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Energy Trends in Developing Asia: Priorities for a Low-Carbon Future

September 2011

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ACRONYMS

ASEAN	Association of Southeast Asian Nations
ADB	Asian Development Bank
APCF	Asia-Pacific Carbon Fund
APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Center
AQ	air quality
BAU	business as usual
BNEP	Bloomberg New Energy Finance
BP	British Petroleum
Btoe	billion tons of oil equivalent
BTU	British thermal unit
CAI	Clean Air Initiative
CDM	Clean Development Mechanism
CERs	certified emissions reductions
CO_2	carbon dioxide
tCO_2	metric tons of carbon dioxide
$MtCO_2$	million metric tons of carbon dioxide
CPO	crude palm oil
DGNREEC	Directorate General of New-Renewable Energy and Energy Conservation (Indonesia)
DSM	demand-side management
ECO-Asia CDCP	Environmental Cooperation-Asia Clean Development and Climate Program
EE	energy efficiency
EEA	European Environment Agency
EECHI	Energy Efficiency and Conservation Clearing House Indonesia
EEFP	Energy Efficiency Financing Platform
EGAT	Energy Generating Authority of Thailand
EIA	United States Energy Information Administration
ESCO	energy service company
EU	European Union
FAO	United Nations Food and Agriculture Organization
FEEED	Framework for Energy Efficient Economic Development
GDP	gross domestic product
GHG	greenhouse gas
GW	gigawatt
GWe	gigawatt electrical
GWh	gigawatt-hour (equivalent to billion watt-hours)
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRG	International Resources Group
JI	Joint Implementation
kWh	kilowatt-hour (equivalent to thousand watt-hours)
LNG	liquefied natural gas
MEPS	minimum energy performance standards
MTEE	Market Transformation for Energy Efficiency

Mt	million tons (metric tons)
$MtCO_2e$	million tons (metric tons) carbon dioxide equivalent
Mtoe	million tons (metric tons) oil equivalent
MW	megawatt
MWh	megawatt-hour (equivalent to million watt-hours)
NAAQS	National Ambient Air Quality Standards
NASEO	National Association of Energy Officials (United States)
NDRC	National Development and Reform Commission (China)
NMEEE	National Mission on Energy Efficiency
NO_2	nitrogen dioxide
NOAA	United States National Oceanic and Atmospheric Administration
OECD	Organization for Economic Cooperation and Development
PAT	Perform, Achieve, and Trade
$PM_{2.5}$	particulate matter with aerodynamic diameters of 2.5 micrometers or less
PM_{10}	particulate matters with aerodynamic diameters of 10 micrometers or less
ppm	parts per million
PV	photovoltaic
RD&D	research, development, and deployment
RDMA	Regional Development Mission for Asia
RE	renewable energy
REN21	Renewable Energy for the 21st Century
SMEs	small and medium enterprises
SO_2	sulfur dioxide
SPP	small power producer
tCO_2e	tons of carbon dioxide equivalent
TERI	The Energy Resources Institute (India)
TOE	tons of oil equivalent
TW	terawatt
TWh	terawatt-hours (equivalent to trillion watt-hours)
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WEO	World Energy Outlook
WHO	World Health Organization

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EXECUTIVE SUMMARY

Introduction

Background and Objective of the Report

During the next 25 years, the direction that Asian countries take to meet their energy needs will have a profound impact on global climate change, energy security, local environmental conditions, human health, and the world economy. Five years ago, in its 2007 report, *From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change*, the US Agency for International Development Regional Development Mission for Asia (USAID/RDMA) examined the key trends and drivers affecting energy supply and demand in developing Asia.[1]

This report follows up on the 2007 report by examining the most recent data and trends related to primary energy supply, final energy demand, electricity generation and demand, greenhouse gas (GHG) emissions, and clean energy investment, as well as associated policies and targets. The objective of this report is to provide a thorough review of energy trends in developing Asia in order to understand: (1) the drivers of energy demand; (2) the impacts of increased energy demand on energy security and greenhouse gas emissions; and (3) the prospects for the scale-up of clean energy in developing Asia economies. The report also reviews and analyzes key trends and other relevant information on clean energy options in an effort to prioritize and rank energy efficiency sub-sectors and renewable energy resources in terms of their potential to deliver reductions in GHG emissions across Asia.

The report focuses primarily on Asia's six largest developing countries in terms of energy consumption – China, India, Indonesia, the Philippines, Thailand, and Vietnam – but the regional analysis also includes an additional six countries that are members of the Association of South East Asian Nations (ASEAN).[2] The report adopts a regional lens by analyzing and comparing trends in historical and projected energy demand, by fuel and by country, across developing Asia. The report is intended to serve as a resource for both the public and private sector, including policy-makers, business leaders, researchers, and advocates working in Asia to promote clean energy investments that address global climate change and development.

Data Sources

This report relies exclusively on information available in the public domain and collects, analyzes, and cites that information in order to provide the reader with a broad overview of trends in energy demand, GHG emissions, and clean energy in the Asia region. The report drafting team relied on data presented by the International Energy Agency (IEA) in its *World Energy Outlook 2010* and by the Asian Development Bank (ADB) in its *Energy Outlook for Asia and the Pacific 2010*. The data originate from the Asia-Pacific Energy Research Center (APERC), and in most cases are a combination of historical data for 1990 to 2008 with future projections from 2008 to 2030 based on the "Business-as-Usual" Scenario from IEA's *World Energy Outlook 2010*. Information on renewable energy is derived primarily from REN21,[3] a global policy network that prepares an annual status report on the renewable energy industry. Information on energy efficiency comes from a variety of sources, including a recent IEA survey on energy efficiency governance. Information on clean energy investment trends comes from the United Nations Environment

[1] USAID (2007). The report was commissioned by USAID to analyze regional energy trends and develop a set of clean energy priorities for its regional program, the Environmental Cooperation-Asia Clean Development and Climate Program.

[2] The additional countries include Brunei Darussalam, Cambodia, Laos, Malaysia, Singapore, and Burma.

[3] REN21 is the Renewable Energy Policy Network for the 21st Century.

Programme (UNEP) Sustainable Energy Finance Initiative, as well as from REN21.

Drivers of Energy Demand

Rising Incomes

Developing Asian economies currently use much less energy per capita compared to the United States or their industrialized Asian neighbors. On average, the six Asian focus countries in this report use about one-quarter as much energy per capita as Japan, Korea, and Taiwan, and about one-tenth as much energy per capita as the US. But this is rapidly changing, and energy demand in Asia will increase as incomes rise. With regard to electricity, for example, international comparisons show that for approximately every additional $10,000[4] in per capita annual income, daily per capita electricity consumption increases by about 1.6 kilowatt-hours (kWh). For example, under a "business-as-usual" scenario – without intensive national efforts to improve the efficiency of energy use – as incomes rise, the per capita electricity use of China, currently about 2 kWh/capita per day, will eventually increase to the current level of more industrialized nations such as Spain or Korea (around 4-6 kWh/capita per day) and then of nations such as France, Germany, and Australia (around 6-7 kWh/capita per day).[5]

Urbanization and Energy Consumption

One of the major drivers of energy use is urbanization, and the related growth of industrialization and transportation energy demand as incomes rise and cities grow. In recent years, urbanization[6] in developing Asia has increased at unprecedented levels, and it will continue increasing over the next 30 years. Currently, about half of the world's most populous cities are located in Asia. Six out of the 21 cities in the world with 10 million or more inhabitants are in China, India, and the Philippines. By 2030, more than half of the world's urban populations will live in Asian cities.[7]

As people begin to live and work in buildings, their energy consumption increases significantly. For example, day-to-day operational demands for lighting, air conditioning, heating, and appliances account for one-fourth of China's total energy use. Almost 75 percent of annual global office space construction is taking place in Asia,[8] which leads to great increases in energy use and emissions, as buildings are associated with 40 percent of global energy use. In fact, residential and commercial buildings in China use more energy than do the country's iron, steel, and cement industries combined.[9]

Impacts on Energy Security and GHG Emissions

Energy Security Concerns

Asia is increasingly reliant on imported fossil fuels, which will lead to energy insecurity and the potential for regional conflict. Over the past decade, oil imports have increased by 140 percent in Asia.[10] Overall, it is projected that the share of Asia's primary oil demand that will be met by imports will increase from 55 percent in 2009 to 68 percent in 2020 and 83 percent in 2030.[11] In 2008, Asia was a net exporter of natural gas. As regional demand for natural gas to fuel power-generating plants and some industrial and transportation uses increases, Asia's status as a net exporter will change rapidly.

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[4] All dollar ($) figures used in this report shall refer to US dollars unless otherwise indicated.

[5] In general, electricity demand is related and proportional to energy demand.

[6] Urbanization is defined by the United Nations as the increase in population living in areas classified as urban according to criteria used by each area or country. United Nations Population Division, *World Urbanization Prospects The 2009 Revision: Highlights*, p. 11. (United Nations: New York). Retrieved from http://esa.un.org/unpd/wup/Documents/WUP2009_Highlights_Final.pdf.

[7] Asia Business Council, http://events.cleantech.com/tianjin/sites/default/files/2-MarkClifford-SSTEC_Cleantech_Focus_2010.pdf.

[8] Vikas Vij. Asia Gearing Up For Green Building Construction Boom. *Just Means*. 24 March 2011. Retrieved from http://www.justmeans.com/Asia-Gearing-Up-for-Green-Building-Construction-Boom/47588.html.

[9] *Id.*

[10] NASEO (2010).

[11] IEA (2010B), Table 3.8, p. 135.

By 2030, it is projected that Asia will import 30 percent of its natural gas needs.

GHG Emissions and Climate Change

Atmospheric concentrations of carbon dioxide (CO_2) were 280 parts per million (ppm) during the pre-industrial era, but are now at 388 ppm and are rising about 2 ppm every year. This increase is directly related to increased combustion of fossil fuels (with land use change contributing about 17 percent of total emissions). As a result, continued warming of the global climate system is "unequivocal" according to the Intergovernmental Panel on Climate China (IPCC).[12] In order to stabilize atmospheric concentrations of GHGs and avoid more serious and potentially catastrophic impacts of global climate change, it is internationally agreed that the average global temperature rise cannot exceed 2 degrees Celsius. This translates to stabilizing GHGs at or below 450 ppm. Achieving this stabilization would require a decrease in total global emissions of 50-70 percent below 2005 levels by 2050.[13]

Trends in Energy Demand and GHG Emissions in Developing Asia

Energy Supply and Demand Trends

In 2010, for the first time, the energy demand in developing countries equaled demand in developed countries. Looking forward, more than 90 percent of the growth in global energy demand over the next 20 years will come from developing countries.

While developing Asia accounts for nearly 50 percent of the global population, it accounts for just over one-quarter (28 percent) of global primary energy demand, with more than half of this (17 percent of the global total) in China. By 2030, developing Asia's share of global energy demand is expected to rise to 38 percent.

[12] IPCC (2007).
[13] See Asian Development Bank, "ADB Climate Change Programs," http://www.adb.org/Documents/Brochures/Climate-Change/2010/adb-climate-change-programs-brochure.pdf#page=8 and IPCC (2007).

Asian economies are relatively more coal-intensive than the rest of the world, accounting for more than half (53 percent) of world coal consumption. This is significant because coal is a major contributor to local and regional pollution and also greenhouse gas emissions, since coal has the most CO_2 per unit of energy produced compared to other fossil fuels.

Overall, coal will remain the dominant fuel in Asia and is projected to supply 45 percent of energy in 2030, down from 54 percent in 2008. Oil use will rise due to increased motorization, and oil's share of primary energy will increase from 21 percent to 25 percent.

Electricity generation in Southeast Asia, China, and India will double by 2030, with increasing production from almost all energy sources. From 2008 to 2030, the production of electricity from coal will increase by 77%, three-fold from natural gas, 12-fold from nuclear, 50-fold from biomass, and 44 percent from hydroelectric power, while production from oil will decrease by 15 percent. While coal will continue to be the dominant fuel in the power sector, its share will decrease from 69 to 59 percent of total electricity generation.

With increasing international and Japanese domestic concern about nuclear power following the recent disaster at the Fukushima Daiichi nuclear plant in Japan, Japan is reconsidering the planned scale-up in electrical generation from nuclear power. There are currently 60 nuclear power plants planned for construction globally[14] – over half in Asia. Nuclear energy provides 1.9 percent of electricity production in China and 2.5 percent of electricity production in India, and nuclear plants are currently planned to be built in all six focus countries.

Asia's Contribution to GHG Emissions

In 2008, developing Asian economies accounted for one-third (33 percent) of global energy-related CO_2 emissions. By 2030, this share is expected to rise to 45 percent of the global total, and most of this (35

[14] For context, in 2009, there were 435 reactors operating globally. During the period of 2000 to 2009, on average there were about four to five old nuclear power plants being retired (taken off line) each year (Schneider 2009).

percent of the global total) will come from Southeast Asia, China, and India.

Over the next 20 years, CO_2 emissions in the six focus countries are expected to increase by 55 percent, from 8.7 billion metric tons of carbon dioxide equivalent (tCO_2e)[15] in 2008 to 13.5 billion tCO_2e in 2030. Two-thirds of these emissions – 9 billion metric tons annually – will be from China.

Based on their sheer size, China and India are the largest contributors to energy demand and greenhouse gas emissions in developing Asia. Together, they currently account for 86 percent of coal use and 81 percent of oil use in developing Asia. They also account for 91 percent of energy-related CO_2 emissions within developing Asia.

Prospects for the Scale-Up of Clean Energy in Developing Asia

Renewable Energy

Globally, renewable energy currently supplies about 18 percent of electricity generation, and most of this (15 percent of total global generation) is provided by hydropower. Other non-hydro renewable energy sources accounted for 3 percent of global electricity production in 2008. As of 2009, the major players in renewable energy power capacity included the United States, Europe, China, and India. Overall, developing countries currently account for more than one-third of renewable generating capacity if hydropower is excluded, and half of renewable generating capacity if hydropower is included, with most of this capacity in China and India.

While renewable energy sources have a long way to go to outpace fossil fuel energy in terms of total electricity production, the rate at which new renewable energy capacity is being added will soon eclipse the new capacity of fossil-fuel power generation. Between 2008 and 2009, newly added renewable power capacity constituted nearly half (47 percent) of total new power capacity worldwide.

Recent trends reflect the increasing significance of developing Asia in advancing renewable energy. Non-OECD Asia, led by China and India, has the fastest projected growth in renewable electric power generation worldwide.[16] Electricity generation from renewable energy sources in developing Asia is projected to grow at an average annual rate of 5 percent, which would increase the renewable share of the region's total generation from 15 percent in 2007 to 20 percent in 2035.

Within developing Asia, many countries have set targets for increasing renewable energy shares in the overall national energy mix, and the goals vary widely. These include short-term and medium-term targets, as well as targets for individual sources of renewable energy, such as solar, where applicable. Overall, China and Thailand have the most aggressive targets for increasing the percentage of energy generation from renewable sources.

Clean Energy Investment

In its *World Energy Outlook (WEO) 2010*, the IEA presents a "450 ppm" scenario that will keep atmospheric CO_2 concentrations from rising beyond 450 parts per million (ppm), in order to limit the average global temperature rise to 2 degrees Celsius. To achieve the GHG emissions cuts called for in the 450 ppm scenario, the IEA estimates that *additional global investment will be needed in the range of $13.5 to $18 trillion, or $540 billion to $720 billion annually at a global level.*[17] Investment needs for energy infrastructure in Asia over the next 25 years will average $400 billion, with three-quarters of this investment for the power sector.

Global investment in clean energy quadrupled from 2004 to 2008, reaching $159 billion. The investment continued to rise to $160 billion in 2009 and $211 billion in 2010.

[15] The term tCO_2e reflects metric tons throughout this report, unless otherwise indicated.

[16] EIA, http://www.eia.doe.gov/oiaf/ieo/electricity.html.

[17] IEA (2010B, pp. 379, 401. The *WEO 2010* report does not provide a detailed table with breakdowns of the incremental investment by country or sector.

For the first time, in 2010 Asia and the Pacific had the largest share of global investment in clean energy, at $59 billion. China and India account for nearly 90 percent of this investment.

Energy Efficiency (EE) Investment

The role of energy efficiency investment is often hidden or obscured in the discussion of overall investment in clean energy. In fact, there is a large disconnect between the potential of energy efficiency and its actual implementation. For example, the projections in the *World Energy Outlook* noted above indicate that 57 percent of future GHG emissions reductions needed by 2030 to limit the increase in global temperature to 2 degrees Celsius (the 450 Scenario) will be achieved through energy efficiency measures. The reality, however, is that the amount of investment going into energy efficiency is a small fraction of what is needed to realize this potential.

Because of the dispersed nature of energy efficiency investments, it is difficult to assess the potential for investment in energy efficiency across the Asia region. However, two recent studies show the scale of potential for energy efficiency investment.

The amount of energy efficiency investment needed in China has been estimated at $432 billion by 2020, or $43 billion annually, based on achieving the aggressive government energy savings rates of 4.4 percent per year during the period 2010 to 2020.[18]

An assessment for India found a potential for energy efficiency investment over five years of $60 billion, or $12 billion annually. The main areas identified were agricultural pumping, municipal pumping, street lighting, commercial buildings, and small and medium enterprises (SMEs).

Energy Efficiency Must Be the Top Priority

This report concludes by comparing and prioritizing clean energy measures in terms of their cost-effective potential to mitigate GHG emissions. It includes a review of cost curves representing the cost and GHG abatement potential of more than 152 different clean energy technology options and measures. Based on the review, the report presents a simplified ranking system that provides an "at a glance" view of which clean energy options are most cost-effective and have the highest potential for reducing greenhouse gas emissions.

Energy efficiency measures ranked highest, as they require less investment to achieve the same amount of energy savings as would investment in other options such as wind, solar, and carbon capture and storage. The top six priority clean energy options are all energy-efficiency measures: efficient lighting, efficient residential appliances and equipment, residential building efficiency, commercial building efficiency, motor-systems efficiency, and light-vehicle efficiency.

According to *World Energy Outlook*, energy efficiency measures can cost-effectively provide from 57 to 65 percent of the greenhouse gas emissions reductions needed to achieve climate stabilization. However, the current amount of investment in, and deployment of, energy efficiency is a fraction of the hundreds of billions of dollars needed annually to achieve the GHG emissions reductions needed to stabilize the global climate. The clear conclusion from this is that there is a lack of capacity in the region to plan, design, and finance energy efficiency on a scale commensurate with the urgency of the risks posed by energy insecurity and climate change.

[18] Yongchun WANG, Managing Director, GoodHope Capital. Presentation at China Energy Conservation Investment Forum. Beijing. June 24-25, 2011. The target is set in China's Mid-to-Long Term Special Energy Conservation Plan promulgated by the National Development Reform Commission.

SECTION 1. INTRODUCTION

1.1 Background

During the next 25 years, the direction that Asian countries take to meet their energy needs will have a profound impact on global climate change, energy security, environmental and human health, and the world economy. Five years ago, in its 2007 report, *From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change*, the US Agency for International Development Regional Development Mission for Asia (USAID/RDMA) examined the key trends and drivers affecting energy supply and demand in developing Asia.[19] This report follows up on the 2007 report by examining the most recent data and trends related to primary and final energy demand, electricity generation and demand, greenhouse gas emissions, and potential for scaling up energy efficiency and renewable energy.

The report also reviews and analyzes information on the prioritization of clean energy options in an effort to prioritize and rank energy efficiency sub-sectors and renewable energy resources in terms of their potential to deliver reductions in greenhouse gas emissions across Asia.

The report focuses primarily on Asia's six largest energy consuming developing countries – China, India, Indonesia, the Philippines, Thailand, and Vietnam[20] – but the regional analyses also include an additional six countries in the Association of South East Asian Nations (ASEAN).[21] The report adopts a regional lens by analyzing and comparing trends in historical and projected energy demand, by fuel and by country, across developing Asia.

This report was prepared by the USAID/RDMA-supported Environmental Cooperation-Asia Clean Development and Climate Program (ECO-Asia CDCP) and is intended to serve as a resource for both the public and private sector, including policy-makers, business leaders, researchers, and advocates working in Asia to promote clean energy investments that address global climate change and development.

1.2 Structure of the Report

This report is divided into two parts, with sections covering a number of aspects of the energy sector in Asia, as well as energy security, climate change impacts, and investment potential.

Part 1 describes the drivers of Asia's growing energy demand and then provides data on historical and projected trends for primary energy demand, electricity generation, and greenhouse gas (GHG) emissions. This is followed by a section analyzing trends in the intensity of energy consumption and greenhouse gas emissions.

Part 2 describes the possibilities and priorities for a clean energy future, with sections on energy efficiency (EE), renewable energy (RE), the importance of policy and regulation, and trends in clean energy investment. It concludes with a section prioritizing clean energy options, and a set of conclusions.

[19] USAID (2007). The term "developing Asia" includes China, India, and all other non-OECD Asian countries. The 2007 report looked at the six focus countries of ECO-Asia CDCP (China, India, Indonesia, the Philippines, Thailand, and Vietnam), which account for 76 percent of the GDP of developing Asia.
[20] These six countries were chosen because they are the focus countries of the USAID ECO-Asia CDCP program.
[21] The additional six countries include Brunei, Cambodia, Laos, Malaysia, Burma, and Singapore. Data from these countries are included in the regional dataset of trends in primary energy demand, final energy demand, and greenhouse gas emissions. Together, the 12 countries account for 82 percent of the GDP of developing Asia.

Table 1. Indicators at a Glance for Developing Asia and the World (2008)

Indicators	Southeast Asia,[22] China, and India[23]	World	Developing Asia as a % of world total
Demographics			
Population (millions)	3,033	6,688	45%
GDP (billion constant 2000 US dollars)	4,329	40,482	11%
GDP/Capita (thousand constant 2000 US dollars per person)	1.42	6	24%
Energy			
Total Primary Energy Supply (million tons of oil equivalent, or Mtoe)	3,292	12,271	27%
Coal	1,749	3,315	53%
Oil	698	4,059	17%
Gas	222	2,596	8.6%
Nuclear	22	712	3.1%
Hydro	66	276	24%
Biomass, Waste and Others	490	1,314	37%
Primary Energy Demand Per Capita (tons of oil equivalent, or TOE/person)	1.09	1.83	60%
Primary Energy Demand Per GDP (TOE/constant 2000 $)	760	303	250%
Electricity			
Electricity Generation (TWh)	4,990	20,183	25%
Coal	3,452	8,273	42%
Oil	119	1,104	11%
Gas	413	4,303	9.6%
Nuclear	83	2,731	3.0%
Hydro	910	3,208	28%
Biomass Waste and Others	14	565	2.5%
Electricity Generation Per Capita (kWh/population)	1,602	3,017	53%
Electricity Generation Per GDP (TWh/billion constant 2000 US dollars)	1.12	0.49	230%
CO_2 Emissions			
Total CO_2 Emissions (Mt)	8,974	29,260	31%
CO_2 Emission/Capita (tCO_2/capita)	2.96	4.37	68%
CO_2 Emissions/GDP (tCO_2/million constant 2000$)	2,073	722	290%

Source: IEA website: http://iea.org/country/index_nmc.asp.

[22] The countries included in Southeast Asia are: Brunei, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam, and Burma.
[23] Southeast Asia, China, and India, which together comprise 82% of the GDP of all developing Asia.

1.3 Report Methodology and Data Sources

In order to accurately describe, compare, and contrast trends in energy consumption and greenhouse gas emissions, the project team reviewed a number of references, including the International Energy Agency (IEA), the Asian Development Bank (ADB), the Asia Pacific Energy Research Center (APERC), and the World Bank.[24] It was essential to develop a common data set for comparison of these trends across the region, by country, by sector, and by fuel type.

The project team relied on data presented by IEA in its *World Energy Outlook (WEO) 2010*, and by ADB in its *Energy Outlook for Asia and the Pacific 2010*. The data originate from the Asia-Pacific Energy Research Center, and the data presented are in most cases a combination of historical data for 1990 to 2008 with future projections from 2008 to 2030 based on the "Business as Usual" Scenario from IEA's *World Energy Outlook 2010*. Information on renewable energy is derived primarily from REN21 (Renewable Energy for the 21st Century), a global policy network that prepares an annual status report on the renewable energy industry. Information on energy efficiency comes from a variety of sources, including a recent IEA survey on energy efficiency governance. Information on clean energy investment trends comes from the United Nations Environment Programme (UNEP) Sustainable Energy Finance Initiative, as well as from REN21. The methodology for reviewing and selecting the data for analysis is described in Attachment B at the end of this report.

1.4 How Developing Asia Compares to the World

Table 1 compares developing Asia[25] to the world according to a number of key demographic, energy, and greenhouse gas indicators. Key points include that:

- Developing Asia accounts for 45 percent of the global population.
- Gross Domestic Product (GDP) per capita for developing Asia is 24 percent of the global average.

With regard to energy consumption, developing Asia accounts for:

- 27 percent of global primary energy demand
- 53 percent of world coal consumption
- 31 percent of global energy-related CO_2 emissions.

Energy intensity in developing Asia is much lower per person than the global average, but much higher per unit of economic output:

- Primary energy demand per capita is 60 percent of the global average
- Primary energy demand per unit GDP is 2.5 times the global average.

CO_2 emissions in developing Asia are also much lower per person than the global average, but much higher per unit of economic output:

- CO_2 emissions per capita are 68 percent of the global average
- CO_2 emissions per unit of GDP are 2.9 times the global average.

1.5 Comparison of the Six Asian Focus Countries

Table 2 shows the main demographic indicators for the six focus countries in this report. Together, these six countries comprise 76 percent of all the

[24] A complete list of references is shown in the References section at the end of the report.

[25] Within the scope of the study, it was not possible to get a comprehensive data set with historical trends, future projections, and breakdowns by fuel type for energy and CO_2 for all developing countries in Asia. Wherever possible, the report presents data from a data set that comprises Southeast Asia, China, and India, which together comprise 82% of the GDP of all developing Asia. Attachment B shows a breakdown of the GDP for Asian countries.

GDP in Asia. China and India account for nearly 84 percent of the population and more than 85 percent of GDP of the six countries analyzed. Of the six countries, Thailand has the highest per capita GDP, at $2,600, followed by $1,960 for China, $1,200 for the Philippines, $1,100 for Indonesia, $700 for India, and $600 for Vietnam.[26]

Table 2. Indicators at a Glance for the Six Focus Countries (2008)

Indicators	China	India	Indonesia	Philippines	Thailand	Vietnam	Total
Demographics							
Population (millions)	1,326	1,140	228	90	67	86	2,937
Population (% of the six-country total)	45.1%	38.8%	7.8%	3.1%	2.3%	2.9%	100.0%
GDP (billion constant 2000 US dollars)	2602.6	825.8	247.2	110.7	178.3	55.7	4,020
GDP (as % of the six-country total)	64.7%	20.5%	6.1%	2.8%	4.4%	1.4%	100.0%
GDP/capita (thousand constant 2000 $/person)	1.96	0.7	1.1	1.2	2.6	0.6	NA

Sources: IEA website: http://iea.org/country/index_nmc.asp.

[26] Based on 2008 data.

PART 1: ENERGY TRENDS IN DEVELOPING ASIA

SECTION 2. ASIA'S GROWING ENERGY DEMAND IN CONTEXT

Key Points

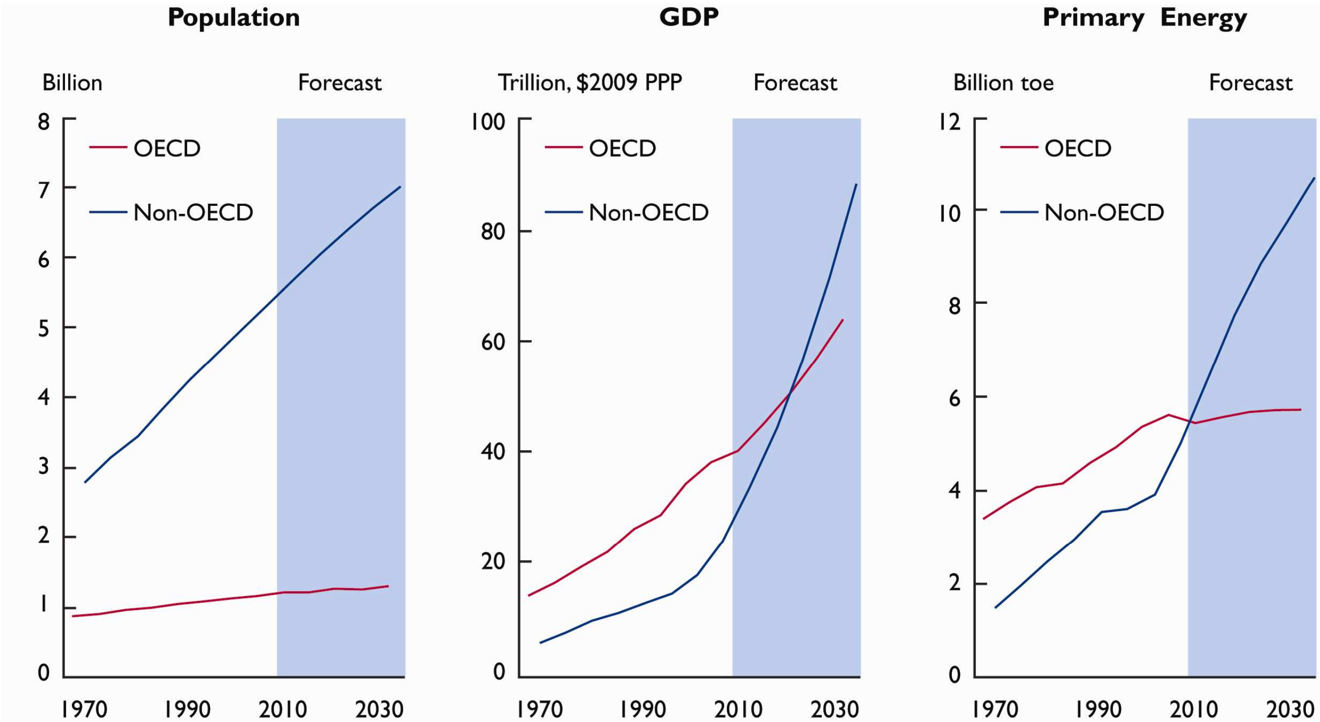
- In 2010, for the first time, the total primary energy demand in developing countries equaled demand in developed countries.
- One of the major drivers of energy use in Asia is urbanization. By 2030, more than half of the world's urban populations will live in Asian cities. Almost 75 percent of total annual global office space construction is taking place in Asia.
- As Asian economies continue to grow rapidly during the next 10 to 20 years, it is expected that per capita energy use will substantially increase. Some countries will even reach the current levels of industrialized nations.
- The rapidly increasing trade in fossil fuels is leading to increasing concern among Asia's energy policymakers about energy security. The share of Asia's primary oil demand that will be met by imports will increase from 55 percent in 2009 to 68 percent in 2020 and 83 percent in 2030.
- Increasing emissions from burning fossil fuels will exacerbate climate change, and the damage to agriculture and coastlines in Southeast Asia alone would cost 1.9 percent of the region's GDP by 2100, compared to a projected adaptation cost of 0.2 percent of GDP.
- Fossil fuel emissions adversely impact air quality, and urban air pollution is linked to more than 2 million deaths worldwide each year. In Asian cities, levels of small particulate pollutants (PM_{10}) are far above acceptable international standards; reducing emissions will also benefit human health.

2.1 Trends and Drivers of Energy Demand

Global energy demand continues to increase due to the impact of ongoing increases in population, increases in personal wealth (as reflected in GDP per capita), and increasing urbanization throughout the developing world.

Figure 1 shows the differences between industrialized countries (members of the Organization for Economic Cooperation and Development, or OECD) and developing (non-OECD) countries in terms of the forces driving increased energy demand. The chart at left in Figure 1shows that over the next 20 years, the population in industrialized countries will increase marginally, to slightly more than 1 billion, while the population in developing countries will increase substantially, from 5 billion to 7 billion people. This increase in population drives increases in energy demand, which is also increasing due to per capita increases in wealth (center chart).

Figure 1. Trends in Population, GDP, and Energy Demand in Industrialized and Developing Countries Worldwide



Source: BP Energy Outlook (2010)

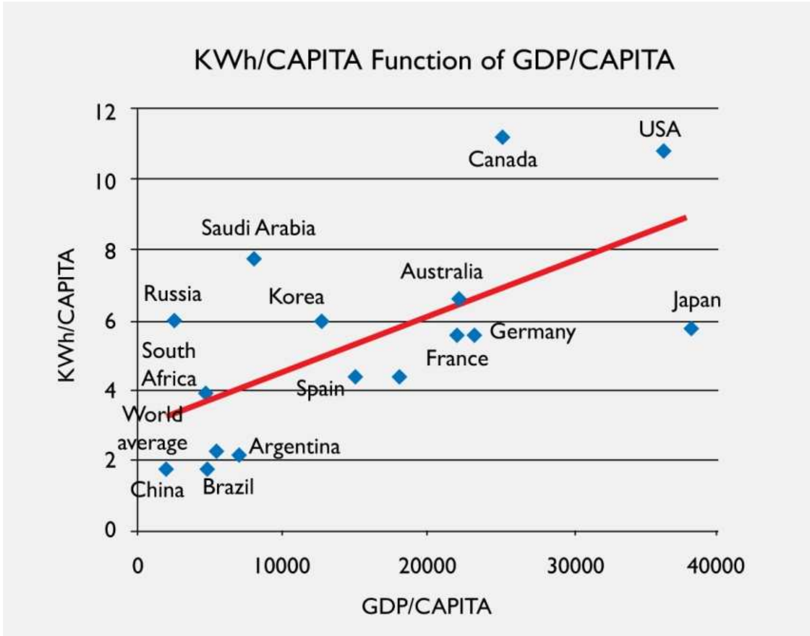
The chart at right in Figure 1 shows that *in 2010, for the first time, the total primary energy demand in developing countries equaled demand in developed countries,* at slightly less than 6 billion tons of oil equivalent (Btoe). Over the next 20 years, energy demand in industrialized countries is projected to stay relatively constant, while energy demand in developed countries is expected to increase by 80 percent, to nearly 11 Btoe, with most of that demand growth occurring in Asia.

Per Capita Income and Energy Demand

Figure 2 shows the relationship that is driving energy demand in Asia. The chart demonstrates the relationship between per capita income and per capita energy use for 15 countries, ranging from China, which has per capita income of about $2,000 per year, to the US and Japan, which both have per capita incomes of nearly $40,000 per year. At any level of per capita income, there is a substantial amount of variation. For example, US per capita electricity use is nearly twice as high as that of Japan, even with approximately the same per capita income levels. Overall, the chart shows the upward trend of per capita electricity use that economies take on as their per capita incomes rise. The best-fit line shows that for approximately every additional $10,000 in per capita annual income, daily per capita electricity consumption increases by about 1.6 kWh.

The relevance for Asia is that as the per capita incomes of developing Asian economies increase there will be corresponding increases in per capita energy use. For example, under a "business-as-usual" (BAU) scenario – without intensive national efforts to improve the efficiency of energy use – as incomes rise, the per capita electricity use of China, which is currently at about 2 kWh per capita per day, would increase to reach the current level of more industrialized nations such as Spain or Korea (around 4-6 kWh per capita per day) and then of

Figure 2. How Per Capita Income Drives Electricity Demand



Source: IEA (2006) pp. 48-57.

nations like France, and Germany (around 6 kWh/capita per day).[27]

The reason for this relationship is fairly straightforward: as incomes rise, people use the increased disposable income to purchase consumer goods, which include more energy-intensive appliances and equipment for the home that provide amenity and improve the quality of their life. The typical progression of appliance ownership includes lamps for lighting, radios, televisions, water boilers, refrigerators, water heaters, and air conditioners.

As Asian economies develop, the challenge is to put in place policies and measures that help countries develop along a more efficient pathway, so that their trajectories are below the line (which represents an average of current global practice), instead of on or above the line.

[27] In general, electricity demand is related and proportional to energy demand.

Urbanization and Energy Consumption

One of the major drivers of energy use is urbanization. In recent years, urbanization[28] in developing Asia has increased at unprecedented levels, and it will continue increasing over the next 30 years. In China, for instance, the annual rate of growth in urban populations from 2000 to 2005 was 4.2 percent, and urban populations are projected to increase at an annual rate of between 0.8 percent and 2.3 percent over the next 30 years.[29]

Currently, about half of the world's most populous cities are located in Asia. Six out of the 21 cities in the world with 10 million or more inhabitants are in China, India, and the Philippines. In addition, China

[28] Urbanization is defined by the United Nations as the increase in population living in areas classified as urban according to criteria used by each area or country. United Nations Population Division, *World Urbanization Prospects The 2009 Revision: Highlights*, p. 11 (United Nations: New York). Retrieved from http://esa.un.org/unpd/wup/Documents/WUP2009_Highlights_Final.pdf.

[29] United Nations Department of Economic and Social Affairs, http://esa.un.org/unpd/wup/unup/index_panel3.html.

and India each have an estimated 59 and 43 cities, respectively, with populations greater than 1 million.[30] By 2030, more than half of the world's urban populations will live in Asian cities.[31]

In developing Asia, urbanization is synonymous with development, as energy grids are being extended and new buildings are being constructed to accommodate the increasing populations in cities. As more people begin to live and work in buildings, they become larger energy "consumers" – for instance, day-to-day building operational demands for lighting, air conditioning, heating, and appliances account for one-fourth of China's total energy use.

Additionally, almost 75 percent of total annual global office space construction is taking place in Asia,[32] which leads to great increases in energy use and emissions, as building construction and operations combined account for 40 percent of global energy use. In fact, residential and commercial buildings in China use more energy than do the country's iron, steel, and cement industries combined.[33]

If urban dwellers continue with BAU practices, using three times the energy of rural dwellers, developing Asian cities will face increasing challenges of maintaining enough power supply to meet growing demands. Effective implementation of policies promoting energy efficiency and intelligent building systems is therefore critical to Asia's long-term sustainable development.

2.2 Impacts of Increased Energy Consumption

Like the rest of the world, the majority of Asia's energy comes from fossil fuels, and this poses numerous challenges in terms of the economy, the environment, global climate change, and energy security. Two of the main challenges that Asian energy policymakers face are energy security and climate change. Air pollution from mobile and stationary sources of fossil fuel combustion (e.g., cars and power plants, respectively) also has significant public health and environmental impacts.

Energy Security and Oil Import Dependency

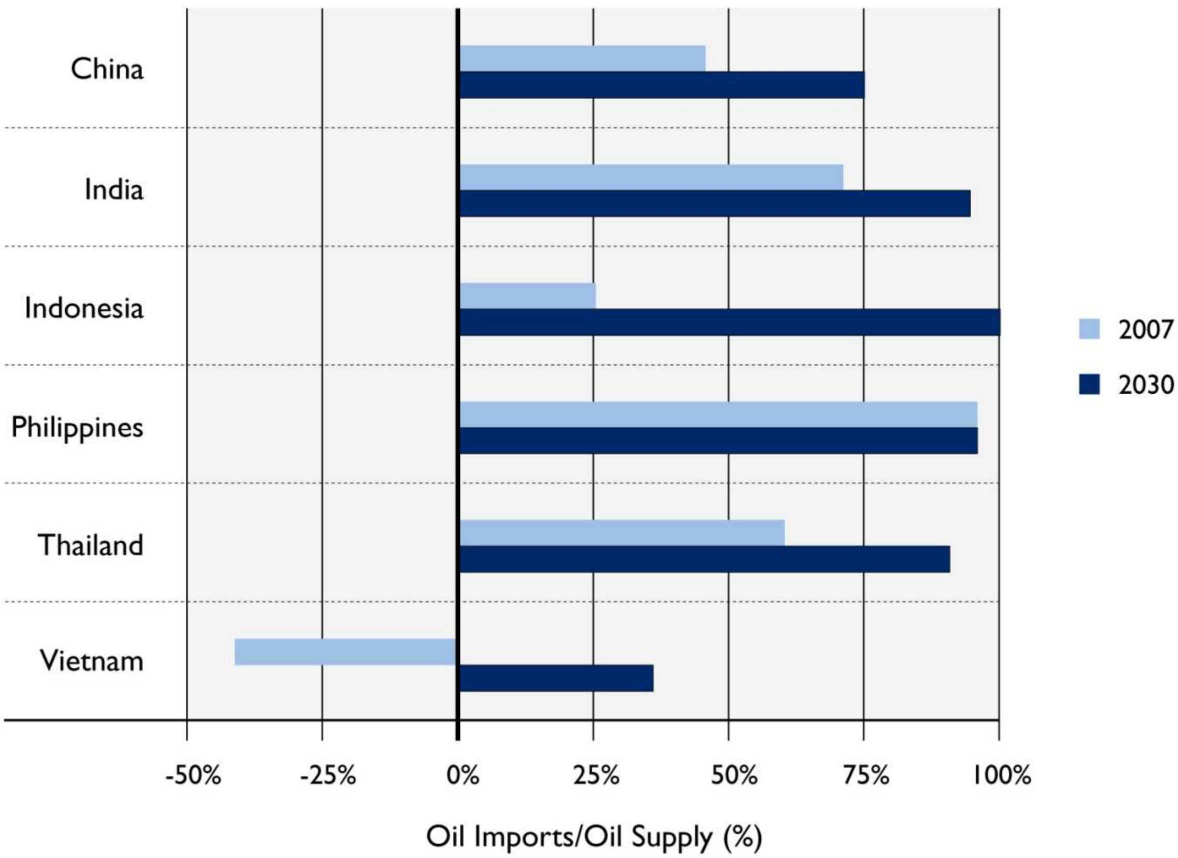
The growing reliance on the energy trade, both globally and in Asia, has significant energy security implications. Some countries, as the result of both their energy needs and the presence of few or no accessible fossil fuel sources within their borders, will be relying on ever-larger shares of imported fuel to meet national demand. In order to maintain economic progress, developing Asia must maintain energy security; yet Asia's growing dependence on imported forms of energy (not only oil, but also gas and coal) poses a significant risk to energy security.

Over the past decade, oil imports have increased by 140 percent in Asia.[34] In Southeast Asia, during the past decade, Indonesia and Malaysia have shifted from being net oil-exporting countries to net oil importers, and Indonesia officially suspended its membership in OPEC in January 2009. Vietnam is expected to become a net oil importer by 2015.[35] By 2030, Southeast Asia will import 90 percent of the oil it consumes, and more than half of this will come from the Middle East.[36]

Figure 3 shows how oil import dependency will grow between 2007 and 2030 for the six focus countries. China will increase its net imports from just under 50 percent in 2007 to 75 percent in 2030; India will increase from just under 75 percent in 2007 to 94 percent in 2030; Indonesia will increase from 30 percent in 2007 to 100 percent in 2030; the Philippines will maintain its current level of import dependency, at about 95 percent; and Thailand will increase its net imports from 60 percent in 2007 to 85 percent in 2030. Vietnam will

30 See http://en.wikipedia.org/wiki/List_of_cities_in_the_People%27s_Republic_of_China_by_population and http://en.wikipedia.org/wiki/List_of_most_populous_cities_in_India.
31 Asia Business Council, http://events.cleantech.com/tianjin/sites/default/files/2-MarkClifford-SSTEC_Cleantech_Focus_2010.pdf.
32 BCG 2009.
33 *Id.*
34 NASEO (2010).
35 The Institute of Energy Economics, Japan, "Energy Sector Situation in Vietnam," available at http://eneken.ieej.or.jp/data/2558.pdf.
36 NASEO (2010).

Figure 3. Trends in Oil Import Dependency in the Six Focus Countries



Sources: Data for China, Indonesia, Philippines, Thailand, and Vietnam are from US Energy Information Administration web site: http://www.eia.doe.gov/countries/cab.cfm?fips=IN. Data for India from Rehman (2008) and TERI (2010).

transition from a net oil *exporting* country to eventually importing a net of more than 30 percent of its oil by 2030.

Overall, the share of Asia's primary oil demand that will be met by imports will increase from 55 percent in 2009 to 68 percent in 2020 and 83 percent in 2030.[37] This increasing reliance on imports from developing Asian economies will put increasing strain on the sources of global supply, leading to an increase in energy security problems and related geopolitical tensions.

The net reliance on imported coal for the region as a whole will not be as significant as for oil. The share of Asia's primary hard-coal demand that will be met by imports will increase only slightly, from 2 percent in 2009 to 6 percent in 2030. India's net imports of coal will increase more than five-fold, from 52 Mtoe in 2008 to 281 Mtoe in 2030, accounting for 37 percent of its primary hard-coal demand. Although its net coal imports will be small, China will increasingly rely on imported coal to power coal-generating plants in the urban and industrial centers in its eastern coastal area. Indonesia will remain a significant net exporter of coal, exporting more than twice as much coal as it uses domestically.[38]

In 2008, the Asia region as a whole was a net exporter of natural gas. But this situation will change rapidly, as natural gas is becoming a fuel of choice as a cleaner fossil fuel for power generation, industry, and in some cases transportation. By 2030,

[37] IEA (2010B), Table 3.8, p. 135.

[38] IEA (2010B), Table 6.4, p. 212.

it is projected that 30 percent of the natural gas used in Asia will be imported. For China, imports will account for 53 percent of domestic natural gas demand in 2030. For India, the import share will be 43 percent in 2030.[39]

Greenhouse Gases and Climate Change

Warming of the climate system has led to a shift in many physical and biological systems such as melting ice caps, rising sea levels, ocean acidification, and increased precipitation in some parts of the world alongside decreased precipitation in other parts of the world, earlier spring timing events, and shifts in animal and plant ranges. Most of the observed increase in global average temperatures is unequivocally due to the observed increase in anthropogenic greenhouse gas (GHG) concentrations.[40]

Carbon dioxide (CO_2), a natural product of fossil-fuel combustion and the most significant GHG by volume, is a GHG in that it absorbs significant amounts of infrared radiation, gradually leading to an increase in global temperatures. Atmospheric concentrations of CO_2 were 280 ppm during the pre-industrial era, but are now at 388 ppm and are rising about 2 ppm every year.[41] The primary driver of this is consumption of fossil fuels. Between 1751 and 2010, approximately 337 billion metric tons of carbon emissions were released into the atmosphere from the consumption of fossil fuels and cement production. Half of these emissions have occurred since the mid-1970s.[42] (Significant additional emissions also result from land use change.)

In order to stabilize atmospheric concentrations of GHGs and avoid more serious and potentially catastrophic impacts of global climate change, the international community has agreed that average global temperature rise should not exceed 2 degrees Celsius. This translates to stabilizing GHGs at or below 450 ppm, which would require a decrease in emissions of 50 to 70 percent below 2005 levels by 2050.[43]

Economically speaking, inaction in addressing the growth of GHG emissions, and thus needing to cope with the impacts of climate change, will cost more than taking action now to mitigate climate change by implementing emissions reductions measures. The well-known Stern Review suggests that implementation of policies to stabilize GHGs below 450 ppm would cost only 1 percent of global GDP, but that inaction could lead to damages equivalent in the long-term up to a 20 percent reduction in global GDP.[44]

Southeast Asia could face damage to its agriculture and to the coastal zones of Vietnam, Thailand, Indonesia, and the Philippines, amounting to 1.9 percent of GDP by 2100, as compared to the adaptation cost of 0.2 percent of GDP.[45] The region is already geographically prone to weather-related natural disasters and climate change is expected to amplify these disasters.

Air Quality Impacts Due to Fossil Fuel Combustion

Combustion of fossil fuels, especially coal, releases into the atmosphere large quantities of noxious gases (e.g., nitrogen dioxide, sulfur dioxide), particulate material (particles less than 10 micrometers that can penetrate the deepest part of the lungs), and toxic or otherwise dangerous materials (mercury, other heavy metals, radioactive particles). These pollutants have local and regional impacts on health, the economy, and the environment. Adverse health effects include heart disease, lung cancer, and premature death. The

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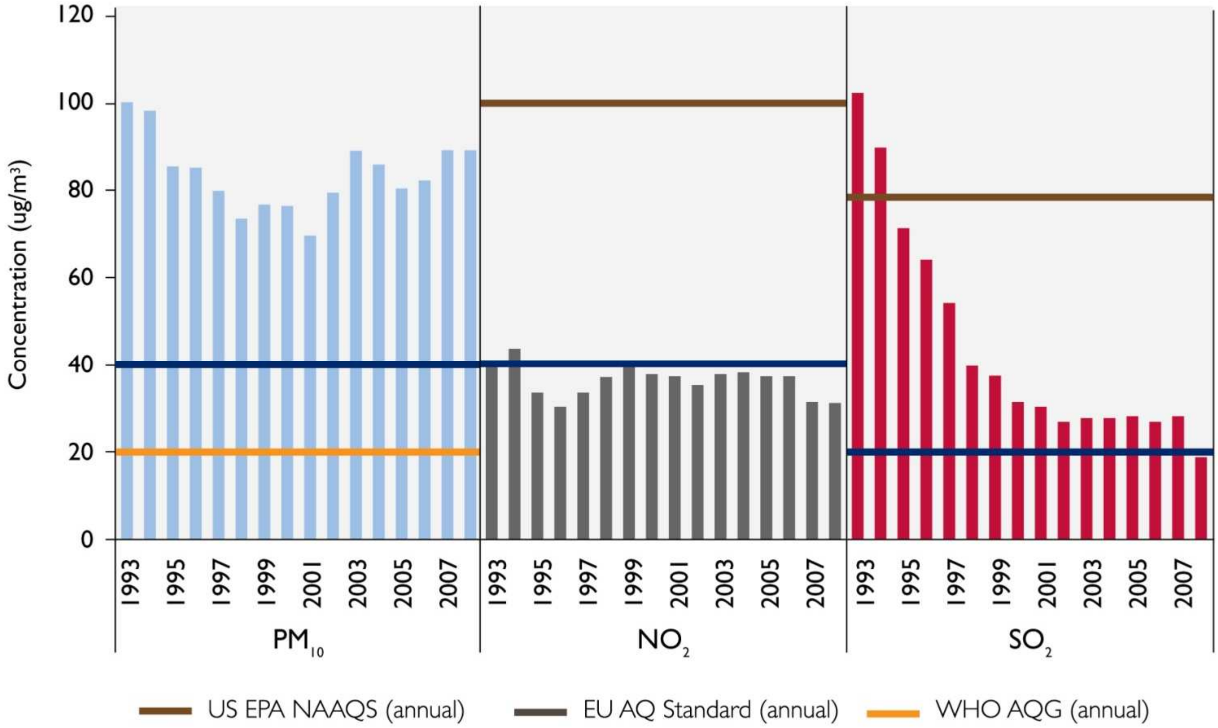
39 IEA (2010B), Table 5.5, p. 193.
40 IPCC (2007).
41 See www.350.org/en/about/science.
42 Boden et al. (2010).
43 See Asian Development Bank, "ADB Climate Change Programs," http://www.adb.org/Documents/Brochures/Climate-Change/2010/adb-climate-change-programs-brochure.pdf#page=8 and IPCC (2007).
44 Stern, N. (2006). "Summary of Conclusions" (PDF). *Executive summary (short)*. Stern Review Report on the Economics of Climate Change (pre-publication edition). HM Treasury. http://www.hm-treasury.gov.uk/d/CLOSED_SHORT_executive_summary.pdf. Retrieved 2011-07-13.
45 Asian Development Bank, "ADB Climate Change Programs," http://www.adb.org/Documents/Brochures/Climate-Change/2010/adb-climate-change-programs-brochure.pdf#page=8.

Figure 4. Annual Average Ambient Air Quality Levels in Selected Asian Cities (1993-2008)



Source: Clean Air Initiative-Asia (2010)[48]

Notes: AQ = air quality; μg/m3 = micrograms per cubic meter; US EPA = United States Environmental Protection Agency; NAAQS = National Ambient Air Quality Standards; EU = European Union; WHO = World Health Organization; AQG = air quality guidelines; PM10 = particles with aerodynamic diameters of 10 micrometers or less; NO2 = nitrogen dioxide; SO2 – sulfur dioxide.

economic losses resulting from health costs and productivity losses are equivalent to between 2 and 4 percent of GDP of Asian cities.[46]

Urban air pollution is linked to more than 2 million deaths worldwide each year, with 90 percent of air pollution in cities attributable to vehicle emissions.[47]

In developing Asia, countries have designed and are implementing clean air programs, but air pollution from particulate matter (PM_{10}), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) remain chronic problems. Figure 4 shows the annual average air quality statistics in Asian cities for PM_{10}, NO_2, and SO_2. Levels of PM_{10}, which is attributed to burning fossil fuels in vehicles, power plants, and various industrial processes, remain far above World Health Organization (WHO) Air Quality Guidelines.

[46] http://www.environment-health.asia/userfiles/file/HL5_5_1PB_Air%20TWG%20July2010.pdf.

[47] World Health Organization, http://www.who.int/mediacentre/factsheets/fs313/en/; United Nations Environment Programme, http://www.unep.org/urban_environment/issues/urban_air.asp.

[48] The air quality data is compiled by CAI-Asia Center from official sources (publications, personal communications) for 243 Asian cities, as of April 2010. See http://baq2010.org/sites/default/files/CA%20Scorecard%20Pilot%20Cities%20Summary%20of%20Results.pdf.

SECTION 3. ENERGY SUPPLY AND CONSUMPTION TRENDS

Key Points

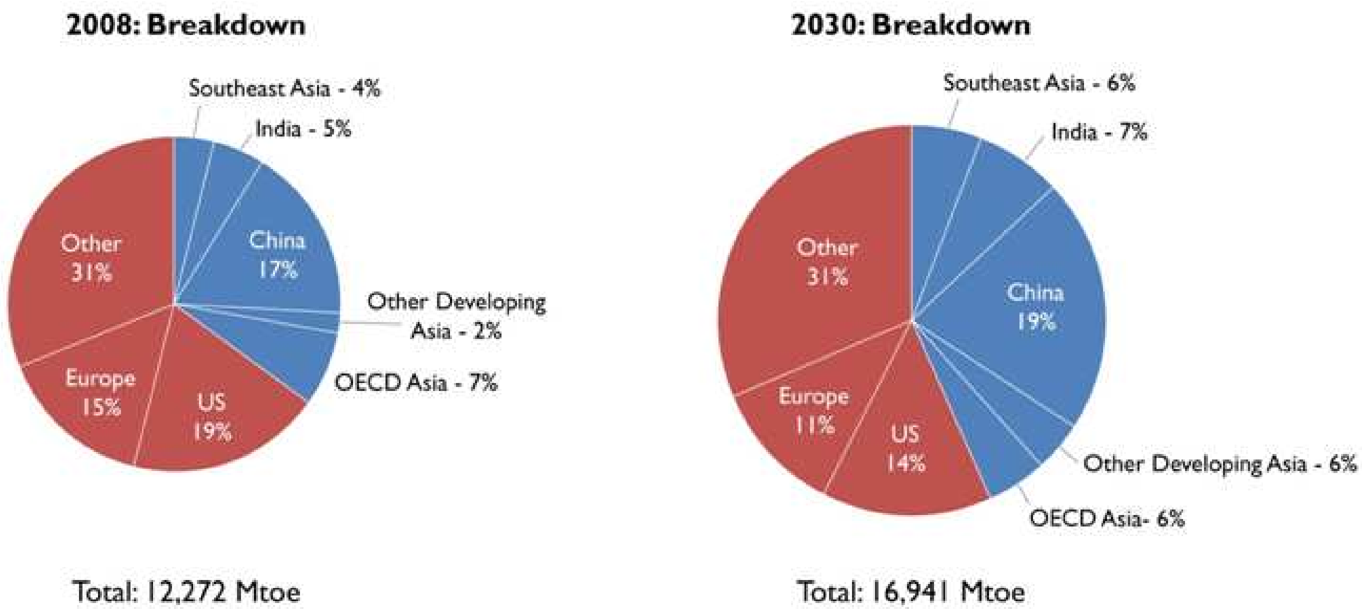
- During the next 20 years, 93 percent of the growth in global energy demand will come from developing countries.
- Asia's share of global primary energy supply will increase from 35 percent in 2008 to 44 percent in 2030, with nearly all of the growth coming from developing Asian economies.
- Oil will be the largest source of new energy supply for Southeast Asia, China, and India during the next 20 years, followed by coal, and natural gas.
- Coal will remain the dominant fuel in Asia. Although it is projected to supply 45 percent of primary energy in 2030, down from a 54 percent share in 2008, coal consumption overall will increase by more than one-third by 2030. Coal supplies 66 percent of China's energy needs and 42 percent of India's. Oil use will also grow rapidly due to increased motorization and its share will rise from 21 percent to 25 percent.
- By 2030, the demand for natural gas, nuclear, biomass and waste energy, and hydro power will increase, but their shares will still be small relative to coal and oil.
- Among the focus countries, China and India are the largest energy consumers, with combined shares of 86 percent of coal use and 81 percent of oil use. Both countries will continue to play a dominant role in the region's (and world's) energy consumption for the next 20 years.
- Final energy demand in the focus countries will increase by about two-thirds, from 2,146 Mtoe in 2008 to 3,452 Mtoe in 2030. Currently, coal has the largest share, followed by oil, biomass and waste, and electricity. Nonetheless, in 2030, oil will dominate final energy demand, followed by electricity, biomass and waste, and coal.

3.1 Global Energy Supply

In its *2010 Energy Outlook*, British Petroleum projects that global energy consumption is expected to grow at a rate of 1.7 percent per year from 2010 to 2030 and 93 percent of this growth is expected to come from developing countries.

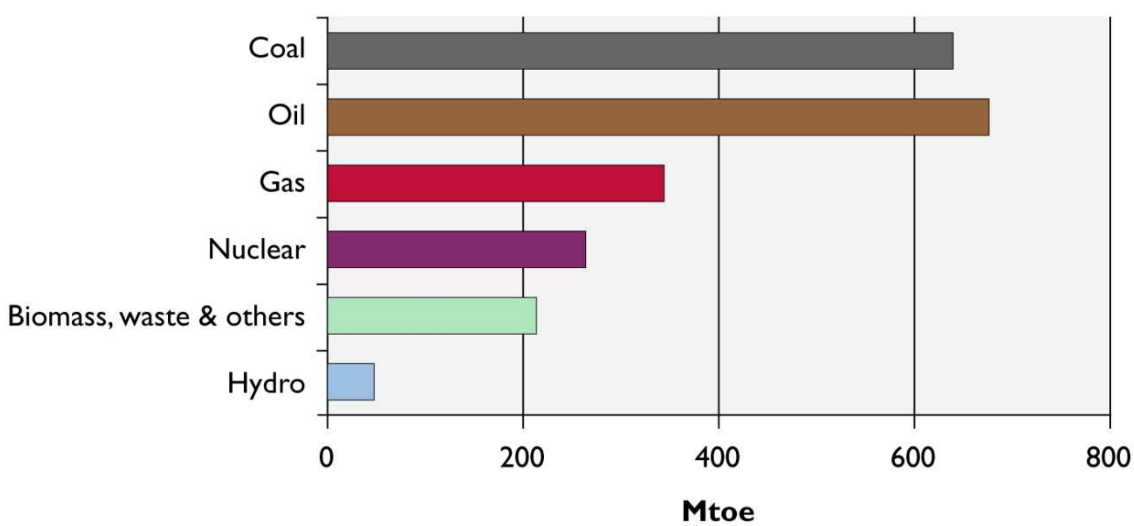
In the context of trying to limit GHGs, the projections for growth in primary energy supply are daunting. According to IEA projections, global primary energy supply will increase by 38 percent from 2008 to 2030, or from 12,272 million tons of oil equivalent (Mtoe) to 16,941 Mtoe. Asia's share of primary energy supply during this period will increase from 35 percent to 44 percent, with nearly

Figure 5. Energy Demand Regional Breakdowns for 2008 and 2030



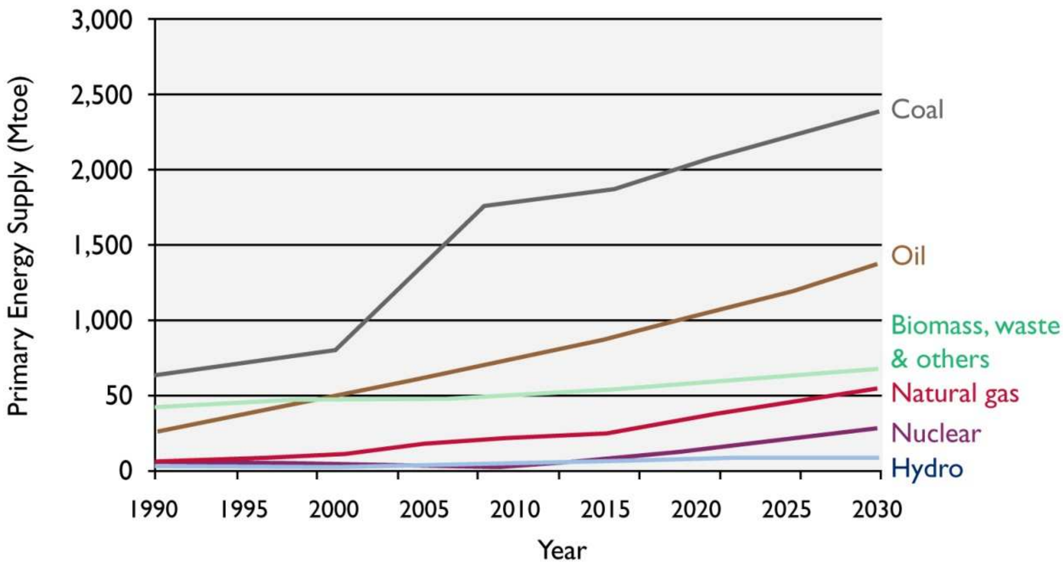
Source: ADB (2010 B), based on IEA, APERC, the World Bank, 2008 values from IEA's website: http://iea.org/country/index_nmc.asp and WEO (2010) excel sheets.

Figure 6. Incremental Primary Energy Supply by Fuel Type for Southeast Asia, India, and China (2008-2030)



Source: ADB (2010 B), based on IEA, APERC, World Bank and 2008 values from International Energy Agency website: http://iea.org/country/index_nmc.asp.

Figure 7. Primary Energy Supply for Southeast Asia, China, and India by Fuel Type



Source: ADB (2010 B), based on IEA, APERC, the World Bank, and 2008 values from IEA's website: http://iea.org/country/index_nmc.asp.

all of the growth coming from energy demand in developing Asian economies (see Figure 5).

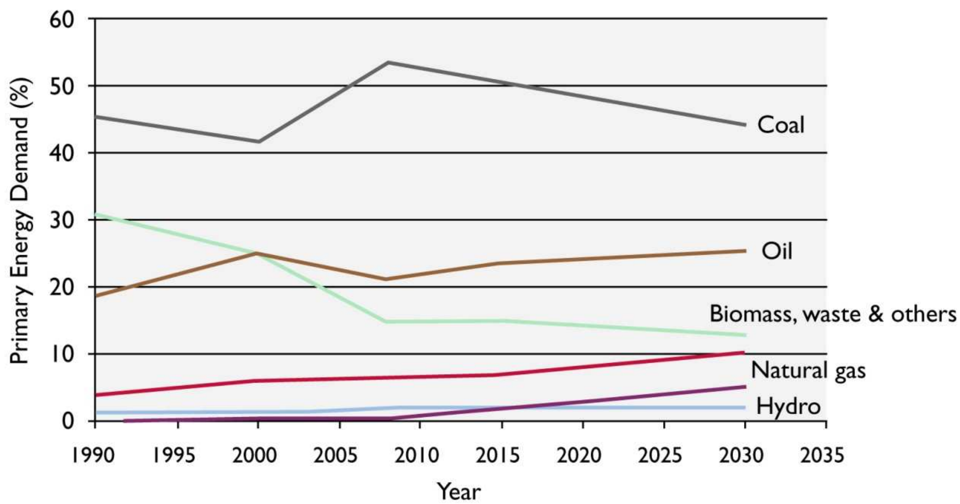
Under "business-as-usual" assumptions, nearly all of the new energy supplied for Asia will come from three fossil fuel sources – oil, coal, and natural gas. Oil will be the largest source of new energy supply for Southeast Asia, China, and India during the next 20 years, with nearly 700 Mtoe of new oil supply, followed by coal with about 650 Mtoe of new supply, and natural gas with about 350 Mtoe of new supply. Nuclear power will account for more than 250 Mtoe of new supply, while biomass and waste will supply just over 200 Mtoe (see Figure 6).

Figure 7 shows the historical trends and future projections, from 1990 to 2030, for the supply of different fuel types for Southeast Asia, China, and India. Figure 8 shows how the share of each fuel type has changed over time and is expected to change during the coming 20 years.

Some of the main trends for developing Asia are:

- Coal use will increase substantially, but more slowly than some other fuels, such as oil. However, if compared to other fuels, the share of coal will decrease from 54 percent in 2008 to 45 percent in 2030.
- Oil demand will increase at a faster rate due to increased motorization and use of oil in transport: oil's share of primary energy supply in Asia will go from 21 percent in 2008 to 25 percent in 2030.
- The share of natural gas will gradually increase from 7 percent in 2008 to 11 percent in 2030.
- The share of nuclear primary energy supply will increase five-fold, from 1 percent in 2008 to 5 percent in 2030.
- The total amount of biomass and waste energy will increase, but its share will decrease slightly, from 15 percent in 2008 to 13 percent in 2030. These projections assume that increased use of biomass for thermal power (electricity and heat) will be partially offset by decreased use of traditional biomass for cooking and heating.
- The total amount of hydropower will increase, but its share will stay constant at around 2 percent of primary energy supply.

Figure 8. Market Shares of Primary Energy Fuel Types for Developing Asia



Source: ADB (2010 B), based on IEA, APERC, the World Bank, and 2008 values from IEA's website: http://iea.org/country/index_nmc.asp.

3.3 Detailed Comparison of the Six Focus Countries for Primary Energy

Table 3 shows detailed country comparisons of primary energy supply by fuel type in the six focus countries, based on 2008 data. The table shows supply for each fuel type in absolute terms (Mtoe), then shows supply for each fuel as a share of the national primary energy supply for that country, and then as a share of the regional supply for that fuel. For example, coal provided 66.4 percent of China's primary energy in 2008, and accounted for 80.9 percent of total coal supply in these six Asian countries.

The comparison leads to a few key conclusions:

- China and India currently account for 86 percent of coal use and 81 percent of oil use in developing Asia.
- China is most dependent on coal as an energy source, with 66 percent of its energy supplied by coal. In comparison, 42 percent of India's energy is supplied by coal.
- China and India are the only countries with significant nuclear power programs, and these provide 2.4 percent and 1.6 percent, respectively, of national primary energy supply.
- Hydropower is a significant source of energy, supplying more than 42 percent of Vietnam's primary energy needs, more than 26 percent for Indonesia and India, 20 percent for the Philippines, 19 percent for Thailand, and 10 percent for China.
- China and Thailand have the highest per capita energy use, at 1.6 Mtoe per person, followed by Indonesia at 0.9 Mtoe per person, Vietnam at 0.7 Mtoe per person, and India and the Philippines each at 0.5 Mtoe per person.

Final Energy Demand

Final energy[49] consumption reflects the way that energy is used at the application or end use. Note that final energy measurements do not take into

[49] Final energy is the useful, secondary energy available to the final use, for example heat (hot water) for a radiator or electricity from the plug at home.

Table 3. Energy Indicators at a Glance for the Six Focus Countries (2008)

Indicators	China	India	Indonesia	Philippines	Thailand	Vietnam	Total
Total Primary Energy Supply (Mtoe)	2,116	621	199	41	107	59	3,143
Coal (Mtoe)	1,406	261	37	7	15	12	1,738
Coal (as % of national total)	66.4%	42.0%	18.6%	17.1%	14.0%	20.3%	NA
Coal (as % of regional total)	80.9%	15.0%	2.1%	0.4%	0.9%	0.7%	100.0%
Oil (Mtoe)	355	169	48	9	56	13	650
Oil (as % of national total)	16.8%	27.2%	24.1%	22.0%	52.3%	22.0%	NA
Oil (as % of regional total)	54.6%	26.0%	7.4%	1.4%	8.6%	2.0%	100.0%
Gas (Mtoe)	18	4	NA	NA	NA	NA	22
Gas (as % of national total)	0.9%	0.6%	NA	NA	NA	NA	NA
Gas (as % of regional total)	81.8%	18.2%	NA	NA	NA	NA	100.0%
Nuclear (Mtoe)	50	10	1	1	1	2	65
Nuclear (as % of national total)	2.4%	1.6%	0.5%	2.4%	0.9%	3.4%	NA
Nuclear (as % of regional total)	76.9%	15.4%	1.5%	1.5%	1.5%	3.1%	100.0%
Hydro (Mtoe)	203	164	53	8	20	25	473
Hydro (as % of national total)	9.6%	26.4%	26.6%	19.5%	18.7%	42.4%	NA
Hydro (as % of regional total)	42.9%	34.7%	11.2%	1.7%	4.2%	5.3%	100.0%
Primary Energy Supply Per Capita (TOE/Person)	1.60	0.54	0.87	0.45	1.58	0.69	0.96
Primary Energy Supply Per GDP (TOE/constant 2000 $)	810	750	800	370	600	1,060	732

Sources: ADB (2010B), based on IEA, APERC, World Bank, and 2008 values from International Energy Agency

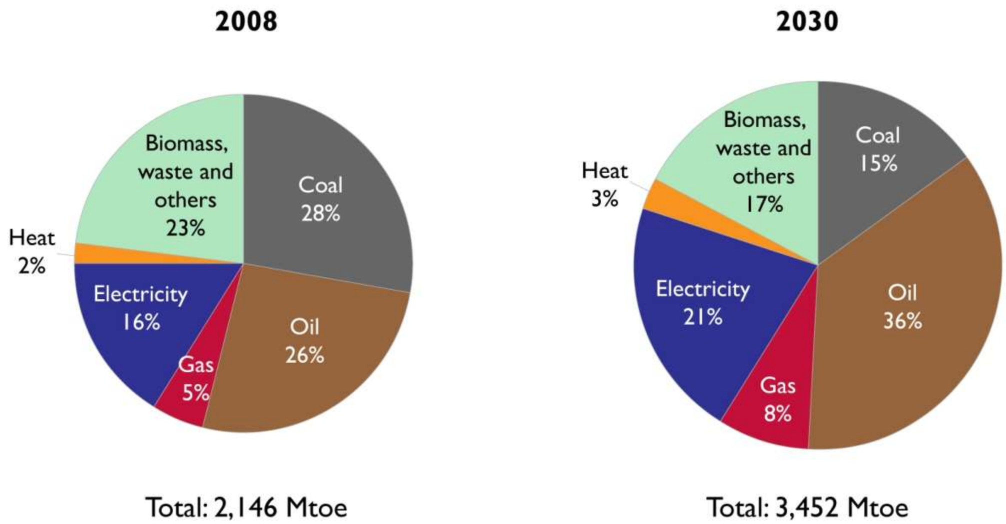
account the losses that occur during the transformation and distribution of the energy, so comparisons of final energy consumption between different fuel types can be misleading. For example, a comparison of final electricity consumption to final oil consumption would be inappropriate: in a typical power plant, only about 20 to 25 percent of the primary energy input into the power plant will reach the end user in terms of electricity. This is because thermal power plants typically have an efficiency of 30-35 percent, and there are additional losses through transmission and distribution on the order of 10-20 percent, depending on the country or region.

Figure 9 shows final energy consumption by fuel type for 2008, with the business-as-usual projection for 2030. During the next 20 to 25 years, final energy demand in China, India, and Southeast Asia will increase by about two-thirds, from 2,146 Mtoe in 2008 to 3,452 Mtoe in 2030.

Coal currently has the largest share of final energy consumption, at 28 percent, followed by oil at 26 percent, biomass at 23 percent, and electricity at 16 percent. In 2030, oil will dominate final energy demand at 36 percent, followed by electricity at 21 percent, biomass and waste at 17 percent, and coal at 15 percent.

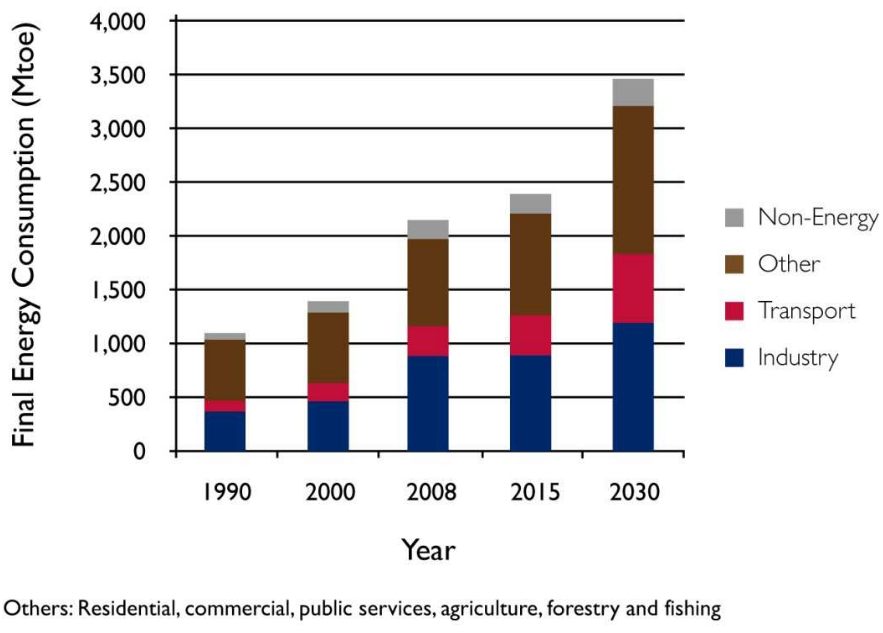
The collection of data on final energy demand is not well-developed in Asia, and it is often difficult to find data on the breakdown of final energy use across different economic sectors, or on end-use applications. Figure 10 shows data on final energy consumption for China, India, and Southeast Asia, broken down by economic sector. It is projected that consumption in 2030 will be largest in the "other" category, which includes residential, commercial, public services, agriculture, forestry, and fishing sectors. The next largest sector is industry, followed by transport.

Figure 9. Final Energy Consumption by Fuel Type Breakdowns for 2008 and 2030 for Southeast Asia, India and China



Source: ADB (2010 B), based on IEA, APERC, World Bank, and 2008 values from IEA's website: http://iea.org/country/index_nmc.asp.

Figure 10. Final Energy Consumption by Sector for China, India, and Southeast Asia (1990-2030)



Source: ADB (2010 B), based on IEA, APERC, World Bank and 2008 values from International Energy Agency.

SECTION 4. ELECTRICITY GENERATION AND CONSUMPTION TRENDS

Key Points

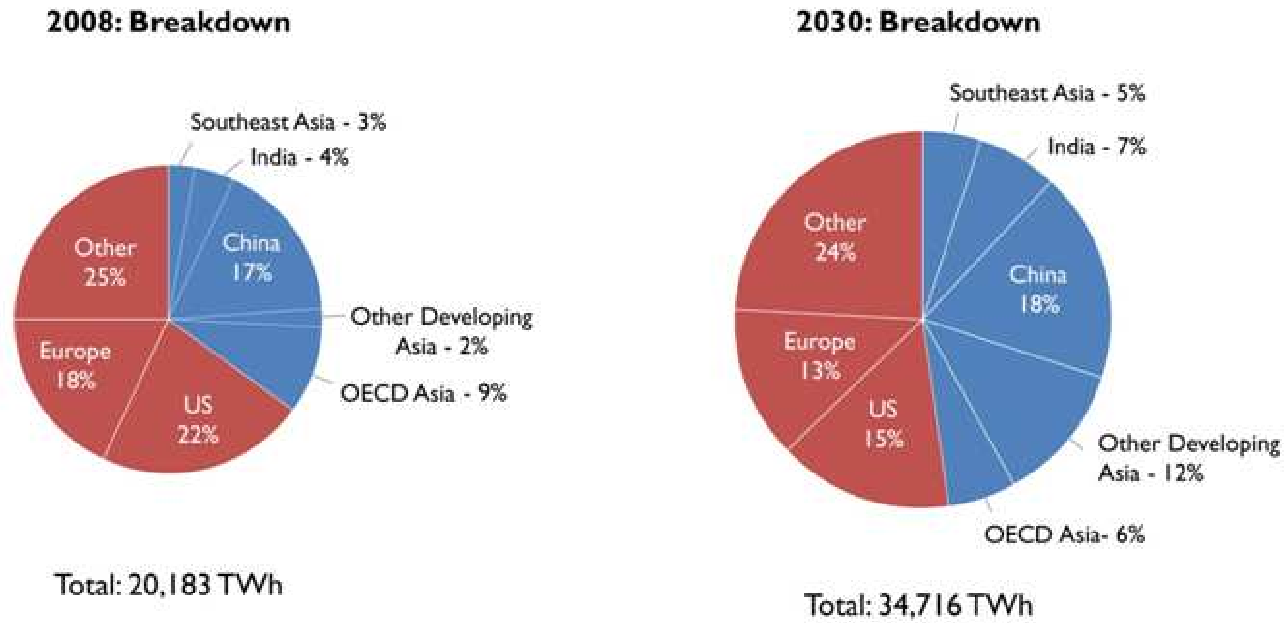
- Asia's share in global electricity generation will increase from 35 percent to 48 percent between 2008 and 2030, with nearly all of the new electricity demand coming from developing Asia.
- Electricity generation in China, India, and Southeast Asia will increase by more than 100 percent by 2030. This rate of growth will outpace growth in primary energy supply.
- Coal-fired electricity production will increase by 77 percent from 2008 to 2030. While coal will continue to be the dominant fuel, its share will decrease slightly, from 69 to 59 percent of electricity generation.
- For the next 20 years, reliance on other fuels for generating electricity in developing Asia will increase more rapidly, to replace some of the share of coal. Natural gas will play a greater role with its share increasing from 8 percent to 12 percent.
- Although electricity from biomass will increase more than 50-fold, its share of total electricity produced will still be minimal, between less than 1 percent to 4 percent.
- All six focus countries plan to construct nuclear power plants, and China has 22 nuclear power plants currently under construction. Since the recent Fukushima nuclear crisis in Japan, the future of plans to expand nuclear power has become unclear, although recent plans had been for more than a 12-fold increase in electricity production from nuclear power between 2008 and 2030.
- Production of hydropower will increase by 44 percent from 2008 to 2030, but the share of hydroelectric power in overall electricity production will decrease from 18 percent to 13 percent.

4.1 Current Trends in Electricity Generation/Consumption

Global Electricity Generation

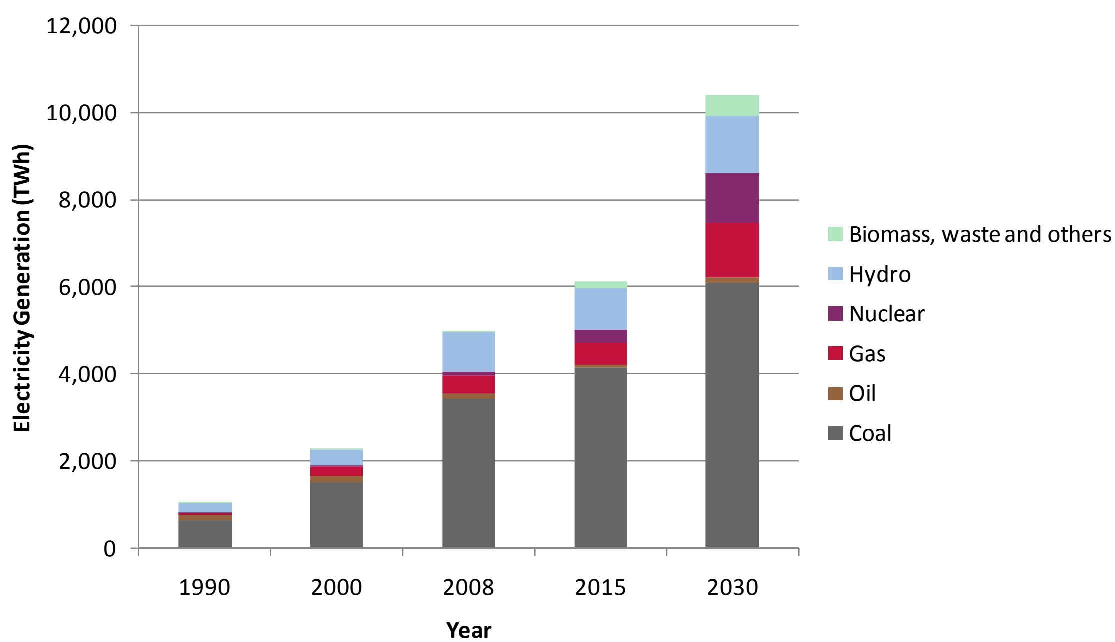
Global electricity generation will increase by 72 percent from 2008 to 2030. Asia's share of global electricity generation will increase from 35 percent to 48 percent during this period, in response to the growing electricity demand coming from developing Asia. Together, China, India, Southeast Asia, and other developing Asian economies will account for 42 percent of global electricity generation by 2030 (see Figure 11).

Figure 11. Breakdown of Global Electricity Generation by Region (2008 and 2030)



Source: ADB (2010 B), based on IEA, APERC, the World Bank, 2008 values from IEA's website: http://iea.org/country/index_nmc.asp and WEO 2010 excel sheets.

Figure 12. Past and Projected Electricity Production by Fuel Type for China, India, and Southeast Asia (1990-2030)



Electricity Generation in Asia

Growth of electricity generation in Asia will outpace growth in primary energy supply. While primary energy supply is expected to increase by 65 percent in Southeast Asia, China, and India between 2008 and 2030, electricity generation is projected to increase by more than 100 percent.

Figure 12 shows the 40-year trend for electricity production in the region, with a more than ten-fold increase from 1990 to the level of production projected in 2030.

One of the main trends in electricity generation expected over the next 20 years for developing Asia is that coal will continue to be the dominant fuel for the power sector. Coal-fired electricity production will increase by 77 percent, from 3,450 TWh in 2008 to 6,110 TWh in 2030. While coal will continue to be the dominant fuel, its overall share will decrease, from 69 to 59 percent of electricity generation.

During the next two decades, developing Asia will increasingly rely on alternatives to coal for generating electricity. For example:

- Production of electricity from natural gas will increase three-fold, from 413 TWh in 2008 to 1,270 TWh in 2030, and the overall share of natural gas in electricity production will increase from 8 percent to 12 percent.

- Production of electricity from nuclear will increase more than 12-fold, from 83 TWh in 2008 to 1,140 TWh in 2030, and the share of nuclear in overall electricity production will increase more than five-fold, from 2 percent to 11 percent.

- Production of electricity from biomass will increase more than 50-fold, from 9 TWh in 2008 to 474 TWh in 2030, and the share of biomass in overall electricity production will increase from less than 1 percent to 4 percent.

- Production of electricity from hydroelectric power will increase by 44 percent, from 910 TWh in 2008 to 1,310 TWh in 2030, but the share of hydroelectric power in electricity production will decrease from 18 percent to 13 percent.

- Production of electricity from oil will decrease by 15 percent from 119 TWh in 2008 to 100 TWh in 2030, and the share of oil in overall electricity production will decrease from 3 percent to 1 percent.

Trends in Nuclear Power

Global Trends

Globally, nuclear power generates 16 percent of electricity, and accounts for 6.3 percent of final energy production, and 2 percent of primary energy consumption. Presently, there are 436 nuclear reactors in operation worldwide, but nuclear power may decrease as it is projected that there are more plants that will go offline over the next 20 years than there are in the planning process.[60]

The authoritative report on the status of nuclear power plants worldwide is the *World Nuclear Industry Status Report*. As the report makes clear, there was a significant decline in nuclear reactor production beginning in the mid 1980s. It also demonstrates that new reactors have not been coming on-line during the past 10 years at a rate rapid enough to replace the lost capacity from the older reactors that are being shut down.

Figure C1 in Attachment C shows the evolution of nuclear generating capacity since 1954. Capacity reached a peak of 322 GW in 1989, and total generating capacity has increased only marginally over the past 20 years – to 370 GWe in 2009. The number of reactors in operation peaked at 444 in 2002 and has gone down slightly since then, to 435.

Nuclear power is characterized by large up-front costs, long construction times, and cost overruns that typically amount to 30 percent of the project cost. All nuclear plants built to date worldwide have required large public subsidies to achieve financing. The government provides guarantees for the final storage or disposal of radioactive waste, and environmental costs are excluded from electricity prices.

During the past 15 years, nuclear and wind technology produced a comparable amount of energy (with nuclear comprising 2.6 billion kWh, and wind 1.9 billion kWh), but subsidies to nuclear power outweighed that of wind by a factor of over 40 ($39.4 billion versus $900 million, respectively).

Nuclear Power in Asia

There are currently 60 nuclear power plants planned for construction globally and more than half of these are in Asia. Nuclear plants are planned to be built in all six focus countries (see Table C2 in Attachment C). Nuclear power currently provides 1.9 percent of electricity production in China and 2.5 percent of electricity production in India. The Philippines has a nuclear plant that is completely constructed and contains fuel rods, but has never been operational due to safety and maintenance concerns.

Carbon Abatement Costs

World Energy Outlook 2007 includes nuclear power as part of its 450 scenario. However, compared to other measures, including energy efficiency and clean energy generation, nuclear power is projected to make a relatively small contribution to lowering CO_2 emissions of 6 percent by 2050.

Ultimately, the level of investment in nuclear energy may depend in part on the carbon emissions abatements costs for nuclear energy versus other fuel types. Currently, these projections vary widely. A 2009 study by McKinsey Consulting puts the price tag at 10 Euros ($14.8) per ton of CO_2e. However, a 2010 study by Exelon suggests that estimated costs for nuclear are much higher – in the range of $60-70 per ton of CO_2e.

Fukushima and the Future of Nuclear Power

In addition to a history of cost overruns on nuclear power plants, another drawback to nuclear power is concern over health and safety. Adding to the major accidents which occurred at Three Mile Island in the United States in 1979 and, more seriously, Chernobyl, Ukraine in 1986, public perception and acceptance of nuclear power – both globally and within Asia – have been significantly damaged following the tsunami disaster at the Fukushima Daiichi plant in Japan in March 2011.

In aftermath of the Fukushima nuclear crisis, many countries, including Japan, China, Germany, Switzerland, Israel, Malaysia, Thailand, United Kingdom, and the Philippines, have reviewed their nuclear power programs. While Germany plans to shut down all of its nuclear power plants by 2022, China, Indonesia, and Vietnam still plan to continue their nuclear programs.

Some uncertainty remains over the future of nuclear power. Some expect that, with the fear of nuclear power generation, there will be a shift of demand from nuclear to natural gas and liquefied natural gas (LNG). However, as natural gas and LNG prices are partially linked to high oil prices, their replacement potential is still limited by their high prices. The Government of Japan now aims to replace electricity from nuclear power with renewable energy, with plans to provide solar panels to 10 million homes in order to produce 20 percent of the country's electricity by 2020.

Nevertheless, it is too early to predict the future of nuclear power. As the world is looking for low GHG emissions energy sources to serve growing demand and mitigate climate change, it may be hard to ignore the nuclear option.

Table 4. Electricity Indicators at a Glance for the Six Focus Countries (2008)

Indicators	China	India	Indonesia	Philippines	Thailand	Vietnam	Total
Electricity Production (TWh)	3,457	830	149	61	147	73	4,717
Coal (TWh)	2,733	569	61	16	32	15	3,426
Coal (as % of national total)	79.1%	68.6%	40.9%	26.2%	21.8%	20.5%	N/A
Coal (as % of regional total)	79.8%	16.6%	1.8%	0.5%	0.9%	0.4%	100.0%
Oil (TWh)	23	34	43	5	2	2	109
Oil (as % of national total)	0.7%	4.1%	28.9%	8.2%	1.4%	2.7%	N/A
Oil (as % of regional total)	21.1%	31.2%	39.4%	4.6%	1.8%	1.8%	100.0%
Gas (TWh)	31	82	25	20	102	30	290
Gas (as % of national total)	0.9%	9.9%	16.8%	32.8%	69.4%	41.1%	N/A
Gas (as % of regional total)	10.7%	28.3%	8.6%	6.9%	35.2%	10.3%	100.0%
Nuclear (TWh)	68	15	NA	NA	NA	NA	83
Nuclear (as % of national total)	2.0%	1.8%	NA	NA	NA	NA	NA
Nuclear (as % of regional total)	81.9%	18.1%	NA	NA	NA	NA	100.0%
Hydro (TWh)	585	114	12	10	7	26	754
Hydro (as % of national total)	16.9%	13.7%	8.1%	16.4%	4.8%	35.6%	NA
Hydro (as % of regional total)	77.6%	15.1%	1.6%	1.3%	0.9%	3.4%	100.0%
Biomass, Waste and Others (TWh)	2	2	N/A	N/A	N/A	N/A	4
Biomass, Waste and Others (as % of national total)	0.1%	0.2%	N/A	N/A	N/A	N/A	
Biomass, Waste and Others (as % of regional total)	50.0%	50.0%	N/A	N/A	N/A	N/A	100.0%
Electricity Production Per Capita (kWh/Population)	2,608	728	655	673	2,113	847	1,271*
Electricity Production Per GDP (TWh/thousand constants 2000 $)	1.25	1.01	0.6	0.55	0.8	1.31	0.92*

* average value (not total)
Sources: ADB (2010 B), based on IEA, APERC, World Bank, and 2008 values from International Energy Agency website: http://iea.org/country/index_nmc.asp
Note: N/A = not available

4.2 Detailed Comparison of the Six Focus Countries for Electricity Consumption

Table 4 shows detailed country comparisons of electricity consumption by fuel type in the six focus countries based on 2008 data. For each country, the table shows electricity consumption by fuel type in absolute terms (TWh), then shows each fuel type's share of national electricity consumption, and the country's corresponding share of regional electricity consumption of that fuel. For example, coal was used to generate 68.6 percent of India's electricity consumption in 2008, and India accounted for 16.6 percent of total coal demand in these six Asian countries for electricity consumption.

The comparison leads to a few key conclusions:

- Coal is a significant fuel in electricity production in all countries, ranging from 79 percent in China, to 69 percent in India, 41 percent in Indonesia, 26 percent in the Philippines, 22 percent in Thailand, and to 21 percent in Vietnam.

- Natural gas plays a small role in electricity generation in China, India, Indonesia, and the Philippines, but has a significant role in Thailand (69 percent share) and Vietnam (41 percent share).

- Oil plays a very small role in electricity generation (less than 10 percent) in all countries except for Indonesia, where it accounts for 29 percent of power generation.

- Among the six countries, only China and India have nuclear electricity generation, accounting for 2.0 percent and 1.8 percent, respectively, of electricity generation in 2008.

- China has the highest per capita electricity consumption, at 2,600 kWh, followed by Thailand, at 2,100 kWh, with consumption levels in the other four countries ranging from 660 to 850 kWh.

SECTION 5. GREENHOUSE GAS EMISSIONS TRENDS

Key Points

- Annual global emissions of anthropogenic greenhouse gases increased by 70 percent from 1970 to 2004.
- A total of 56.6 percent of anthropogenic emissions are from combustion of fossil fuels (i.e., are energy-related).
- The share of CO_2 emissions from the combustion of fossil fuels from developing Asian economies will go from 33 percent to 45 percent during 2008-2030. Emissions from China, India, and Southeast Asia combined will account for 35 percent of global emissions in 2030.
- Over the past four decades, emissions from coal combustion have increased more than eight-fold – from 828 million tCO_{2e} in 1971 to 6.76 billion tCO_2e in 2008
- In 2008, China and India accounts for 91 percent of energy-related CO_2 emissions within developing Asia.
- By 2030, China's CO_2 emissions will be 9 billion metric tons annually – more than three times greater than India's and more than eight times greater than the emissions of any of the remaining focus countries.

5.1 Historical Trends in GHG Emissions

This section of the report is focused on understanding historical trends and possible future scenarios for emissions of CO_2 from combustion of fossil fuels (i.e., energy-related GHG emissions).

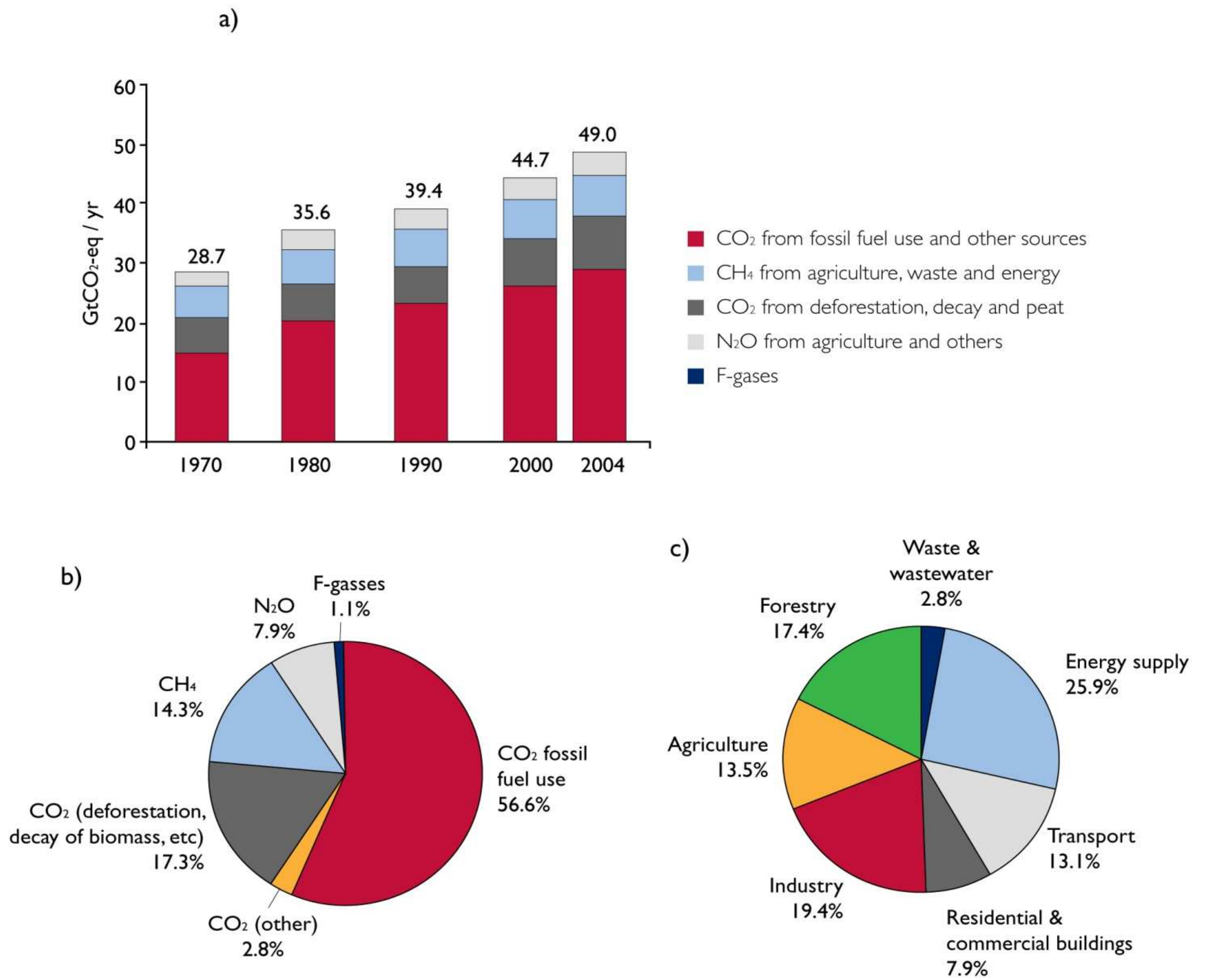
Emissions of Anthropogenic Greenhouse Gases

Figure 13 displays the most complete set of data on anthropogenic sources of GHG emissions, as developed by the Intergovernmental Panel on Climate Change (IPCC).[50] The key trends and facts with regard to these emissions are:

- Annual emissions of greenhouse gases (expressed as CO_2 equivalent) increased by 70 percent from 1970 to 2004
- Fossil fuel emissions of CO_2 comprise 56.6 percent of total emissions
- Emissions from deforestation and forest degradation account for 17.4 percent of emissions
- Methane, which is a by-product of both livestock production and landfills is 25 times as

[50] IPCC (2007).

Figure 13. Emissions of Anthropogenic Greenhouse Gases from 1970 to 2004
Chart a) shows global emissions from 1970 to 2004. Chart b) shows the share of different types of GHG emissions in total emissions, in terms of CO_2 equivalent (CO_2e). Chart c) shows the share of emissions from different sectors in total emissions, in terms of tCO_2e.



[51]

Source: IPCC Report (2007)

intense a greenhouse gas as carbon dioxide, and accounts for approximately 14% of net emissions

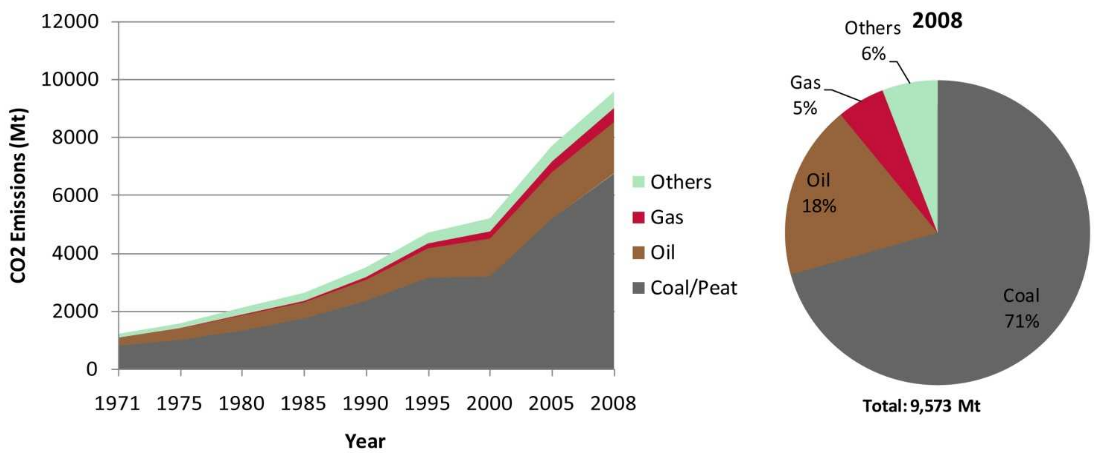
- Approximately two-thirds of emissions are associated with energy: 26 percent with energy supply, 19 percent with industry, 14 percent with transport, and 8 percent with buildings

Nearly all of the energy-related GHG emissions (94 percent) are CO_2; a small amount consist of methane (CH_4) (5 percent), and nitrous oxide (N_2O) (1 percent).[52] The GHG figures reported in this section represent CO_2, and do not include the other energy-related GHG emissions represented by CH_4 and N_2O.

[51] F gases are fluorinated greenhouse gases. These are powerful greenhouse gases that contribute to global warming if released into the atmosphere.

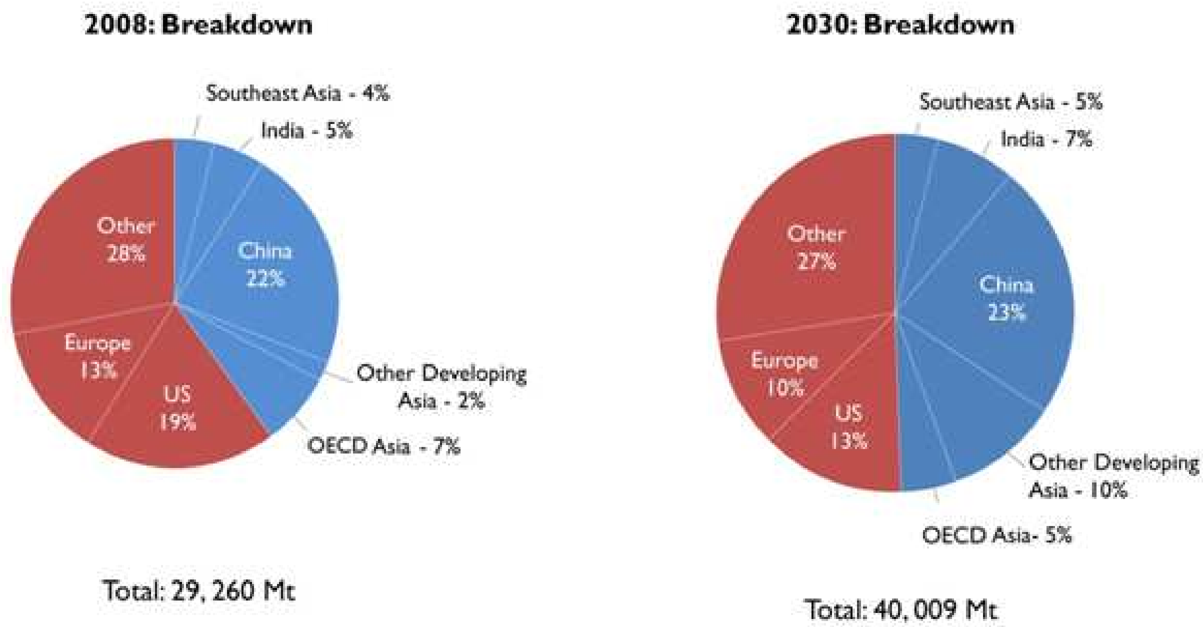
[52] IEA (2010B), page 18. Energy-related emissions include emissions from fuel combustion, and "fugitive emissions" which are intentional or unintentional releases of gases resulting from production, processes, transmission, storage and use of fuels (e.g., CH_4 emissions from coal mining or oil and gas systems).

Figure 14. Historical CO_2 Emissions by Fuel Type for China, India, and Southeast Asia (1970-2008)



Source: IEA (2010A)

Figure 15. Regional Breakdown of Global Energy-Related CO_2 Emissions in 2008 and 2030



Source: ADB (2010 B), based on IEA, APERC, the World Bank, 2008 values from IEA's website: http://iea.org/country/index_nmc.asp and WEO 2010 Excel spreadsheets.

In addition to nitrous oxide and methane, other greenhouse gases (such as the chlorofluorocarbons, CFC11 CFC12) also contribute to global warming, and all of which have higher global warming potential (i.e., radioactive forcing) than CO_2. However, data from the National Oceanic and Atmospheric Administration (NOAA) indicate that CO_2 emissions over the past two decades have accounted for approximately 80 percent of the observed atmospheric warming overall.[53]

[53] According to WMO (2010), the NOAA Annual Greenhouse Gas Index shows that from 1990 to 2009, radiative forcing by all long-lived greenhouse gases increased by 27.5%, with CO_2 accounting for nearly 80% of this increase.

Emissions of Greenhouse Gases from Combustion of Fossil Fuels

Historical Trends

Figure 14 shows a four-decade trend of fossil fuel-related CO_2 emissions growth, from 1971 to 2008. The main observations are:

- Over the past 40 years, energy-related CO_2 emissions have doubled from 15 billion tCO_2e in 1970 to an estimated 29.4 billion tCO_2e in 2008.

- *Emissions from coal* increased more than eight-fold – from 828 million tCO_2e in 1971 to 6.76 billion tCO_2e in 2008.

- *Emissions from oil* increased more than six-fold – from 273 million tCO_2e in 1971 to 1.78 billion tCO_2e in 2008.

- *Emissions from natural gas* increased more than 50-fold – from 9.2 million tCO_2e in 1971 to 485 million tCO_2e in 2008.

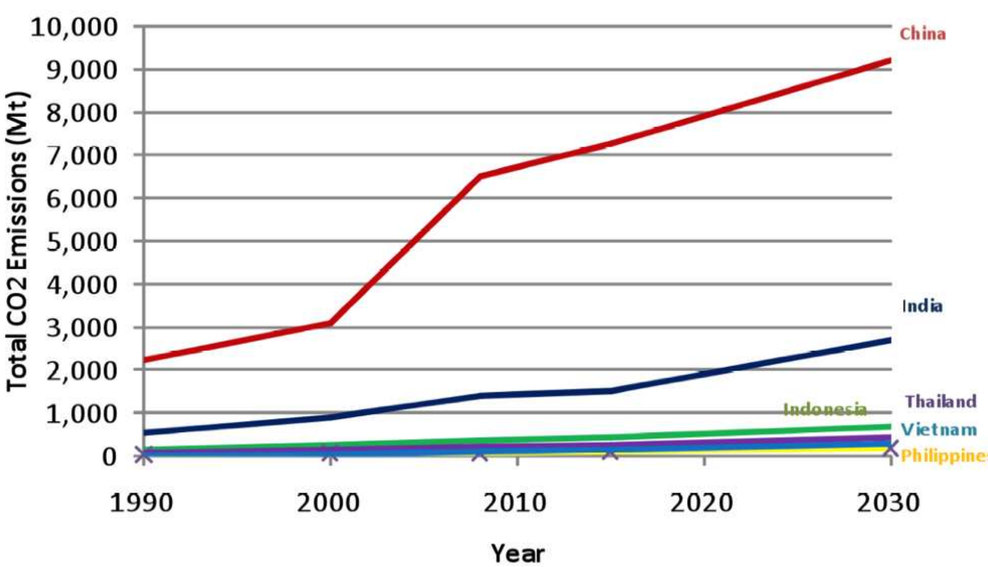
- Coal is the dominant source of fossil fuel-related GHG emissions in developing Asia, accounting for 71 percent of emissions in 2008.

Future Projections

Global emissions of CO_2 from fossil-fuel combustion are projected to increase by more than one-third from 2008 to 2030 – from 29 million metric tons to 40 million metric tons. The share from developing Asian economies will go from 33 percent to 45 percent during this time period. By 2030, emissions from fossil fuel combustion in China, India, and Southeast Asia are projected to increase by 55 percent and account for 35 percent of the global total (see Figure 15).

Looking forward, the IEA estimates in its business-as-usual scenario that global emissions of energy-related GHGs will increase by more than 25 percent over the next two decades, from 30 billion metric tCO_2e in 2010 to close to 40 billion tCO_2e by 2030. For developing Asia, emissions are

Figure 16. Historical and Projected Energy-Related CO_2 Emissions from Fuel Combustion for Each of the Six Focus Countries by Country (1990-2030)



Source: ADB (2010 B), based on IEA, APERC, World Bank, and 2008 values from International Energy Agency website: http://iea.org/country/index_nmc.asp

Table 5. Summary of CO_2 Emissions from Fossil Fuel Combustion for the Six Focus Countries (2008)

Indicators	China	India	Indonesia	Philippines	Thailand	Vietnam	Total (or Average)
CO_2 Emissions (million tCO_2e)	6,508	1,427	385	72	230	103	8,725
CO_2 Emissions (as % of regional total)	74.6%	16.4%	4.4%	0.8%	2.6%	1.2%	100.0%
CO_2 Emission/capita (tCO_2e/capita/year)	4.91	1.3	1.7	0.8	3.4	1.2	2.22
CO_2 Emissions/GDP (tCO_2/ million constant 2000 US dollars)	2,501	1,730	1,610	651	1,290	1,851	1,606

Source: International Energy Agency's website: http://iea.org/country/index_nmc.asp

projected to increase by about 55 percent – from 9.6 billion tCO_2e in 2008 to about 14 billion tCO_{2e} in 2030.

Figure 16 shows historical trends as well as future projections over the next two decades for energy-related CO_2 emissions for the six focus countries. The projections are according to the BAU Scenario in IEA's *World Energy Outlook 2010*. Under this scenario, China's emissions will increase to more than 9 billion tCO_2e per year, India's will rise to slightly under 3 billion tCO_{2e} per year, and the other four focus countries will each be under 1 billion tCO_2e per year.

5.2 Comparison of CO_2 Emissions from the Six Focus Countries

Table 5 compares CO_2 emissions across the six focus countries based on 2008 data. For each country the table shows absolute emissions in terms of millions of metric tons of carbon ($MtCO_2e$) per year, national emissions as a percentage of the regional total, and per capita emissions.

China and India together accounted for 91 percent of energy-related CO_2 emissions in the six focus countries in 2008. China's per capita CO_2 emissions, at 4.9 tCO_2e per capita per year, are currently more than twice the regional average of 2.2 tCO_2e per capita per year. Thailand's per capita emissions also significantly exceed the regional average, at 3.4 tCO_2e per capita per year.

By 2030, China's CO_2 emissions will be 9 billion metric tons annually – more than three times greater than India's and more than eight times greater than the emissions of any of the remaining focus countries.[54]

5.3 Voluntary Targets for GHG Emissions Reductions

So-called "Non-Annex I" countries listed under the United Nations Framework Convention on Climate Change (UNFCCC), which are mostly comprised of developing countries, do not have obligation or commitment to reduce their GHG emissions under the current Kyoto Protocol but they can participate through Clean Development Mechanism (CDM). However, more recently, several Non-Annex I countries have expressed their willingness to voluntary reduce their emissions and to set non-binding targets.

Table 6 presents these targets for seven countries in the Asia-Pacific region: China, India, Indonesia, Papua New Guinea, Singapore, South Korea, and Thailand. These pledges are non-binding or in some cases contingent on a global agreement or international support.

[54] ADB (2010 B), based on IEA, APERC, World Bank, and 2008 values from International Energy Agency website: http://www.iea.org/

Table 6. Voluntary GHG Emissions Reductions Pledges by Non-Annex I Countries in Asia

Country	Change Relative to Baseline					Change Relative to Recent Level			Additional Observations
	Reduction	Baseline		Target		Reduction	Recent Level		
	%	Year	Amount	Year	Amount	%	Year	Amount	
Emissions Intensity Reductions			**kgCO_2e/$GDP**		**kg/CO_2e/$GDP**				
China	-40% to -45%	2005	0.85 to 1.01	2020	0.47 to 0.51	N/A			Pledge is a decision from the Standing Committee of China's State Council and is domestically binding, but China characterizes it as voluntary under the Copenhagen Accord.
India	-20% to -25%	2005	0.37	2020	0.28 to 0.30	N/A			Pledge is voluntary, not legally binding, and excludes agriculture. A compilation of five modeling studies published by the Indian government indicated that CO_2 intensity would fall 24% to 59% between 2005 and 2030 absent new GHG mitigation policies.
Emissions Intensity Reductions			**MtCO_2e**		**MtCO_2e**			**MtCO_2e**	
Indonesia	-26% to -41%	BAU	N/A	2020	N/A	N/A	2004	1,711	As articulated at the G20, the 26% pledge is unilateral and the 41% pledge is contingent on international support. Only the 26% pledge is included in Appendix II of the Copenhagen Accord.
Papua New Guinea	-50%	N/A	N/A	2030	N/A	N/A	2010	82 to 89	Pledge is "preliminary and conditional" and also includes becoming carbon neutral by 2050.
Singapore	-16%	BAU	N/A	2020	N/A	N/A	1994	27	Pledge is "contingent on global agreement in which all countries implement their commitments in good faith."
South Korea	-30%	BAU	813	2020	569	-4%	2005	594	Prior to COP-15, President Lee Myung-Bak framed the target as a voluntary, unilateral measure.
Thailand	-30%	BAU	280 to 315	2020	400 to 450	adding +37% to 54%	2008	204	Pledge and emissions estimates apply only to the energy sector.

Source: World Resources Institute

SECTION 6. TRENDS IN INTENSITY OF ENERGY CONSUMPTION AND ENERGY-RELATED CO_2 EMISSIONS

Key Points

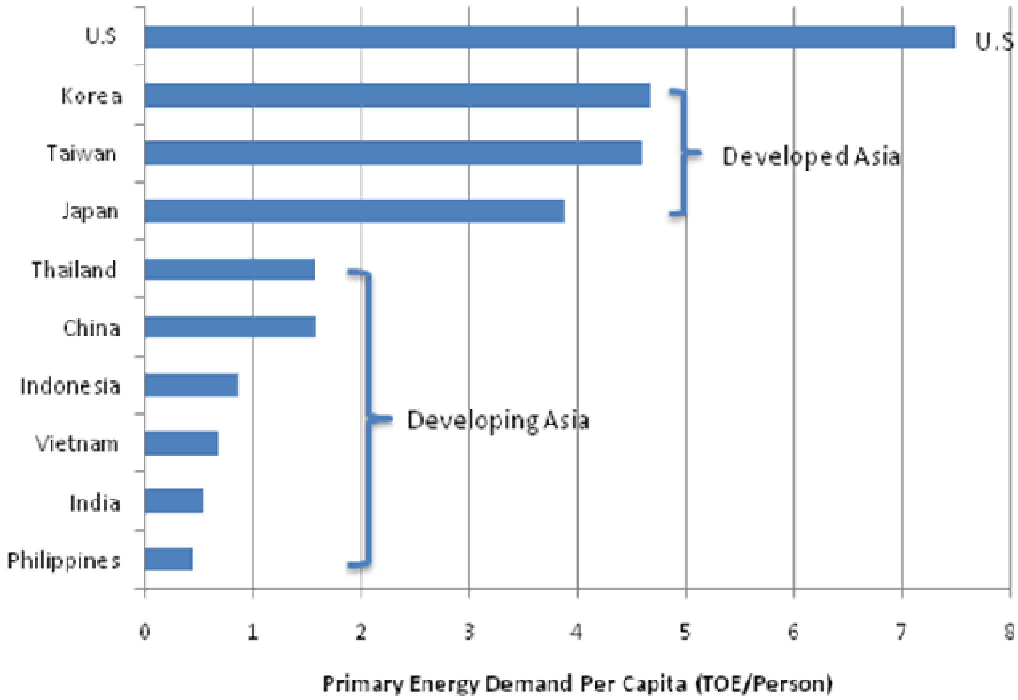
- Over the past 20 years, per capita energy demand for the focus countries has continuously increased. Thailand and China have the highest growth rates and doubled, from about 0.8 to about 1.6 TOE per capita. It is projected that this trend will continue until 2030.
- On the other hand, energy demand per GDP from the focus countries has gradually decreased and will continue this trend until 2030.
- Per capita electricity demand has increased at an even faster rate – nearly five-fold for China and Vietnam, three-fold in Indonesia, two-fold in India and Thailand, and by 63 percent in the Philippines. It is expected that this trend will continue until 2030.
- With regard to electricity demand per GDP, even though China and India show a decreasing trend in electricity intensity per GDP, this is dwarfed by the increases in per capita electricity intensity of both countries for past 20 years.
- Per capita GHG emissions have increased at similar rates in all of the countries. These increases are only partially offset by reductions in energy and GHG emissions intensity per unit of GDP.

6.1 Introduction

Energy intensity is generally defined as the amount of energy consumed to produce a unit of economic output. This value varies across countries depending upon the level of industrialization. The ratio of energy consumed to GDP defines the energy intensity index, and it is an indicator of energy efficiency on a national level. A decrease in energy intensity signifies that less energy is used per unit of economic output. Decreasing energy intensity yields additional benefits, including cost savings, lower carbon emissions, and reduced dependence on foreign energy supply.

This section mainly focuses on the energy and GHG emission intensities of six Asian focus countries based on ADB and IEA data sets. The first part of this section deals with the primary energy demand per capita and primary energy demand per GDP. The remainder of this section deals with electricity and GHG emission intensities.

Figure 17. Primary Energy Demand Per Capita by Region



Source: International Energy Agency website: http://iea.org/country/index_nmc.asp

6.2 Primary Energy Demand

Primary Energy Demand and Per capita

The amount of per capita energy use is a measure of how intensively different economies use energy. On average, the US, at about 7.5 TOE per capita, uses about 70 to 90 percent more energy per capita than developed East Asian countries (Japan, Korea, and Taiwan, at about 4.0 to 4.6 TOE per capita) and about 5 to 15 times more energy per capita than the six Asian focus countries in this report (Thailand and China at about 1.6 TOE per capita; and India, Indonesia, the Philippines and Vietnam at less than 1 TOE per capita). This comparison is shown in Figure 17.

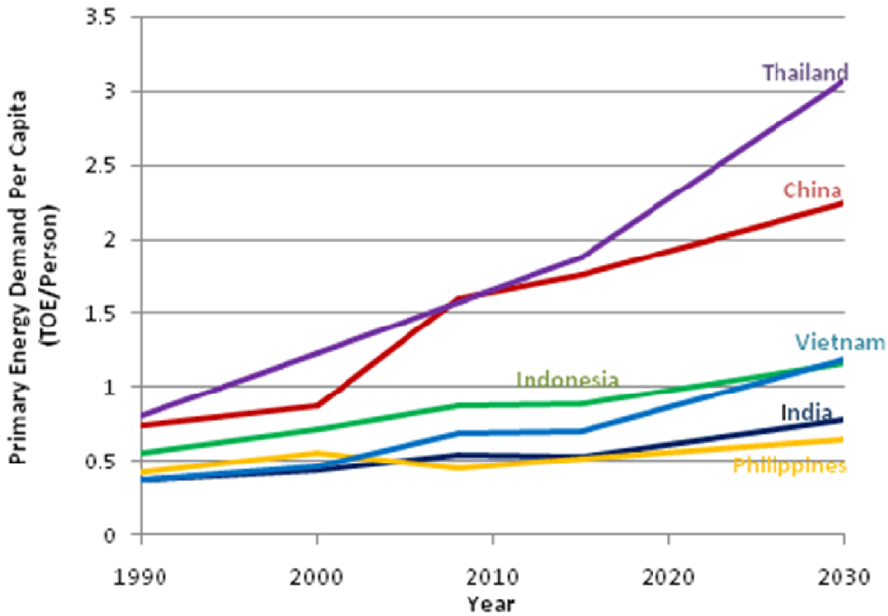
As described in Section 2 of this report, per capita energy demand tends to increase with income. This means that over time, a country's energy demand may increase not only as its population increases, but also as its per capita income increases.

Over the past 20 years, Thailand's and China's per capita energy demand has approximately doubled, from about 0.8 to about 1.6 TOE per capita. According to ADB and IEA projections, by 2030 Thailand will reach about 3 TOE per capita, and China will reach just under 2.5 TOE per capita. Per capita energy demand in the other four focus countries will be lower, in the range of about 0.6 to 1.2 TOE per capita by 2030. These differences are primarily a function of differences in average personal income between the countries. These trends are shown in Figure 18.

Primary Energy Demand Per GDP

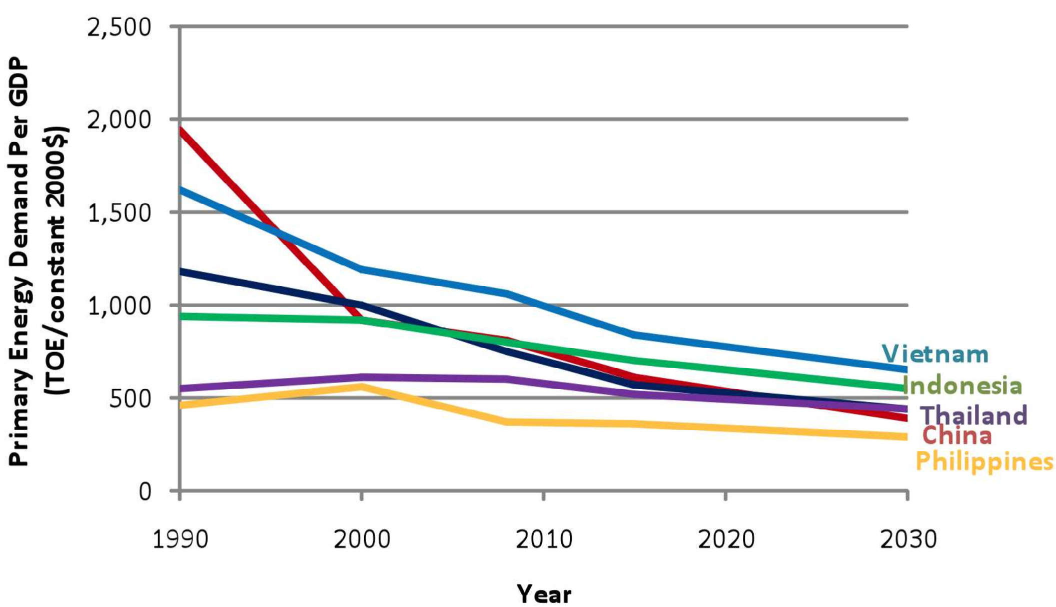
Countries tend to become more efficient in terms of their energy use per unit of economic output (GDP) as they develop. This is due to increases in mechanization and changes in economic structure, from manufacturing-based to more service-oriented.

Figure 18. Primary Energy Demand Per Capita for the Six Asian Focus Countries



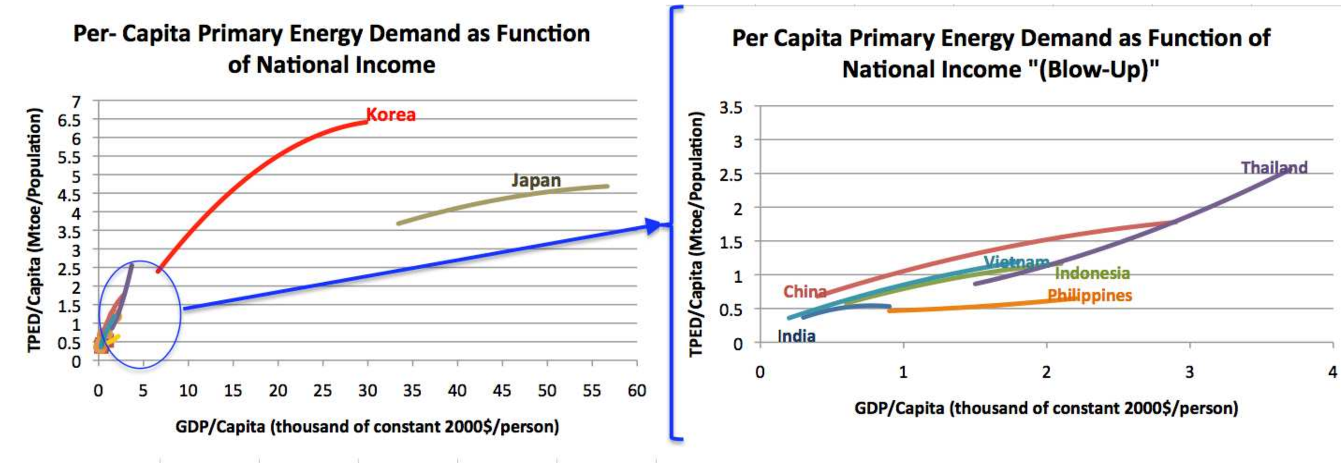
Source: ADB (2010 B), based on IEA, APERC, World Bank, and 2008 values from International Energy Agency website: http://iea.org/country/index_nmc.asp

Figure 19. Primary Energy Demand Per GDP for the Six Asian Focus Countries



Source: ADB (2010B), based on IEA, APERC, the World Bank, and 2008 values from IEA's website: http://iea.org/country/index_nmc.asp

Figure 20. Evolution of National Energy Demand as a Function of National Income



Source: ADB (2010 B), based on IEA, APERC, World Bank, and 2008 values from IEA's website: http://iea.org/country/index_nmc.asp

For example, most of the six focus countries have reduced their energy intensity – as measured by energy demand per GDP – over the past 20 years by significant amounts, in the range of 10 to 40 percent, with China achieving the most dramatic decrease. On average, for Southeast Asia, India, and China, energy intensity per GDP has decreased by 42 percent, from 1,332 TOE per US dollar in 1990 to 760 TOE per US dollar in 2008. Over the coming 20 years, energy intensity is projected to decrease by an additional 45 percent, to 412 TOE per US dollar in 2030.

Figure 19 shows primary energy demand per GDP for the six Asian focus countries. These projections show improved energy efficiency (in terms of energy required per unit of economic output) for all six of the countries. The main observations include:

- The most dramatic decrease occurred in China, which reduced its energy per GDP ratio from 1,942 TOE per US dollar in 1990 to 810 TOE per US dollar (58 percent reduction).
- There were also substantial decreases in energy intensity per GDP in India (36 percent) and Vietnam (34 percent).
- There were small decreases in energy intensity per GDP for Indonesia (15 percent) and the Philippines (20 percent).
- Thailand was the one exception: its energy intensity per GDP increased, by 8.4 percent, from 553 TOE per US dollar in 1990 to 600 TOE per US dollar in 2008.

The above charts and data indicate that, on the one hand, per capita energy demand is increasing for the developing Asian economies as incomes rise over time, while on the other hand, energy intensity per unit of economic output (GDP) is falling over time. How do these two factors interact?

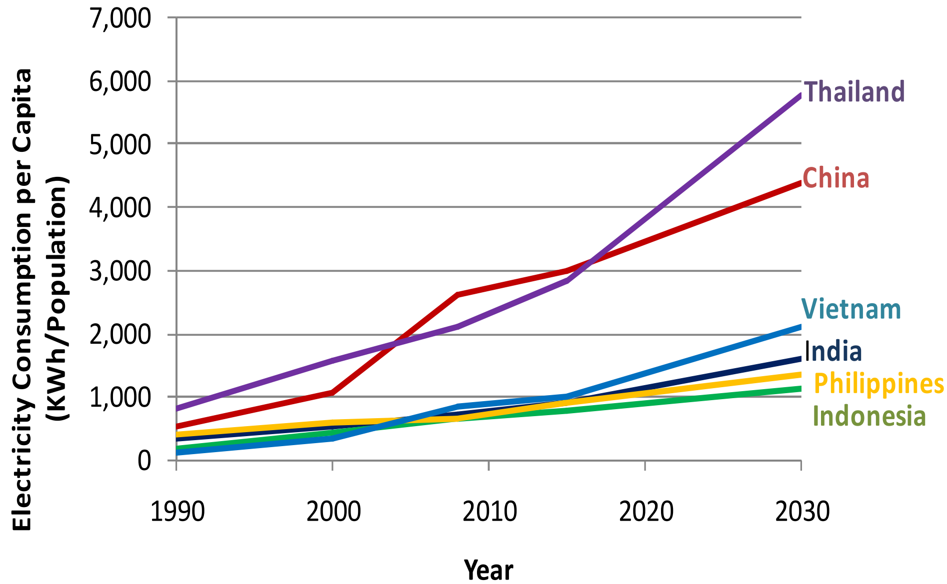
Figure 20 puts energy intensity and income growth together, showing empirical data on how the energy use of a country typically develops over time as a function of their economic development. The charts show per capita energy demand as a function of per capita income.

The left chart is the primary chart, showing data on per capita energy demand (y axis) as a function of GDP per capita. In the left chart, Korea and Japan represent two of Asia's industrialized economies. Japan has maintained a lower level of energy intensity per capita than Korea.

For example, when Japan had an average per capita income of about $30,000 per capita, it had a per capita energy demand of about 3.5 Mtoe. The Korean economy is now at about $30,000 per capita, and it has a much more energy intensive, at about 6.5 Mtoe. This is probably primarily due to the fact that Korea has more energy-intensive heavy industry than Japan relative to its population size. It may also be in part that the Korean economy is less efficient than Japan's economy.

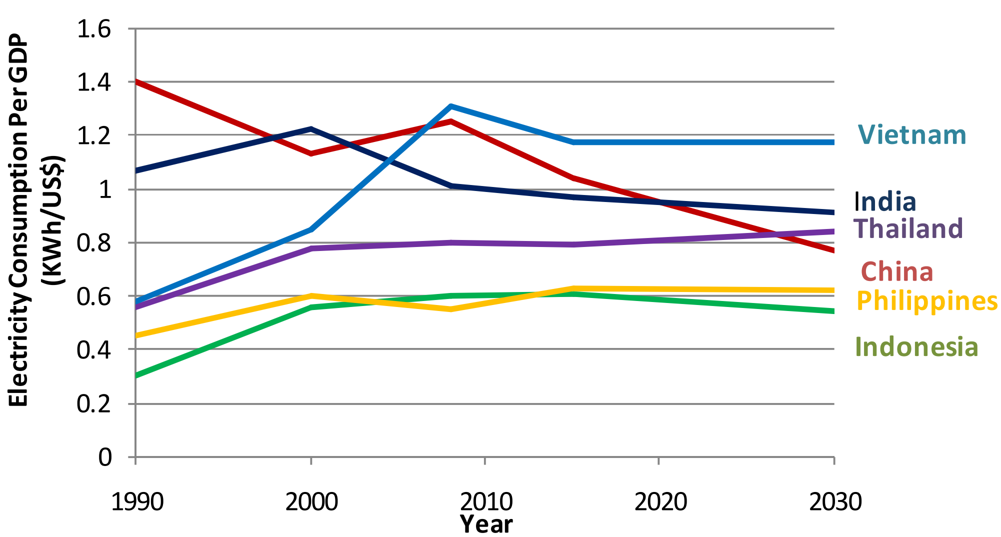
The chart on the right is a magnification of the data located on the lower left-hand corner of the chart on the left and shows details of the energy development pathways for the six focus countries. All of the countries have similar upward trends of energy intensity as their per capita income grows.

Figure 21. Electricity Intensity Expressed as Electricity Consumption per Capita. This chart shows electricity consumption per capita for the six focus countries.



Source: ADB (2010B), based on IEA, APERC, World Bank and 2008 values from IEA's website: http://iea.org/country/index_nmc.asp

Figure 22. Electricity Consumption per GDP for the Six Asian Focus Countries.



Source: ADB (2010 B), based on IEA, APERC, World Bank, and 2008 values from IEA website: http://iea.org/country/index_nmc.asp

6.3 Electricity

Electricity Demand and Per Capita

The relationship of electricity demand per capita is very similar to that for energy demand per capita. As incomes rise over time, so does per capita electricity use. The increases are fairly predictable. For instance, with electrical equipment, the first appliances purchased as incomes rise are equipment for lighting, then a radio and/or television, then refrigerator, then air conditioner, and so on.

Figure 21 shows the evolution of per capita electricity use over the past two decades, as well as projected electricity use for the next two decades, for the six focus countries. On average, per capita electricity consumption is projected to increase more than six-fold from 437 kWh/capita in 1990 to 3,000 kWh/capita in 2030.

Other main observations include:

- For China, per capita electricity intensity has increased nearly five-fold, from 540 kWh/capita in 1990 to 2,608 kWh/capita in 2008.
- For Thailand, per capita electricity intensity has more than doubled, increasing from 814 kWh/capita in 1990 to 2,113 kWh/capita in 2008.
- During the past 20 years, per capita electricity intensity increased more than five-fold in Vietnam, more than tripled in Indonesia, more than doubled in India, and increased by 63 percent in the Philippines.
- These four countries are projected by 2030 to have per capita electricity intensity levels just one-third to one-sixth the levels of Thailand and China.

Electricity Demand Per GDP

In rapidly developing economies, as incomes rise and people purchase electrical appliances for the first time, electricity demand growth typically increases faster than the GDP growth rate. This can be due to a number of factors, such as a greater level of adoption and use of appliances, or a shift in the country's economy toward energy-intensive manufacturing.

In contrast, when GDP rises faster than electricity demand, this indicates the economy is using less electricity per unit of GDP and is generally getting more energy efficient.

Figure 22 shows the trends for the six focus countries:

- For the four ASEAN countries, electricity use per GDP was increasing rapidly during the 1990s and leveled off during the 2000s, except for Vietnam, which has seen its electricity use per GDP continue to rise.
- The electricity intensity per GDP decreased by more than 10 percent in China and 5 percent in India over the past 20 years.
- For India, electricity use per GDP increased slightly from 1990 to 2000, after which time it started falling.
- In China, the electricity use per GDP fell from 1.4 kWh per US dollar in 1990 to 1.13 kWh per US dollar in 2000, and then increased slightly to 1.25 kWh per US dollar in 2008. The main reason for this decline in the 1990s was a decrease in electricity consumption in China's industrial sector.[55] In the coming 20 years, electricity use per GDP in China is expected to fall by more than 30 percent, from 1.2 to less than 0.8 kWh per US dollar.
- Even though China and India show a decreasing trend in electricity intensity per GDP, this is dwarfed by the increases in per capita electricity intensity of China and India for past 20 years.

[55] Lewis et al. (2003). During the 1990s, there was industrial restructuring that was taking place with the main focus to reduce economic losses. China was also making changes in its economy in preparation for accession to the World Trade Organization and as a result was restructuring industries, increasing its competitiveness, and enforcing one-time closures of some inefficient industries. Together, these factors led to a reduction in energy intensity.

6.4 CO_2 Emissions

CO_2 Emissions and Per Capita

Increases in per capita GHG emissions track closely with per capita energy and electricity demand. Figure 23 shows the trends in emissions per capita for the six focus countries. The main observations are:

- China and Thailand show dramatic increases in per capita CO_2 emissions. Over the past 20 years, China's emissions intensity has increased 151 percent, and it is projected to increase an additional 28 percent by 2030.

- Thailand's emissions intensity has increased by 126 percent from 1990 to 2008, and it is projected to increase by an additional 79 percent by 2030.

- Increases per capita CO_2 emissions are projected for India, Indonesia, the Philippines, and Vietnam, but these countries will have per capita CO_2 emissions that are just one-sixth to one-half the projected levels for Thailand and China in 2030.

CO_2 Emissions Per GDP

As with energy intensity, all countries are expected to maintain relatively low CO_2 emissions intensity, or reduce emissions intensity, and emit significantly less CO_2 per unit of GDP, with most of the countries ending up in the range of 1,000 to 2,000 metric tons of CO_2 per US dollar by 2030 (see Figure 24). The main observations are:

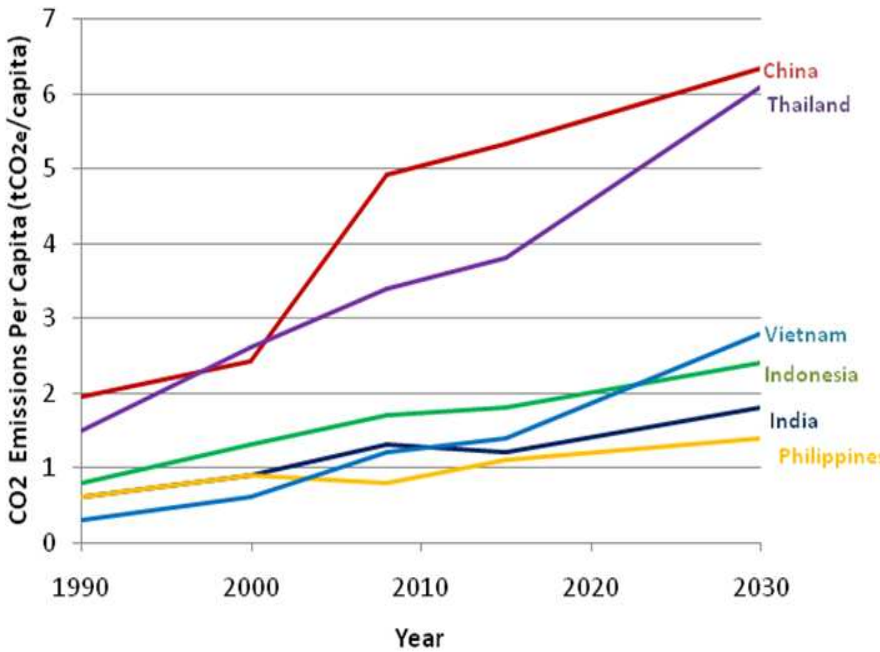
- China's CO_2 emissions per unit of GDP decreased by 50 percent from 1990 to 2008.

- India's CO_2 emissions per unit of GDP fell by 15 percent over the same period, and the Philippines' emissions per unit of GDP fell by 2 percent.

- The other countries actually saw an increase in CO_2 emissions per unit of GDP over the past 20 years: 24 percent for Thailand, 25 percent for Indonesia, and 60 percent for Vietnam.

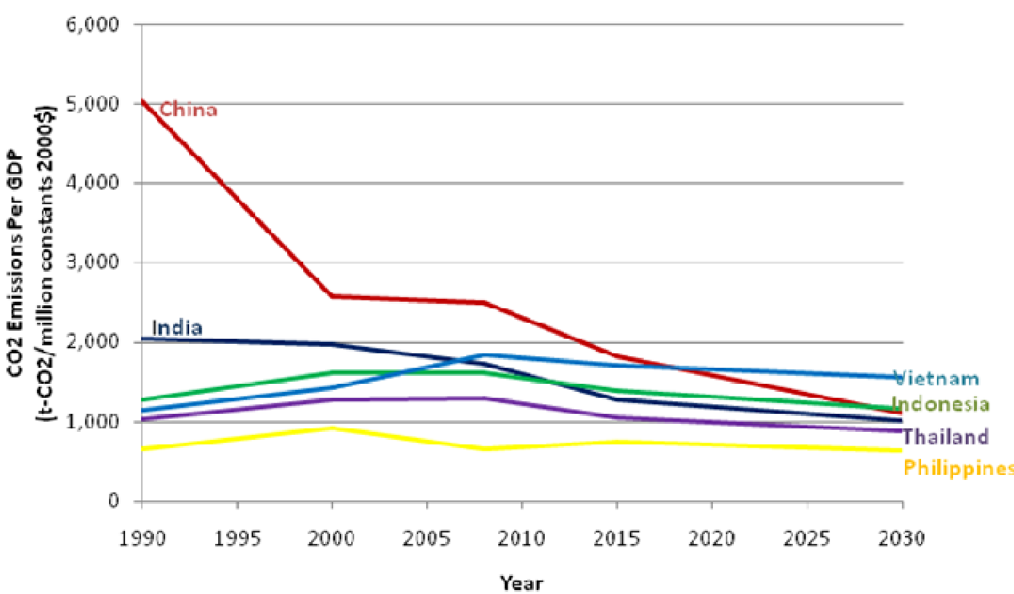
In summary, increases in CO_2 emissions per capita have been dramatic for all six focus countries, and these rates of increase are expected to continue under a business-as-usual scenario. During the 1990s, China saw dramatic decreases in CO_2 emissions per GDP, and India saw modest decreases, while the four ASEAN countries saw increases in CO_2 emissions per unit of GDP. But the stable or slightly falling levels of CO_2 emissions per GDP will not be enough to offset per capita CO_2 emissions increases. It is expected that CO_2 emissions in the six focus countries will continue to grow rapidly over the next 20 years, increasing by 55 percent, from 8.7 billion metric tons of CO_2 in 2008 to 13.5 billion metric tons of CO_2 in 2030.

Figure 23. CO_2 Emissions per Capita for the Six Asian Focus Countries



Source: ADB (2010B), based on IEA, APERC, World Bank, and 2008 values from IEA's website: http://iea.org/country/index_nmc.asp

Figure 24. CO_2 Emissions per GDP for the Six Asian Focus Countries



Source: ADB (2010B), based on IEA, APERC, World Bank, and 2008 values from IEA's website: http://iea.org/country/index_nmc.asp

PART 2: PRIORITIES FOR A CLEAN ENERGY FUTURE

SECTION 7. ENERGY EFFICIENCY: POTENTIAL AND TRENDS

7.1 The Global Energy Efficiency Disconnect

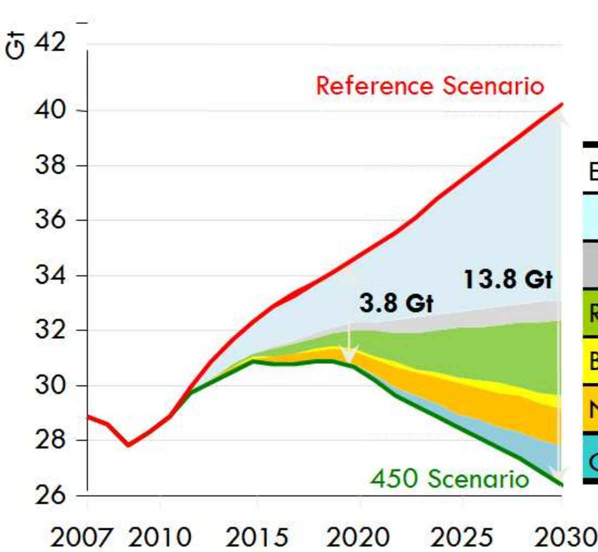
The discussion of the role of energy efficiency in the context of climate change is characterized by a large disconnect between the potential of energy efficiency and its actual implementation. The most glaring example of this disconnect can be seen by comparing the projections in the IEA's World Energy Outlook with the amount of funding being provided for energy efficiency programs in the developing world.

Figure 25 shows the WEO's 450 scenario, which describes the impact of a number of aggressive policy and technical measures needed to achieve "climate stabilization," i.e., limiting atmospheric concentrations of CO_2 to 450 ppm with a corresponding limit to an increase in average global temperatures to 2 degrees Celsius over pre-industrial levels.

In order to achieve the 450 ppm level, GHG emissions must be reduced by 14 billion metric tons by 2030. Under the WEO scenarios, energy efficiency accounts for 65 percent of GHG emissions reductions by 2020 and 57 percent of GHG emissions reductions by 2030. Ninety percent of these emissions reductions come from end-use efficiency measures and 10 percent through improvements in power plant efficiency.

The reality, however, is that the amount of investment going into energy efficiency typically represents a fraction of the amount of investment

Figure 25. Global Scenario for Reducing Greenhouse Gas Emissions



Share of abatement %

	2020	2030
Efficiency	65	57
End-use	59	52
Power plants	6	5
Renewables	18	20
Biofuels	1	3
Nuclear	13	10
CCS	3	10

Source: IEA (2009)

going into renewable energy projects and programs, and this is generally true for both public- and private-sector investments and funding.[56] Without greater investment in energy efficiency, it is unlikely to meet its potential for achieving emissions reductions, and will not be able to achieve the abatement levels modeled in the WEO analysis.

The IEA carried out an international survey of governments to estimate the financial and staffing resources devoted to the design development, implementation, and evaluation of energy efficiency policies and programs in their countries. The IEA received 20 responses from 112 countries indicating annual energy efficiency spending ranging from over 0.2 percent of GDP (Hungary) to nil (Namibia), with most countries spending 0.02 percent to 0.15 percent of GDP on energy efficiency.[57] But the IEA also concludes that the lack of consistent data on funding invested into energy efficiency makes it difficult to compare expenditure levels across countries, or to come up with an overall level of investment into energy efficiency programs.

7.2 Potential for Investment

It is difficult to reliably assess both potential and actual investment in energy efficiency across the Asia region. The *World Energy Outlook* scenario, which shows 57 percent of the needed GHG reductions by 2035 resulting from energy efficiency, implies investment levels in the hundreds of billions of dollars. However, because of the dispersed nature of energy efficiency investments, it is difficult, if not impossible, to estimate the "energy efficiency" component of clean energy investments.[58]

Most studies that have examined the potential for end-use energy efficiency have found cost-effective potential savings on the order of 15-20 percent per sector, but have also found very little of this realized due to a range of barriers, including limited awareness of decision-makers, inadequate access to technology, ineffective institutional structures, and limited access to financing.[59]

The potential for energy efficiency investment in China has been estimated at $432 billion by 2020, based on achieving the aggressive government energy savings rates of 4.4 percent per year during the period 2010 to 2020. This level of annual savings is needed to achieve the targets set out in China's Mid-to-Long Term Special Energy Conservation Plan.[60]

An assessment for India found a potential for energy efficiency investment over five years of $60 billion, or $12 billion annually. The main areas identified were agricultural pumping, municipal pumping, street lighting, commercial buildings, and small and medium enterprises (SMEs).[61]

A study of the potential for investment in energy efficiency improvements in the private sector in six countries in Southeast Asia (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam) found a potential of $6.6 billion in cost-effective energy efficiency investments, with $3.7 billion in the commercial sector and $2.9 billion in the industrial sector. The study also found the annual savings potential from these investments to be a total of $1.4 billion. Average payback times for the efficiency

[56] Global annual investment in clean energy in 2010 was more than $211 billion, and this was almost entirely for renewable energy. UNEP/BNEF indicates the difficulties of tracking energy efficiency investments because they are an order of magnitude less than investments in renewable energy and they are widely dispersed across tens of millions of buildings and factories. UNEP/BNEF acknowledged this and accordingly in 2011 changed the title of its annual report on clean energy investment and removed the words "energy efficiency" from the title. The title now reads: *Global Trends in Renewable Energy Investment: Analysis of Trends and Issues in the Financing of Renewable Energy.*

[57] IEA (2010C).

[58] Section 9 of this report reviews clean energy investment, globally and in Asia. The investment figures reported for clean energy are almost entirely for renewable energy, since it is difficult to capture the sum of many dispersed investments on energy-efficiency measures by residential consumers, building owners, factory owners, and managers of transportation fleets and systems.

[59] USAID (2007).

[60] Yongchun WANG, Managing Director, GoodHope Capital. Presentation at China Energy Conservation Investment Forum. Beijing. June 24-25, 2011. The target is set in China's Mid-to-Long Term Special Energy Conservation Plan promulgated by the National Development Reform Commission.

[61] Limaye (2011).

measures were 4.6 to 3.2 years in the industrial sector and 7.2 years in the commercial sector.[62]

7.3 Energy Efficiency Institutions, Laws, Plans, and Targets

It is impossible to scale up deployment of energy efficiency and renewable energy technologies and measures without establishing strong[63] policy frameworks and then drafting effective and practical implementing rules and regulations.

There are a number of cross-cutting mechanisms that can stimulate clean energy investment include pricing mechanisms,[64] regulatory and control mechanisms, fiscal measures and tax incentives, carbon credits, integrated resource planning, public procurement requirements for clean energy, promotional and market-based mechanisms, and technology development and commercialization.

Policy and regulatory mechanisms focused specifically on energy efficiency include energy efficiency portfolio standards, energy efficiency certificates (white certificates), feed-in tariff for energy efficiency (standard offer), demand-side management bidding, building energy codes, minimum energy performance standards (MEPS) for appliances and equipment, and energy labeling,

The past decade has seen much progress in the development of energy efficiency policies and institutions in the Asia region. Significant laws and regulations have been passed to support energy efficiency in all six Asian focus countries. At the same time, however, measurable progress in capturing the energy efficiency potential remains relatively slow.

[62] ReEx Capital Asia (2010).

[63] A "strong" policy framework can be defined as being clear, transparent, enforceable, and with effective monitoring and compliance mechanisms.

[64] Pricing issues include tariffs as well as removal of subsidies for fossil fuels, or introduction of preferential pricing mechanisms to support clean energy.

All six of the focus countries have institutional structures, laws, action plans, and targets in place to guide and support energy efficiency efforts. These are summarized in Table 7, which is based on an international survey carried out by the International Energy Agency, and was updated with data from the Asia-Pacific Energy Research Center, as well as some national data.[65]

All of the countries have an energy efficiency framework law except for the Philippines. All six focus countries also have dedicated agencies responsible for implementing energy efficiency plans and programs, and have national energy-saving plans or programs in place to guide their efforts. The table also shows that each country has national energy-savings targets in place.

The Philippines and Vietnam have set absolute energy savings targets, with the Philippines' adopting a goal of reducing final energy demand by 10 percent by 2014. Vietnam's goal is to reduce total energy consumption by 5 to 8 percent by 2015.

Other targets are based on energy intensity. For example, China's 11th Five-Year Plan calls for a 20 percent reduction in energy intensity between 2005 and 2010, Indonesia's target calls for annual reductions in energy intensity of 1 percent through 2025, and Thailand has set a target of reducing energy intensity per GDP by 25 percent by 2030.

China and India have also set targets related to GHG emissions. China has a target of reducing CO_2 emissions per unit of GDP by 40 to 45 percent by 2020, and India has a target for a 20-25 percent reduction in CO_2 emissions intensity by 2020.

[65] IEA (2010C) and APERC (2010C).

Table 7. Summary of Energy Efficiency Institutions, Laws, and Targets in the Six Focus Countries

Country	Energy Efficiency Institutions	Energy Efficiency Law		Energy Efficiency Strategy/Action Plan		Targets			
		Name	Year	Name	Year	Description	Target	Base-line Year	Target Year
China[66]	• Ministry of Science & Technology • National Development & Reform Commission (NDRC) • Resource Conservation and Environmental Protection Department in NDRC	Energy Conservation Law	2007[67]	11th Five-year Plan	2006	Reduce energy intensity relative to baseline year	20%	2005	2010
				Medium- and Long-term Plan for Energy Conservation	2004	Reduce CO_2 emissions per unit of GDP by 40-45%	40-45%	2005	2020
India[68]	• Bureau of Energy Efficiency (BEE)	Energy Conservation Act	2001	• National Action Plan on Climate Change • National Mission on Enhanced Energy Efficiency	2008	Reduce emissions intensity of GDP	20-25%	2005	2020
Indonesia[69]	• Ministry of Energy and Mineral Resources • National Energy Council (Dewan Energy Nasional) • Directorate General of Renewable Energy and Energy Efficiency	• The Energy Law • Regulation 70 on Energy Conservation	• 2007 • 2009	• National Energy Conservation Master Plan (2005); • National Energy Management Blueprint (2006) • National Energy Policy (2006)		Decrease energy intensity by 1% annually and decrease energy-GDP elasticity to below 1%			2025

[66] Prime Minister's Office. National Action Plan on Climate Change http://pmindia.nic.in/climate_change.htm and National Mission for Enhanced Energy Efficiency: http://india.gov.in/allimpfrms/alldocs/15659.pdf.
[67] The 2007 law is a revision of a previous energy conservation law.
[68] APERC Institute of Energy Economics. Compendium of Energy Efficiency Policies of APEC Economies: China (April 2010). Accessed online at http://www.ieej.or.jp/aperc/CEEP/China.pdf.
[69] APERC Institute of Energy Economics. Compendium of Energy Efficiency Policies of APEC Economies: Indonesia (April 2010). Accessed online at http://www.ieej.or.jp/aperc/CEEP/Indonesia.pdf.

Country	Energy Efficiency Institutions	Energy Efficiency Law		Energy Efficiency Strategy/Action Plan		Targets			
		Name	Year	Name	Year	Description	Target	Base-line Year	Target Year
Philippines[70]	• Department of Energy	none		• National Energy Efficiency and Conservation Program (Philippine Energy Plan 2007-2014)	2004	Achieve an estimated potential cumulative energy savings of 9.08 million barrels of oil equivalent			2014
						Reduce final energy demand	10%	2007	2014
Thailand[71]	• Ministry of Energy • Department of Alternative Energy Development and Efficiency (DEDE) in MOEN • Energy Policy & Planning Office (EPPO) in MOEN • Energy Conservation Center of Thailand (ECCT)	Energy Conservation & Promotion Act (No. 2)	2007	Energy Efficiency Improvement Programs		Reduce the energy intensity of GDP 25% by 2030	25%	2005	2030
						Improve energy intensity	8%	2005	2015
Vietnam[72]	• Ministry of Industry & Trade; Energy Efficiency and Conservation Office	Energy Conservation & Efficient Use Law	2010	National Programme on Energy Efficiency & Conservation (Vietnam National Energy Efficiency Program)	2006	Reduce total energy consumption	5%	1011	2010
						Reduce total energy consumption	8	1015	

[70] APERC Institute of Energy Economics. Compendium of Energy Efficiency Policies of APEC Economies: Philippines (April 2010). Accessed online at http://www.ieej.or.jp/aperc/CEEP/Philippines.pdf.
[71] APERC Institute of Energy Economics. Compendium of Energy Efficiency Policies of APEC Economies: Thailand (April 2010). Accessed online at http://www.ieej.or.jp/aperc/CEEP/Thailand.pdf.
[72] APERC Institute of Energy Economics. Compendium of Energy Efficiency Policies of APEC Economies: Viet Nam (April 2010). Accessed online at http://www.ieej.or.jp/aperc/CEEP/Viet%20Nam.pdf.

7.4 Recent Trends in Country Energy Efficiency Programs

China

China has strong central government leadership in setting energy efficiency policies and goals, with responsibility for overseeing implementation by subnational governments. In 2007, the government established the National Energy Conservation and Emissions Reduction Leading Group, which is chaired by the Prime Minister and comprised of ministry-level leaders of relevant agencies. Provincial Leading Groups have also been established, and these are chaired by governors. China also has strict monitoring and evaluation mechanisms in place at the national and local levels.[73]

China made significant progress in implementing energy efficiency measures between 2005 and 2010 as reflected by its nearly 20 percent reduction in energy intensity (per GDP). China recently established important national demand-side management (DSM) regulations that require grid companies to meet concrete energy savings obligations, which are set at 0.3 percent of sales volume and 0.3 percent of maximum sales load compared with previous year.[74]

There are incentives in place to allow the cost of funding DSM to be recovered through tariffs. Funding for DSM comes from surcharges on tariffs, premiums on flexible pricing mechanisms, and the fiscal budget.

India

The Bureau of Energy Efficiency, established under the Ministry of Power, is a centralized energy efficiency agency with a wide range of powers and functions for promoting energy efficiency. BEE is mandated on a national level to implement a number of energy efficiency initiatives under the Energy Conservation Act of 2001, and it has authority in the areas of lighting, appliances, building, agriculture, and municipalities.[75]

It is estimated that to date BEE's energy efficiency initiatives have reduced energy demand by 5,000 MW.

A recent, major enabling policy instrument for energy efficiency in India is the National Mission on Energy Efficiency (NMEEE), which targets reduction of Specific Energy Consumption, which is the amount of energy used per unit of production. NMEE has four components:

- *Perform, Achieve, and Trade (PAT).* This is a market-based mechanism to enhance the cost-effectiveness of improving energy efficiency in energy-intensive industries through certifications of energy savings, which can be traded.

- *Market Transformation for Energy Efficiency (MTEE).* This is aimed at accelerating the shift to energy-efficient appliances in designated sectors through innovative measures to make the products more affordable.

- *Energy Efficiency Financing Platform (EEFP).* This platform creates mechanisms that help finance DSM programs in all sectors by capturing the value of future energy savings.

- *Framework for Energy Efficient Economic Development (FEEED).* This is another financing framework that develops fiscal instruments to promote energy efficiency.

Indonesia

As a government response to climate change, and in an effort to promote clean energy development, the Indonesian Ministry of Energy and Mineral Resources established a new Directorate General of New-Renewable Energy and Energy Conservation (DGNREEC) in August 2010. The new agency acts as a policy-maker, regulator, and champion for the development of renewable energy resources and adoption of energy efficiency initiatives in Indonesia.

[73] Zhang (2011).
[74] Yang (2011).
[75] This section is based on Kumar (2011).

The new institutional set-up has been accompanied by a change of paradigm in national energy management, to become more demand-oriented. Instead of focusing on whether supply is enough to meet the growing demand, the new mind-set is to focus on whether demand has been adequately managed through the implementation of energy efficiency initiatives. DGNREEC has established that energy efficiency and conservation are a faster and cheaper way to add new supply capacity compared to constructing new power plants. In March 2011, DGNREEC began enforcing provisions under Government Regulation 70/2009, which requires that all entities with energy consumption more than 6,000 barrels of oil equivalent per year establish an energy efficiency program, appoint an energy manager within the organization, conduct regular energy audits, and implement and report the audit recommendations. This requirement applies to organizations in both the public and private sectors, and also both profit and non-profit organizations. The government target is that 650 organizations will be in compliance with the regulation, and that the resulting savings will be equivalent to the development of a 2,000 MW power plant.

With the pressure of high oil prices, DGNREEC is also working together with the Directorate General of Oil and Gas to promote fuel savings in transportation and power generation, with the ultimate impact of reducing the amount of government's fuel subsidy. In March 2011, DGNREEC established the Energy Efficiency and Conservation Clearing House Indonesia (EECCHI), a facility to promote and share best practices knowledge in energy efficiency and conservation (www.konservasienergiindonesia.info).

DGNREEC expects that through these efforts, it can realize its goal for Vision 25/25: reduce energy demand in 2025 by 34 percent compared to the business-as-usual scenario, and to have renewable energy will contribute 25 percent of the Indonesian energy mix in 2025.

Philippines

The Philippines established a DSM framework in 1996. This was set up by the Electricity Regulatory Board, which was reorganized in 2001 as part of electric power sector restructuring and subsequently reconstituted as the Energy Regulatory Commission.[76]

The lead energy efficiency agency in the Philippines is the Department of Energy, which oversees seven major electricity end-use efficiency programs:

- Power Conservation and Demand
- Government Energy Management
- Energy Management Services/ Energy Audit
- Standards/Labeling for Household Appliances
- Voluntary Agreement Program
- Recognition Award Program (buildings)
- Philippine Energy Efficiency Project (PEEP), which has reduced peak demand by 27 MW

Singapore

Although Singapore is not considered a developing country, it is a part of ASEAN and its activities in clean energy provide an important example for its ASEAN neighbors. Singapore has taken an innovative approach to solve its multi-agency problems in promoting energy efficiency by setting up the Energy Efficiency Program Office, which is an inter-agency committee to drive and coordinate whole-of-government energy efficiency efforts.

The increasing complexities in energy efficiency policy require better coordination and more integration of the elements needed within smart communities, which aim to integrate smart grids, buildings, homes, electric cars, and energy-efficient appliances.

Important multi-agency programs in Singapore include:

- *Sustainable Singapore Blueprint 2009* targets a 35 percent improvement in energy intensity from 2005 levels by 2030, and a 20 percent improvement in energy intensity by 2020. It also provides a broad outline of objectives for national of energy efficiency policy.

[76] This section is based on Habitan (2011).

- *Inter-Ministerial Committee on Climate Change 2007* was established following the 2009 UNFCCC Conference of the Parties in Copenhagen. It has unilaterally pledged to reduce GHG emissions by 7 to 11 percent below business-as-usual levels by 2020.

Thailand

Thailand's Ministry of Energy oversees all energy efficiency and renewable energy activities. The Energy Policy and Planning Office is responsible for the Ministry's policy framework and initiatives. The Department of Alternative Energy Development and Efficiency is the lead implementing agency on energy efficiency and is responsible for buildings and factories and minimum efficiency performance standards for appliances and equipment. The Electricity Generating Authority of Thailand (EGAT) has a DSM Office that implements voluntary programs to improve the efficiency of appliances and equipment such as lighting.

DSM activities in Thailand have generated 2,000 MW (12,210 GWh) in savings. This has been primarily due to efforts to promote energy efficient air conditioners, lighting, and refrigerators.[77] Since 2000, DSM funding has been stable at roughly 0.06 percent of EGAT's annual budget (1 percent of annual profit).[78]

Vietnam

Vietnam's first government decree on energy efficiency was passed in 2003, and in 2006 a National Programme on Energy Efficiency and Conservation was initiated. At the same time, the government set national energy efficiency targets and guidelines for labeling of energy efficient products.[79]

In 2010, a new National Energy Efficiency and Conservation Law passed, effective January 2011. The law covers all economic sectors and has four major programs: management of designated enterprises; standard and labeling of energy-using equipment; financial incentives and support; and institutional arrangements. The law also provides for a budget for energy efficiency programs in state agencies and the establishment of a National Energy Use Database.

The National Target Program on Energy Efficiency, Phase 2, sets a target to reduce national energy consumption by 5 to 8 percent by 2015. It also enhances the legal framework and policy on energy efficiency, includes standards and labeling for appliances and equipment, provides action plans for energy-intensive industries, and provides for energy efficiency programs in the building and transport sectors.

77 Phumarapand (2011).
78 Id.
79 This section is based on Toan (2011).

SECTION 8. RENEWABLE ENERGY: POTENTIAL AND TRENDS

Key Points

- Renewable energy supplies about 26 percent of global power-generating capacity and 18 percent of global electricity generation, and during 2009, newly added renewable power capacity constituted 47 percent of total new power capacity added worldwide.
- Under current plans, electricity generation from renewable energy sources in developing Asia is predicted to grow at an average rate of 5 percent annually, increasing the region's total renewable energy generation from 15 percent in 2007 to 20 percent in 2035.
- Within Thailand, Philippines, Indonesia, Singapore, Malaysia, Vietnam (the "ASEAN-6"), IEA predicts that the total "realizable potential"[1] for renewable electricity in 2030 is 1.8 times the total electricity consumption in the region compared to 2007 levels.
- Within developing Asia, many countries have set targets for increasing the share of renewable energy in the overall energy mix. Countries have short-term and medium-term targets, as well as targets for individual sources of renewable energy (e.g., solar, wind, etc.).

8.1 Global Overview of Renewable Energy

Renewable Energy as a Share of Primary Energy

Between 2008 and 2009, global primary energy supply decreased by 1.1 percent, the first decline since 1982, largely due to the global economic contraction.[80] Consumption of traditional forms of energy – like oil and natural gas – fell, while consumption of renewable forms of energy increased.

During the coming two decades, fossil fuels are still expected to continue supplying most of the energy used worldwide. However, the share of renewable energy will increase significantly relative to liquid fuels, coal, natural gas, and nuclear. Figure 26 provides a comparison of the different fuels from 1990 to present, with projections to 2035.[81]

Renewable Energy Electricity Production

Renewable energy currently supplies about 18 percent of global electricity generation, and most of this (15 percent of total global generation) is provided by hydropower. Thus, other non-hydro renewable energy sources accounted for 3 percent of global electricity production in 2008. The balance of electricity production is provided by fossil fuels, at 69 percent, and nuclear power, at 13 percent (see Figure 27).

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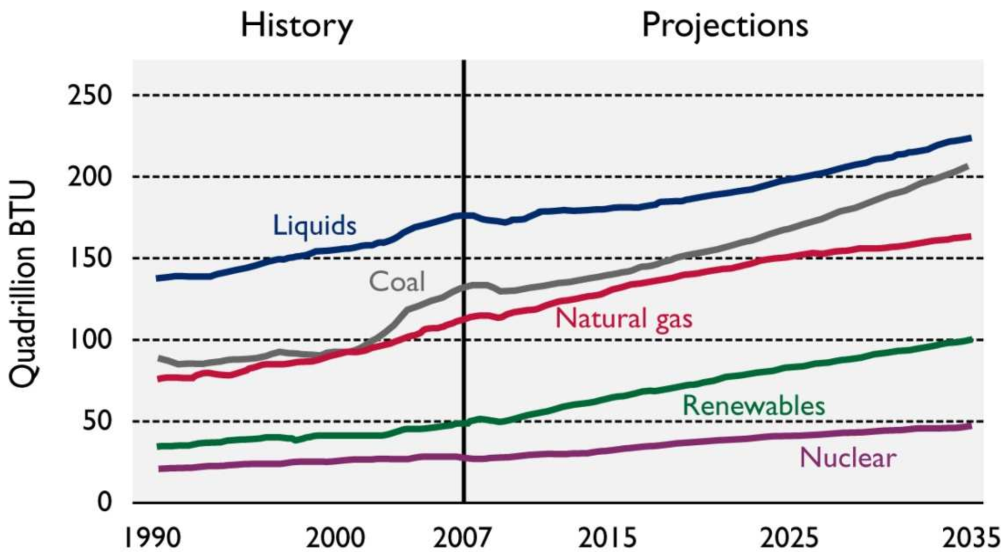
80 Solar Buzz, http://www.solarbuzz.com/facts-and-figures/markets-growth/market-share.

81 USEIA (2010).

Figure 26. World-Marketed Energy Use by Fuel Type (1998-2035) (quadrillion BTU)



Source: EIA International Energy Outlook 2010.

Renewable Energy Generating Capacity

While renewable energy sources have a long way to go to outpace fossil fuel energy in terms of overall electricity production, the rate at which new renewable energy capacity is being added will soon eclipse the new capacity of fossil-fueled power generation. During 2009, newly added renewable power capacity constituted 47 percent of total new power capacity added worldwide.[82]

In 2009, there was 1,230 GW of renewable capacity (including large hydro) installed globally, accounting for roughly 26 percent of total global power generating capacity (4,800 GW).[83]

In 2009, renewable power accounted for more than three times as much *installed capacity* as nuclear power, and roughly 38 percent as much installed capacity as fossil fuel-burning power plants worldwide (see Figure 28). Excluding hydropower of all sizes[84], other sources of renewable energy capacity totaled 305 GW in 2009 and made up 6 percent of total power generating capacity.

Developing countries accounted for more than one-third of renewable generating capacity if hydropower is excluded (110 GW), and half of renewable generating capacity if hydropower is included (650 GW). In 2009, the four largest countries or regions in terms of installed capacity were the European Union (EU), with 246 GW, China with 226 GW, the US with 144 GW, and Germany with 51 GW.[85]

During the period 2004 to 2009, installed capacity for many renewable energy technologies grew at rates of 10 to 60 percent annually.[86] Solar photovoltaic (PV) systems had the highest rate of increase of all renewable energy sources, with a 60 percent annual average growth rate. Biofuels also grew rapidly – at an average annual rate of 20 percent for ethanol and 51 percent for biodiesel.

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82 REN21 (2010), Figure 17.

83 This is an increase from 2004 when renewable energy capacity was 880 GW and accounted for 23 percent of total global power generating capacity.

84 The REN21 report defines "large hydro" as plants larger than 10 MW of capacity.

85 REN21 (2010), Table R4.

86 REN21 (2010), p. 15.

Other renewable energy resources, like biomass power and hydropower, grew at a global average annual rate of 3 to 6 percent, comparable to that of fossil fuels, which grew at 3 to 5 percent per year.[87]

In 2009 there was a surge in growth of non-hydro renewable energy installations, with nearly 80 GW of capacity added globally. Solar energy led the charge, with an annual growth of 41 percent for solar thermal and 53 percent for grid-connected solar PV.[88] Seven GW of solar PV capacity was added in 2009.

Meanwhile, worldwide wind power capacity grew by 32 percent in 2009, adding 38 GW of new capacity, to reach a global total of 159 GW. China, the United States, and India accounted for much of this growth. The United States added 10 GW of wind power in 2009, maintaining its status as the global leader in existing wind power capacity, with 35 GW.[89] China added 13.8 GW of wind power generating capacity, which constituted 39 percent of China's total renewable energy additions for the year. [90] China ranked second in the world with a total wind generating capacity of 26 GW. India added 1.3 GW of wind generating capacity and ranked fifth worldwide with a total of 10.9 GW by the end of 2009.[91]

The top five countries (US, China, Germany, Spain, and India) accounted for 73 percent of global wind capacity in 2009, with the United States and China together providing more than 38 percent of the global total.

Geothermal

Indonesia and the Philippines have the most potential for geothermal electricity generation in the world, as both lie within the "Ring of Fire" volcanic zone. The Philippines currently produces 2.6 GW of geothermal electricity and ranks second worldwide in geothermal energy capacity, while Indonesia produces 1.1 GW[92] and currently ranks third.[93] These numbers will increase in the future, as Indonesia has an estimated geothermal theoretical potential of about 27 GW (40 percent of the world's reserves) with only 4 percent of this currently being utilized[94] while the Philippines is only utilizing half of its potential geothermal resources.[95]

8.2 Renewable Energy Trends in Developing Asia

Recent trends reflect the increasing significance of developing Asia in advancing renewable energy. Developing Asia, led by China and India, has the fastest projected regional growth in electric power generation worldwide.[96] Electricity generation from renewable energy sources is predicted to grow at an average rate of 5 percent annually, which would increase the renewable share of the region's total generation from 15 percent in 2007 to 20 percent in 2035. Within the ASEAN-6,[97] IEA predicts that the total "realizable potential"[98] for renewable electricity in 2030 is 1.8 times the total level of electricity consumption in the region in 2007.

This section will provide a brief overview of trends and potential for hydro, wind, solar, geothermal, and biofuel resource utilization within the region.

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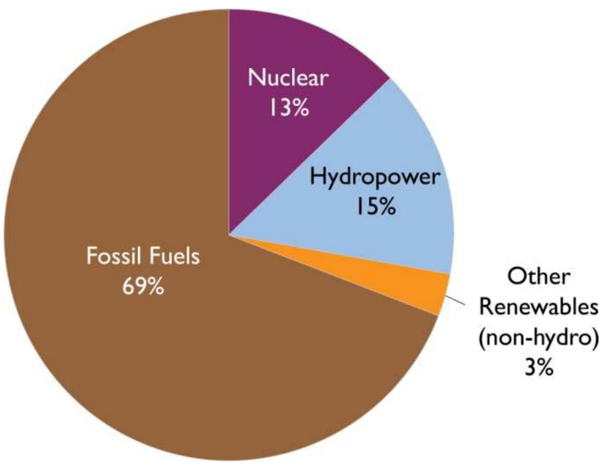
[87] REN21 (2010), Figure 2.
[88] REN21 (2010), Figure 2.
[89] REN21, p. 16.
[90] World Wind Energy Association, "World Wind Energy Report 2009," available at http://www.wwindea.org/home/index.php?option=com_content&task=view&id=266&Itemid=43&limit=1&limitstart=1.
[91] World Wind Energy Association, http://www.wwindea.org/home/index.php.

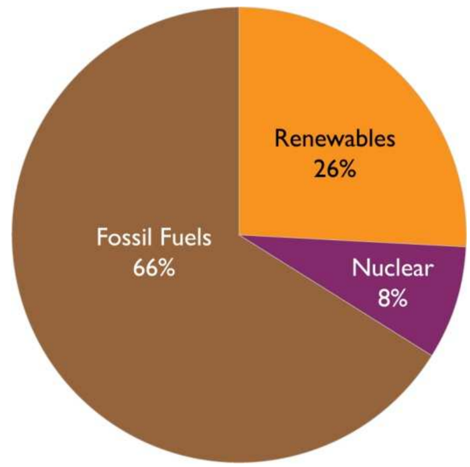
[92] The Jakarta Globe, http://www.thejakartaglobe.com/business/indonesias-ambitious-geothermal-goals-seen-requiring-big-changes/371620.
[93] REN21 (2010).
[94] National Geological Agency of Indonesia, http://b-dig.iie.org.mx/BibDig/P10-0464/pdf/0128.pdf.
[95] http://b-dig.iie.org.mx/BibDig/P10-0464/pdf/1616.pdf.
[96] EIA, http://www.eia.doe.gov/oiaf/ieo/electricity.html.
[97] Countries include Thailand, Philippines, Indonesia, Singapore, Malaysia, Vietnam, which represents 95 % of the region's energy demand in 2007 and 98 % of electricity generation according to the IEA *World Energy Outlook 2009*.
[98] IEA defines a "realizable potential" as representing the maximum achievable potential for a specific technology, assuming that all barriers can be overcome and countries have effective policies in place. IEA's calculations consider overall energy system constraints but not relative costs.

Figure 27. World Electricity Production by Source (2008)



Source: REN21 (2010), Figure 3

Figure 28. World Generating Capacity by Source (2009)



Source: REN21 (2010), Figure 16.

Hydropower

New hydropower projects, both small and large scale, are very prevalent in China, India, the Philippines, Thailand, and Vietnam. Although rapid development of hydroelectric power has raised concerns about adverse environmental, economic, and social impacts, particularly along the Mekong River Basin, in general hydropower is expected to be the predominant source of renewable electricity growth in developing Asia in the coming years, primarily from mid-to large-scale power plants.

China has many large-scale hydroelectric projects under construction.[99] China's overall hydroelectricity generation is expected to increase by 3.9 percent per year, which would triple China's total hydroelectricity generation by 2035.

India plans to more than double its installed hydropower capacity by 2030. India's Central Electricity Authority has identified 40.9 GW of hydroelectric capacity that it intends to build. More than one-third of the announced plans are under construction and will be completed by 2020.[100]

The power sector in the Philippines has a significant share of renewables-based production, with hydropower covering more than 14 percent of electricity needs.[101]

In Vietnam, hydropower represented 43 percent of the country's electricity production in 2007.[102] Almost 50 hydropower facilities with a combined total of 3.4 GW of capacity are under construction in Vietnam's Son La province, including a 2.4 GW facility that will be completed in 2015.[103]

Wind Energy

China and India are world leaders in wind power generation, and both are expected to continue increasing wind power generation, as much of its potential has yet to be realized. In 2009, China had 26 GW of installed wind power, and this increased

[99] This includes the Three Gorges Dam, which will expand its capacity to 22.4 GW (from 18.2 GW) by 2012. Additionally, the 12.6 GW Xiluodu project is scheduled for completion in 2015 as part of a 14-facility hydropower development plan.

[100] EIA, http://www.eia.doe.gov/oiaf/ieo/electricity.html.
[101] IEA (2010), p. 26.
[102] IEA (2010), p. 26.
[103] EIA, http://www.eia.doe.gov/oiaf/ieo/electricity.html.

by 50% in 2010 to reach 41.8 GW.[104] China aims to have 100 GW of wind power capacity installed by 2020.[105] India's onshore wind power potential is 50 GW, and had nearly 11 GW installed in 2009.[106]

Besides China and India, the Philippines has the most developed wind power generation in the region with an installed capacity of 33 MW in 2008. In Indonesia and Thailand, wind power is significantly less prevalent. Thailand had 5.6 MW of installed wind power in 2010 and Indonesia had 2 MW of installed wind power in 2008.

Solar PV

Developing Asia has great potential for solar PV but has yet to tap into this potential. Solar PV comprises a negligible share of the region's overall total installed capacity. However, India, China, and the Philippines are making significant progress in increasing solar PV capacity.

At the end of 2005, the total installed capacity for solar PV was about 70 MW, with most of this energy being utilized to power rural areas in China. By the end of 2009, installed solar PV capacity increased to 220 MW. China plans to increase this amount to 30 GW by 2020.

India's installed capacity for solar PV was 2 to 2.5 MW, which constitutes less than 1 percent total domestic electricity generation. However, India has embarked on a National Solar Mission which is targeting installation of 20 GW of grid-connected solar power by 2022.

In Thailand, more than 3,200 MW of solar PV and solar thermal projects have been proposed under the small power producer (SPP) and very small power producer (VSPP) programs. However, as of December 2010, just 26 MW was operational and selling to the grid.[107]

The Philippines has installed a 950 kW solar PV system in Cagayan de Oro City, which at the time of completion was the largest solar PV plant in the developing world.[108] To date, a total of about 500 MW of solar PV have been installed.

Biofuels

Thailand, China, and India produce sizable volumes of ethanol and biodiesel, and are among the top 15 countries in the world producing biofuels.[109]

Global production of biofuels tripled between 2004 and 2008, and an estimated 77 billion liters of ethanol and 12 billion liters of biodiesel were produced worldwide in 2008.[110] In Asia, in response to policy incentives and favorable economics, production of biofuels grew five-fold from just over 2 billion liters in 2004 to almost 12 billion liters in 2008. Notably, biodiesel production went from virtually zero in 2004 to close to 1.8 billion liters by 2008.

Table 8 shows current biofuels feedstocks and production in selected Asian countries. India, Indonesia, and Thailand had the most dramatic increases in biodiesel production between 2007 and 2008. Biodiesel production in Thailand is projected to rise steadily over the next few years while production in Malaysia, Philippines, and Indonesia is projected to continue to increase in the range of 25 to 60 percent annually.[111] Vietnam recently started producing ethanol in 2009.[112] APEC estimates that if Vietnam utilized all of its cane molasses and 10 percent of cassava and corn production to make

104 Wikipedia, Wind Power in the People's Republic of China, http://en.wikipedia.org/wiki/Wind_power_in_the_People's_Republic_of_China.
105 Wikipedia, Renewable energy in China, http://en.wikipedia.org/wiki/Renewable_energy_in_China#Wind_power. A key barrier to achieving this target is the fact that approximately 30 percent of installed wind capacity remains unconnected to the grid at the end of each year.
106 http://www.renewableenergyindiaexpo.com/India's-RE-Sector-Potential-and-Investment-opportunities-SSM.pdf.
107 Energy Policy and Planning Office, Thailand. March 14, 2011. Summary tables for SPP and VSPP programs posted at www.eppo.go.th/power/data/index.html.
108 REN21 p. 20.
109 REN 21 (2010), Table R6. China is the fifth largest producer, Thailand is ninth, and India 14th.
110 USAID (2009), OECD-FAO (2008).
111 IEA (2010), p. 36.
112 USEIA, http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=79&pid=79&aid=1.

Table 8. Current Biofuels Feedstocks and Production in Selected Asian Countries[114]

Country	Currently Used Feedstocks		Ethanol Production (millions of liters)		Biodiesel Production (millions of liters)	
	Ethanol	Biodiesel	2007	2008	2007	2008
China	Maize/corn, wheat, cassava	Waste vegetable oil	5,564	6,686	355	355
India	Molasses	Jatropha, pongamia	2,450	2,562	45	317
Indonesia	Molasses, cassava	CPO	177	212	241	753
Malaysia	None	CPO	63	70	217	443
Philippines	Sugarcane	Coconut oil	62	105	257	211
Thailand	Molasses, cassava	CPO, waste cooking oil	285	408	0	48
Vietnam	Molasses, cassava	Animal fat (catfish oil) and used cooking oil	140	164	0	0
		Total	**8,741**	**10,207**	**1,115**	**1,772**

Source: OECD-FAO (2008), Milbrant and Overend (2008), and Elder et al. (2008) cited in USAID (2009)
Note: CPO = crude palm oil.

ethanol, the country could produce about 320 million liters per year.[113]

8.3 Renewable Energy Policies, Regulations, and Targets

Policies and Regulations

Table 9 provides a summary of policy and regulatory instruments being used in developing Asia to support the development of renewable energy sources. The chart includes: feed-in tariffs; renewable portfolio standards;[115] capital subsidies, grants, and rebates; investment or other tax credits; tax reductions and exemptions; tradable renewable energy certificates (in India only); energy production payments or tax credits; and net metering.

The four most commonly used instruments are: feed-in tariffs; capital subsidies, grants, and rebates; tax credits; and other tax mechanisms. Feed-in tariffs have been introduced worldwide in at least 50 countries and 25 states/provinces as of 2010, although the Philippines, Indonesia, and Vietnam have not yet implemented them.[116]

Targets

By early 2010, more than 100 countries had some type of policy target and/or promotion policy related to renewable energy. The European Union (EU) and the United States have put forth aggressive renewable energy targets[117] while targets within

[113] http://www.biofuels.apec.org/me_vietnam.html.
[114] Because official Chinese figures for biodiesel production were not available for 2008, 2007 levels were used. Ethanol figures represent total ethanol production. It is estimated that in most countries, fuel ethanol is one-quarter to one-third of the total production. OECD-FAO (2008) was chosen to ensure uniformity of data assumptions and data quality. Country level biofuels production estimates are available. However, they differ significantly from the OECD-FAO data. For example, OECD-FAO and the Ministry of Energy, Thailand, report biodiesel production in Thailand in 2008 to be 48 million liters and 400 million liters, respectively. Moreover, within a country, official production figures differed. For example, two official sources within the Philippines estimated biodiesel production volumes as relative values between the countries rather than absolute values.
[115] A feed-in tariff is a policy mechanism designed to accelerate investment in renewable energy technologies by offering long-term contracts to renewable energy producers, typically based on the cost of generation of each different technology. A Renewable Portfolio Standard (RPS) is a regulation that requires increased production of energy from renewable energy sources, such as wind, solar, biomass, and geothermal.
[116] REN 21 (2010), p. 11.
[117] Collectively, the EU aims to meet 20 percent of its energy demands through renewable energy by 2020. The European Environment Agency estimates that 31-34 percent of electricity will come from green energy by 2020. Wind power will account for 41 percent of that amount, while hydro and biomass will represent 31 percent and 19percent, respectively. In the United States, President Obama stated in the February 2011 State of the Union address that he wants 80 percent of electricity to come from "clean sources" by 2035. Within the US, individual states like California have set renewable energy targets. In

Table 9. Policies and Regulations to Promote Renewable Energy in Developing Asian Countries

Country	Feed-in tariff	Renewable Portfolio Standard/quota	Capital subsidies, grants, rebates	Investment or other tax credits	Sales tax, energy tax, excise tax, or VAT reduction	Tradable RE certificates	Energy production payments or tax credits	Net metering	Public investment, loans, or financing	Public competitive bidding
China	✓	✓	✓	✓	✓		✓		✓	✓
India	✓*	✓*	✓	✓	✓	✓	✓		✓	
Indonesia	✓			✓	✓					
Malaysia									✓	
Mongolia	✓									✓
Pakistan	✓							✓		
Philippines	✓	✓	✓	✓	✓		✓	✓	✓	✓
Sri Lanka	✓									
Thailand	✓				✓				✓	
Vietnam [a]		✓					✓			

Source: Modified from REN21 (2010). Table 2.
Note: [a] Data for Vietnam from APERC (2010C). Entries with an asterisk (✓*) mean that 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, leading to lack of implementation or impacts. Policies known to be discontinued have been omitted. Many feed-in policies are limited in scope or technology. Some policies shown may apply to other markets besides power generation, for example solar hot water and biofuels. [b] The countries in bold are the focus countries of this report.

developing Asia vary widely from being modest (as in Vietnam) to being comparable to targets set in the EU and the US (as in China).

Within developing Asia, many countries have set targets for increasing renewable energy shares in the overall energy mix, and the goals vary widely. Table 10 shows each country's renewable energy targets, which include short-term and medium-term targets, as well as targets for individual sources of renewable energy (e.g., target for solar), where applicable.

Overall, China and Thailand appear to have the most aggressive targets for increasing renewable energy's share in the total energy mix. China has set the target of increasing renewable electricity installed capacity to 362 GW by 2020, which would represent 15 percent of the country's total installed capacity. Thailand has a goal of increasing renewable energy's share of electricity to 5.6 GW by 2022, which would represent 14.1 percent of the country's total installed capacity. These figures are significant considering that overall energy demand and consumption will rise as these countries become more developed over time.

Vietnam has set a more modest goal of increasing primary energy from renewables to 5 percent in 2020, which is an increase from 3 percent in 2010. However, Vietnam is still a net exporter of crude oil and coal, and the country has only recently started implementing new forms of renewable energy such as wind, solar, and biofuels. In anticipation that the country will become a net importer of oil in the near future, Vietnam has established targets specifically for biofuels, which are to meet 1 percent of domestic gasoline and oil demand in 2015 and 5 percent of oil demand in 2025.

2002, California set a target of 20 percent renewable energy by 2010 and 33 percent by 2020.

With regard to solar PV, every country but the Philippines and Vietnam have implemented extremely aggressive mid-term targets. China will increase solar PV installed capacity from 400 MW to 1.8 GW by 2020; India from 2-2.5 MW in 2010 to 20 GW by 2022; Indonesia from 12 MW in 2008 to 80 MW by 2025; Thailand from 15 MW in 2010 to 500 MW by 2022; and Vietnam from 51 "units" in 2015 to 262 "units" in 2025. Each of these countries is rich in solar resources and likely anticipates increasing solar PV capacity over time as the technology becomes less expensive to install.

Table 10. Renewable Energy Targets for the Six Focus Countries

Country/Target	Actual	Year	Target	Year	Target	Year	Target	Year	Target	Year
China										
Renewables	10%	2010	10%[118]	2010	—	—	—	—	—	—
Electricity from Renewables	226 GW	2009	—	—	362 GW [a] 15% [b]	2020	—	—	—	—
Biomass	3.2 GW	2009	—	—	30 GW	2020	—	—	—	—
Wind	25.8 GW	2009	—	—	30 GW[119]	2020	—	—	—	—
Solar PV/Concentrating Solar Power (CSP)	400 MW	2009	—	—	1.8 GW[120]	2020	—	—	—	—
Solar Thermal	105 $GW_{thermal}$	2008	150 million m^2	2010	300 million m^2	2020	—	—	—	—
Hydro	117 GW [c]	2005	190 GW [c]	2010	300 [a] [c]	2020	—	—	—	—
Small Hydro	33 GW	2009	—	—	—	—	—	—	—	—
Biofuels (Ethanol)	2.1 billion liters/year	2009	—	—	13 billion liters/year	2020	—	—	—	—
Biofuels (Biodiesel)	0.4 billion liters/year	2009	—	—	2.3 billion liters/year	2020	—	—	—	—
India										
Renewables	15 GW	2010	12.5 GW added	2012	40 GW	2020			17%	2025
Electricity Share from Renewables	4%	2008	6%	2011	15%	2020	15%[121]	2022	—	—
Biomass/Cogeneration	1.5 GW	2009	1.7 GW added	2012	—	—	—	—	—	—
Wind	10.9 GW	2009	9 GW added	2012	—	—	—	—	—	—
Solar PV/CSP	~ 0	2009	1.1 GW	2013	10	2017	20	2022	—	—
Solar Thermal	—	—	—	—	15 million m^2	2017	20 million m^2	2022	—	—
Small Hydro	2 GW	2009	1.4 GW added	2012	—	—	—	—	6 GW	2025
Waste-to-Energy	—	—	400 MW added	2012	—	—	—	—	—	—

118 Achieved 2010 target in 2008.
119 Unofficial target of 150 GW shown in REN21.
120 Unofficial target of 20 GW shown in REN21.
121 Share of added capacity 2002-2022.

Country/Target	Actual	Year	Target	Year	Target	Year	Target	Year	Target	Year
Indonesia										
Primary Energy from Renewables	—	—	—	—	—	—	17%[122]	2025	—	—
Electricity from Renewables	—	—	—	—	—	—	9.4 GW	2025	—	—
Biomass	—	—	—	—	—	—	810 MW	2025	—	—
Wind	2 MW	2008	—	—	—	—	255 MW	2025	—	—
Solar PV	12 MW	2008	2 MW additional	2010	—	—	80 MW	2025	—	—
Hydro	8% of electricity	2008	—	—	—	—	—	—	—	—
Geothermal	5% of electricity	2008	—	—	—	—	6 GW[123]	2025	—	—
Waste-to-Energy	—	—	—	—	—	—	—	—	—	—
Biofuels (Ethanol)	—	—	5% of consumption [b]	2010	—	—	15% of consumption [b]	2025	—	—
Biofuels (Biodiesel)	—	—	10% of consumption [b]	2010	—	—	20% of consumption [b]	2025	—	—
Philippines										
Primary Energy from Renewables	—	—	—	—	—	—	—	—	—	—
Electricity from Renewables	—	—	4.7%[124]	2013	—	—	10.6 GW	2030	—	—
Biomass	—	—	76 MW	2010	94 MW	2015	267 MW	2030	—	—
Wind	33 MW	2008	—	—	—	—	—	—	—	—
Solar PV	—	—	—	—	—	—	—	—	—	—
Hydro	15% of electricity supply	—	Double from 2003 levels	2013	—	—	—	—	—	—
Geothermal	17% of electricity supply	—	—	—	—	—	—	—	—	—

122 IEA (2010) reports a target of 15% for 2025, p. 45.
123 IEA (2010) reports a 5% target for 2050.
124 Requires adding 4.5 GW of capacity during 2003-2013.

Country/Target	Actual	Year	Target	Year	Target	Year	Target	Year	Target	Year
Waste-to-Energy	—	—	—	—	—	—	3 GW	2030	—	—
Biofuels (Ethanol)	5% minimum blend[125] [b]	2009	10% minimum blend[126]	2011	—	—	—	—	—	—
Biofuels (Biodiesel)	2% minimum blend	2009	2% minimum blend	2011	20%	2025	—	—	—	—
Thailand										
Primary Energy from Renewables	—	—	—	—	19.1%	2016	20.4%	2022	—	—
Electricity from Renewables	—	—	10.6%	2011	12.7%	2016	5.6 GW[127]	2022	—	—
Biomass	1.65 GW	2010	2.8 GW	2011	3.22 GW	2016	3.7 GW	2022	—	—
Biogas	—	—	80 MW	2011	90 MW	2016	120 MW	2022	—	—
Wind	5.6 MW	2010	115 MW	2011	375 MW	2016	800 MW	2022	—	—
Solar PV	15 MW [d]	—	55 MW	2011	95 MW	2016	500 MW	2022	—	—
Solar Thermal	49 $MW_{thermal}$ [b]	2007	17,500 m^2 [b]	2011	—	—	—	—	—	—
Hydro	58.85 MW	2010	185 MW	2011	281 MW	2016	328 MW	2022	—	—
Waste-to-Energy	13.13 MW	2010	—	—	—	—	160 MW	2022	—	—
Biofuels (Ethanol)	0.4 billion liters	2009	—	—	—	—	20% of oil consumption [128] [c]	2022	—	—
Biofuels (Biodiesel)	0.6 billion liters	2009	—	—	—	—			—	—
Vietnam										
Primary Energy from Renewables	—	—	3% [a]	2010	—	—	5% [a]	2020	11% [a]	2050
Electricity from Renewables	—	—	523 MW[129][e]	—	1,986 MW[130] [e]	2015	3,341 MW[131][e]	2025	—	—
Biomass	—	—	—	—	—	—	310 MW	2025	—	—
Biogas	—	—	—	—	274 MW	2015	529 MW	2025	—	—
Wind	—	—	—	—	—	—	659 MW	2025	—	—

125 Production target = 230 million liters/year.
126 Mandatory requirement; production target = 490 million liters/year.
127 Reported as 14.1% target, p. 59.
128 Ethanol and biodiesel to substitute for 20% of oil consumption.
129 513 MW grid-connected; 10 MW off-grid.
130 1,905 MW grid-connected; 81 MW off-grid.
131 3,212 MW grid-connected; 129 MW off-grid.

Country/Target	Actual	Year	Target	Year	Target	Year	Target	Year	Target	Year
Solar PV	—	—	—	—	51 MW	2015	262 MW	2025	—	—
Hydro	43%	2007	—	—	—	—	—	—	—	—
Geothermal	—	—	—	—	—	—	150 MW	2025	—	—
Waste-to-Energy	—	—	—	—	—	—	52 MW	2025	—	—
Biofuels (Ethanol & Biodiesel	—	—	—	—	250,000 tons[132]	2015	1.8 million tons[133]	2025	—	—

Sources

[a] Data drawn from REN21 Renewables Global Status Report 2010 unless otherwise noted
[b] Deploying Renewables in Southeast Asia, OECD/IEA 2010
[c] Meritas Guide on Renewable Energy
[d] Department of Alternative Energy Development and Efficiency. "Solar Energy Development: Thailand Case". July 2010 (Dr. Twarath Sutabutr, Deputy Director-General)
[e] Center for Renewable energy and CDM Institute of Energy. "Strategies and Policies to Support Renewable Energy and Energy Efficiency Development in Vietnam". October 2010 (Nguyen Duc Cuong, Director)

Primary References

REN21 and IEA draw on the following primary references: **China:** Renewable Energy Law (2005); Renewable Energy Development and Utilization Promotion Law; 11th Five-Year Plan for Sustainable Development. **India:** Electricity Act; Jawaharlal Nehru National Solar Mission. **Indonesia:** Green Energy Policy; National Energy Policy (Blueprint of National Energy Management 2005-2025). **Philippines:** Renewable Energy Act of 2008; Philippines Energy Plan; Alternative Fuels Programme; Biofuels Act. **Thailand:** Renewable Energy Development Plan. **Vietnam:** National energy development strategies for Vietnam up to 2020 (Decision No. 1855/QD-TTg, 2007); National Power development master plan period 2006-2015 (Decision No. 110/QD-TTg, 2007).

132 Meeting 1% of domestic gasoline and oil demand.
133 Meeting 5% of domestic gas and oil demand.

SECTION 9. CLEAN ENERGY INVESTMENT TRENDS

Key Points

- Investment needs for energy infrastructure in Asia over the next 25 years will total nearly $10 trillion, three-quarters of which will be allocated towards the power sector.
- Global investment in clean energy nearly quadrupled from 2004 to 2008, reaching $159 billion. The investment continued to rise to $160 billion in 2009 and $211 billion in 2010.
- For the first time in 2010, Asia and the Pacific had the largest share of global investment in clean energy with $59 billion. Since 2004, clean energy investment in Asia and the Pacific has increased 15-fold.
- In 2009, China moved ahead of the US for the first time as the country with the highest level of investment in renewable energy. In 2010 China had $49.8 billion in new investment, compared to $41 billion for Germany and $29.6 billion for the US.
- Asset financing of utility-scale renewables accounted for more than 70 percent of total new clean energy financing.
- Multilateral banks and development agencies provided a total of $65 billion in funding for the energy sector between 1997 to 2005. Together, funding for energy efficiency and renewable energy accounted for 30 percent of development assistance funding for the energy sector in 2005.
- The Clean Development Mechanism is seen as an important source of investment for renewable energy project developers in Asia, but the level of investment is still relatively small.

9.1 Energy-Sector Investment Needed in Asia

In its *World Energy Outlook 2010*, the IEA estimates that the investment needs for energy infrastructure in developing Asia will total nearly $10 trillion over the next 25 years. This translates to an average annual level of investment of $400 billion, with three-quarters of this investment for the power sector.

About half of the region's investment will be in China, about one-quarter of the region's investment will be in India, and the remaining one-quarter will be among other developing Asian countries (see Table 11).

Further, IEA estimates in World Energy Outlook 2010 that, in order to achieve the GHG emissions cuts needed to meet the 450 ppm scenario, additional global investment will be required in the range of $13.5 trillion to $18 trillion, which

Table 11. Expected Investment in Energy Supply Infrastructure (2010-2035) (billion US dollars)

	Coal	Oil	Gas	Power	Biofuels	Total Cumulative Investment	Average Annual Investment
China	263	475	360	4,000	32	5,130	205
India	56	207	216	1,883	17	2,380	95
Other Developing Asia	56	222	560	1,314	13	2,163	87
Developing Asia	375	904	1,136	7,197	62	9,673	387
Rest of World	346	7,149	5,965	9,409	273	23,143	926
World	721	8,053	7,101	16,606	335	32,816	1,313

Notes: The investments levels in this table are for the New Policies Scenario. The WEO 2010 report does not provide a detailed breakdown by country and sector of energy infrastructure investment under the Current Policies (i.e., Business-as-Usual) Scenario, but the Current Policies Scenario has a total investment level that is $4.5 trillion higher for the period than the $32.8 trillion in this table. Source: IEA (2010B, p. 94).

translates to an annual global investment of $540 billion to $720 billion.[134]

9.2 Investment in Clean Energy

Investment Trends Globally and in Asia

Global investment in clean energy quadrupled from 2004 to 2008, reaching $159 billion. The investment continues to rise to $160 billion in 2009 and $211 billion in 2010 (see Figure 29).

In 2005, OECD countries accounted for nearly 77 percent of global investment in clean energy, and non-OECD countries accounted for 23 percent. The non-OECD share rose to 29 percent in 2007, and then to 40 percent in 2008, reaching approximately $94 billion. Brazil, China, and India accounted for nearly all of non-OECD's 2008 investment (97 percent).[135]

For the first time in 2010, Asia and the Pacific had the largest share of global investment in clean energy, at $59 billion. Figure 30 shows the trend for clean energy investments in the Asia-Pacific region from 2004 to 2010. Annual investment during this period increased nearly fifteen-fold.[136]

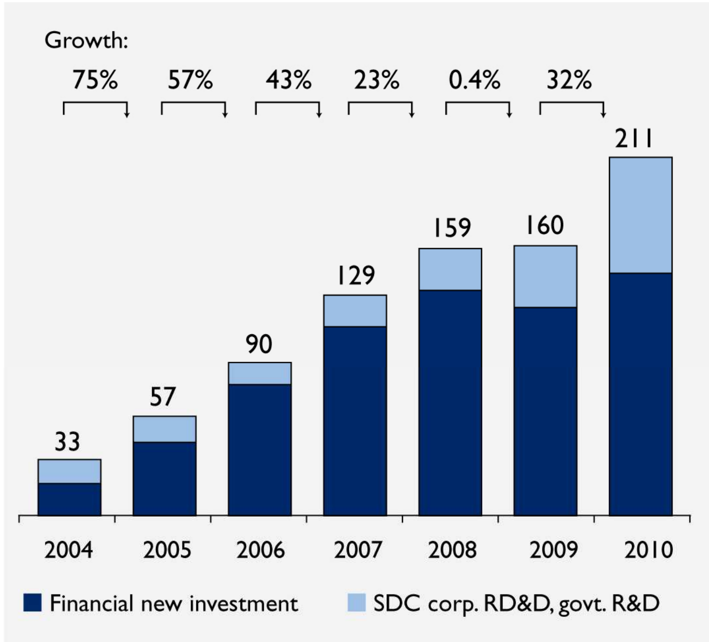
China and India account for nearly 90 percent of the 2010 clean energy investment in the Asia-Pacific – with $49 billion for China and $3.8 billion for India. New investments in clean energy in Indonesia, the Philippines, Thailand, and Vietnam were in the range of $200 to 700 million per country .[137]

China. In 2009, China moved ahead of the US as the country with the highest financial investment in clean energy, and it maintained this position in 2010, with $49.8 billion in new investment. The dominant form of investment in Chinese clean energy was made via asset finance, which accounted for $29.2 billion (87 percent) of the total investment in clean energy in China in 2009 (up from $22.0 billion in 2008). Public market fundraising reached $4.4 billion in 2009, a dramatic increase from $0.2 billion the previous year. Venture capital and private equity investments were relatively insignificant in China at $0.2 billion, down from $0.7 billion in 2008.

China accounted for 28 percent of global financial investment in clean energy, and its level of investment grew 53 percent between 2008 to 2009. China expects that the renewable power share of

[134] IEA (2010B), pp. 379, 401. The *WEO 2010* report does not provide a detailed table with breakdowns of the incremental investment by country or sector.
[135] UNEP (2011), p. 217.
[136] UNEP/BNEF (2010), p. 19.
[137] UNEP (2010).

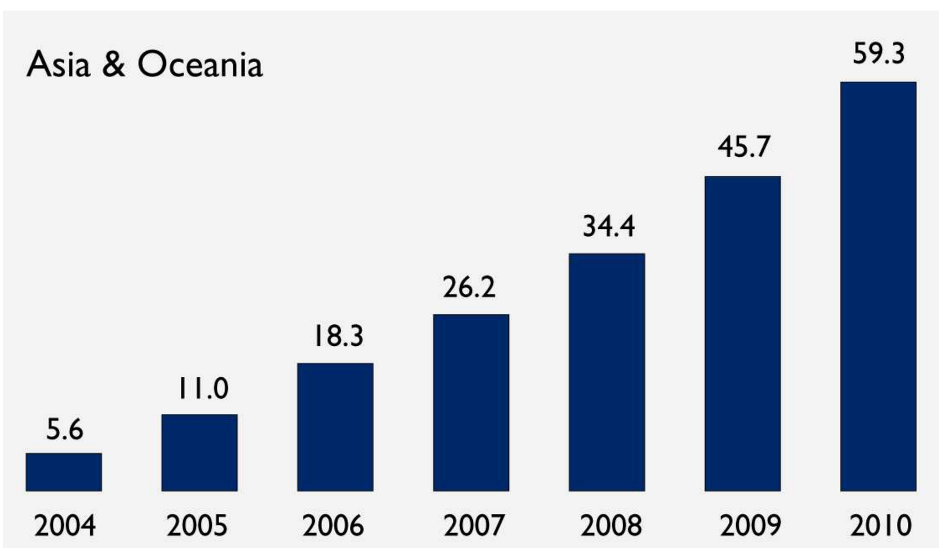
Figure 29. Global New Investment in Sustainable Energy (2004-2010)



SDC = small distributed capacity. New investment volume adjusts for re-invested equity. Total values include estimates for undisclosed deals

Source: UNEP/BNEF (2010)

Figure 30. New Clean Energy Investments in Asia & Pacific (2004-2010)



Source: UNEP/BNEF (2010)
Note: units = $4 billion

its total energy consumption will rise to 15 percent by 2020.

Wind attracted 81 percent of new financial investment in clean energy in 2009, with $27.2 billion in new funding. China added 13.8 GW, which effectively doubled its wind capacity. In 2009, solar attracted $3.3 billion of investment, and biomass attracted $3 billion.

India. Financial investment in clean energy in India stood at $2.7 billion in 2009, down 21 percent from the $3.4 billion seen in 2008. Nevertheless, India still ranks eighth highest in the world for clean energy financial investment. Asset finance is the largest form of clean energy investment in the country at 73 percent of the total. However, it dropped from $3.1 billion in 2008 to $1.9 billion in 2009. Public market activity in India made up the bulk of the remaining clean energy financial investment, accounting for 25 percent of the national total, or $0.7 billion. Private equity and venture capital activity in India constituted a very small proportion of clean energy investment, at just 4 percent, or $0.1 billion. This was down from $0.4 billion in 2008.

The wind energy sector was the largest recipient of new investment in India in 2009 at $1.6 billion, representing 59 percent of the national total. Biomass attracted $0.6 billion of investment, and solar attracted $0.1 billion of investment in 2009.

Southeast Asia. According to the IEA, investment in new renewable energy production capacity increased more than twelve-fold between 2004 and 2009 – from less than $200 million in 2004 to more than $2.5 billion in 2009. The investments were predominantly in biofuels, followed by biomass and waste, and small hydro. Geothermal and onshore wind accounted for very small levels of investment in 2009.[138]

Clean Energy Investment by Technology Type

Based upon the investment figures for China and India above, it is safe to assume that wind is the most dominant renewable energy technology in Asia in terms of new investment. Note, however, that detailed breakdowns of investment by clean energy technology for all of Asia are not currently available.

Globally, wind also accounts for the majority of new renewable energy technology investment, at 56 percent of the total. Solar accounts for 20 percent of new global investment, biofuels accounts for 6 percent, and small hydro and energy-smart technologies each account for about 3 percent.

9.3 Types of Financing

The dominant investment type in 2009 was asset financing of utility-scale renewables, accounting for more than 70 percent of the total. This is followed by research, development, and deployment (RD&D), at 17 percent, and public markets, at 9 percent. Venture capital and private equity investment accounted for just 3 percent of new investment in 2009.

Funding from Multilateral Banks and Development Agencies

UNEP's *Global Trends in Sustainable Energy Investment 2010* report compiles and analyzes development assistance funding for renewable energy worldwide. Their review estimated a total of $7.5 billion in assistance funding for the year 2009.[139]

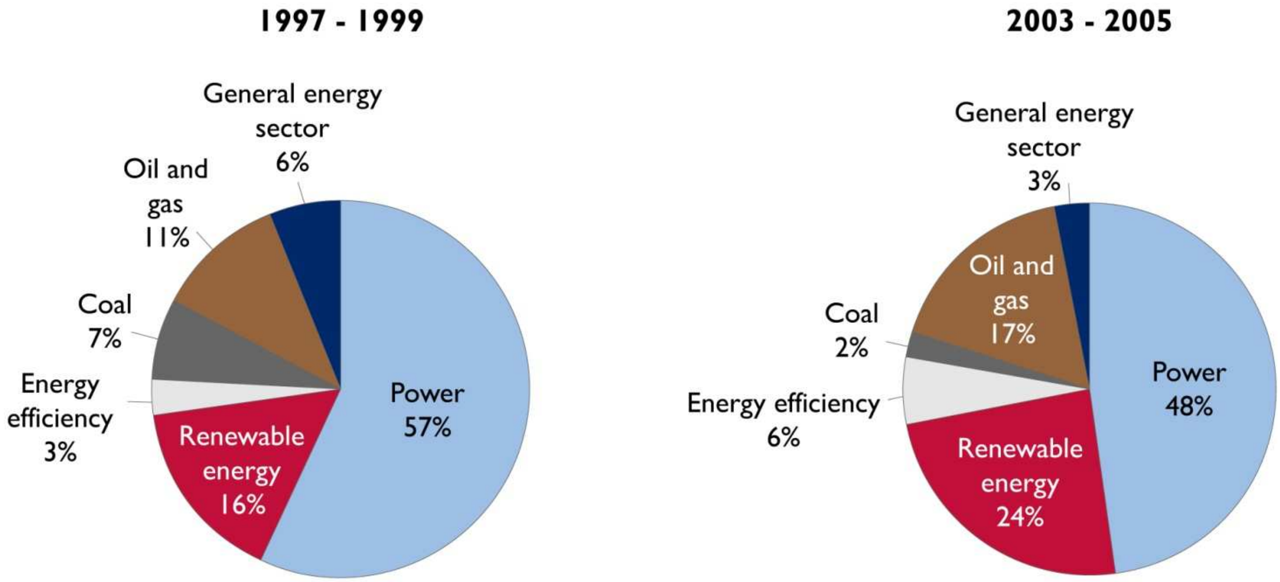
An independent study by Tirpak and Adams also conducted a detailed analysis of development assistance and focused on the energy sector for the period 1997 to 2005. The total funding amount for this period reached $65 billion, with annual funding levels in the range of $5 billion to 10 billion. These figures are consistent with UNEP's report.

Tirpak and Adams also analyzed the breakdown of funding by type of energy measure during two separate three-year periods – 1997 to 1999 and 2003 to 2005 (see Figure 31). Their analysis found that the level of funding for energy efficiency

[138] Olz and Beerepoot (2010). Figure 4.1, p. 79.

[139] UNEP (2010).

Figure 31. Bilateral and Multilateral Support for Energy Sector Assistance, by Sector Area: Comparison of Two Three-Year Periods (1997-1999 vs. 2003-2005)



Note: Total funding during 1997-2005 was $64.8 billion. Funding during 1997-1999 was $24.2 billion. Funding during 2003-2205 was $20.4 billion.
Source: Tirpak and Adams (2008), p. 148

doubled – from 3 to 6 percent. The level of funding for renewable energy increased by 50 percent – from 16 to 24 percent. Their analysis also found a shift in emphasis from the funding of physical projects to the provision of technical assistance for policy development and institution building.

9.4 Carbon Finance

The Global Carbon Market

The term carbon finance refers to the monetization of future cash flows from the advance sale of carbon reduction credits.[140] Each ton of carbon emissions is assigned a price, relative to an established emissions ceiling (which depends upon the jurisdiction or trading scheme). Those who exceed the ceiling can offset their emissions by buying credits while they transition to cleaner infrastructure. Generally, credits are allotted based upon proving a reduction in carbon emissions when compared to business-as-usual levels. The capital from emissions credits can provide revenue and offset the high initial investment of renewable energy projects.

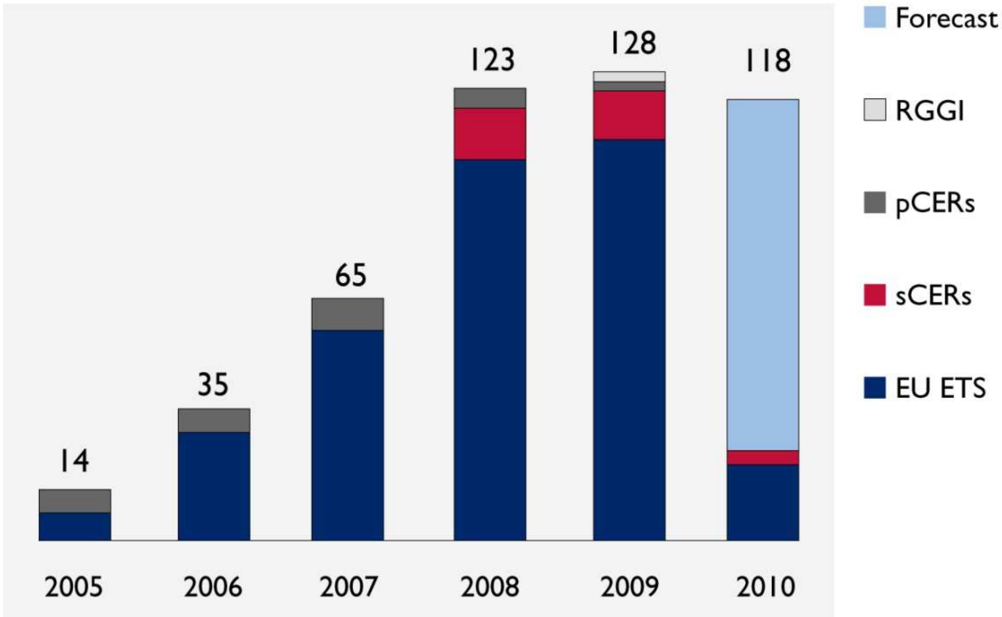
The global carbon market increased more than eight-fold from 2005 to 2008. For the past two to three years, the market has stabilized at about $120 billion to $130 billion per year (see Figure 32).

The carbon market has three sub-categories: the main allowances market; spot and secondary Kyoto offsets; and project-based transactions.[141]

[140] Olz 2010, p. 82.

[141] Under the Kyoto Protocol, countries set quotas on the emissions of installations run by local business and other organizations. Each business or organization is assigned an "allowance" of credits, where each unit gives the owner the right to emit one metric ton of carbon dioxide or other equivalent greenhouse gas. A carbon "offset" is a reduction in emissions of carbon or greenhouse gases made in order to compensate for or to offset an emission made elsewhere.

Figure 32. Trends in the Value of the Global Carbon Market (2005-2009)



Note: units = billion US dollars
Source: UNEP/BNEF 2011

The Carbon Finance group at the World Bank estimated the value of the main allowances market at $122.8 billion in 2009, up 21 percent from 2008. The value of the spot and secondary Kyoto offsets decreased by more than 30 percent in 2009, to $17.5 billion. Project-based transactions, which include the Clean Development Mechanism, Joint Implementation (JI), and voluntary markets increased by about $3.4 billion in 2009, down 54 percent from 2008. The value of the carbon market increased only slightly in 2009, while the trading volume of carbon credits doubled.[142]

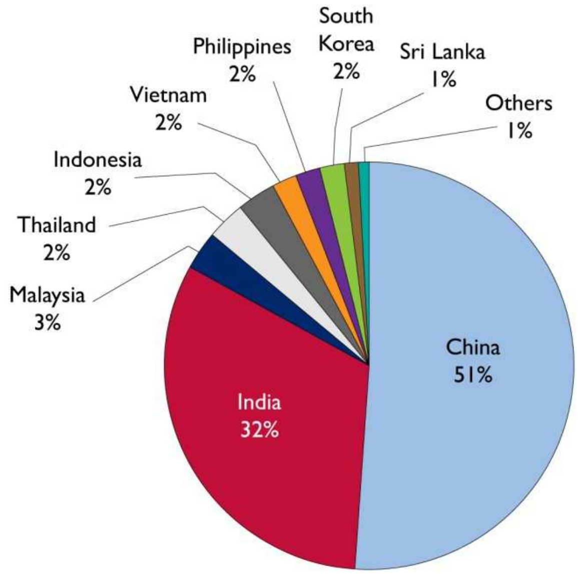
The CDM Market in Asia

The CDM is seen as an important source of investment for many renewable energy project developers in the Asia region. As of October 2010, there were 2,453 total CDM projects officially registered with the CDM Executive Board, including 981 in China and 539 in India. A total of 78 percent of all CDM projects are in the Asia-Pacific region, and more than 80 percent of these are in China and India (see Figure 33). Of total CDM projects, 65 percent are classified as Energy Industries (renewable and non-renewable sources), Energy Distribution, and Energy Demand.

To date, the value of Certified Emission Reductions (CERs) that have been issued in the ASEAN region may be worth less than $100 million, of which most are in Vietnam. However, the UNFCCC expects

[142] According to the World Bank, the value of the carbon market increased by 6.4 percent in 2009, and the trading volume of the carbon market increased by more than 100 percent, indicating that the price of carbon credits dropped (but not necessarily the number of projects) (World Bank Group 2010). The United Nations Environment Program (UNEP) reports that the value of the total global traded carbon market increased by 4 percent in 2009 (to $128 billion), while trading volumes rose by 96 percent. UNEP also reports that the carbon market inflows component in 2009 (project-based transactions via the CDM, JI, and voluntary markets) measured $3.4 billion, which is the same as World Bank estimates. UNEP reports that in 2009, the value of the total global traded carbon market increased by 4 percent (to $128 billion) while trading volumes rose by 96 percent.

Figure 33. Percentage of CDM projects (excluding rejected projects) by country in Asia



Source: Olz (2010), p.84

$32 million in credits to originate annually per country in the ASEAN region.[143]

Regionally across Asia, CDM projects in renewable energy are expected to contribute a 37 percent share of the regional cumulative total of 2.29 billion metric tons of CO_2e emissions reductions in 2012.[144] It is estimated that the sale of these CERs could generate $27.25 billion in revenue, representing a significant source of export revenue that Asian countries could earn through the CDM to stimulate renewable energy deployment.[145]

There are no definitive figures on the value of the carbon market in Asia, but relative to the global total it is currently very small and limited to the CDM and voluntary markets.[146] For example, there are no data to indicate how much of the $40 billion that was invested in renewable energy in Asia in 2009 can be attributed to carbon credits. Additionally, the $128 billion value of the carbon market in 2009 reflects traded assets, and not necessarily the investment into actual projects.

Future of the Carbon Market

It is hard to predict the future of the carbon market and its potential in boosting clean energy investments at this stage.

The majority of the current global carbon markets depends largely on demand drivers from policy and regulatory. The lack of international binding agreement under the UNFCCC process after the first commitment period of the Kyoto Protocol leaves the carbon markets unpredictable and volatile.

A survey[147] conducted by the World Bank found that most respondents were not optimistic that a binding agreement after the Kyoto Protocol could be achieved in the short-term. However, there was optimism about the possibility of a binding agreement in the longer term. Respondents believed that a non-binding multilateral accord is more likely in the short term. This suggests that voluntary carbon market is expected to have a greater role during the transition period.

[143] Kneeland (2010).
[144] Olz (2010), p. 84.
[145] Olz (2010) made this estimate by assuming an average CER price in 2009 at $11.90, with the aim of developing an approximate idea of the impact of carbon credit revenue on renewable energy development in Asian markets.
[146] The Asian Development Bank has two types of funds to stimulate financing of carbon projects – the Asia-Pacific Carbon Fund (APCF) and the Future Carbon Fund. The APCF provides upfront co-financing to CDM projects for future delivery of CERs. The APCF closed on May 2007, with $151.8 million in commitments, invested entirely into renewable energy projects. The Future Carbon Fund complements the APCF, and provides upfront financing for projects that continue to generate carbon credits after 20121. The Future Carbon Fund closed on March 2010 with $115 million.[146]
[147] World Bank, State and Trends of Carbon Market 2011, Environment Department.

SECTION 10. PRIORITIZATION OF CLEAN ENERGY OPTIONS

Key Points

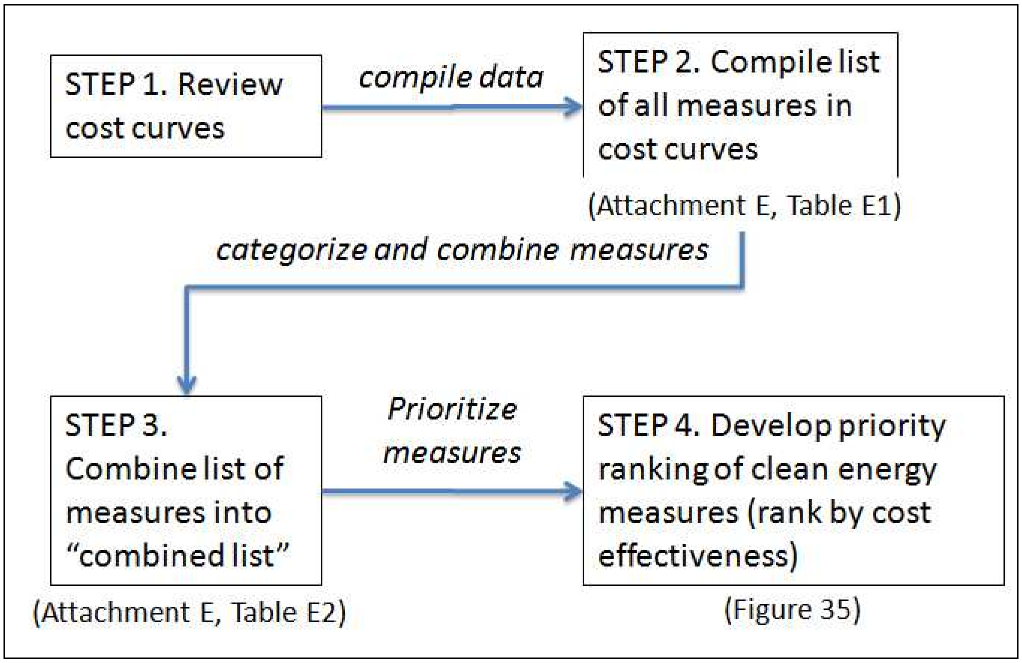
- Global emissions must be reduced by 30 percent by 2030 in order to achieve the 450 Scenario, and a delay of action of more than 10 years would mean missing this goal.
- The report ranks clean energy measures, which are prioritized by cost-effectiveness in terms of reducing greenhouse gas emissions enough to achieve the 450 Scenario.
- Energy-efficiency measures rank highest, as they require less investment to achieve the same amount of energy savings as would investment in other options like wind, solar, and carbon capture and storage.
- The top five options for energy-efficiency measures are: efficient lighting; residential appliance and equipment efficiency; commercial building efficiency; motor-systems efficiency; and light-vehicle efficiency.
- The most effective supply-side options include nuclear power-plant upgrades and coal and gas plant efficiency improvements.

10.1 Scenarios for Abatement of GHG Emissions

"Clean energy" is a very broad term and typically refers to energy efficiency measures, renewable energy measures, or supply-side options that result in reduced pollution and emissions of greenhouse gases. From a policy perspective, it is important to have a method for comparing a range of available clean energy options in terms of both their cost effectiveness ("bang for the buck") as well as the magnitude of the potential emissions reductions each measure can achieve. This section presents a review of available data on clean energy options and prioritizes the options in terms of their cost effectiveness. Typically, a key challenge for policy-makers is to make informed decisions as they establish policies and regulations to improve national energy security and mitigate greenhouse gas emissions. Based on the data analyses in this section, policy-makers will be able to compare, prioritize, and select clean energy measures to apply in their countries, and in some cases at a regional level (e.g., harmonization of standards for efficient appliances and equipment). The data in this report on energy and GHG trends are derived primarily on the ADB's *Energy Outlook for Asia and the Pacific,* which draws in data from the IEA, the Asia-Pacific Energy Research Center, and The World Bank.

In *World Energy Outlook 2009*, IEA presents a scenario for limiting atmospheric CO_2 concentrations to 450 ppm by 2030 (known as the 450 Scenario). This scenario refers to a set of measures that, if implemented, will collectively limit the buildup of atmospheric CO_2 emissions to not more than 450 ppm, and accordingly limit the rise in global average temperatures to no more than 2

Figure 34. Methodology for Reviewing Cost Curves and Developing Priority Ranking of Clean Energy Measures



degrees Celsius. In the scenario, based on prioritizing mitigation measures by cost, 57 percent of the GHG emissions reductions in 2030 are from energy efficiency, 23 percent from renewable energy including biofuels measures, 10 percent from nuclear, and 10 percent from carbon capture and storage.

10.2 Methodology: Reviewing Cost Curves in Order to Prioritize Options in Developing Asia

Figure 34 shows the methodology used to develop a priority ranking of clean energy measures for this report. The program analysis team focused on reviewing, analyzing, and summarizing existing data in order to develop a simplified ranking of clean energy options that could be applied in developing Asia. This simplified ranking provides guidance to policymakers, civil society, the private sector, and funders providing technical assistance on clean energy and climate change.

A "cost curve" for greenhouse gas abatement provides the most informative data on the cost-effectiveness and overall abatement potential of different technologies and measures. Each measure is assigned a cost, which is based on the cost of implementing the measure relative to a baseline scenario. The cost curve also shows the amount of CO_2 or CO_2e emissions reductions for each measure.

A number of existing GHG abatement cost curves were reviewed, with the aim of developing a comprehensive list, with priority ranking, of clean-energy options that could be applied in developing Asia. One of the leading organizations developing cost curves is McKinsey & Company, which has assessed more than 200 GHG abatement opportunities across 10 major sectors and 21 regions around the world.[148] McKinsey concludes from its global analysis that the potential exists to reduce GHG emissions enough by 2030 to contain

148 McKinsey has been supported by ten leading global companies and organizations: The Carbon Trust, ClimateWorks, Enel, Entergy, Holcim, Honeywell, Shell, Vattenfall, Volvo, and WWF.

Table 12. Consolidated List of GHG Abatement Measures from Review of Studies

Buildings, Appliances, Equipment
- Efficient lighting
- Residential appliances and equipment
- Residential buildings
- Commercial building efficiency
- Efficient heating
- Building codes

Industry
- Motor systems efficiency
- Industrial energy efficiency
- Industrial process efficiency
- Industrial EE measures – cement
- Industrial EE measures – steel
- Mining efficiency
- Petroleum processing measures
- Coal plant measures
- Transmission and distribution efficiency
- Chemical and gas industry

Power Generation – Non-Renewable
- Coal plant measures
- Gas plant improvements
- Coal to gas shift
- Coal mining measures
- Nuclear upgrades
- Nuclear Power
- Carbon capture and storage (CCS)

Power Generation – Renewable
- Geothermal
- Biomass
- Small hydropower
- Solar thermal
- Solar PV
- Wind energy
- Wind (onshore)
- Wind (offshore)

Transportation
- Transportation efficiency measures
- Light-vehicle efficiency
- Hybrid vehicles
- Electric vehicles
- Plug-in hybrids

Agriculture and Forestry
- Nutrient and tillage management
- Improved agricultural practices
- Grassland management
- Land and forest restoration
- Afforestation measures
- Reforestation measures
- Forestry measures

Other
- Landfill gas
- Biofuels
- Smart grid measures
- Cogeneration (combined heat and power)

global warming below 2 degrees Celsius. It also concludes that the investment in GHG abatement measures is manageable at a global level, but that a delay in action of even 10 years would mean missing the 2 degrees Celsius target.

Besides McKinsey, the other cost curves reviewed include Exelon (a US-based electric utility) and Bloomberg New Energy Finance (BNEP, a provider of information and analysis on clean energy, low carbon technologies, and the carbon markets).[149] The five cost curves cover a variety of countries and regions. The cost curves were reviewed, a consolidated list of 152 measures, and the cost and abatement potential of each measure was recorded.

[149] Bloomberg New Energy Finance (YEAR), Exelon (2010), and McKinsey & Company (2008, 2009A, 2009B).

These 152 measures were then compiled into a list of 47 measures, grouped into seven major categories: buildings, appliances, and equipment; industry; non-renewable power generation; renewable power generation; transportation; agriculture and forestry; and other. Table 12 shows the consolidated list of measures. Attachment E provides more information on the cost curve analysis, and includes tables showing the individual and consolidated measures.

10.3 Prioritization Results

Figure 35 shows the consolidated list of 47 GHG abatement measures prioritized by relative cost effectiveness. It is, in essence, a simplified cost curve, addressed at policymakers and interested stakeholders, with the objective of providing an approximate relative ranking of different clean energy measures in terms of their ability to cost-effectively mitigate GHG emissions. The figure provides policymakers with an "at a glance" view of which options are most cost-effective and which options have the highest potential.

The options are ordered from lowest cost (most negative) to highest cost (most positive). The options near the top of the figure are negative cost (i.e., yield cost savings), and thus are top priorities for implementation. Options in the bottom half of the figure, below the dashed line, have a positive cost and will be more expensive to implement.

Many of these measures have significant GHG abatement potential, indicated in the right-hand column as the relative magnitude of GHG abatement potential for each measure (low, medium, or high). Color coding in the figure denotes demand-side (end-use efficiency) options in green, supply-side options in blue, and agriculture, forestry and other land-use options in orange.[150]

Figure 36 shows that you get the "biggest bang" for a program budget by investing in efficiency measures such as efficient lighting, appliances, and equipment used in buildings and factories. The figure also indicates that measures such as solar PV, carbon capture and storage, and offshore wind require a greater investment to mitigate GHG emissions.

It is important to note that the figure is not intended to provide detailed information on the measures or to replace the detailed cost curves analyzed by the program team, or to replace the detailed analysis needed during the design of clean energy programs. In order to make detailed comparisons of the costs and benefits of clean energy options in their economies, policy-makers and stakeholders should look at the detailed cost-curve studies cited above, look at other cost-curve or prioritization studies carried out for their countries, or include such detailed analyses in the design of their policies and programs.

It should be noted that the GHG abatement measures analyzed here do not include lifestyle and behavioral options, or public awareness and education campaigns, since the cost curves analyzed focus on specific technologies or measures. The measures analyzed here also do not include policy tools and fiscal instruments such as import duty reductions, tax incentives, and pricing mechanisms (such as feed-in-tariffs). Other types of abatement measures can also include city and urban planning, improving mass transit, and incentives to purchase vehicles with improved fuel economy, to insulate buildings, to share rides, improving education and public awareness of energy options, and the like. All of these other measures can have very significant abatement potentials at low or negative cost, but they are beyond the scope of this analysis.

10.4 Energy efficiency Options are a Top Priority

It is not surprising that energy efficiency measures are the top-priority option for GHG abatement. All top six options are energy efficiency measures:

- Efficient lighting
- Residential appliances and equipment
- Residential buildings
- Commercial building efficiency
- Motor-systems efficiency
- Light-vehicle efficiency

Most of these measures also have significant GHG abatement potential. Beyond these measures, most of the negative-cost energy-related options are energy efficiency options. This result is consistent with IEA's *World Energy Outlook 2009*, which estimated that energy efficiency measures could deliver up to 57 percent of GHG reduction in the 450 Scenario.

[150] As a rule, the cost curves do not evaluate policy instruments, since it is extremely difficult to estimate the impact of a policy, as opposed to a specific energy technology. However the Exelon (2010) cost curve included alternative energy credits, which is a financial incentive policy measure, and this is shown in the summary figure.

The most cost-effective supply-side options (the ones near the top of the chart) are nuclear power-plant upgrades, coal and gas plant efficiency improvements, petroleum processing measures, and transmission and distribution system efficiency. Further down the list, but still with negative cost, are smart grid measures, geothermal energy, energy generation from landfill gas, biofuels, and small hydropower.

In the cost curves analyzed, the negative-cost options account for anywhere between 13 to 41 percent of the total GHG abatement potential. Three of the cost-curve references that the project team analyzed stated that the negative-cost options could account for 30% of the total GHG abatement potential.[151]

Renewable sources of energy dominate the bottom half of the figure (positive cost options). They are among the more expensive GHG abatement options. However, they are viewed as more sustainable over the longer term since they do not rely on fossil fuels and have very large abatement potential. Since nearly all renewable energy sources have a fairly rapidly declining cost curve, renewable energy is also expected to become more cost-effective over time, especially as the cost of fossil fuels stays constant or increases. Indeed, with continued technological improvements and cost reductions in renewable energy, a tipping point will be reached where most renewable energy sources will have negative costs relative to fossil fuels.

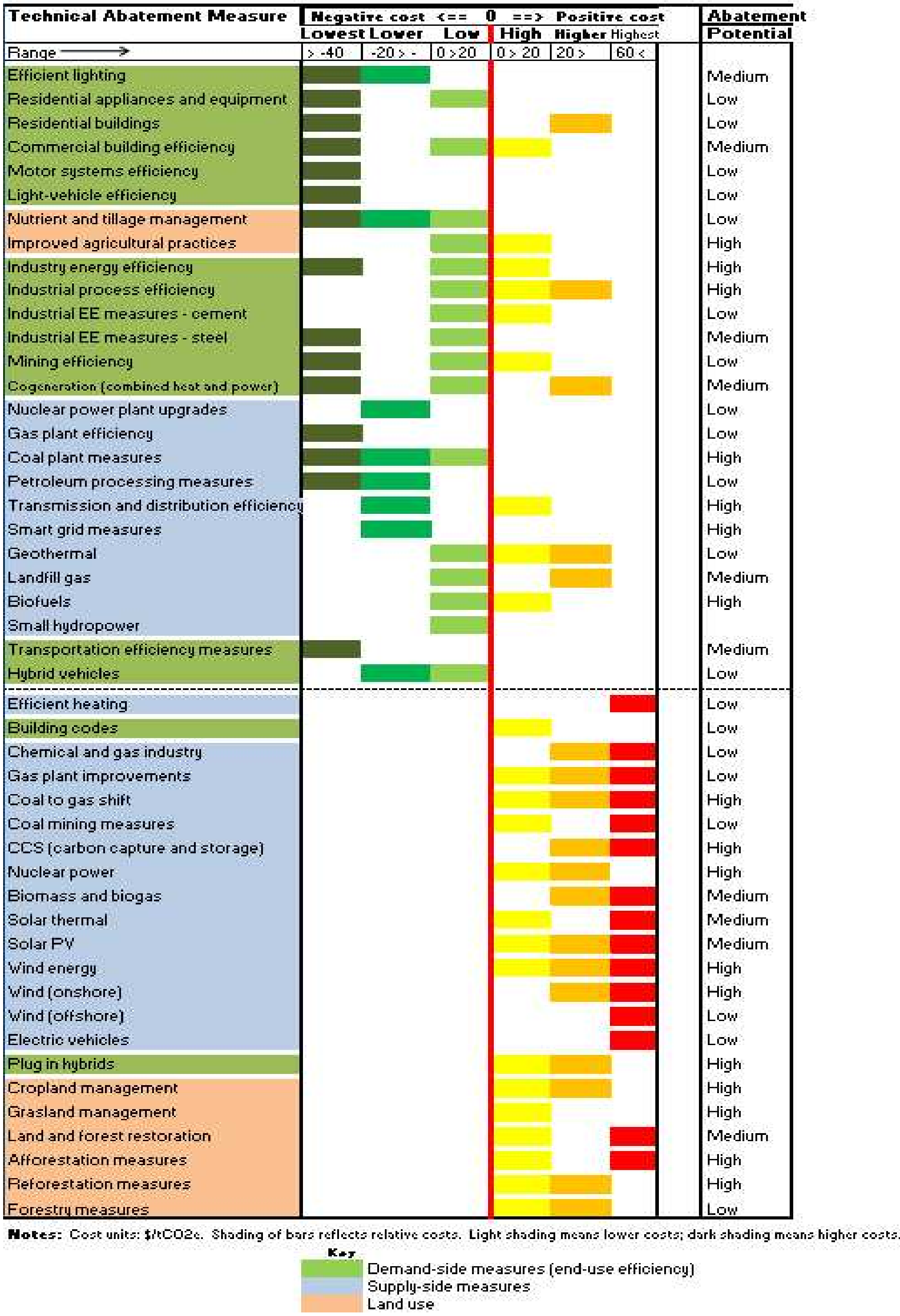
The question is often raised when the idea of "negative costs" of GHG abatement is discussed:

Why are all options with a negative cost not already implemented when they clearly save money over an extended period of time?

The answer to this question is complex, and has to do with a general reluctance on the part of consumers to spend money now to save money later – any purchase with a payback period longer than a year or two may not be acceptable to consumers or business owners. Part of the answer also has to do with the problem of misaligned financial incentives. For example, the landlord of a commercial or residential building may not implement energy-saving measures if tenants pay for utilities. Also, customers often purchase low-cost, low-energy efficiency appliances either because the eventual cost of energy saved is not easily apparent to them or because they cannot afford the higher initial cost of an energy-efficient appliance. Energy efficiency programs implemented by governments and electric utilities address these, and other barriers, and can easily justify themselves in terms of cost-effectiveness. For example, programs that provide financial incentives for the purchase of energy-efficient lighting and appliances typically cost just a fraction of the cost of the business-as-usual alternative of building a fossil-fuel fired power plant.

[151] The approximate share of the GHG abatement provided by negative cost options is 13% for Bloomberg New Energy Finance; and ~30% for McKinsey Global, McKinsey Australia, and Exelon.

Figure 35. Prioritized Ranking of GHG Abatement Options. The figure shows a list of 43 measures, based on a review of several international cost curves of the GHG abatement potential of clean energy options.[152]



[152] This analysis is based on a detailed review and compilation of measures in a number of international studies of the marginal abatement cost for GHG reduction measures. Given limitations in resources, the project team was not able to do a detailed analysis and comparison of options being implemented in the six focus countries. While this methodology has some limitations, it does provide a systematic, transparent, and traceable methodology for assessing the relative effectiveness of available GHG mitigation options. The methodology for analyzing and compiling these options from the cost curves is described in Attachment E.

SECTION 11. CONCLUSIONS

The Challenge

This report highlights the stark challenge facing Asia as it balances the challenge of meeting the basic needs of its citizens, while ensuring energy security, preserving the environment, and pursuing low carbon development as part of international efforts to address global climate change.

Developing Asian economies currently use much less energy per capita than the US or their industrialized Asian neighbors. On average, the US, at about 7.5 TOE per capita, uses about 70 to 90 percent more energy per capita than Japan, Korea, and Taiwan and about 5 to 15 times more energy per capita than the six Asian focus countries in this report. Yet, this is rapidly changing, as incomes rise in developing Asian economies, and, along with this, associated energy demand.

The growing demand for energy by Asia's developing economies will have significant energy security implications. Over the past decade, oil imports have increased by 140 percent in Asia.[153] By 2030, five of the six focus countries will be importing 75 percent or more of their oil.[154] This increasing reliance on imports from developing Asian economies will put increasing strain on the sources of global supply, creating the potential for energy security problems and related geopolitical tensions.

Developing Asia's Role in Global Energy Growth and Emissions

In 2010, for the first time, the demand for energy in developing countries equaled demand in developed countries. Looking forward, more than 90 percent of the growth in global energy demand over the next 20 years will come from developing countries.

Asia's large population and rapid economic growth mean that it will play an ever-larger role in global energy demand, and resulting greenhouse gas emissions.

In 2008, developing Asian economies accounted for 28 percent of global primary energy demand and 33 percent of global CO_2 emissions from the combustion of fossil fuels. By 2030 these shares will rise to 38 percent for primary energy and 45 percent for CO_2 emissions. Most CO_2 emissions – 35 percent of the global total – will come from China, India, and Southeast Asia.

Over the next 20 years, CO_2 emissions in the six focus countries are expected to increase by 55 percent, from 8.7 billion metric tons of CO_2e in 2008 to 13.5 billion metric tons of CO_2e in 2030.

Based on their sheer size, China and India are the largest contributors to energy demand and greenhouse gas emissions in developing Asia. Together, they account for 86 percent of coal use and 81 percent of oil use in developing Asia. They also account for 91 percent of energy-related CO_2 emissions within developing Asia.

By 2030, China's CO_2 emissions will be 9 billion metric tons annually – more than three times greater than India's and more than eight times greater than the emissions of the four ASEAN countries reviewed in this report.

Developing Asia's increasing share of global energy demand and greenhouse gas emissions, coupled with the energy security concerns associated with the rapid rise in imports of oil and other fossil fuels, provide an opportunity for Asia leaders and policy-makers. By scaling up current plans for the deployment of clean energy, the Asian economies can reduce their spending of foreign reserves on

[153] NASEO (2010).
[154] This excludes Vietnam, which will transition from a net oil *exporting* country to eventually importing a net of more than 30 percent of its oil by 2030.

oil imports, improve their economic competitiveness, and mitigate emissions of greenhouse gases and other pollutants from fossil-fuel combustion that have significant environmental and health impacts (i.e., NO_x and SO_2, and particulates).

Energy Efficiency and Renewable Energy

The IEA's *World Energy Outlook 2009* found that 57 percent of the GHG reductions needed by 2030 would have to come from energy efficiency. Such savings are technically possible, yet to achieve these efficiency levels would require investment levels in the hundreds of billions of dollars.

Most studies that have examined the potential for end-use energy efficiency have found cost-effective potential savings on the order of 15-20 percent per sector, but have also found very little of this realized due to a range of barriers, including limited awareness of decision-makers, inadequate access to technology, ineffective institutional structures, and limited access to financing.[155]

Renewable energy currently supplies only about one quarter (26 percent) of global power-generating capacity and only 18 percent of global electricity generation. But there has been a marked and sustained trend toward investment in renewables. During 2009, for example, total investment in renewable energy was 85 percent of the amount spent on new fossil power plants ($187 billion for renewables versus $219 billion for fossil-fuelled power plants).

Clearly, clean energy is a future area of growth for Asia's energy sector. This trend will continue, and within one to two years investment in renewables will exceed that for new fossil power plants in the region.

Clean Energy Investment

Global investment in clean energy quadrupled from 2004 to 2008, reaching $159 billion. The investment continued to rise to $160 billion in 2009 and $211 billion in 2010.

Within Asia and the Pacific, annual investment increased nearly fifteen-fold from 2004 to 2010 – from $4 billion per year in 2004 to nearly $60 billion 2010. China and India accounted for nearly 90 percent of this investment.

This boom in investment in clean energy represents both an opportunity and a challenge. At present, there does not appear to be a lack of funding available for investment in clean energy businesses and projects. Yet at the same time, this is also a challenge, since large amounts of investment need to be channeled to projects that are effective. In addition, there is the challenge of designing and putting in place policy and regulatory frameworks that can facilitate this clean energy revolution.

Energy Efficiency Must be the Priority

The report reviewed cost curves representing the cost and GHG abatement potential of more than 152 different clean energy technology options and measures. Based on the review, the report presents a simplified ranking system that provides an "at a glance" view of which clean energy options are most cost effective and which options have the highest potential for reducing greenhouse gas emissions.

Energy efficiency measures ranked highest, as they require less investment to achieve the same amount of energy savings as would investment in other options like wind, solar, and carbon capture and storage. The top six priority options are all energy efficiency measures: efficient lighting, residential appliances and equipment, residential buildings, commercial building efficiency, motor-systems efficiency, and light-vehicle efficiency.

155 USAID (2007).

Energy efficiency measures are expected to provide from 57 to 65 percent of the greenhouse gas emissions reductions needed to achieve climate stabilization. However, the amount of investment into energy efficiency is a fraction of the hundreds of billions of dollars annually needed to achieve this objective.

The clear conclusion from this is that there is a lack of capacity in the region to plan, design, and finance energy efficiency on a scale commensurate with the urgency of the risks posed by energy insecurity and climate change.

The Importance of Policy and Regulation

Given the increasing level of interest in clean energy, and the associated rapid growth of investment – $59 billion was invested into clean energy businesses and programs in Asia during 2010 – the stage is set for a transition away from fossil fuels and into the clean energy sector. However, nearly all of the clean energy investment in Asia is in renewable energy, and not nearly enough is being invested into energy efficiency measures, which are the most cost-effective type of clean energy investment.

The level of investment in clean energy – and especially energy efficiency – that is needed to adequately address climate change will not materialize without serious and sustained efforts to reform governance, policy, and regulation in the energy sector.

While there is an enormous amount of activity throughout Asia in the design and implementation of clean energy policies, regulations, and programs, there is no effective regional body or network to promote coordination, learning, sharing of experience, and continuous improvement in clean energy policy and regulation. Progress must be made in the area of governance, policy, and regulation in order for developing Asia to successfully manage the transition from energy systems that are primarily fossil-based to systems that are dominated by clean, renewable, and sustainable sources of energy.

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ATTACHMENT A: COMPARISON OF KEY INDICATORS FOR DEMOGRAPHICS, ENERGY, AND CO_2 EMISSIONS

Table A1. Indicators at a Glance for the Six Focus Countries (2008)

Indicators	China	India	Indonesia	Philip-pines	Thailand	Vietnam	Total
Demographics							
Population (millions)	1,326	1,140	228	90	67	86	2,937
GDP (billion constant 2000 $)	2602.6	825.8	247.2	110.7	178.3	55.7	4,020
GDP/Capita (Thousand constant 2000 $/person)	1.96	0.7	1.1	1.2	2.6	0.6	NA
Energy							
Total Primary Energy Demand (Mtoe)	2,116	621	199	41	107	59	3,143
Coal (Mtoe)	1,406	261	37	7	15	12	1,738
Coal (as % of national total)	66.4%	42.0%	18.6%	17.1%	14.0%	20.3%	NA
Coal (as % of regional total)	80.9%	15.0%	2.1%	0.4%	0.9%	0.7%	100.0%
Oil (Mtoe)	355	169	48	9	56	13	650
Oil (as % of national total)	16.8%	27.2%	24.1%	22.0%	52.3%	22.0%	NA
Oil (as % of regional total)	54.6%	26.0%	7.4%	1.4%	8.6%	2.0%	100.0%
Gas (Mtoe)	18	4	NA	NA	NA	NA	22
Gas (as % of national total)	0.9%	0.6%	NA	NA	NA	NA	NA
Gas (as % of regional total)	81.8%	18.2%	NA	NA	NA	NA	100.0%
Nuclear (Mtoe)	50	10	1	1	1	2	65
Nuclear (as % of national total)	2.4%	1.6%	0.5%	2.4%	0.9%	3.4%	NA
Nuclear (as % of regional total)	76.9%	15.4%	1.5%	1.5%	1.5%	3.1%	100.0%
Hydro (Mtoe)	203	164	53	8	20	25	473
Hydro (as % of national total)	9.6%	26.4%	26.6%	19.5%	18.7%	42.4%	NA
Hydro (as % of regional total)	42.9%	34.7%	11.2%	1.7%	4.2%	5.3%	100.0%
Primary Energy Demand Per Capita (Mtoe/Population)	1.6	0.54	0.87	0.45	1.58	0.69	0.96
Primary Energy Demand Per GDP (TOE/constant 2000 $)	810	750	800	370	600	1,060	732
Electricity							
Electricity Generation (TWh)	3,457	830	149	61	147	73	4,717
Coal (TWh)	2,733	569	61	16	32	15	3,426
Coal (as % of national total)	79.1%	68.6%	40.9%	26.2%	21.8%	20.5%	NA
Coal (as % of regional total)	79.8%	16.6%	1.8%	0.5%	0.9%	0.4%	100.0%
Oil (TWh)	23	34	43	5	2	2	109

Indicators	China	India	Indonesia	Philip-pines	Thailand	Vietnam	Total
Oil (as % of national total)	0.7%	4.1%	28.9%	8.2%	1.4%	2.7%	NA
Oil (as % of regional total)	21.1%	31.2%	39.4%	4.6%	1.8%	1.8%	100.0%
Gas (TWh)	31	82	25	20	102	30	290
Gas (as % of national total)	0.9%	9.9%	16.8%	32.8%	69.4%	41.1%	NA
Gas (as % of regional total)	10.7%	28.3%	8.6%	6.9%	35.2%	10.3%	100.0%
Nuclear (TWh)	68	15	NA	NA	NA	NA	83
Nuclear (as % of national total)	2.0%	1.8%	NA	NA	NA	NA	NA
Nuclear (as % of regional total)	81.9%	18.1%	NA	NA	NA	NA	100.0%
Hydro TWh)	585	114	12	10	7	26	754
Hydro (as % of national total)	16.9%	13.7%	8.1%	16.4%	4.8%	35.6%	NA
Hydro (as % of regional total)	77.6%	15.1%	1.6%	1.3%	0.9%	3.4%	100.0%
Biomass, Waste and Others (TWh)	2	2	NA	NA	NA	NA	4
Biomass, Waste and Others (as % of national total)	0.1%	0.2%	NA	NA	NA	NA	
Biomass, Waste and Others (as % of regional total)	50.0%	50.0%	NA	NA	NA	NA	100.0%
Electricity Generation Per Capita (kWh/Population)	2,608	728	655	673	2,113	847	1,271
Electricity Generation Per GDP (TWh/thousand constants 2000 $)	1.25	1.01	0.6	0.55	0.8	1.31	0.92
Energy-Related CO_2 Emissions							
CO_2 Emissions (Mt)	6,508	1,427	385	72	230	103	8,725
CO_2 Emissions (as % of regional total)	74.6%	16.4%	4.4%	0.8%	2.6%	1.2%	100.0%
CO_2 Emission/capita (Mt/Population)	4.91	1.3	1.7	0.8	3.4	1.2	2.22
CO_2 Emissions/GDP (t - CO_2/million constant 2000$)	2,501	1,730	1,610	651	1,290	1,851	1,606

ATTACHMENT B: GDP FIGURES FOR DEVELOPING ASIA

Table B1. GDP for Developing Countries in Asia (billion 2000 US dollars)

No.	Country	GDP in 2008
1	Afghanistan	
2	Armenia	4.68
3	Azerbaijan	18.5
4	Georgia	5.46
5	Kazakhstan	37.27
6	Kyrgyz Republic	1.98
7	Pakistan	112.53
8	Tajikistan	1.68
9	Turkmenistan	8.58
10	Uzbekistan	22.93
11	Hong Kong	241.34
12	Mongolia	1.94
13	China	2602.6
14	Taipei	416.51
15	Fiji	
16	New Guinea	
17	Timor	
18	Bangladesh	73.95
19	Bhutan	
20	India	825.8
21	Maldives	
22	Nepal	7.31
23	Sri Lanka	24.17
24	Brunei	6.88
25	Cambodia	7.52
26	Indonesia	247.2
27	Lao PDR	
28	Malaysia	139.6
29	Burma	19.16
30	Philippines	110.7
31	Singapore	135.46
32	Thailand	178.3
33	Vietnam	55.7
Total	**Developing Asia**	**5,307.75**

Table B2. GDP for China, India, and Southeast Asia (billion 2000 US dollars)

No.	Country	GDP in 2008
1	China	2602.6
2	India	825.8
3	Burma	19.16
4	Brunei	6.88
5	Cambodia	7.52
6	Indonesia	247.2
7	Lao PDR	
8	Malaysia	139.6
9	Philippines	110.7
10	Singapore	135.46
11	Thailand	178.3
12	Vietnam	55.7
Total	**Southeast Asia, China, and India**	**4,328.92**
Total	**As share of developing Asia's GDP**	**81.6%**

Table B3. GDP for the Six Asian Focus Countries (billion 2000 US dollars)

No.	Country	GDP in 2008
1	China	2602.6
2	India	825.8
3	Indonesia	247.2
4	Philippines	110.7
5	Thailand	178.3
6	Vietnam	55.7
Total	**Six Focus Countries**	**4,020.3**
Total	**As share of developing Asia's GDP**	**75.7%**

ATTACHMENT C: STATUS OF NUCLEAR POWER IN THE WORLD

Figure C1. Status of Nuclear Power in the World (as of August 2009)

Countries	Nuclear Reactors[156]				Power[157]	Energy[158]
	Operating	Average Age	Under Construction[159]	Planned[160]	Share of Electricity[161]	Share of Commercial Primary Energy
Argentina	2	31	1	1	6% (=)	2%
Armenia	1	30	0	0	39% (-)	?%
Belgium	7	29	0	0	54% (=)	14%
Brazil	2	18	0	1	3% (=)	1%
Bulgaria	2	20	2	0	33% (=)	18%
Canada	18	26	0	3	15% (=)	6%
China	11	8	16	29	2% (=)	<1%
Czech Republic	6	18	0	0	32% (+)	14%
Finland	4	30	1	0	30% (=)	20%
France	58	24	1	1	76% (=)	39%
Germany	17	28	0	0	28% (=)[162]	11%
Hungary	4	24	0	0	37% (=)	14%
India	17	18	6	10	2% (=)	<1%
Iran	0	0	1	2	0% (-)	0
Japan	53	24	2	13	25% (-)	11%
Lithuania	1	22	0	0	73% (+)	26%
Mexico	2	18	0	0	4% (=)	1%
Netherlands	1	36	0	0	4% (=)	1%
Pakistan	2	24	1	2	2% (=)	<1%
Romania	2	8	0	2	18% (+)	7%
Russia	31	27	9	7	17% (=)	5%
Slovakia	4	19	2	0	56% (+)	21%
Slovenia	1	28	0	0	42% (=)	?%
South Africa	2	25	0	3	5% (=)	2%

156 According to IAEA PRIS August 2009, http://www.iaea.org/programmes/a2/index.html unless noted otherwise.
157 In 2008, based on IAEA PRIS, May 2009.
158 In 2008, according to BP, "Statistical Review of World Energy", June 2009.
159 As of May 2009.
160 Adapted from WNA; the WNA lists an addition 13 planned units in potential newcomer countries; see http://www.world-nuclear.org/info/reactors.html accessed on 28 May 2009.
161 412 A +/-/= in brackets refer to change in 2008 versus the level in 2007; a change of less than 1% is considered =.
162 German statistics (AG Energiebilanzen) give the share in the gross national power generation as only 23.3%.

Countries	Nuclear Reactors[156]				Power[157]	Energy[158]
	Operating	Average Age	Under Construction[159]	Planned[160]	Share of Electricity[161]	Share of Commercial Primary Energy
South Korea	20	17	5	7	36% (=)	14%
Spain	8	26	0	0	18% (=)	9%
Sweden	10	31	0	0	42% (-)	31%
Switzerland	5	34	0	0	39% (=)	21%
Taiwan	6	28	2		19% (=)	8%
Ukraine	15	21	2	0	47% (=)	16%
United Kingdom	19	28	0	0	13% (-)	6%
USA	104	30	1	0	20% (=)	8%
EU27	144	25	6	0	28% (=)	12%
Total	**435**	**25**	**52**	**11**	**ca. 14%**	**5.5%**

Figure C1. Installed Nuclear Generating Capacity Worldwide (1954-2009)

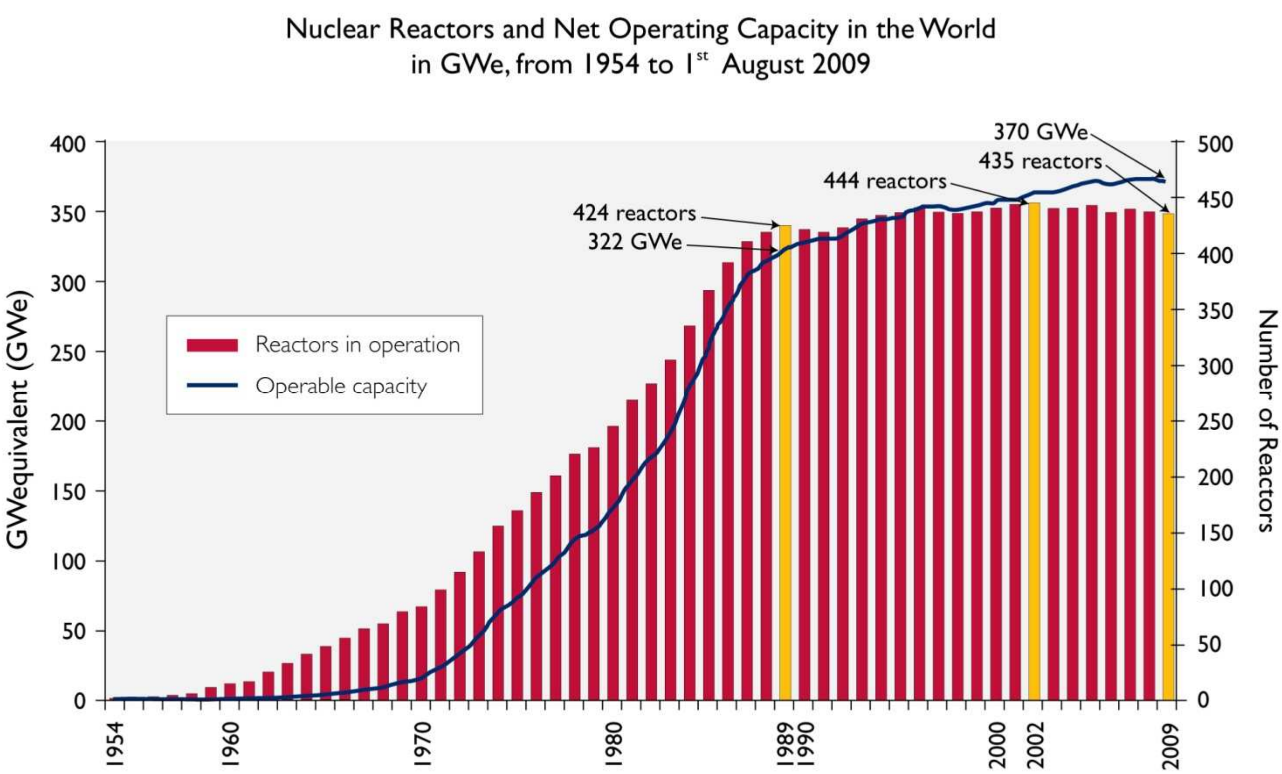


Table C2. Status of Nuclear Power Plants in the Six Focus Countries.

Country	Units in Operation	Units Offline	Units Under Construction	Units Planned for Construction	Proposals	Research Reactors[b]	Target
China	11 (8 GWe)	**0**	22 (24.6 GWe)	35	120	13	National plans call for 80 GWe nuclear by 2020
India	19 (4.3 GWe)	**0**	4	20	24	5	Plans are for 20 GWe by 2020
Indonesia	0	**0**	**0**	2	4	3	Aims to meet 2% % of power demand from nuclear by 2017
Philippines	0	1	**0**		1	1	
Thailand	0	**0**	**0**	2	8	1	5 GW online by 2020
Vietnam	0	**0**	**0**	2	8	1	Two planned reactors totaling 2 GWe

Source: World Nuclear Association (2010)
[b] Research reactors comprise a wide range of civil and commercial nuclear reactors which are generally not used for power generation

ATTACHMENT D: METHODOLOGY FOR DATA REVIEW AND ANALYSIS

USAID Statement of Work

The USAID Statement of Work called for researching and preparing data on the following trends, for 25 years before present and 25 years into the future.

Energy trends

- Energy generation and consumption trends for each country by fuel type and by sector, including energy intensity per capita and per unit of economic output;
- Energy generation and consumption trends for all countries by fuel type, including energy intensity per capita and per unit of economic output;
- Total energy consumption for the region, including energy intensity per capita and per unit of economic output;
- Electricity generation and consumption trends for each country by fuel type and sector;
- Energy efficiency and renewable energy targets for each country, as well as levels of investment needed to meet climate stabilization (i.e., 450 ppm of CO_2).

GHG emissions trends

- GHG emissions from each fuel type by country and by sector described in carbon dioxide (CO_2) equivalent and, if possible, broken out to the three main greenhouse gases from energy, namely carbon dioxide, methane, and nitrous oxide;
- Based on the above, total GHG emissions by fuel type for developing Asia;
- Based on the above, total GHG emissions from all energy sources for developing Asia (including the pie chart graphic showing growth from the current year to 2030);
- GHG emissions per capita for each country and for the region;
- GHG emissions intensity (measured against unit of economic output) for each country and for the region.

Key References Consulted

The project team reviewed an extensive list of references in order to fulfill the study terms of reference, which called for reviewing and analyzing historical trends and future projections for developing Asia of primary energy consumption, final energy demand, electricity production, and greenhouse gas emissions.

The key references reviewed included:

- IEA, *World Energy Outlook 2010* (IEA 2010);
- IEA, *IEA Statistics, 2010 Edition;*
- IEA's energy statistics on the IEA web site (www.iea.org);
- ADB, *Energy Outlook for Asia and Pacific*, October 2009 (ADB 2009); and
- APERC, *Energy Supply and Demand Outlook (4th Edition)*, 2009 (APERC 2009).

Energy Outlook for Asia and Pacific 2009, published by the Asian Development Bank, was the primary source of data for this report. The projections to 2030 are based on the report's business-as-usual (BAU) scenario. The main data sought were:

- primary energy consumption by fuel type, by sector, and by country;

- final energy consumption by fuel type, by sector, and by country;

- electricity generation by fuel type, by sector, and by country; and

- CO_2 emissions by fuel type, by sector, and by country

Data on Energy Trends

Based on these data sets, the project team compiled and organized data, and prepared excel spreadsheets for each of the six focus countries and for the Southeast Asia region. *Energy Outlook for Asia and Pacific 2009* was considered the best reference amongst others because it provided data on historical trends and future projections that were consistent for all countries. The data by ADB was not only based on one reference, but was based on careful research across references including APERC, IEA, and The World Bank. ADB's systematic, consistent format of data presentation for all countries took into consideration various references, which encouraged the project team to use ADB data for all of the tables and charts on Asia related to primary energy, final energy, and electricity consumption.

The IEA's *World Energy Outlook 2010* has data and projections based on a Current Policies Scenario (Business-as Usual, or BAU); a New Policies Scenario; and a 450 parts per million (PPM) scenario. In the New Policies Scenario, WEO 2010 has data with historical data and projections, but has country-specific data for only India and China. Efforts were made to get annual data from IEA, but the process was expensive and would have resulted in delays. APERC has country-level data and information on countries, but it was difficult to build on their data set for two reasons: first, APERC data does not cover India, which is one of the six focus countries for this report, and second, APERC data was not systematically arranged across countries in one common, easy-to-use format. Since ADB had sourced all these references (IEA's World Energy Outlook, APERC, etc.) for their *Energy Outlook for Asia and Pacific*, we chose to use the ADB dataset was chosen as the reference dataset for this report.

For detailed data for 2008, the project team relied on the IEA website for each of these six focus countries and for all countries in Southeast Asia for the energy, electricity, and emissions data mentioned above. ADB did not have this data for 2008.

Data on Greenhouse Gas Emissions

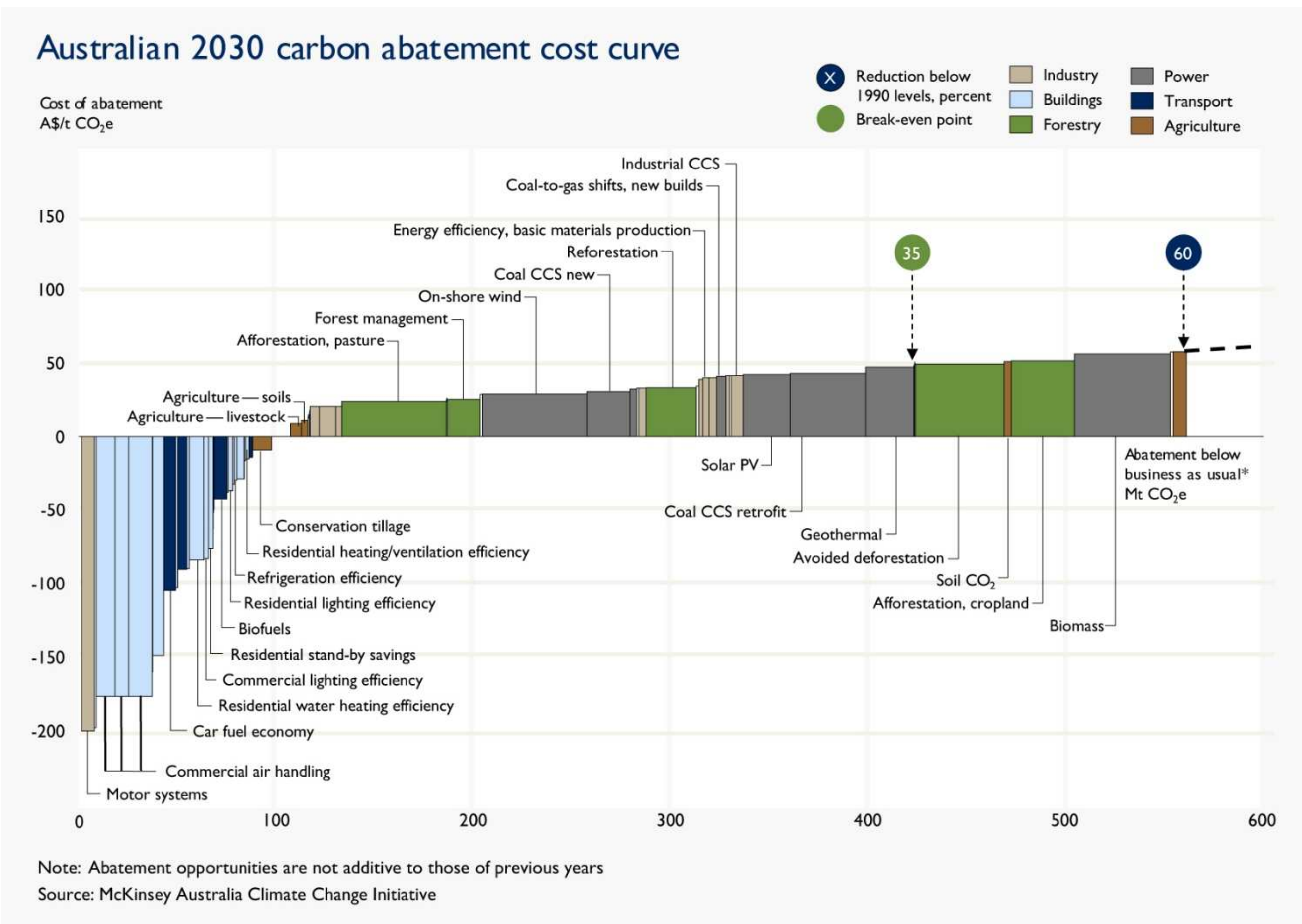
For analysis of greenhouse gas emissions trends, the project team relied on the IEA publication: *CO_2 Emissions from Fuel Combustion Highlight 2010*. This publication was a useful reference to gather historical information, compile data, and prepare charts on emissions by fuel type for six of the focus countries and also on a regional level.

IEA's *World Energy Outlook 2010* was a useful source for global and regional data. The ADB *Energy Outlook for Asia and Pacific, 2009* had total emissions for each country, but did not have breakdowns by fuel. By contrast, the IEA's *CO_2 Emissions from Fuel Combustion Highlight 2010* had breakdowns by fuel, and this was the most useful reference for reviewing and analyzing trends in greenhouse gas emissions across the six countries.

ATTACHMENT E: ANALYSIS OF COST CURVES FOR ABATEMENT OF GREENHOUSE GAS EMISSIONS

A number of different *GHG abatement cost curves* were reviewed, with the aim of developing a comprehensive list, with priority ranking, of clean-energy options that could be applied in developing Asia. The cost curves reviewed were prepared by McKinsey & Company, Exelon (a US electric utility) and Bloomberg New Energy Finance.[163] It is worth noting that, given the assignment timeframe, the program team was unable to examine the underlined modalities and assumptions of the cost curves mentioned above.

Figure E1. A Carbon Abatement Cost Curve for Australia (McKinsey & Company 2008).



163 Bloomberg New Energy Finance (2010), Exelon (2010), McKinsey & Company (2009A), McKinsey (2009B), McKinsey (2008).

The cost curves are commonly used in energy and climate policy to analyze and compare the cost effectiveness and potential of different GHG abatement technologies and practices. Figure E1 is a typical cost curve prepared by McKinsey & Company. The cost of each measure is shown by the height of each bar. Bars that are below the x-axis (or 0 cost line) represent *negative-cost* measures. Bars that are above the x-axis represent *positive-cost* measures. The width of each bar represents the estimated GHG abatement potential in terms of amount of CO_2e, typically per year.

The first thing one notices about the cost curves is that many of the measures appear as "negative" costs on the chart. This means that the cost to implement these measures results in savings to society through reductions in energy costs and through avoidance of investments in the business as usual scenario (e.g., investment in efficient buildings and appliances can avoid the need to invest in power plants).

The results of cost curves can differ depending on the assumed scenario, the future projection date, and the location where the measures will be applied. This is because cost curves are based on a number of assumptions, including the cost of a given abatement measure, projected to some future date, the expected savings or output from that measure, and the cost and characteristics of the baseline (BAU) scenario, to name a few. The projections are based on assumptions in "scenarios" in which future behavior and costs are estimated. Furthermore, the price of many options is highly dependent on the assumed future price of energy, such as electricity, coal, or petroleum products. Many items that are shown as having a positive cost at present will have a negative cost when the price of electricity or petroleum is sufficiently high.

There are regional and national differences between cost curves, but broadly speaking, the differences in the performance of a GHG abatement measures across the regions will be less than the differences between different categories of abatement measures (i.e., efficiency vs. fossil-fueled power plants). Moreover, since there are few detailed cost curves for countries in developing Asia, the program team used a set of cost curves were used from different sources that were applicable to different regions such as global, Australia, and China. In summary, these cost curves constitute the best source of data on clean-energy abatement options available at present.

For this report, a simplified chart was prepared to compare the cost effectiveness of a combined list of 47 GHG abatement measures, developed based on the five cost curves that were reviewed. The chart provides policymakers with an "at a glance" view of which options are most cost effective and which options have the highest potential.

Table E1. Comprehensive List of Measures for GHG Abatement. These measures were collected from a review of cost curves that have been developed to prioritize the cost and potential of GHG abatement measures internationally. The table shows the relative level of abatement cost for each measure; the relative level of abatement potential for each measure; the region for which the cost curve was developed; and the reference.[164]

No.	Technical Abatement Measures Range	Abatement Cost						Abatement Potential			Region/ Country	Reference
		Lowest	Lower	Low	High	Higher	Highest	Low	Med	High		
		> -40	-20 > -40	0 >20	0 > 20	20 > 60	60 <					
	Negative Cost Measures											
1	Lighting: switch incandescent to LED (residential)	✔						✔			Global	McKinsey
2	Residential electronic	✔						✔			Global	McKinsey
3	Residential appliances	✔						✔			Global	McKinsey
4	Insulation retrofit(commercial)	✔						✔			Global	McKinsey
5	Motor systems efficiency	✔						✔			Global	McKinsey
6	Retrofit residential HVC	✔						✔			Global	McKinsey
7	Cropland nutrient management	✔						✔			Global	McKinsey
8	Tillage and residual management	✔						✔			Global	McKinsey
9	Insulation retrofit (residential)		✔					✔			Global	McKinsey
10	Cars full hybrid		✔					✔			Global	McKinsey
11	Clinker substitution by fly ash		✔					✔			Global	McKinsey
12	Waste recycling			✔					✔		Global	McKinsey
13	Electricity from landfill gas			✔					✔		Global	McKinsey
14	Efficiency improvements other industry			✔						✔	Global	McKinsey

164 The bins used to categorize *negative-cost measures* was 0 to -20 US$/metric ton of CO_2 equivalent (CO_{2e}) (low); -20 to -40 US$/metric ton of CO_{2e} (lower); and -40 US$/metric ton of CO_{2e} and below (lowest). For *positive-cost measures*, the bins used were 0 to 20 US$/metric ton of CO_{2e} (low); 20 to 60 US$/metric ton of CO_{2e} (medium); and 60 US$/metric ton of CO_{2e} and above (high).

No.	Technical Abatement Measures Range	Abatement Cost						Abatement Potential			Region/ Country	Reference
		Lowest	Lower	Low	High	Higher	Highest	Low	Med	High		
		> -40	-20 > -40	0 >20	0 > 20	20 > 60	60 <					
15	Rice management			✔				✔			Global	McKinsey
16	Small Hydro			✔							Global	McKinsey
17	1st generation biofuels			✔							Global	McKinsey
18	Coal refinement	✔							✔		Global	Exelon 2010
19	Nuclear upgrades		✔					✔			Global	Exelon 2010
20	Lighting		✔						✔		Global	Bloomberg
21	Smart grid		✔					✔			Global	Bloomberg
22	Smart grid-AMI with visual display AMI		✔							✔	Global	Bloomberg
23	Building management systems			✔				✔			Global	Bloomberg
24	Hybrid vehicles			✔				✔			Global	Bloomberg
25	Geothermal			✔				✔			Global	Bloomberg
26	Landfill gas power generation			✔				✔			Global	Bloomberg
27	Transportation	✔							✔		China	McKinsey
28	Efficient lighting	✔						✔			China	McKinsey
29	TRT(top pressure recovery turbine)	✔						✔			China	McKinsey
30	Petroleum processing	✔						✔			China	McKinsey
31	Super and ultra-super critical		✔							✔	China	McKinsey
32	Nutrient Management		✔					✔			China	McKinsey
33	CDQ			✔				✔			China	McKinsey
34	Efficient BF			✔					✔		China	McKinsey
35	Clinker substitute			✔				✔			China	McKinsey
36	Ammonia			✔				✔			China	McKinsey
37	NSP			✔				✔			China	McKinsey
38	Efficient cooking			✔				✔			China	McKinsey
39	Small boiler			✔							China	McKinsey
40	Rice nutrient management			✔							China	McKinsey

No.	Technical Abatement Measures Range	Abatement Cost						Abatement Potential			Region/ Country	Reference
		Lowest	Lower	Low	High	Higher	Highest	Low	Med	High		
		> -40	-20 > -40	0 >20	0 > 20	20 > 60	60 <					
41	Methane utilization			✔							China	McKinsey
42	Residual heat power generation			✔				✔			China	McKinsey
43	Commercial retrofit energy-waste reduction	✔						✔			Australia	McKinsey
44	Other industry energy efficiency	✔								✔	Australia	McKinsey
45	Commercial retrofit HVAC	✔						✔			Australia	McKinsey
46	Residential appliances and electronics	✔						✔			Australia	McKinsey
47	Mining energy efficiency	✔						✔			Australia	McKinsey
48	Residential lighting	✔						✔			Australia	McKinsey
49	Residential new buildings	✔						✔			Australia	McKinsey
50	Improving thermal efficiency of gas plants	✔						✔			Australia	McKinsey
51	Commercial lighting retrofit	✔						✔			Australia	McKinsey
52	Commercial elevators and appliances	✔							✔		Australia	McKinsey
53	Diesel car and light-duty commercial efficiency improvement	✔						✔			Australia	McKinsey
54	Commercial buildings retrofit insulation	✔						✔			Australia	McKinsey
55	Reduced cropland emissions	✔						✔			Australia	McKinsey
56	Gasoline car and light commercial efficient improvement	✔						✔			Australia	McKinsey
57	Cogeneration	✔							✔		Australia	McKinsey
58	Commercial retrofit water heating	✔						✔			Australia	McKinsey
59	Reduced T&D losses		✔					✔			Australia	McKinsey

No.	Technical Abatement Measures Range	Abatement Cost						Abatement Potential			Region/ Country	Reference
		Lowest	Lower	Low	High	Higher	Highest	Low	Med	High		
		> -40	-20 > -40	0 >20	0 > 20	20 > 60	60 <					
60	Operational improvements in existing coal plants		✔					✔			Australia	McKinsey
61	Petroleum and gas maintenance		✔					✔			Australia	McKinsey
62	Mining VAM oxidation			✔				✔			Australia	McKinsey
63	Active livestock feeding			✔				✔			Australia	McKinsey
	Positive Cost Measures											
64	Reduced slash and burn agriculture conversion				✔					✔	Global	McKinsey
65	Reduced pastureland conversion				✔					✔	Global	McKinsey
66	Grassland management				✔				✔		Global	McKinsey
67	Geothermal				✔			✔			Global	McKinsey
68	Organic soil restoration				✔				✔		Global	McKinsey
69	Building efficiency				✔			✔			Global	McKinsey
70	2nd generation bio fuels				✔					✔	Global	McKinsey
71	Degraded land restoration				✔			✔			Global	McKinsey
72	Nuclear				✔					✔	Global	McKinsey
73	Degraded forest restoration				✔				✔		Global	McKinsey
74	Cars plug in				✔					✔	Global	McKinsey
75	Low penetration wind				✔					✔	Global	McKinsey
76	Solar CSP				✔				✔		Global	McKinsey
77	Solar PV				✔				✔		Global	McKinsey
78	High penetration wind					✔		✔			Global	McKinsey
79	Reduced intensive agriculture conversion					✔			✔		Global	McKinsey
80	Power plant biomass co-firing					✔		✔			Global	McKinsey
81	Coal CCS (carbon capture and storage)					✔		✔			Global	McKinsey

No.	Technical Abatement Measures Range	Abatement Cost Lowest > -40	Lower -20 > -40	Low 0 >20	High 0 > 20	Higher 20 > 60	Highest 60 <	Abatement Potential Low	Med	High	Region/ Country	Reference
82	Iron and steel CCS (carbon capture and storage)					✔		✔			Global	McKinsey
83	Coal CCS					✔		✔			Global	McKinsey
84	Gas plant					✔		✔			Global	McKinsey
85	New natural gas plants				✔			✔			Global	Exelon
86	Coal to gas plant				✔			✔			Global	Exelon
87	Cogeneration					✔		✔			Global	Exelon
88	Wind power						✔		✔		Global	Exelon
89	Biomass generation						✔	✔			Global	Exelon
90	Clean coal with CCS						✔		✔		Global	Exelon
91	Solar photovoltaic						✔	✔			Global	Exelon
92	Wind				✔			✔			Global	Bloomberg
93	Industrial improvements				✔			✔			Global	Bloomberg
94	Soil sequestration				✔			✔			Global	Bloomberg
95	Crop rotations				✔			✔			Global	Bloomberg
96	Afforestation				✔			✔			Global	Bloomberg
97	Forest management				✔			✔			Global	Bloomberg
98	Efficiency for commercial and residential retrofits				✔			✔			Global	Bloomberg
99	Wind				✔					✔	Global	Bloomberg
100	Afforestation-mid cost				✔				✔		Global	Bloomberg
101	Solar PV					✔		✔			Global	Bloomberg
102	Efficiency for residential new builds					✔		✔			Global	Bloomberg
103	Plug in vehicles					✔		✔			Global	Bloomberg
104	Nuclear					✔			✔		Global	Bloomberg
105	CCS					✔				✔	Global	Bloomberg
106	Landfill projects					✔		✔			Global	Bloomberg

No.	Technical Abatement Measures Range	Abatement Cost						Abatement Potential			Region/ Country	Reference
		Lowest	Lower	Low	High	Higher	Highest	Low	Med	High		
		> -40	-20 > -40	0 >20	0 > 20	20 > 60	60 <					
107	Gas industry projects					✔		✔			Global	Bloomberg
108	Biomass						✔	✔			Global	Bloomberg
109	Electric vehicles						✔	✔			Global	Bloomberg
110	Afforestation-high cost						✔	✔			Global	Bloomberg
111	CCS-retrofit post combustion coal						✔	✔			Global	Bloomberg
112	Coal mine, oil industry, high GWP, wastewater projects						✔	✔			Global	Bloomberg
113	Coal gas shift						✔	✔			Global	Bloomberg
114	CCS-new build, pre combustion						✔	✔			Global	Bloomberg
115	CCS retrofit, oxy-fuel, coal						✔	✔			Global	Bloomberg
116	Gas industry projects-high cost						✔	✔			Global	Bloomberg
117	CBM utility underground				✔					✔	China	McKinsey
118	Coal mining upscale				✔			✔			China	McKinsey
119	Building code management				✔			✔			China	McKinsey
120	Grass land management				✔			✔			China	McKinsey
121	Replacing small plants with large ones				✔					✔	China	McKinsey
122	Degraded crop land restoration				✔			✔			China	McKinsey
123	Degraded grassland recovery				✔			✔			China	McKinsey
124	NSP replacement				✔			✔			China	McKinsey
125	Improved agronomy				✔			✔			China	McKinsey
126	Building code commercial				✔			✔			China	McKinsey
127	Nuclear					✔		✔			China	McKinsey
128	Reforestation					✔				✔	China	McKinsey
129	Afforestation						✔			✔	China	McKinsey
130	Efficient heating						✔	✔			China	McKinsey
131	Solar						✔	✔			China	McKinsey

No.	Technical Abatement Measures Range	Abatement Cost						Abatement Potential			Region/ Country	Reference
		Lowest	Lower	Low	High	Higher	Highest	Low	Med	High		
		> -40	-20 > -40	0 >20	0 > 20	20 > 60	60 <					
132	Onshore wind						✔			✔	China	McKinsey
133	Mining VAM oxidation				✔			✔			Australia	McKinsey
134	Aluminum energy efficiency				✔			✔			Australia	McKinsey
135	Pasture and grass land management				✔					✔	Australia	McKinsey
136	Reduced deforestation and re growth clearing				✔					✔	Australia	McKinsey
137	Crop land carbon sequestration					✔		✔			Australia	McKinsey
138	Reforestation of marginal land					✔				✔	Australia	McKinsey
139	Strategic reforestation of re marginal land					✔				✔	Australia	McKinsey
140	Chemical processes and fuel shift					✔				✔	Australia	McKinsey
141	Onshore wind					✔		✔			Australia	McKinsey
142	Coal to gas shift					✔				✔	Australia	McKinsey
143	Biomass/biogas					✔			✔		Australia	McKinsey
144	Improved forest management					✔		✔			Australia	McKinsey
145	Geothermal					✔		✔			Australia	McKinsey
146	Capital improvements to existing gas plants						✔	✔			Australia	McKinsey
147	Coal CCS						✔	✔			Australia	McKinsey
148	Solar thermal						✔		✔		Australia	McKinsey
149	Degraded farm land restoration						✔		✔		Australia	McKinsey
150	Wind offshore						✔	✔			Australia	McKinsey
151	Solar PV						✔	✔			Australia	McKinsey
152	Gas CCS						✔	✔			Australia	McKinsey

References: Global = McKinsey & Company (2009A); China = McKinsey & Company (2009B); Australia = McKinsey and Company (2008); Bloomberg New Energy Finance (2010); Exelon (2010).

Table E2. Summary of Technical Abatement Measures and Consolidation into Combined Measures. This table shows how the list of 152 negative-cost measures from the cost curves are combined into a single set of 47 measures and grouped into 7 major categories.

Ref. No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
Buildings, Appliances, Equipment		
1	Lighting: switch incandescent to LED (residential)	**Efficient lighting**
20	Lighting	
28	Efficient lighting	
48	Residential lighting	
51	Commercial lighting retrofit	
3	Residential appliances	**Residential appliances and equipment**
6	Retrofit residential HVC	
38	Efficient cooking	
46	Residential appliances and electronics	
9	Insulation retrofit (residential)	**Residential buildings**
49	Residential new buildings	
102	Efficiency for residential new builds	
4	Insulation retrofit(commercial)	**Commercial building efficiency**
23	Building management systems	
43	Commercial retrofit energy-waste reduction	
45	Commercial retrofit HVAC	
52	Commercial elevators and appliances	
54	Commercial buildings retrofit insulation	
58	Commercial retrofit water heating	
69	Building efficiency	
98	Efficiency for commercial and residential retrofits	
130	Efficient heating	**Efficient heating**
119	Building code management	**Building codes**
126	Building code commercial	
Industry		
5	Motor systems efficiency	**Motor systems efficiency**
12	Waste recycling	**Industrial energy efficiency**
14	Efficiency improvements other industry	
39	Small boiler	

Ref. No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
44	Other industry energy efficiency	
93	Industrial improvements	
36	Ammonia	**Industrial process efficiency**
134	Aluminum energy efficiency	
140	Chemical processes and fuel shift	
37	NSP (New suspension pre-heater and pre-calciner kilns)	**Industrial EE measures--cement**
124	NSP replacement	
29	TRT (Top pressure recovery turbine)	**Industrial EE measures--steel**
33	CDQ (Coke Dry Quenching waste heat recovery)	
34	Efficient blast furnace	
47	Mining energy efficiency	**Mining efficiency**
62	Mining VAM oxidation	
133	Mining VAM oxidation	
30	Petroleum processing	**Petroleum processing measures**
61	Petroleum and gas maintenance	
11	Clinker substitution by fly ash	**Coal plant measures**
35	Clinker substitute	
59	Reduced T&D losses	**Transmission and distribution efficiency**
117	CBM utility underground (conduction band minimum)	
107	Gas industry projects	**Chemical and gas industry**
116	Gas industry projects-high cost	
Power Generation -- Non Renewable		
18	Coal refinement	**Coal plant measures**
31	Super and ultra-super critical	
60	Operational improvements in existing coal plants	
84	Gas plant	**Gas plant improvements**
85	New natural gas plants	
146	Capital improvements to existing gas plants	
86	Coal to gas plant	**Coal to gas shift**
113	Coal gas shift	
142	Coal to gas shift	
112	Coal mine, oil industry, high GWP, wastewater projects	**Coal mining measures**
118	Coal mining upscale	
19	Nuclear upgrades	**Nuclear upgrades**

Ref. No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
72	Nuclear	**Nuclear Power**
104	Nuclear	
127	Nuclear	
81	Coal CCS (carbon capture and storage)	**Carbon capture and storage (CCS)**
82	Iron and steel CCS (carbon capture and storage)	
83	Coal CCS	
90	Clean coal with CCS	
105	CCS	
111	CCS-retrofit post combustion coal	
114	CCS-new build, pre combustion	
115	CCS retrofit, oxy-fuel, coal	
147	Coal CCS	
152	Gas CCS	
Power Generation -- Renewable		
25	Geothermal	**Geothermal**
67	Geothermal	
145	Geothermal	
80	Power plant biomass co-firing	**Biomass**
89	Biomass generation	
108	Biomass	
143	Biomass/biogas	
16	Small Hydro	**Small hydropower**
76	Solar CSP	**Solar thermal**
148	Solar thermal	
77	Solar PV	**Solar PV**
91	Solar photovoltaic	
101	Solar PV	
131	Solar	
151	Solar PV	
75	Low penetration wind	**Wind energy**
78	High penetration wind	
88	Wind power	
92	Wind	
99	Wind	

Ref. No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
132	Onshore wind	**Wind(onshore)**
141	Onshore wind	
150	Wind offshore	**Wind(offshore)**
Transportation		
27	Transportation	**Transportation efficiency measures**
53	Diesel car and light-duty commercial efficiency improvement	**Light-vehicle efficiency**
56	Gasoline car and light commercial efficient improvement	
10	Cars full hybrid	**Hybrid vehicles**
24	Hybrid vehicles	
109	Electric vehicles	**Electric vehicles**
74	Cars plug in	**Plug-in hybrids**
103	Plug in vehicles	
Agriculture and Forestry		
7	Cropland nutrient management	**Nutrient and tillage management**
8	Tillage and residual management	
32	Nutrient Management	
40	Rice nutrient management	
55	Reduced cropland emissions	
15	Rice management	**Improved agricultural practices**
63	Active livestock feeding	
121	Replacing small plants with large ones	
125	Improved agronomy	
65	Reduced pastureland conversion	**Grassland management**
66	Grassland management	
120	Grass land management	
123	Degraded grassland recovery	
135	Pasture and grass land management	
71	Degraded land restoration	**Land and forest restoration**
73	Degraded forest restoration	
122	Degraded crop land restoration	
149	Degraded farm land restoration	
96	Afforestation	**Afforestation measures**
100	Afforestation-mid cost	

Ref. No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
110	Afforestation-high cost	
129	Afforestation	
128	Reforestation	**Reforestation measures**
136	Reduced deforestation and re growth clearing	
138	Reforestation of marginal land	
139	Strategic reforestation of re marginal land	
97	Forest management	**Forestry measures**
144	Improved forest management	
Other		
13	Electricity from landfill gas	**Landfill gas**
26	Landfill gas power generation	
41	Methane utilization	
106	Landfill projects	
17	1st generation biofuels	**Biofuels**
70	2nd generation biofuels	
21	Smart grid	**Smart grid measures**
22	Smart grid-AMI with visual display AMI	
42	Residual heat power generation	**Cogeneration (combined heat and power)**
57	Cogeneration	
87	Cogeneration	

Ref No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
Buildings, Appliances, Equipment		
1	Lighting: switch incandescent to LED (residential)	**Efficient lighting**
20	Lighting	
28	Efficient lighting	
48	Residential lighting	
51	Commercial lighting retrofit	
3	Residential appliances	**Residential appliances and equipment**
6	Retrofit residential HVC	
38	Efficient cooking	
46	Residential appliances and electronics	
9	Insulation retrofit (residential)	**Residential buildings**
49	Residential new buildings	

Ref. No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
102	Efficiency for residential new builds	
4	Insulation retrofit(commercial)	**Commercial building efficiency**
23	Building management systems	
43	Commercial retrofit energy-waste reduction	
45	Commercial retrofit HVAC	
52	Commercial elevators and appliances	
54	Commercial buildings retrofit insulation	
58	Commercial retrofit water heating	
69	Building efficiency	
98	Efficiency for commercial and residential retrofits	
130	Efficient heating	**Efficient heating**
119	Building code management	**Building codes**
126	Building code commercial	
Industry		
5	Motor systems efficiency	**Motor systems efficiency**
12	Waste recycling	**Industrial energy efficiency**
14	Efficiency improvements other industry	
39	Small boiler	
44	Other industry energy efficiency	
93	Industrial improvements	
36	Ammonia	**Industrial process efficiency**
134	Aluminum energy efficiency	
140	Chemical processes and fuel shift	
37	NSP (New suspension pre-heater and pre-calciner kilns)	**Industrial EE measures – cement**
124	NSP replacement	
29	TRT (Top pressure recovery turbine)	**Industrial EE measures – steel**
33	CDQ (Coke Dry Quenching waste heat recovery)	
34	Efficient blast furnace	
47	Mining energy efficiency	**Mining efficiency**
62	Mining VAM oxidation	
133	Mining VAM oxidation	
30	Petroleum processing	**Petroleum processing measures**
61	Petroleum and gas maintenance	
11	Clinker substitution by fly ash	**Coal plant measures**

Ref. No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
35	Clinker substitute	
59	Reduced T&D losses	**Transmission and distribution efficiency**
117	CBM utility underground (conduction band minimum)	
107	Gas industry projects	**Chemical and gas industry**
116	Gas industry projects-high cost	
Power Generation -- Non Renewable		
18	Coal refinement	**Coal plant measures**
31	Super and ultra-super critical	
60	Operational improvements in existing coal plants	
84	Gas plant	**Gas plant improvements**
85	New natural gas plants	
146	Capital improvements to existing gas plants	
86	Coal to gas plant	**Coal to gas shift**
113	Coal gas shift	
142	Coal to gas shift	
112	Coal mine, oil industry, high GWP, wastewater projects	**Coal mining measures**
118	Coal mining upscale	
19	Nuclear upgrades	**Nuclear upgrades**
72	Nuclear	**Nuclear Power**
104	Nuclear	
127	Nuclear	
81	Coal CCS (carbon capture and storage)	**Carbon capture and storage (CCS)**
82	Iron and steel CCS (carbon capture and storage)	
83	Coal CCS	
90	Clean coal with CCS	
105	CCS	
111	CCS-retrofit post combustion coal	
114	CCS-new build, pre combustion	
115	CCS retrofit, oxy-fuel, coal	
147	Coal CCS	
152	Gas CCS	
Power Generation -- Renewable		
25	Geothermal	**Geothermal**
67	Geothermal	

Ref. No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
145	Geothermal	
80	Power plant biomass co-firing	**Biomass**
89	Biomass generation	
108	Biomass	
143	Biomass/biogas	
16	Small Hydro	**Small hydropower**
76	Solar CSP	**Solar thermal**
148	Solar thermal	
77	Solar PV	**Solar PV**
91	Solar photovoltaic	
101	Solar PV	
131	Solar	
151	Solar PV	
75	Low penetration wind	**Wind energy**
78	High penetration wind	
88	Wind power	
92	Wind	
99	Wind	
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Transportation		
27	Transportation	**Transportation efficiency measures**
53	Diesel car and light-duty commercial efficiency improvement	**Light-vehicle efficiency**
56	Gasoline car and light commercial efficient improvement	
10	Cars full hybrid	**Hybrid vehicles**
24	Hybrid vehicles	
109	Electric vehicles	**Electric vehicles**
74	Cars plug in	**Plug-in hybrids**
103	Plug in vehicles	
Agriculture and Forestry		
7	Cropland nutrient management	**Nutrient and tillage management**
8	Tillage and residual management	

Ref. No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
32	Nutrient Management	
40	Rice nutrient management	
55	Reduced cropland emissions	
15	Rice management	**Improved agricultural practices**
63	Active livestock feeding	
121	Replacing small plants with large ones	
125	Improved agronomy	
65	Reduced pastureland conversion	**Grassland management**
66	Grassland management	
120	Grass land management	
123	Degraded grassland recovery	
135	Pasture and grass land management	
71	Degraded land restoration	**Land and forest restoration**
73	Degraded forest restoration	
122	Degraded crop land restoration	
149	Degraded farm land restoration	
96	Afforestation	**Afforestation measures**
100	Afforestation-mid cost	
110	Afforestation-high cost	
129	Afforestation	
128	Reforestation	**Reforestation measures**
136	Reduced deforestation and re growth clearing	
138	Reforestation of marginal land	
139	Strategic reforestation of re marginal land	
97	Forest management	**Forestry measures**
144	Improved forest management	
Other		
13	Electricity from landfill gas	**Landfill gas**
26	Landfill gas power generation	
41	Methane utilization	
106	Landfill projects	
17	1st generation biofuels	**Biofuels**
70	2nd generation biofuels	
21	Smart grid	**Smart grid measures**

Ref. No.	Technical Abatement Measures (original version, as stated in references)	Technical Abatement Measures (combined version)
22	Smart grid-AMI with visual display AMI	
42	Residual heat power generation	**Cogeneration (combined heat and power)**
57	Cogeneration	
87	Cogeneration	

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