Chapter 1
Asia's Local Air Pollution and Impacts on Global Climate Change

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Abstract Asia has become one of the global economic centers responsible for nearly 30 % of global GDP as of 2011. This may not be too surprising when we consider the fact that 55 % of global population is concentrated in this area. However, considering the fact that Asia accounted for only 15 % of the global economy in 1973, it can be said that the change over the past 40 years has been quite considerable. At the same time, energy consumption increased along with economic growth. Furthermore, now Asia has a huge share of air pollution and greenhouse gases emission. The purpose of this chapter is to organize the data of the current situation where energy consumption is increasing along with economic growth in Asia and to have an overview of local air pollution and global environmental problems brought about as a result of energy consumption. We will analyze the energy structure in Asia which has low energy efficiency and large environmental impacts. However, as for local air pollution, the indications are showing that it has been on a course of improvement in recent years. Finally, the future outlook is examined based on that given by the International Energy Agency (IEA).

Keywords Air pollution • Climate change • Energy and development • Asia

1.1 Economic Growth and Energy Consumption in Asia: What Is the Key to Energy Saving?

First of all, we need to confirm the position of Asia in the whole world economy, energy, and environment. As shown in Table 1.1, the GDP of Asia accounted for 27.4 % of the global economy as of 2011, representing a huge increase in the impact on the global economy compared with the 15.1 % figure in 1973. Big changes can be seen among the shares of each country. Japan produced more than 70 % of Asian GDP in 1973; however, its share decreased to 30.4 % in 2011, indicating multi-polarization, in particular the robust growth rates of China and India. The GDP of

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Table 1.1 Economic, energy, and CO_2 emission indicators for the world, regional, and each country in Asia

	1973			2011		
	Real GDP (billion US$)	Energy consumption (million toe)	CO_2 emission (million tons)	Real GDP (billion US$)	Energy consumption (million toe)	CO_2 emission (million tons)
North America	5,995	1,887	5,070	16,296	2,421	5,726
Latin America	1,615	275	545	5,282	809	1,606
EU	9,305	2,316	6,732	20,537	2,900	6,433
EU (OECD)	8,040	1,371	3,993	17,965	1,719	3,650
Africa	494	212	273	1,760	700	1,048
Middle East	553	58	152	2,378	671	1,635
Oceania	438	65	190	1,356	136	397
Asia	3,260	1,109	2,427	17,952	5,036	13,841
Japan	2,293	321	891	5,464	457	1,174
China	220	427	975	6,503	2,723	8,561
Hong Kong	31	3	10	240	14	48
Taiwan	45	12	39	466	110	262
Korea	102	21	70	1,052	260	577
Singapore	19	4	10	244	35	62
Brunei	6	0	1	13	3	9
Indonesia	90	38	33	755	194	399
Malaysia	27	6	14	259	78	189
Philippines	55	17	27	207	31	78
Thailand	39	15	22	319	121	229
Vietnam	11	15	18	113	62	132
India	217	164	207	1,813	759	1,801
World	21,659	6,105	15,962	65,560	13,031	31,811

Source: The Energy Data and Modelling Center, IEEJ (2014)

China accounted for 36.2 % of the whole of Asia, surpassing Japan in 2011. The GDP of India in the same year was 10.0 %.

China is not only one example, but a lot of countries in Asia are also on a course of economic development based on industrialization, which mandates a rapid increase in energy consumption. China, which accounts for the largest energy consumption in the area, surpassed the USA in 2010 to become a nation with the highest energy consumption in the world. However, the increase in energy consumption is more than six times as much, while the size of its economy increased by nearly 30 times. On the other hand, India has increased its economy by over eight times, while its energy consumption grew by nine times. Similarly, the rate of energy consumption has increased more than the rate of economic growth in Korea, Indonesia, Malaysia, and Thailand. On the other hand, Taiwan and Japan have improved their energy efficiency.

When GDP-specific energy consumption (energy consumed to produce 100 million dollars worth of GDP) is focused, China showed a huge improvement in energy efficiency, from 194,000 tons in 1973 to 42,000 tons in 2011. However, compared with the Japanese GDP specific energy consumption of 8,000 tons in 2011, it still remains at lower than one fifth of the level. When compared at the level as of 1973, the GDP-specific energy consumption of India was 76,000 tons, at a better standard than China was. Though India has achieved energy efficiency improvement, its GDP specific energy consumption in 2011 stayed at 42,000 tons, at the same level as China was.

Energy efficiency improvement and energy saving that China has accomplished in less than 40 years deserve a high valuation, though their energy efficiency level still remains low. In the background, it is pointed out that China was under a planned economic system prior to 1978 when economic reform was launched. Under a planned economic system, users just received distributed energy according to government plan without paying any cost. Therefore users used up all the distributed energy because of no incentive for energy saving, resulting in serious waste of energy. However, the market mechanism was introduced into energy trading after the 1980s. Furthermore, the price level has been raised gradually. So now, the price of coal, which is the main energy source in China, is determined in reflection of the market balance between demand and supply (Horii 2014a, b). As a result, users became aware of saving energy costs, which led to increasing energy efficiency as a whole.

Meanwhile, India began to grow out of its planned economy in the 1990s, somewhat later than China, but the price of energy is still kept low in consideration for the low income class (or the demand of industries hiding behind it) (Horii 2013). A massive blackout involving 600 million people occurred in July 2012 because of a chronic deficiency in investment for electricity generation facility reinforcement due to the fact that the price of electricity is kept artificially low. Furthermore, the price of coal, the fuel for power generation, is kept artificially low by government policies, which leads to deficient supply. Importing coal from overseas to make up for the deficiency is not economically viable due to high imported coal prices and the low price of electricity. As we have seen here, a low energy price can be a restricting factor on energy supply, and in addition to that, demand will not decrease because of artificial suppression of price rises during deficient supply. This results in severe shortage of supply and increase of energy waste. The difference between China and India indicates the importance of market function to promote energy saving.[1]

[1] Energy theft is said to amount to nearly 20 % of power generation in India despite the low price of electricity. Therefore, some argue that raising the price of electricity is difficult in practice. However, it is better to assist low-income people with welfare policies such as cash handouts to match the amount of electricity price increase. By doing so, low income people also will have an incentive for electricity saving so that they can keep more of the handout at hand (and the unused money may be spent on children's education, etc., which is better for society). It is expected that

Table 1.2 Subsidy for lower energy price in Asia (2011)

	Ratio to GDP				Ratio to government's revenue			
	Oil	Electricity	Gas	Coal	Oil	Electricity	Gas	Coal
China	0.00	0.15	n.a.	n.a.	0.00	0.68	n.a.	n.a.
India	1.25	0.32	0.17	0.00	6.75	1.72	0.90	0.00
Indonesia	2.58	0.66	0.00	0.00	14.51	3.69	0.00	0.00
Thailand	0.15	1.64	0.14	0.25	0.66	7.24	0.61	1.08
Malaysia	1.24	0.33	0.31	0.00	5.67	1.49	1.41	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.54	n.a.	n.a.	n.a.	9.35	n.a.	n.a.	n.a.
Laos	0.00	n.a.	n.a.	n.a.	0.00	n.a.	n.a.	n.a.
Cambodia	0.00	n.a.	n.a.	n.a.	0.00	n.a.	n.a.	n.a.
World	0.30	0.22	0.16	0.01	0.91	0.64	0.48	0.03

Source: IMF (2013)

Further still, typical cases where energy saving was compromised due to suppressed energy prices are seen in Indonesia and Malaysia. Both were once prominent oil-/gas-producing nations. They maintained a system to keep domestic energy prices low based on the idea of returning the benefit from natural resources to their citizens. However, the growth in energy production has been stagnating, and the subsidy, along with rising international prices, imposes a heavy burden on the economy and finance. As is seen from Table 1.2, a lot of countries pay an energy subsidy in Asia, which is one of the main factors holding back improvements in energy efficiency.

1.2 Increasing Impact on Climate Change: High Dependency on Coal

Next, the impact on the environment is examined. As indicated in Table 1.1, the Asian share in world CO_2 emission shows a large increase, from 15.2 % in 1973 to 43.5 % in 2011. Unlike traditional air pollutants, there is no abatement technology which is economically available to reduce CO_2 emissions completely.[2] Although CO_2 is a major component of greenhouse gas, it is inevitably emitted into the air accompanied by use of fossil fuels. Therefore there is a high correlation between CO_2 emission and energy consumption. Yet in those countries where alternative

energy wasting can be eliminated as a whole, leading to a good result where supply deficiency is eased.

[2] Even with carbon capture and storage (CCS) technology which is considered most promising, it cost 4,200 yen per ton CO_2 in Japan as of 2013. The target is to decrease the cost to 1,000 yen per ton to achieve commercialization in the 2020s.

energy use is developed, such as nuclear energy and renewable energy, the amount of emission is lower. Moreover, in those countries where fossil fuel with a higher carbon content, i.e., coal, is mainly used, the emission is greater than those countries where gas is often used.

As is mentioned previously, Asia's share of CO_2 emission in the world (43.5 %) is far greater than its GDP share (27.4 %) mainly due to low energy efficiency. In addition, the CO_2 emission share is slightly larger than the energy share (38.6 %) because carbon intensity in the energy structure is high, especially when the dependency rate on coal as an energy source is high. As shown in Table 1.3, 67.2 % of world coal consumption as of 2011 was in Asia. Considering the fact that the proportion in 1973 was a mere 22.0 %, this increase indicates coal was the fuel of choice when trying to meet the increasing demand for energy as Asia was about to launch its economic takeoff. When the breakdown in each country is focused, coal consumption in China is predominantly excessive. Coal consumption in China is as much as 73.3 % of the Asian total and 49.2 % of the world's total. Consumption in India is also very high. Coal consumption in Taiwan, Korea, and Indonesia is also fairly high, though the quantity is much lower compared with these two countries.

What we should focus on is the fact that consumption of coal and oil in Europe is decreasing, indicating a shift to natural gas and nuclear energy. In North America, the rate of conversion from coal to gas is expected to make a huge leap due to the expansion of shale gas production. On the other hand, a lot of countries are expected to increase their dependency on coal, which will be examined later according to the future prediction of the IEA. In particular, a large increase is predicted in India. Furthermore, coal is expected to become the main energy source in Indonesia due to restrictions placed on domestic oil/gas production.

Meanwhile, coal consumption volume in China will continue to increase for a while, but the ratio of coal in primary energy is expected to decrease because the growth of other energy sources will be correspondingly greater. It is also partly because coal price had been on rise until 2012 since around the mid of 2000s, due to coal pricing reform, and coal is now not very specially cheap energy, compared with other energies, as before (Horii 2014a). In addition, China is also actively introducing renewable energy and now is the largest country with the largest wind power capacity in the world. As is seen in Table 1.3, China holds the highest level of other energy sources including renewable energy.[3] Hydropower and nuclear capacity are also expanding rapidly.

[3] By the way, this figure is high also in Africa and India. This is because consumption of so-called traditional biomass energy, that is, firewood and animal manure, makes up a large proportion. On the other hand, the figure in China is mostly modern renewable energy, such as wind power and solar energy.

Table 1.3 Energy consumption structure in the world, regional, and each country in Asia (unit: million toe)

	1973						2011					
	Coal	Oil	Gas	Nuclear	Hydro	Other	Coal	Oil	Gas	Nuclear	Hydro	Other
North America	326	897	552	27	40	45	499	868	652	238	60	104
Latin America	8	154	33	–	9	71	38	372	189	8	66	136
EU	773	1,068	357	23	42	53	537	824	1,006	313	68	152
EU (OECD)	425	732	135	19	29	31	304	579	428	236	43	129
Africa	38	41	3	–	3	127	107	148	94	4	10	337
Middle East	1	43	14	–	0	0	11	319	338	0	2	1
Oceania	24	31	4	–	2	4	50	47	30	–	4	5
Asia	330	400	16	3	14	346	2,536	1,198	478	110	91	623
Japan	58	249	5	3	6	–	107	206	100	27	7	10
China	205	52	5	–	3	162	1,859	442	108	23	60	231
Hong Kong	0	3	–	–	–	0	8	4	2	–	–	0
Taiwan	2	9	1	–	0	–	41	40	15	11	0	3
Korea	8	13	–	–	0	–	80	94	42	40	0	4
Singapore	0	4	–	–	–	0	–	25	8	–	–	2
Brunei	–	0	0	–	–	0	–	0	3	–	–	–
Indonesia	0	11	0	–	0	27	32	73	35	–	1	53
Malaysia	0	4	0	–	0	2	16	28	29	–	1	4
Philippines	0	9	–	–	0	8	8	12	3	–	1	7
Thailand	0	7	–	–	0	8	18	47	31	–	1	24
Vietnam	2	4	–	–	0	9	16	21	7	–	3	15
India	36	24	1	1	2	100	326	166	50	9	11	197
World	1,501	2,816	979	53	110	646	3,776	4,136	2,787	674	300	1,358

Source: Same with Table 1.1

1.3 Current Situation of Traditional Air Pollution: Basically Improving

Based on the analysis on the feature of the energy structure in Asia, let us confirm the current emission situation of local air pollutants. Table 1.4 shows the SO_2 concentration in major cities of Asia. 2010 data are not available for some cities; however, looking at comparable cities, an improvement can be observed in all cities except for Jakarta (Indonesia) which showed worsened SO_2 concentration. Although the most serious pollution is taking place in China, compared with Tokyo, Beijing and Shanghai, more than five times higher level of pollution is observed, but these cities showed an improvement in SO_2 concentration when compared with the figures in 2010. Beijing had succeeded in lowering to less than half of the concentration. This is because major SO_2 pollution comes from fixed sources such as power generation plants and factories. In China, such fixed pollutant sources are often located in the northern cities such as Beijing, but the introduction of flue-gas desulfurization (FGD) equipment into power generation plants was promoted during the 11th Five-Year Plan period (2006–2010). The introduction of FGD equipment reflects a major reduction in SO_2 emission. Both Beijing and Shanghai are still at a higher standard, but already the situation is more serious in Jakarta. The worsening situation in Jakarta can be considered to be related to the development of industrialization in Indonesia in recent years, in particular the increase in the number of coal-fired power plants.

Table 1.4 SO_2 concentration in major cities of Asia (unit: annual average ppm)

Country	City	2000	2010
Japan	Tokyo	0.004	0.002
	Osaka	0.006	0.004
Korea	Seoul	0.006	0.005
China	Beijing	0.025	0.011
	Shanghai	0.016	0.01
	Hong Kong	0.01	0.004
Taiwan	Taipei	0.004	0.004
Philippines	Manila	0.010 (2001)	n.a.
Vietnam	Hanoi	0.003	n.a.
	Ho Chi Minh	0.006 (2003)	n.a.
Malaysia	Kuala Lumpur	0.004	n.a.
Indonesia	Jakarta	0.004	0.018
Singapore	Singapore	0.008 (2001)	0.004
Thailand	Bangkok	0.004 (2001)	0.002
Myanmar	Yangon		n.a.
India	Delhi	0.006	n.a.
	Mumbai	0.003	n.a.
	Kolkata	0.005	n.a.
	Chennai	0.003	n.a.

Source: Various sources

Table 1.5 NO_2 concentration in major cities of Asia (unit: annual average ppm)

Country	City	2000	2010
Japan	Tokyo	0.028	0.02
	Osaka	0.024	0.017
Korea	Seoul	0.035	0.034
China	Beijing	0.035	0.028
	Shanghai	0.044	0.024
	Hong Kong	0.046	0.059
Taiwan	Taipei	0.031	0.029
Philippines	Manila	0.022 (2001)	n.a.
Vietnam	Hanoi	0.005	n.a.
	Ho Chi Minh	0.043	n.a.
Malaysia	Kuala Lumpur	0.011	n.a.
Indonesia	Jakarta	0.015	0.011
Singapore	Singapore	0.016 (2001)	0.012
Thailand	Bangkok	0.031 (2001)	0.02
Myanmar	Yangon		n.a.
India	Delhi	0.015	n.a.
	Mumbai	0.015	n.a.
	Kolkata	0.040 (2002)	n.a.
	Chennai	0.008	n.a.

Source: Various sources

Next, let us look at the situation of NO_2 concentration by referring to Table 1.5. Cities with available data showed improvement also in NO_2 concentration from 2000 to 2010 with the exception of Hong Kong Central. The number of NO_2-generating fixed sources such as power generation plants and factories increased during this period. And unlike SO_2, emission from mobile sources such as automobiles accounts for a large proportion. The number of privately owned vehicles in China underwent a rapid increase, from 16.09 million in 2000 to 78.02 million in 2010 as shown in Table 1.6. In the whole of Asia, the number of vehicles rapidly increased from 139.78 million in 2000 to 244.91 million in 2010, accounting for 23.3 % of the world's total (18.2 % as of 2000). China's contribution rate to the increase in the whole of Asia is a dominating 60.8 %, but other countries including Indonesia, Malaysia, Thailand, and India show high growth rates as well. Though the number of privately owned vehicles is increasing, NO_2 concentration is decreasing. The reason for this is considered to be that older vehicles with higher discharge rates were largely replaced by newly disseminated vehicles with advanced NO_2 abatement technology during this period.

The NO_2 emission level in Beijing and Shanghai is not at the worst level in Asia. The figures are worse in Hong Kong, Taipei, and Seoul. The reason for high NO_2 concentration in these cities is largely because of the impact of vehicle exhaust emission, which is usually a major cause of NO_2 concentration in major cities. China has a great deal of pollution from fixed sources; however, power generation plants and factories are often located in the suburbs, geographically distant from the

Table 1.6 Number of vehicles owned in the world, regional, and each country in Asia (unit: thousands)

	2000	2010
North America	239,046	263,114
Latin America	54,681	94,355
EU	284,660	372,718
EU (OECD)	238,065	290,079
Africa	19,646	29,117
Middle East	14,168	28,651
Oceania	14,950	18,701
Asia	139,775	244,906
Japan	72,370	74,997
China	16,089	78,018
Hong Kong	490	781
Taiwan	5,549	6,826
Korea	12,060	17,941
Singapore	561	798
Brunei	181	253
Indonesia	5,412	15,829
Malaysia	5,242	10,050
Philippines	2,434	3,119
Thailand	6,120	10,700
Vietnam	372	1,190
India	9,420	19,282
World	766,926	1,051,562

Source: Same with Table 1.1

center of the city. Therefore, their contribution to NO_2 concentration in cities is limited. Conversely, vehicle emission is discharged in the cities, having a direct impact on NO_2 concentration. These features, which are different from those of SO_2, are considered to be the reason for the high figure in Hong Kong and Taipei where traffic concentration is high. In Beijing, the size of the city itself is large enough to disperse traffic more or less. Moreover, in Shanghai, taking measures such as restrictions on issuing vehicle registration numbers to limit the number of vehicles entering the city may have an impact on NO_2 concentration.

The next item to consider is suspended particulate matter. As shown in Table 1.7, Beijing and Shanghai, both in China, have by far the most serious pollution among all Asian cities. It is easy to understand the fact that repeated occurrence of serious smog in China, in which not even 20 m of visibility could be secured, attracted worldwide attention. PM2.5, which is thought to be identified as a causative agent of smog, was not included in the object for monitoring as of 2010; therefore, no data is available to understand the time series variation of PM2.5. It was not until after 2012 when PM2.5 is officially monitored in China. The suspended particulate matter which has been conventionally monitored in the traditional environmental regulation is PM10 which has much larger particles than PM2.5. In fact, a lot of countries in Asia mainly focus on PM10 in their environmental regulations (even in

Table 1.7 PM concentration in major cities of Asia (annual average mg/m^3)

Country	City	2000	2010
Japan (SPM)	Tokyo	0.039	0.021
	Osaka	0.034	0.023
Korea (PM10)	Seoul	0.06	0.049
China	Beijing (PM10)	0.162	0.121
	Shanghai (SPM)	0.156	0.079
	(PM10 since June 2000)	0.1 (2001)	n.a.
	Hong Kong (PM10)	0.066	0.059
	Hong Kong (PM2.5)	0.044	0.036
Taiwan	Taipei	0.056	0.055
Philippines	Manila (PM10)	0.075	
	Manila (PM2.5 since 2001)	0.045 (2001)	0.033 (2009)
Vietnam (PM10)	Hanoi	0.126	n.a.
	Ho Chi Minh	0.5 (2001)	n.a.
Malaysia	Kuala Lumpur (PM10)	0.045	n.a.
Indonesia	Jakarta (PM10)	0.052	0.049
Singapore	Singapore (PM10)	0.08 (2001)	0.026
	Singapore (PM2.5)	0.021 (2004)	0.017
Thailand	Bangkok (PM10)	0.083	0.061 (2009)
Myanmar	Yangon	n.a.	n.a.
India	Delhi (PM10)	0.12 (2001)	0.26
	Mumbai	0.109	n.a.
	Kolkata	0.125	n.a.
	Chennai	0.09	n.a.

Source: Various sources

Japan, it was after 2009 when PM2.5 was included in the objects for environmental regulation).

From Table 1.7, a decreasing trend of PM10 concentration is observed in many cities in Asia except for Delhi. Although the absolute amount in Beijing and Shanghai is high, however, we can say that they have shown considerable improvement in the past 10 years.[4] Dust and soot are the main components of PM10 pollutants, and introduction of dust and soot removal devices including electric dust collectors and bug filters was enforced in power generation plants and factories. As a result, dust and soot emission in China showed a significant decrease, down from 11.65 million tons in 2000 to 8.29 million tons in 2010. However, suspended particulate matter includes sand dust (not only the expansion of desertification but also increased construction work in cities) and aerosol which is the

[4] As was described previously, official monitoring data of PM2.5 did not exist until after 2012; however, observation figures by NASA satellite data revealed that Beijing and Shanghai accomplished over 5 % improvement in annual average concentration when periods 2001–2003 and 2008–2010 are compared (Zell et al. 2012).

second transformation of SO_2 and NO_2. Therefore multiple factors need to be examined. The technology for reducing SPM can be introduced at a far lower cost than the cost of flue-gas desulfurization equipment or denitrification equipment. Technical countermeasures are expected to make advances.

We have seen the overview of the current situation of local air pollution in major cities in Asia. Different from the general impression, it should be stressed again that the pollution situation is improving in many cities in Asia. It is because those countries can afford to introduce environmental abatement technology owing to economic development, typically seen in the dissemination of flue-gas desulfurization (FGD) equipment in China. Also lowering NO_2 concentration is considered to come from advancement of NO_2 emission reduction technology for vehicles. On the other hand, final products of companies are shifted to those with same quality but with lower environmental impacts, for example, by use of information technology, bringing the effect of decreased pollution emission. As Asia continues to experience economic growth, it is important to adequately reflect the cost brought about by wasted energy and environmental pollution in pricing and to develop effective and practical environmental regulation in order to encourage the introduction of the environmental technology.

1.4 Future Outlook for Energy Demand and Environmental Problems in Asia

Finally, we will examine the future outlook of air pollution in Asia and global warming problems based on the forecast by the International Energy Agency (IEA). Table 1.8 shows the estimate of energy demand for 2025 and 2035 in Japan, China, India, and ASEAN.[5] Obviously China will be consuming nearly 1.7 times more energy than the USA, and its world share will reach a dominant 23.8 % in 2025. However, the annual average growth rate is forecast to be 2.4 % for the years 2011–2025. Considering the fact that China was expanding energy consumption at annual average rate of 9.1 % in the 2000s, the projected rate of increase is greatly reduced in comparison. The increase rate will be only 0.7 % in the period of 2025–2035, with a slight decline in the world share to 23.4 %. Meanwhile, the absolute amount of energy consumption in Japan and the USA will decrease in 2035 in comparison with that for 2011. The absolute volume of energy consumption in China will still increase in 2035; however, it is expected that policies and regulations to convert the

[5] IEA shows energy demand outlook in three scenarios: Current Politics Scenario where current standard of energy saving and environmental regulation is extended, New Policies Scenario where policies and regulation with high probability of introduction are included based on current international debate, and 450 ppm Scenario where CO_2 concentration is restricted to 450 ppm (= rise in temperature is maintained within 2°). IEA itself seems to consider probability highest in its New Policies Scenario. Therefore, this paper will introduce the New Policies Scenario as the future outlook.

Table 1.8 Energy demand forecast of Asian major countries and USA (unit: million toe)

	2025							2035						
	Coal	Oil	Gas	Nuclear	Hydro	Other	Total	Coal	Oil	Gas	Nuclear	Hydro	Other	Total
Japan	107	156	102	50	8	36	458	98	131	103	45	9	57	443
China	2,166	667	331	195	113	314	3,786	2,135	726	442	248	122	387	4,060
India	499	273	94	32	20	227	1,146	681	380	143	53	32	251	1,539
ASEAN	192	274	168	4	13	154	804	279	313	208	8	18	177	1,004
USA	437	728	630	233	26	210	2,264	411	614	646	241	27	304	2,242
World	4,312	4,548	3,576	979	430	2,030	15,877	4,428	4,661	4,119	1,119	501	2,558	17,387

Source: IEA (2013), IEA and ERIA (2013) economic structure to one with better energy efficiency will be introduced, in a similar way to the process in Japan and the USA.

Meanwhile, India will continue to greatly expand energy consumption. The annual average growth rate of energy consumption toward 2025 in India is 3.0 %, and the 2025–2035 forecast is also 3.0 %. That is to say, India's economic development system at present, with a large energy and environmental burden, is expected to continue. Steady economic growth is also expected in ASEAN countries. Energy consumption growth is forecasted to be 2.8 % until 2025, and the period of 2025–2035 is 2.2 %. As a result, India will share 8.9 %, and ASEAN will share 5.7 % of the world total in 2035.

Let us look at the change of energy sources composition. China is forecast to experience a major transition between 2011 and 2025 and also 2035. The absolute volume of coal consumption is decreasing, and therefore, component ratio of coal in the primary energy in 2025 and 2035 will account for 57.2 % and 52.6 %, respectively, representing a huge decrease from the 73.0 % of 2011 indicated in Table 1.3. Total energy consumption is increasing though coal consumption is slowing down, which means other energy sources are increasing. Comparing Tables 1.3 and 1.8, the increased volume of oil and gas consumption is considerable. The consumption of oil will be almost twice as much in the period from 2011 to 2035. It seems to be expected that motorization will continue to advance, and demand for transportation energy will increase. In addition, gas is an alternative for coal, and currently fuel switch from coal to gas is positioned as a key measure against air pollution (especially against PM2.5). Therefore gas consumption is expected to grow more than four times as much as it is now. Nuclear energy is even higher, expected to grow more than ten times bigger. Although the incident at Fukushima Daiichi Nuclear Power Plant had a temporary effect to slow down nuclear power plant construction in China, it is now being accelerated again after reinforcements in safety control systems after 2012 (Horii 2014b). Another target to raise the ratio of nonfossil energy to 15 % by 2020 is also promoting construction of nuclear energy, along with hydropower generation, which will grow to more than twice as much.

As we have seen here, China is obviously moving away from coal-dominant energy structure, which will be diversified by other energy sources filling up the gap of coal. Meanwhile, coal dependency will be relatively enhanced in India and ASEAN countries. In India, coal accounted for 43.0 % of primary energy in 2011. The ratio is expected to rise to 43.5 % in 2025 and 44.2 % in 2035. The same can be said for ASEAN countries where the 16.4 % of 2011 will rise to 23.9 % in 2025. Although it is expected to go down to 18.3 % in 2035, however, it will continue to stay at a higher level compared with that in 2011. Coal will keep its importance as energy source for India and ASEAN countries to support energy demand accompanying their development at lower cost.

Such a difference in the future energy demand among Asian countries is naturally reflected in CO_2 emission. As shown in Table 1.9, it is forecasted that CO_2 emission will be reduced in Japan and as the USA. On the other hand, China will continue to greatly increase CO_2 emission, predicted to account for 28.2 % in the whole world in 2025. However, after that toward 2035, CO_2 emission in China

Table 1.9 CO_2 emission forecast of Asian major countries and the USA (unit: million tons)

	2025	2035
Japan	1,036	940
China	10,056	10,238
India	2,780	3,882
ASEAN	1,785	2,284
USA	4,982	4,489
World	35,722	37,242

Source: Same with Table 1.8

is expected to stay at the same level contributed by advancement of growing out of coal. In 2035, China will become predominantly the country of largest emission with a huge difference from the world-second USA. However, the rate of increase is expected to slow down.

On the other hand, CO_2 emission in India and ASEAN will continue to expand reflecting rapid growth in energy demand. 72.5 % of the global increase in CO_2 emission is expected to come from the increase in India between 2025 and 2035. Its share in the world will be 7.8 % in 2025 and 10.4 % in 2035, markedly narrowing the difference from that of the USA. In addition, the CO_2 emission share of ASEAN countries, which accounted for merely 3.7 % in 2011, will steadily rise to 5.0 % in 2025 and 6.1 % in 2035.

1.5 Conclusion

Asia is attracting attention as a center of economic growth in the first half of the twenty-first century, and therefore, it will have a huge impact on the whole world regarding energy consumption and furthermore on the local air pollution and climate change problems accompanied by increasing energy consumption. As has been pointed out in this chapter, Asia is responsible for massive impacts on environment out of all proportion to its economic size, due to low energy efficiency and high dependency on coal. However, a trend for improvement is observed in local air pollution, which is considered to be owing to advancement in introducing environmental abatement technology along with economic growth. In that respect, it is sufficiently possible to achieve both economic growth and environmental solution, whose success depends on system design such as an energy market and environmental regulation.

China will maintain a large presence with its huge energy consumption and environmental impacts not only in Asia but also in the world. However, the current policy trend to promote energy saving moving away from coal dependency and taking environmental countermeasures will also continue. On the other hand, India will continue to reinforce its current coal-dependent structure, increasing its world share of energy consumption and CO_2 emission, although the absolute volume will not be as high as that of China.

Introducing energy saving and environmental abatement technology will become the key for India, and also ASEAN countries, to continue their growth while preventing any increase of the environmental impacts. The experience of China is indicative on this point. It is possible to make a smooth transition to a more efficient growth system if subsidies for lower energy price are abolished, introduction of effective environmental regulation is achieved, and then energy pricing is set to reflect environmental impacts. Chinese companies are showing "Green growth" in environmental technology such as flue-gas desulfurization equipment or renewable energy sources such as solar panels and wind power generation turbines, providing products and solutions at overwhelmingly lower cost than companies in developed countries (Horii 2010). The rise of Chinese companies as suppliers in energy saving and environmental solutions will eventually provide for India and ASEAN countries options to reduce the environmental impacts at lower cost. Currently Asia is a region of mounting issues of energy consumption and environmental burden in the world. It is expected that energy saving/environmental countermeasure technology will be sent out from Asia due to the fact that they are well placed in the field to deal with these issues.[6]

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[6] Needless to say, Japanese companies are expected to contribute to tackle with these issues; however, they are not quite successful in marketing due to the high cost as solution for Asia. It will be necessary for them to develop products with dramatically lower cost through collaboration with Chinese companies. Refer to Horii (2010) for details.

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