs). There are many examples: the PRC is developing clean coal technology; India has introduced energy efficiency certificates in the industry sector; the Philippines uses biodiesel; Nepal is working with biomass; Thailand offers FITs for small-scale power generation from renewable sources; and the Republic of Korea has launched a drive toward "Green Energy Industry."

The similarities between countries is another asset for the DAP region. With similar stages of market development and similar technology needs, particularly in harnessing biomass and coal resources, countries can collaborate in technology and share experiences in designing and implementing policies. A cooperative and collective approach would not only address energy-related issues but also would lead to economic and environmental benefits for the entire region.

Collaboration could include designing a regional, market-based mechanism for promoting sustainable development, drawing on the lessons learned from the successes and failures of the CDM.

Asia and the Pacific also has a large labor force and a large internal market for goods and services. These are potent forces for attracting private investment.

Window of opportunity

Most countries in the region lack adequate infrastructure, particularly to harness renewable energy resources. This presents a window of opportunity to invest in low-carbon technologies and avoid linking their economic progress to an extensive fossil fuel–supporting infrastructure.

Countries, such as the PRC, India, and the Republic of Korea, have committed substantial resources to the large-scale manufacture of renewable energy technologies. A number of countries, such as Bangladesh, Indonesia, and Viet Nam, have set tangible targets to increase the share of renewable energy in their energy mix.

A few countries in the region—in particular, the PRC, the Republic of Korea, India, and Indonesia—have relatively developed technological capabilities in photovoltaic and vacuum-tube solar water heaters, supercritical and ultra-supercritical boilers, wind turbines, and hydropower. This provides an excellent opening for cooperation in technology. A successful regional collaboration could turn the region into a market leader in the field of renewable energy. This would require, however, proactive international support.

Immense opportunities also exist for improving the energy efficiency of end users, particularly the buildings and transport sectors. Here, the private sector can play an important role, especially in the formation of energy service companies and the rapid uptake of energy efficiency technologies.

The fiscal stimulus packages provided in several countries across the globe can also be emulated and used toward the development of low-carbon pathways. Both India and the PRC have introduced such stimulus programs.

A radical shift

Addressing concerns related to energy security and climate change through same interventions appears to be the best route to a low-carbon pathway. This convergence is exemplified in the case studies on energy efficiency and renewable energy technologies discussed in the earlier chapters. However, the energy mix of the region is heavily dominated by coal and oil. The scenario is unlikely to change without a radical shift toward the development of new energy infrastructure. In particular, since many countries have large coal reserves, they are likely to continue to rely on coal to meet their energy requirements, particularly for power generation. Clean coal technologies, such as supercritical/ultra-supercritical and integrated gasification combined cycle (IGCC), will have to be adopted on a large scale. In addition, the deployment of carbon capture and storage may also be important.

End-use energy efficiency can be built by innovative financing mechanisms. In the buildings sector, a system developed in Japan could be used as a role model. There, the government, financial institutions, and private citizens work together to reduce household use of energy in a risk-sharing arrangement. The Japan Housing Finance Agency guarantees a fixed interest rate in its loans to financial institutions which, in turn, provide a fixed and reduced rate of interest to their customers in exchange for an energy consumption reduction certificate. After lending to homeowners, financial institutions transfer the loan bonds to the government agency. The financial institution gets paid, in return, with loan bonds from the agency, which issues mortgage-backed securities to investors. Investors are paid back with interest. The program covers both retrofits and new homes.

Energy service companies will be crucial for the success of energy efficiency programs. So will education: the staff at financial institutions that are asked for funding need to be trained, so that they will understand the benefits, not just the risks, of these new approaches.

Deployment of low-carbon technologies will mean active involvement by industry, but governments must provide supportive policies to ensure that a technology successfully makes the transition from deployment to commercialization.

At the macro level, the DAP region has significant renewable energy resources. However, at the micro level, reliable information on the resources available is insufficient from an entrepreneur's perspective. The region needs to cooperate and map out all renewable energy resources across all countries, especially in the smaller ones. In addition, many of the smaller countries need assistance in developing and implementing plans for low-carbon technology.

The role of governments should be to break down the barriers to the market uptake of new energy technologies. In the formulation of policies, it will become imperative to consider the price of carbon. A higher price of carbon is likely to accelerate deployment of energy-efficient and renewable energy technologies. It will also deepen the impact of market mechanisms, such as the CDM, that provide financing for sustainable development projects.

The governments should build flexibility into their policies to meet the changing environment, taking care not to provide overly generous support to one specific technology that may become inappropriate.

The private sector needs a welcoming environment. Consistency regarding long-term market rules must be maintained so that entrepreneurs can make investment decisions based on calculated risks. Without regulatory certainty, the perceived risk level can undermine incentives for investing in projects that represent major up-front costs.

Since many of the renewable energy technologies are intermittent in nature and also need to be interfaced with the main grid, policies are needed to remove noneconomic barriers, administrative complexities or hurdles, and grid-access issues that affect connection. Public resistance to new technologies can still act as "showstoppers" in many cases, even where renewable energy technologies are economically competitive. New technologies, such as smart grids, can play an important role.

Financing and technology are the gateways to a low-carbon future. And the global community must help pay the tolls through an international financing mechanism and through international cooperation with a long-term perspective on technology research, development, demonstration, and deployment.

Regional cooperation among national laboratories and universities

Basic scientific research with a clear focus on the needs and requirements of the region is necessary for the region to develop its own capacity to develop appropriate technologies. National and university laboratories are the most important players in basic research. While governments have been the main source of funding, industry has increasingly supported basic scientific research at universities since the 1990s (Bozeman 2000). Governments of the region can help develop relationships here, in support of mission-oriented research programs.

As the outcomes of research in basic sciences are highly uncertain, it becomes imperative for the governments of the region to intervene and initiate research. They need to identify, at the regional and national levels, the priorities they want to attach to basic science in energy. They need to develop strategic road maps for the development and deployment of technology. A regional authority should be established to oversee these strategies. It would identify which programs should be university-based and how much the private sector should be involved. It would prepare a budget and select potential center of excellence in the member countries for identified areas of collaborative research.

The idea behind this regional collaboration in the pre-competitive stage of basic research is threefold: cost-sharing (with cost reduction), the scaling-up of research, and the building up of common pools of knowledge. For such collaboration to materialize, ADB will have to play a proactive role, mobilizing governments and encouraging national laboratories and universities to join in. Where appropriate, private companies may also be encouraged to participate.

Regional collaboration from R&D to deployment

Although competition among countries and among companies is a driver of energy technology innovation, there are still significant benefits from increased collaboration. It is proposed that the developing member countries (DMCs) of ADB should pool resources and improve overall cost-effectiveness in research, development, and deployment. The goal is to create a common pool of knowledge at the industry level to achieve global competitiveness and accelerate the spread of technology in Asia and the Pacific.

Many international energy technology collaborations already exist, especially among the Organisation for Economic Co-operation and Development (OECD) countries under the aegis of the International Energy Agency. In addition are R&D networks on various technologies. Similar arrangements are desirable for the DAP region. The collaborations should include biofuels, solar thermal-based power generation and solar heating, second-and third-generation concepts in solar photovoltaic technologies, deep sea offshore technologies, and many areas in industrial process technologies (such as smelt reduction, direct casting, and inert anodes innovations in basic materials production processes; plastic recycling/ energy recovery; and feedstock substitution, such as biopolymer, monomers from biomass, and naphtha products from biomass through the Fischer-Tropsch process).

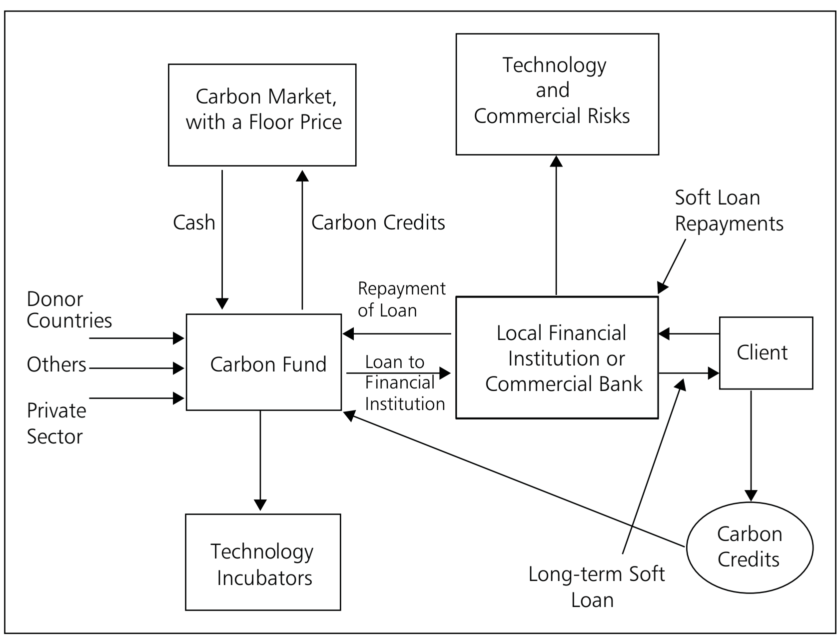
In some areas, it may be possible for these efforts to work together with other policy strands. For example, coherent policies on urban development, public transportation, and health, together with strong efforts to devise and deploy new technologies in these areas, may generate sufficient momentum to ensure the simultaneous and faster development of carbon-free power generation and "smart growth" urban development.

Innovative financing: a new carbon fund

It is suggested that a new financing mechanism be established to support energy efficiency and renewable energy projects, along with technology incubators to support commercialization of new technologies. This new "carbon fund" would be based on the existing international carbon trading regime, with a guaranteed minimum price of emission reduction credits. Figure 9.1 gives a suggested framework.

In this model, the primary funding comes from mandatory contributions from the developed countries, as they are already required under the UNFCCC and the Bali Action Plan to provide financial and technological assistance to developing countries in their adaptation and mitigation activities. The equity in the carbon fund will also be from developing countries, the private sector, venture capitalists, etc. The fund will provide financial assistance for the incremental investment

Figure 9.1: Financing Structure and Funding Mechanism for Low-Carbon Technologies



required in low-carbon technologies and will also cover technical and financial risks.[88] The assistance can be in the form of a long-term soft loan through a financial institution in the country of deployment.

The carbon savings or the certified emission reductions (CERs) generated from the project will be jointly owned, according to a mutually approved formula, by the carbon fund and the project developer. Both parties will be assured of a minimum floor price of the CER, which could be decided by a conference of the parties. The continuous flow of revenue through the emission reduction credits will ensure that the fund is self-sustaining. Joint ownership of the CERs is likely to ensure that the expectations of the entrepreneurs with regard to a possible rise in carbon prices in future provide an adequate market-based incentive to undertake the investment risks.

The carbon fund will also invest in technology incubators and could purchase intellectual property rights of already commercialized technologies to reduce the cost of climate-friendly technologies. The technologies that are supported by the fund for their commercialization should be considered as technologies in the public domain with no intellectual property right costs included.

It is imperative that investments in new energy technologies and infrastructure in the DAP region be gathered globally, involving not only the governments of OECD countries but also the private sector and international financial institutions.

[88] Incremental investment is defined as the difference between the baseline technology and the low-carbon technology in terms of capital cost and the cost of operations and maintenance, costs calculated over the life of the latter.

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APPENDIX I.

Methodology of Report

Methodology

This study is largely based on compiling, synthesizing, and critically analyzing information of six types: (i) existing data on energy need, demand, and supply until 2030; (ii) information on available technologies for all sectors on the demand and supply sides; (iii) regional, national, and sectoral policies; (iv) economic performance of selected countries; (v) performance of multilateral financial institutes in terms of promoting renewable energy and energy efficiency projects in Asia and the Pacific; and (vi) approved clean development mechanism (CDM) projects under the Kyoto Protocol. This analysis has been complemented with a thorough literature survey to (i) identify critical sectors and technologies for particular countries, as well as the region as a whole; (ii) map the regional, national, and sectoral systems of innovations and technological, institutional, and financial capabilities of selected countries; and (iii) synthesize recommendations made by other scholars, researchers, and research institutes. To have a deeper understanding of the issues and gain insights toward finding ways to address the twin challenges of energy security and climate change, this study has also used country case studies and a survey of experts in the region, seeking their views.

Country case studies

The focus of the country case studies is on selected projects or climate-friendly policy interventions. The objective of these case studies is to understand the barriers (technological, political, social, and economic) to adopting energy efficiency and clean energy options and the technological and financial needs of selected countries. These countries (the People's Republic of China, India, and Indonesia) were selected so as to represent all the subregions and the top energy-consuming countries in the region. To learn from the successful experiences of other countries, Japan was taken as a special case study to understand the factors responsible for Japan's transition from an inefficient developing economy to an efficient developed economy. Some failed projects and measures have also been studied to understand the data and knowledge gaps in specific countries. These case studies cover examples of energy efficiency, fuel switching, renewable energy, and clean technologies in different sectors, including buildings, transport, and industry.

The detailed country case studies were also undertaken with a view that they would provide critical insights into what kind of policies, technologies, and other measures work in given different situations. This would help in making context-specific policy recommendations at the end of the study. A country case study focuses on the

- performance of climate-friendly policies and measures;
- reasons for successes and failures of energy efficiency and clean energy activities along the value chain;
- analysis of energy markets and financial sector practices with a view to improving market financing of energy efficiency and clean energy projects;
- lessons for technology transfer and diffusion, design of international financial mechanisms, adequacy of policies and measures, and alignment with energy security and sustainable development needs; and
- strategic directions for enhanced participation in greenhouse gas mitigation (especially energy efficiency and clean energy) activities.

Survey of experts

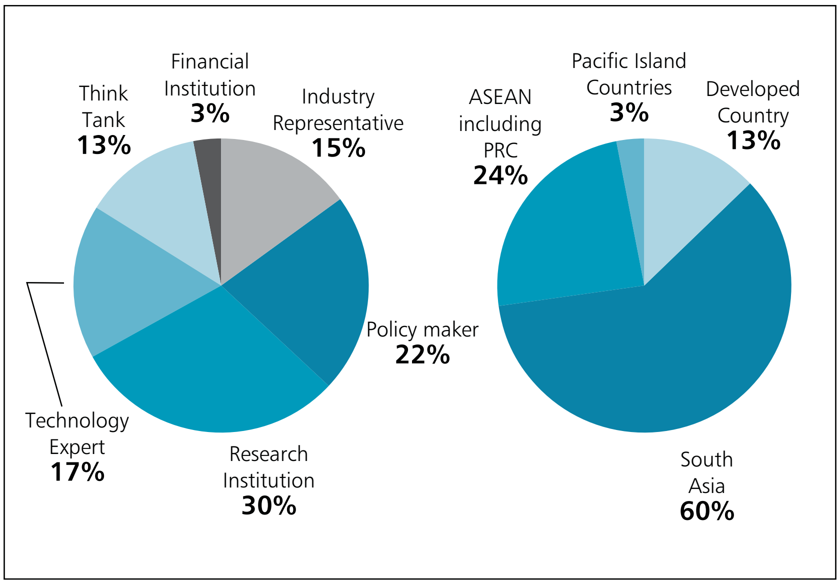
Along with a broader agreement on the major issues of energy security and climate change, a range of opinions on the possible strategies to address related challenges also exists. This diversity is largely due to the different national circumstances of countries and would not necessarily be effectively captured in the published. In this study, a survey of a range of experts in the region was carried out with the objectives of (i) benefiting from the larger experience and tacit knowledge of the respondents, who have been actively engaged with issues of energy security, climate change, concerned technologies, and finance; and (ii) documenting the commonalities and differences across countries that would make transparent the probability of success in emulating specific policies and strategies from one country to another.

Out of about 300 questionnaires sent to energy experts, policy makers, civil society organizations, industry, financial institutions, and researchers in the region, 78 complete responses were received. These responses had a reasonably good geographical and stakeholder spread (Figures A1a and A1b).

The survey addressed itself to the following aspects:

- perceived energy security concerns and risks;
- possibility and scope of shift from fossil fuels to other energy sources;

Figure A1a: Stakeholder Mix of Respondents **Figure A1b: Regional Mix of Respondents**



ASEAN = Association of Southeast Asian Nations, PRC = People's Republic of China.

Source: Expert survey.

- possibility and scope of movement toward energy-efficient technologies and technology systems on demand side, as well as supply side, of the energy sector in a given country or the region;
- barriers to moving to low-carbon pathways in major countries or the region;
- effectiveness of the policy response to energy security concerns; and
- policy recommendations, including finance, to promote energy efficiency and renewable energy.

APPENDIX 2

General conversion factors for energy

To	TJ	Gcal	Mtoe	MBtu	GWh
From	Multiply by				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.63×10^{-3}
Mtoe	4.186×10^{4}	10^{7}	1	3.968×10^{7}	11630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

Gcal = gigacalorie, GWh = gigawatt-hour, MBtu = million British thermal units, Mtoe = Million tons of oil equivalent, TJ = terajoule.

Source: World Energy Outlook (2008).

Average Conversion Factors

Coal	1 Mtoe = 1.9814 million tons
Oil	1 Mtoe = 0.0209 mb/d
Gas	1 Mtoe = 1.2117 bcm

bcm = billion cubic meters.

Source: World Energy Outlook (2008).

Proved Uranium Reserves (RAR) as of 1 January 2005 (thousand tons of uranium) (conventional resources recoverable at up to $130/kgU)

	Recoverable at				Total Recoverable at
	<$40/kgU	$40–80/kgU	<$80/kgU	$80-130/kgU	Up to $130/kgU
PRC	25.8	12.2	38.0		38.0
India					42.6
Indonesia		0.3	0.3	4.3	4.6
Japan				6.6	6.6
Kazakhstan	278.8	99.5	378.3	135.6	513.9
Mongolia	8.0	38.2	46.2		46.2
Turkey		7.4	7.4		7.4
Uzbekistan	59.7		59.7	17.2	76.9
Viet Nam					1.0
Total Asia	**372.3**		**529.9**		**737.2**

kgU = kilogram Uranium, PRC = People's Republic of China.

Source: Survey of Energy Resources (2008).

Uranium: annual and cumulative production at end-2005 (tons of uranium)

Country	2005 Production	Cumulative Production to end-2005
PRC	750	29,169
India	230	8,423
Kazakhstan	4,357	32,715
Mongolia		535
Pakistan	45	1,016
Uzbekistan	2,300	28,069
Total Asia	**7,682**	**100,011**

PRC = People's Republic of China.

Note:

1. Data for the People's Republic of China, India, Pakistan, Romania, Ukraine, and Uzbekistan are estimated.

2. The cumulative production shown for Kazakhstan, Uzbekistan, the Russian Federation, and Ukraine covers only the period 1992–2005 inclusive, as data for earlier years are not available.

Source: Survey of Energy Resources (2008).

APPENDIX 3

Appendix 3.1 Status specifying quotas for renewable energy procurement in different Indian states

State	Quota/Renewable Purchase Obligation	Time Period
Andhra Pradesh	Minimum 5% of total energy consumption (of this 1/2% is to be reserved for wind)	2005–2006, 2006–2007 and 2007–2008
	Minimum 1% of total energy consumption	2006–2007
	Minimum 1% of total energy consumption	2007–2008
	Minimum 2% of total energy consumption	2008–2009
Himachal Pradesh	Minimum 20% of total energy consumption	2007–2010
Haryana	Up to 2% of total energy consumption	2006–2007
	Up to 2% of total energy consumption	2007–2008
	Up to 3% of total energy consumption	2008–2009
	Up to 10% of total energy consumption	2009–2010
Karnataka	Minimum 5% and maximum of 10% of total energy consumption	
Kerala	Minimum 5% of total energy consumption (of this 2% from SHP, 2% from wind, and 1% from all other NCE sources)	2006–2009
Madhya Pradesh	Minimum 0.5% of total energy consumption, including third-party sales from wind energy	2004–2007
Maharashtra	Minimum 3% of total energy consumption	2006–2007
	Minimum 4% of total energy consumption	2007
	Minimum 5% of total energy consumption	2008
	Minimum 6% of total energy consumption	2009
Orissa	3% (for wind and SHP)	2009
Rajasthan	Minimum 7.45% of total energy consumption	2010
	Minimum 8.50% of total energy consumption	2011
	Minimum 9.50% of total energy consumption	
Tamil Nadu	Minimum 10% of total energy consumption	2006–2009
Uttar Pradesh	5% of total energy consumption	
West Bengal	Minimum: 1.9%	2006–2007
	Minimum 3.8%	2007–2008

Appendix 3.2 Interventions to promote renewable energy and energy efficiency in DAP countries

Country	Intervention	Salient Features
Thailand	National Energy Conservation Program	• Compulsory program (designated factories; new factories and buildings, government buildings, existing factories and buildings) • Voluntary program (renewable energy and rural industries, industrial liaison, and R&D) • Complementary program (human resources development, public relations, and program administration Demand-Side Management Programs • High Efficiency Motor Program • Industrial Energy Efficiency Program (promotion of variable speed drives, refrigeration, heating, air-conditioning systems, electrical system quality improvement, lighting, load management; interruptible load and stand-by generation) • Energy Service Business Commercial DSM Program • Commercial Lighting Retrofit Program • New Commercial and Government Buildings Program • Green Building Program • Other programs (attitude-creation program, lighting program, thermal storage program, low-income customer program, ESCO program) Financing Programs Training, education, promotion, and awards
	Energy Saving Label (Energy Label No. 5) of the Electricity Generating Authority of Thailand started in 1994	• Residential sector is the first target of implementation as it comprises 12 million households, which accounts for 22% the country's energy consumption • Current products under program: refrigerator, air conditioner, compact fluorescent lamp, ballast, fan, nutritious brown rice, rice cooker, and electric lamp • Public awareness

continued on next page

Appendix 3.2: continued

Country	Intervention	Salient Features
Viet Nam	Power Development Plan: IPP–BOT (Build-Own-Transfer) (2007 version)	• Granted a tax holiday for first 4 years and 50% exemption for the other 9 years • May exempt from payment of import duties for some imported items for a BOT project • Exempted from taxes if technology transfers needed for the project • May receive loan guarantees, guarantees in respect to offtake obligations, raw material input obligations and other contractual obligations, and specifically guarantees of the obligations of state monopolies regarding the sale of raw materials to, and purchase of products and services from, the project company • Gained the right to use-land free of land rent for project duration. • May grant a mortgage for equipment, plant, factory, contractual rights, other assets and land-use rights in favor of lenders in accordance with the prevailing regulations (does not allow foreign lenders to directly take mortgages over the rights on land use). • After the agreed period, the ownership is transferred to the government with free of any compensation
	Review and deregulation of energy tariff structure toward energy efficiency and conservation	
	Demand-side management	
	Ratification of incentive, rebates, and penalties	
	Availability of national funds for energy efficiency and conservation	
	Enhancement of technical conservation	
	Information, awards, training, and education	

continued on next page

Appendix 3.2: continued

Country	Intervention	Salient Features
Lao People's Democratic Republic	Electricity law for independent power producers – BOOT (Build-Own-Operate-Transfer)	• Private developer owns and operates the project for a specified time period (usually 25–30 years) • Equity participation of the government at agreed ratio. • Guarantees have been used and the government typically takes a 25% equity stake in BOOT projects in hydropower. • Mostly, BOOT project involves multinational groups comprised of several partners • Providing power purchase assurance and import duty exemption • After the agreed period, the ownership is transferred to the government with free of any compensation
Cambodia	Renewable Electricity Action Plan	Grant assistance of $400 is provided for the development of micro- and mini-hydro power plants and $300 is provided for the development of other renewable energy (biomass)
Myanmar	Developing National Guidelines and Preparation of EE&C Master plan	
People's Republic of China	Energy Conservation Law 2007 Renewable Energy Sources 2005 Environmental Impact Assessment Law 2002 Promoting Clean Production 2002 China National Plan for Coping with Climate Change 2007 The Comprehensive Working Scheme on Energy Saving and Cutting Pollution 2007 Mid- Long-Term Development Plan for Renewable Energy 2007 The 11th Five-Year Plan for Energy Development 2007 Renewable Energy Generated Electrical Pricing and Fee Sharing Management Rules 2006	

continued on next page

Appendix 3.2: continued

Country	Intervention	Salient Features
	Management and Monitoring Energy Conservation from Ministry of Coal Industry 2007 Energy Conservation Management Stipulation 2006	
India	National Electricity Policy 2005	Emphasis is on decentralized power generation and distribution, which subsequently identifies renewable energy and energy-efficient distribution systems.
	National Electricity Act 2003	This encourages and stimulates the market of nonconventional energy resources/renewable and co-generation was promoted. This Act provided a huge boost to the renewable industry.
	Energy Conservation Act 2001	The Act provides for the legal framework, institutional arrangement, and a regulatory mechanism at the central and state levels to embark on energy efficiency drive in the country.
	Indian Industry Program for Energy Conservation	Seeks energy conservation for textile, cement, pulp and paper, fertilizer, chlor-alkali, and aluminum.
	National Action Plan for Climate Change	Has a focus on eight missions, of which national Solar Mission has the endeavor to have a substantial increase in solar energy in the total energy mix. Enhancing energy efficiency has also been identified as a key component of the national strategy to combat climate change
	Science and Technology Policy 2003	One of the most important mandates of the policy is technology development, transfer, and diffusion
	Technology Promotion Development and Utilization Program)	An initiative of Ministry of Science and Technology to promote development, deployment, and diffusion of efficient and environmentally sound technologies
	Solar Photovoltaic Program and Solar Energy Program	

continued on next page

Appendix 3.2: continued

Country	Intervention	Salient Features
	Ultra Mega Power Plant Project	For all coal-fired ultra-mega power plants (more than 3,500 MW capacity) in India, use of supercritical technology has been made mandatory
	Biofuels Mission 2003	
	Bio-diesel Purchase Policy 2005	The public sector oil marketing companies will purchase biodiesel, meeting the Bureau of Indian Standard specifications through their select purchase centers at a uniform price. This policy came into effect from 1 January 2006.
	National Bio-fuel Policy 2008	• An indicative target of 20% blending of biofuels (bioethanol and biodiesel) by 2017 • Biodiesel production from non-edible oil seeds in waste/degraded/marginal lands • Import of free fatty acids not permitted. • Bio-ethanol and biodiesel may be brought under the ambit of "Declared Goods" to ensure unrestricted movement of biofuels within and outside the States
Nepal	Rural RE Policy 2006	
	Subsidy Policy 2008	
	Hydro Power Development Policy 2001	
	Electricity Act 1992	
	Electricity Regulation	
	Water Resources Act	
	Three-year Interim Plan (2007–2010)	
Sri Lanka	Sustainable Energy Authority 2008	
	National Energy Policy	
Cook Islands	National Sustainable Development Plan (2007–2012)	
	Purchase Fuel Farms from Private Sector	
	Tax exemption for solar hot water systems	
	Net metering pilot	

continued on next page

Appendix 3.2: continued

Country	Intervention	Salient Features
Indonesia	Geothermal Law (2003)	
	National Energy Policy (2006)	• To decrease oil share in energy mix by increasing the share of coal, natural gas, and new and renewable energy (NRE); • To achieve energy elasticity to less than 1 in 2025 through energy conservation programs; • NRE share in energy mix is to be increased from less than 5% to at least 17% in 2025; • To establish energy pricing policy that reflects the economic value of energy.
	Bio-fuel Development Program (2006) [through a number of presidential/ ministerial decrees]	• To reduce fossil fuel dependency • Energy self-sufficient villages
	Energy Law 2007	
	National Master Plan of Energy Conservation 2005	
	Water and Energy Saving Instruction 2008	
	Government Regulation on Energy Efficiency (Draft)	• Obligation for large energy consumers to conduct energy audit and designate energy manager • Application of energy efficiency labeling for home appliances
	Accelerated Power Generation Capacity Addition Program 2007	• Addition of 10,000 MW coal power plants • Addition of 10,000 MW power plant preferably using renewable energy sources
Malaysia	Five Fuel Diversification Policy 2001	Acknowledges renewables as the fifth energy source in Malaysia besides oil, gas, hydropower, and coal. Set renewable share target of 5% of total electricity generation by 2005.

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Appendix 3.2: continued

Country	Intervention	Salient Features
	Small Renewable Energy Programs (2001)	Encourage and intensify the use of renewable energy in power generation (grid-based)
	Malaysian Building Integrated Photovoltaic project	• To improve significantly the overall technical and nontechnical capabilities of the government and private sectors to design, develop, and fully use building integrated technology, • To develop local building integrated services and manufacturing industries.
	National Biofuel Policy (2006)	Short-term objectives • Establish Malaysian standard specifications for B5 diesel • Selected government fleets will participate in trials for using B5 diesel Medium-term objectives • Establish Malaysian standard specifications for palm oil-based methyl ester biofuel for domestic use and export. • Encourage engine manufacturers to extend their warranties to the use of B5 diesel. • Mandatory use of biodiesel in transport. Long-term objectives • Gradual increase of biodiesel content in diesel blend. • Promotion of Malaysian biofuel technology to Malaysian companies and foreign companies abroad.
	Malaysian Industrial Energy Efficiency Improvement Program	**Target industries:** Cement, rubber, pulp and paper, iron and steel, and ceramics **Key components:** Energy use benchmarking; energy audits and rating, energy efficiency promotions; ESCO support; technology demonstration; local energy-efficient equipment manufacturing support and financial institution participation.

continued on next page

Appendix 3.2: continued

Country	Intervention	Salient Features
	Investment incentives and tax measures for energy efficiency and renewable energy	• Income tax exemption of 70% on statuary income for 5 years or • Investment Tax Allowance of 60% of capital expenditure incurred within 5 years and to be utilized against 70% of the statuary income; and • Import duty and sales tax exemption on machinery and equipment that are not produced locally. Sales tax exemptions are given for machinery and equipment that are produced locally. • Income tax exempt for revenue from certified emission reductions
	Malaysia Electricity Supply Industry Trust Account	The fund is contributed to by major power utility (each contributes 1% of their annual revenue). The fund is used to help government projects and studies on rural electrification, renewable energy, and energy efficiency.
	Renewable Energy Business Fund	To finance the full-scale biomass energy demonstration project that participates under the Biogen program. The fund could provide financing of up to 80% of the total project cost.
	Regional Energy Cooperation	• Malaysia–Thailand Joint Development Authority • ASEAN Power Grid Project with ASEAN neighbors. • Trans-ASEAN Gas Pipeline Project
Philippines	**Energy independence strategy**	• Increasing oil and gas exploration • Pursuing renewable energy • Expanding the use of natural gas • Developing fuel blends • Strengthening the Philippine National Oil Company

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Appendix 3.2: continued

Country	Intervention	Salient Features
	Biofuels Act (2007)	The mandate under the Bio-fuels Law to promote the use of alternative fuels for transport: • (B1) - Minimum of 1% of all diesel engine fuel displaced by biodiesel in 2007 • (B2) - Minimum of 2% blend of biodiesel by 2009 • (E5) - Minimum of 5% of all gasoline volume displaced by bio-ethanol by 2009 • (E10) - Minimum of 10% blend of bio-ethanol by 2011 • All biofuels to be blended with liquid fuels shall be sourced locally
	Renewable Energy Law (2008)	Special incentives • Income tax holiday for the first 7 years of operation • Duty-free importation of renewable energy machinery, equipment, and materials • Special realty tax rates on equipment and machinery • Net operating loss carryover • Corporate tax rate of only 10% • Accelerated depreciation • Zero percent value-added tax • Cash incentive of renewable energy developers for missionary electrification • Tax exemption for carbon credits • Tax credit on domestic capital equipment and services • Feed-in tariff • Net metering for renewable energy
	Energy Efficiency and Conservation Program	• Energy Efficiency Standards and Labeling Program • Government Energy Management Program (all government offices to reduce electricity and fuel consumption by 10%) • Demand-Side Management Program (electric distribution utilities are to influence the timing of their customers) • Energy Audit

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Appendix 3.2: continued

Country	Intervention	Salient Features
		• Efficient Lighting Market Transformation Project: (i) energy conserving design of buildings, (ii) efficient lighting, and (iii) roadway lighting guidelines • Promote efficient lighting–ban the incandescent bulb; comprehensively address mercury pollution; initiative to solve market failure in energy service companies by establishing the Super ESCO; undertake Switch Program (energy-saving program for Metro Manila to replace incandescent bulbs with compact fluorescent lights). • Establishment of Philippine Energy Services & Financing Company–A fully owned subsidiary of state-owned Philippine National Oil Company; to facilitate the development of a viable ESCO throughout the country. • Other programs–Conversion of transport bus into liquefied petroleum gas and compressed natural gas; conversion of tricycles to LPG; conversion of taxis to LPG
Singapore	Mandatory Energy Labelling Scheme 2008	All household refrigerators and air conditioners that are sold in Singapore must be energy-labeled
	Reducing Standby Power Consumption	Public information and encouragement to households to completely switch off appliances that are not in use
	Energy Smart Label	
	Building Control Regulations	
	Green Mark Buildings	
	Green Mark Incentive Scheme	
	The Energy Efficiency Improvement Assistance Scheme	Co-funds up to 50% of the cost of appraisals for buildings and individual facilities.

DAP = developing Asia and the Pacific, DSM = demand-side management, EE&C = energy efficiency and conservation, ESCO = energy service company, LPG = liquefied petroleum gas, MW = megawatt, R&D = research and development, RE = renewable energy.

Appendix 3.3 Energy Efficiency Improvement Program in the People's Republic of China

The People's Republic of China (PRC) plans to implement 10 key energy-saving projects during the 11th Five-Year Plan Period (2006–2010).

1. Transformation of coal-fired industrial boiler (kiln). This project will upgrade low-efficiency industrial boiler and establish regional center for processing and distributing coal used for boilers, eliminate old-technology industrial kilns, and conduct a comprehensive transformation of the existing industrial kilns.

2. Regional co-generation of heat and power. Facilities will be built for heating and industrial use; distribution heat and power cogeneration; heat, power, and cooling co-supply; and thermal power plants for demonstration of the comprehensive utilization of low-calorific value fuels and straw.

3. Utilization of residual heat and pressure. Equipment will be upgraded and built for purely power generation using low-temperature residual heat and pressure difference, with recovery and utilization of by-products, such as inflammable gases and low-calorific value gases.

4. Saving and replacing petroleum. The project will carry out the transformation for saving and replacing petroleum in electric power generation, petrochemicals, building materials, chemicals, transportation, and other industries. It will develop coal liquefied petroleum products, petroleum-replacing alcohol ether fuel, and biomass diesel.

5. Energy-saving electric motor. The project will upgrade low-efficient electric motors; adjust the speed of medium and large varying-duty electric motors, and transform the trailing device of electric motor to achieve energy savings.

6. Optimizing energy system. The project will overhaul the energy-use systems of the oil-refining, ethylene, synthetic ammonia, and steel enterprises.

7. Energy-saving buildings. New buildings will strictly follow 50% energy-saving standard except four municipalities directly under the central government and freezing areas in North PRC, where new buildings will follow 65% energy-saving standard. The PRC will establish low or super low energy-consuming buildings, implement the demonstration projects for the integration of renewable energies into residential and public buildings; and advance the industrialization of new walling materials and energy-saving materials.

8. Green lights project. The project will transform energy-saving lamp production lines, aiming to improve product quality, reduce production cost, and enhance innovation capability.

9. Saving energy in government institutions. Buildings will be upgraded for energy savings and comprehensive electric efficiency. The project will evaluate energy saving and supervision in new buildings. Purchase of energy-saving products by governments will be mandatory.

10. Energy-saving monitoring. The project will upgrade the instruments used in provincial-level energy-saving monitoring and organize the energy-saving auditing of key enterprises that consume large quantity of energy.

APPENDIX 4

Global Status of Renewable Energy Technologies: Characteristics and Costs

Technology	Typical Characteristics	Typical Energy Costs (US cents/kilowatt-hour)
Power Generation		
Large hydro	Plant size: 10 megawatts (MW)–18,000 MW	3–4
Small hydro	Plant size: 1–10 MW	4–7
On-shore wind	Turbine size: 1–3 MW	5–8
	Blade diameter: 60–100 meters	
Off-shore wind	Turbine size: 1.5–5 MW	8–12
	Blade diameter: 70–125 meters	
Biomass power	Plant size: 1–20 MW	5–12
Geothermal power	Plant size: 1–100 MW Type: binary, single- and double-flash, natural steam	4–7
Solar PV (module)	Cell type and efficiency: single-crystal 17%, polycrystalline 15%, amorphous silicon 10%, thin film 9–12%	
Rooftop solar PV	Peak capacity: 2–5 kilowatts-peak	20–80*
Concentrating solar thermal power (CSP)	Plant size: 50–500 MW (trough), 10–20 MW (tower); Types: trough, tower, dish	12–18[!]
Hot Water / Heating		
Biomass heat	Plant size: 1–20 MW	1–6
Solar hot water / heating	Size 2–5 m² (household); 20–200 m² (medium/multi-family); 0.5–2 MWth (large/district heating); Types: evacuated tube, flat-plate	2–20 (household) 1–15 (medium) 1–8 (large)
Geothermal heating / cooling	Plant capacity: 1–10 MW; Types: heat pumps, direct use, chillers	0.5–2
Biofuels		
Ethanol	Feedstock: sugarcane, sugar beet, corn, cassava, sorghum, wheat (and cellulose in the future)	25–30 cents/liter (sugar) 40–50 cents/liter (corn) (gasoline equivalent)
Biodiesel	Feedstock: soy, rapeseed, mustard seed, palm, jatropha, or waste vegetable oils	40–80 cents/liter (diesel equivalent)

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Appendix 4: continued

Technology	Typical Characteristics	Typical Energy Costs (US cents/kilowatt-hour)
Rural (off-grid) Energy		
Mini-hydro	Plant capacity: 100–1,000 kilowatts (kW)	5–10
Micro-hydro	Plant capacity: 1–100kW	7–20
Pico-hydro	Plant capacity: 0.1–1kW	20–40
Biogas digester	Digester size: 6–8 cubic meters	n/a
Biomass gasifier	Size: 20–5,000 kW	8–12
Small wind turbine	Turbine size: 3–100 kW	15–25
Household wind turbine	Turbine size: 0.1–3 kW	15–35
Village-scale mini-grid	System size: 10–1000 kW	25–100
Solar home system	System size: 20–100 watts	40–60

kW = kilowatt, MW = megawatt, m^2 = square meter, PV = photovoltaic, US = United States.

Note: Costs are economic costs, exclusive of subsidies or policy incentives. Typical energy costs are under the best conditions, including system design, siting, and resource availability. Optimal conditions can yield lower costs, and less favorable conditions can yield substantially higher costs. Costs of off-grid hybrid power systems employing renewables depend strongly on system size, location, and associated items, like diesel backup and battery storage. (*) Typical costs of 20–40 cents/kWh for low-latitudes with solar insolation of 2,500 kWh/m^2/year, 30–50 cents/kWh for 1,500 kWh/m^2/year (typical of Southern Europe) and 50–80 cents for 1,000 kWh/m^2/year (higher latitudes). Costs for trough plants; costs decrease as plant size increases.

Source: Renewables 2007 Global Status Report.

Improving Energy Security and Reducing Carbon Intensity in Asia and the Pacific

No segment of the world's economy will be more affected in the drive to reduce greenhouse gas emissions than energy and fuels. The energy sector study, carried out by The Energy and Resources Institute, reviews recent experience in end-use energy efficiency, new technologies, and practices for higher efficiency in fossil fuel energy production as well as ways to expand energy production from renewable sources. Implications for energy security are derived along with recommendations for financing, technology transfer, and associated policy and institutional reforms.

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