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Energy Scenarios for East Asia: *2005-2025*

Sergey Paltsev and John Reilly

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Sergey Paltsev and John Reilly

Abstract

We describe several scenarios for economic development and energy use in East Asia based on the MIT Emissions Prediction and Policy Analysis (EPPA) model, a computable general equilibrium model of the world economy. Historic indicators for Asian economic growth, energy use, and energy intensity are discussed. In the Baseline scenario, energy use in East Asia is projected to increase from around 120 EJ in 2005 to around 220 EJ in 2025. Alternative scenarios were developed to consider: (1) How fast might energy demand grow in East Asia and how does it depend on key uncertainties? (2) Do rising prices for energy affect growth in the region? (3) Would growth in East Asia have a substantial effect on world energy markets? (4) Would development of regional gas markets have substantial effects on energy use in the region and on gas markets in other regions? Briefly, we find that with more rapid economic growth, demand in East Asia could reach 430 EJ by 2025, almost twice the level in the Baseline; rising energy prices place a drag on growth of countries in the region of 0.2 to 0.6% per year; world crude oil markets could be substantially affected by demand growth in the region, with the price effect being as much as $25 per barrel in 2025; and development of regional gas markets could expand gas use in East Asia while leading to higher gas prices in Europe.

Contents

1. INTRODUCTION

The East Asian region is among the fastest-growing regions of the world and its share of the global economy and of energy use has increased substantially over the past 30 years. Thus, continued economic growth in East Asia will strongly affect the world demand for energy. The goal of this paper is to provide several illustrative scenarios of economic development and energy use in the region. For this purpose the MIT Emissions Prediction and Policy Analysis (EPPA) model (Paltsev *et al.*, 2005) is used. It is a computable general equilibrium (CGE) model of the global economy, and has been widely used to study climate change policy and its implications for energy system and technology development.

East Asia, based on the regional disaggregation in the EPPA model, is defined to comprise People's Republic of China; India; Indonesia; Japan; and the dynamic Asian economies of Republic of Korea; Malaysia; Philippines; Singapore; Taiwan Province of China; and Thailand. This definition excludes some countries that are obviously in East Asia, such as Cambodia and Viet Nam. India, which is generally considered as South Asia, is also included, since this

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[*] The scenarios discussed here are developed for the Asian Development Bank project "Shaping the Future: Prospects for Asia's Long-Term Development over the Next Two Decades."

regional grouping contains the countries in the region that dominate its energy use and account for most of the region's gross domestic product (GDP).

China's economy is the fastest-growing economy in the region. The phenomenon of fast growth in that country and its implications for energy demand have attracted considerable attention from researchers (see, for example, Adams & Shachmurove, 2007; Winters & Yusuf, 2007; Zhao & Wu, 2007). There is substantial disagreement on how fast China will grow in the next 10 to 30 years. As pointed out by Altman (2007), some experts predict sustained fast growth. Other experts appeal to an economic convergence theory, which would have growth slowing in developing economies as they catch up with industrial economies, and face diminishing returns as they adopt the most advanced technologies available. At that point, they would need to start to innovate themselves, move to advanced product markets, and compete with industrial countries in these markets. Still other observers wonder whether the political situation in China will remain stable and whether the stresses of rapid growth on the environment and on natural resources there might not undermine growth.

The paper is organized in the following way. In the next section recent trends in economic performance and energy use in the East Asian region are described. Section 3 presents the EPPA model, which is used for scenario development. In Section 4 the baseline scenario is considered. Section 5 then examines several alternative scenarios, where different assumptions about growth rates, energy efficiency, and energy prices are considered. Section 6 concludes.

2. ECONOMIC AND ENERGY INDICATORS, 1970–2000

Since 1970 the economies of the region have more than tripled in size and fossil energy use has increased some 3.5 times as shown in **Tables 1 and 2**. As a result, the region's share of global fossil energy use doubled from about 13% in 1970 to about 26% in 2005. The data in Table 1 are used in the regional disaggregation of the EPPA model. (The complete list of countries in other regions is provided in Paltsev *et al.*, 2005. The data are in 1990 international Geary-Khamis dollars, a conversion from market exchange rates to one corrected to reflect differences in international purchasing power.[1])

The share of East Asia in the world economy rose from 19% to about 32% between 1970 and 2000. While similar data are unavailable for more recent years, continued rapid growth, especially in China and India, means that the region's share of the world economy has likely continued to increase. Within East Asia, China accounted for 38% of GDP in 2000, Japan 23%, India 17%, Other Asia[2] 16%, and Indonesia 6% when GDP is corrected for international purchasing power (Table 1 and **Figure 1**a).

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[1] Several methods can be used to generate economic accounts adjusted to measure "true" relative incomes and outputs of different countries. The well-known purchasing power parity indexes can be constructed in several ways and they produce somewhat different results. In this paper we follow the Maddison (2001) approach and his data when we report the numbers adjusted for international purchasing power.

[2] The "Other Asia" region consists of Malaysia, Philippines, Singapore, Republic of Korea, Taiwan Province of China, and Thailand. Regional aggregations are those used in the EPPA model. Detail on the regional composition is provided in Paltsev *et al.* (2005).

Table 1. Gross Domestic Product Adjusted for International Purchasing Power.

Location	1970	1980	1990	2000
China, People's Rep. of	663	1,100	2,209	4,483
India	470	637	1,098	1,924
Japan	1,014	1,568	2,321	2,669
Indonesia	139	276	451	676
Other Asia*	269	575	1,106	1,896
Total East Asia	2,555	4,156	7,185	11,648
World	13,583	19,767	27,058	36,406
East Asian Share (%)	19	21	27	32

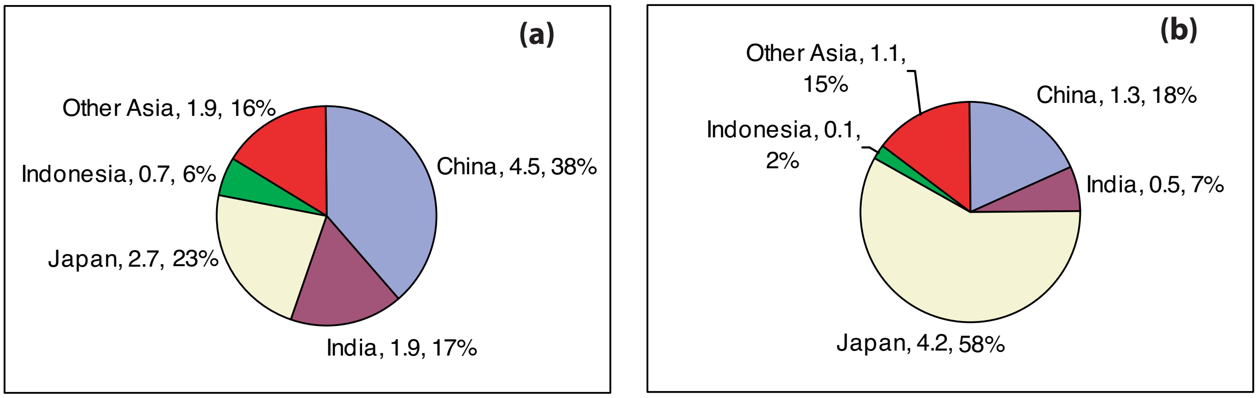
Note: Data are in billion 1990 international Geary-Khamis dollars. Source: Maddison (2001).

*The "Other Asia" region consists of Malaysia; Philippines; Singapore; Korea; Taiwan Province of China; and Thailand.

Table 2. Fossil Fuel Energy Production and Use (exajoules).

	1970		1980		1990		2000	
Location	Prod	Use	Prod	Use	Prod	Use	Prod	Use
China, People's Rep. of	9.9	9.4	18.0	16.5	28.9	26.5	36.4	34.9
India	1.9	2.5	2.9	3.4	6.3	7.1	9.0	12.6
Japan	1.3	9.9	0.6	12.4	0.3	13.1	0.2	15.9
Indonesia	1.9	0.4	4.0	0.9	5.0	2.0	7.5	3.4
Other Asia	0.3	1.9	1.2	5.0	2.8	8.1	4.3	17.7
Total East Asia	15.3	24.0	26.7	38.2	43.3	56.7	57.4	84.4
World	197.1	187.1	254.8	247.5	292.6	284.7	329.4	323.5
East Asian Share (%)	8	13	10	15	15	20	17	26

Source: Calculated from IEA (2005).



Source: Authors' calculations based on Maddison (2001).

Source: Authors' calculations based on Dimaranan (2006).

Figure 1. GDP Shares in East Asia. **(a)** GDP in 2000 adjusted for international purchasing power (in trillions of 1990 International Geary-Khamis dollars) and their shares in East Asia. **(b)** GDP in 2001 at market exchange rates (in trillions of 2001 U.S. dollars) and their shares in East Asia.

The economic shares of the four economies and one subregion ("five locations") within East Asia change when a different exchange rate convention is used, as illustrated in Figure 1, panel b, where GDPs for 2001 are reported at market exchange rates (MER) based on the data from the Global Trade Analysis Project (GTAP) dataset (Dimaranan, 2006). MER-based comparisons result in a different ranking with Japan dominating the region (58%); China and Other Asia are of a comparable economic size (18% and 15%); India's share (7%) is only half that of Other Asia (they are about the same size when adjusted for international purchasing power); and Indonesia's share is only 2%

Annual production and consumption numbers for fossil fuels for 1970–2000 are provided in Table 2. Fossil-fuel energy production in East Asia increased from 15 to 57 exajoules (EJ), with most of the additional production in China. At the same time fossil fuel use increased from 24 to 84 EJ. Only China and Indonesia produce more fossil fuels than they consume. China's production is dominated by coal, whereas Indonesia is a large oil and gas producer. Japan and Other Asia depend heavily on imports. The global share of fossil fuel use by East Asia also increased, from 13% in 1970 to 26% in 2000. These aggregate data for fossil fuels do not show the fact that most of the increase in production has been in coal, at a time when Asia imported more and more oil.

The change in fossil-fuel energy intensity shows very different patterns among the region's economies (**Table 3**). China's fossil energy intensity fell by about 45% in 1970–2000, and Japan's by 39%. However, in India, Indonesia, and Other Asia energy intensity rose. Many of the industrial regions of the world have shown a long-term decline in energy intensity, but that pattern is not as consistent in other countries. Various factors likely affect these trends. Through at least some period of development, growth is likely to become more energy intensive as it involves rapid growth of energy-intensive industry such as steel and cement. In addition, the shift from non-commercial fuels during the development process shows up as an increase in measures of commercial energy intensity, even though total energy use may not be rising as rapidly. Non-commercial fuels are often used very inefficiently. Also, their use is often underreported, and so if energy use were fully accounted, the shift to commercial fuels would likely result in falling energy intensity.

Another important factor in increasing energy use is that as income increases, household demand for energy for air conditioning, appliances, and transportation also likely contributes to increasing energy intensity. Energy pricing and industrial policy can also play an important role. Some of the most energy-intensive industries (iron ore, aluminum) have moved from industrial countries to developing countries, especially to those with lower energy prices.

In sum, though, the intensity of fossil fuel use is the relevant measure in terms of the region's impact on fossil-fuel markets.

Table 3. Fossil-Fuel Energy Intensity Index (1970 = 1).

Location	1980	1990	2000
China, People's Rep. of	1.06	0.85	0.55
India	1.03	1.23	1.25
Japan	0.81	0.58	0.61
Indonesia	1.12	1.59	1.78
Other Asia	1.24	1.04	1.33
World	0.91	0.76	0.64

Note: Fossil-fuel energy intensity is a ratio of fossil fuel use to GDP. For comparability, it is indexed to the 1970 level.
Sources: GDP: Maddison (2001); fossil-fuel use: IEA (2005).

In recent years, various observers have attempted to explain the underlying causes of energy efficiency changes, with a particular focus on China. Zhang (2003) concludes that China's decline in energy intensity between 1980 and 2000 is due to an increase in energy efficiency rather than a structural economic shift. Crompton and Wu (2005) identify technical and structural changes as the main cause for this decline in China. Fisher-Vanden *et al*. (2004, 2006) show a similar decline in energy intensity in China (considering data up to 2000). Hang and Tu (2007) provide data for China up to 2004 and show that aggregate energy intensity has reversed its trend and has been increasing since 2001. In their analysis, they consider coal, oil, and electricity intensities, in addition to aggregate energy intensity. Electricity intensity was relatively stable from 1985 to 2004 (with some reduction from 1990 to 1999 and a relatively small increase from 1999 to 2004). Oil intensity shows only a very slight decline, while aggregate energy intensity is mainly driven by the changes in coal intensity.

Figure 2 illustrates the data for China's energy intensity from different studies. The original units have been indexed relative to 1985. All studies agree on an impressive decline in China's energy intensity between 1995 and 2000, but between 2000 and 2004 the increase in energy consumption was faster than the increase in GDP. Underlying the structural and technological changes in China were large shifts in the organization of the economy as the country moved from a planned economy to one that was more driven by market forces, including adjustments to energy pricing. A significant problem in any analysis of China's energy situation is data quality. Large changes in reported energy use and production in some years may reflect changed reporting approaches rather than actual changes in use, and concerns about black markets in fuels that are not reported at all.

For other countries in the region, Crompton and Wu (2005) show that from 1980 to 1999 energy intensity in Indonesia, Japan, and Thailand was constant while the Republic of Korea's energy intensity increased slightly from the mid-1980s to the mid-1990s. Kasahara *et al.* (2007) provide historical data for energy intensity in Japan and discuss the potential future paths for energy and carbon intensities. They discuss three hypotheses: further increases in energy and carbon efficiency stemming from rising energy prices, efficiency improvements resulting from high economic growth and structural change in the economy, and exhaustion of the immediate sources of energy improvements.

As one looks forward, the outlook for energy-intensity change in the region is far from clear. The two countries that at one stage had contributed the most to improving regional energy intensity, China and Japan, appear to have reversed that trend, or at least stagnated. Technologically, Japan has been at the forefront of energy efficiency. The stagnation in overall intensity appears to stem from growing use of energy in households and for transportation, with slowing improvement in energy efficiency in basic industrial processes. The great improvement in energy intensity in China was likely related to economic reform, whose effect may have run its course or at least depends on how reforms will continue in the future. Energy intensity in other countries in East Asia continues to increase, although the intensity increase in India from 1990 to 2000 was very low, and so perhaps the structural transition from increasing to falling energy intensity (assuming such a pattern exists), is near. Similarly, the income level of Other Asia is fairly high, and its energy intensity increase may slow.

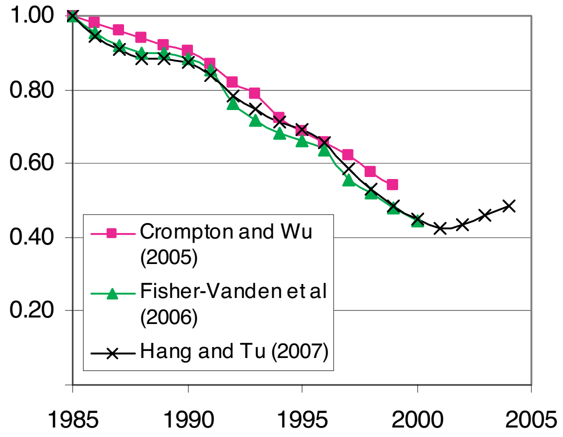


Figure 2. Energy Intensity Index in China (1985=1.00).

3. THE EPPA MODEL

To create illustrative scenarios of the future development of energy use in East Asia, the EPPA model is used. It is a recursive-dynamic multiregional CGE model of the world economy (Paltsev *et al*., 2005). EPPA is built on the GTAP dataset, which accommodates a consistent representation of energy markets in physical units as well as detailed data on regional production and bilateral trade flows (Hertel, 1997; Dimaranan & McDougall, 2002). Besides the GTAP dataset, EPPA uses additional data for greenhouse gases (carbon dioxide, CO_2; methane, CH_4; nitrous oxide, N_2O; hydrofluorocarbons, HFCs; perfluorocarbons, PFCs; and sulphur hexafluoride, SF_6) and air pollutants (sulphur dioxide, SO_2; nitrogen oxides, NO_x; black carbon, BC; organic carbon, OC; ammonia, NH_3; carbon monoxide, CO; and non-methane volatile organic compounds, VOC) emissions based on United States Environmental Protection Agency inventory data and projects. For use in EPPA the GTAP dataset is aggregated into 16 regions and 21 sectors (the sectors are shown in **Table 4**).

Table 4. Sectors in the EPPA model.

Non-Energy	Note: Agriculture, services, energy-intensive products, manufacturing, coal, crude oil, refined oil, and natural gas sectors are aggregated from GTAP data; industrial transportation and household transportation sectors are disaggregated as documented in Paltsev *et al.* (2004); hydropower, nuclear power and fossil-fuel electricity are disaggregated from the electricity sector (ELY) of the GTAP dataset; solar and wind power, biomass, natural gas combined cycle, natural gas combined cycle with CO_2 capture and storage, integrated coal gasification with CO_2 capture and storage, synthetic gas from coal, oil from shale, and liquid fuel from biomass sectors are advanced technology sectors that do not exist explicitly in the GTAP dataset; advanced technology sectors are modeled as described in Paltsev *et al.* (2005).
Agriculture	
Services	
Energy-Intensive Products	
Manufacturing	
Industrial Transportation	
Household Transportation	
Energy	
Coal	
Crude Oil	
Refined Oil	
Natural Gas	
Electric: Fossil	
Electric: Hydro	
Electric: Nuclear	
Electric: Solar and Wind	
Electric: Biomass	
Electric: Natural Gas Combined Cycle	
Electric: Natural Gas Combined Cycle with CO_2 Capture and Storage	
Electric: Integrated Coal Gasification with CO_2 Capture and Storage	
Synthetic Gas from Coal	
Oil from Shale	
Liquid Fuel from Biomass	

Much of the sectoral detail is focused on energy production to better represent different technological alternatives in electric generation. The base year of the EPPA model is 1997. From 2000 it is solved recursively at 5-year intervals. The EPPA model production and consumption sectors are represented by nested Constant Elasticity of Substitution (CES) production functions (or the Cobb-Douglas and Leontief special cases of the CES). The model is written in the GAMS software system and solved using MPSGE modeling language (Rutherford, 1995). The EPPA has been used in a wide variety of policy applications (*e.g.*, Jacoby *et al.*, 1997; Reilly *et al.*, 1999; Babiker, Metcalf & Reilly**,** 2003; Reilly & Paltsev, 2006; CCSP, 2006; Paltsev *et al.*, 2007).

Because of the focus on climate and energy policy, the model further disaggregates the GTAP data for transportation and existing energy supply technologies and includes a number of alternative energy supply technologies that were not in widespread use in 1997 but could take market share in the future under changed energy price or climate policy conditions. Bottom-up engineering details are incorporated in EPPA in the representation of these alternative energy supply technologies. Advanced technologies endogenously enter only when they become economically competitive with existing technologies. Competitiveness of different technologies depends on the endogenously determined prices for all inputs, as those prices depend on depletion of resources, economic policy, and other forces driving economic growth such as savings, investment, energy-efficiency improvements, and productivity of labor. Additional information on the model's structure can be found in Paltsev *et al.* (2005).

4. BASELINE SCENARIO

A key input in the baseline scenario is population, and for this purpose population projections of the United Nations (UN, 2001) are used, as shown in **Table 5**. China and India are the two most populous countries in the world, and as a result near one half of the world population lives in East Asia (according to the above definition). The UN projects greater slowing of population growth in East Asia compared with other regions, resulting in a decrease in East Asia's share in the total world population by 2050. India is projected to surpass China as the country with the largest population by 2050.

Another key element in scenario projections is the development of nuclear power and hydropower. Because of the political nature of expansion of these energy sources, the growth path of capacity for them is specified exogenously in EPPA, but in the case of hydropower is

Table 5. East Asian and World Population through 2025 (millions).

Location	2000	2025
China, People's Rep. of	1,282	1,479.5
India	1,008.9	1,351.8
Japan	127.1	123.8
Indonesia	212.8	274.1
Other Asia	211.4	272.9
Total East Asia	2,842.2	3,502.1
World	6,056.7	7,936.7
East Asian Share (%)	47	44

Source: UN (2001).

based on an assessment of unexploited resources. As mentioned, the EPPA base year is 1997; to be consistent with recent expansion of nuclear power and hydropower, the growth of these sources through 2005 is benchmarked to IEA (2006) data. The levels of production of both types of power shown in **Table 6** are those projected by EPPA including this benchmarking.

Both types play a role in Asia (especially nuclear electricity in Japan and hydroelectricity in China) but they are still a small part of total energy use. Combined, these sources for the region amount to about 3 EJ compared with 84 EJ of fossil energy. To better compare electricity and fossil fuels, electricity sources such as nuclear and hydro are often reported in primary equivalent—the amount of fuel (coal, oil, gas) that would have been required to produce the same amount of electricity for a given conversion efficiency. Electricity conversion efficiencies are on average for most countries in the order of 30–35%. Thus, the primary equivalent of non-fossil sources is about three times that of electricity production. On this basis the region produced about 9 EJ of primary equivalent of nuclear power and hydropower, or still only about 10% of the fossil energy used.

The discussion of energy scenarios for East Asia begins with the baseline scenario. To perform a sensitivity analysis of the baseline results, several alternative scenarios are examined, where different assumptions about growth rates, energy efficiency, and energy prices are considered. As mentioned above, there is a substantial difference in opinion about future economic growth in Asia. In the EPPA model, GDP growth depends on population growth, labor productivity, capital accumulation, economic behavior of the agents, and other parameters of the model. Population growth and labor productivity are exogenous parameters, while decisions about production, consumption, and investment are based on economic optimization. Investments become capital in the next period.

Annual real GDP growth rates for the five locations, as well as aggregated growth rates in non-Asian regions, of the EPPA model and the total world growth rates for the baseline scenario are presented in **Table 7**. As with other components of EPPA, the period from 1997 to 2005 is benchmarked to historical data or to short-term projections where data are not yet available. The baseline has GDP growth slowing in China and India, while recovering from recent slow growth in Indonesia, Japan, and Other Asia. Annual performance of countries in the region for 1997 to 2000 has been quite varied (**Table 8**), and this is clearly a large uncertainty into the future.

Table 6. Nuclear Power and Hydropower Production in 2005 (exajoules).

Location	Nuclear Power	Hydropower
China, People's Rep. of	0.18	0.74
India	0.06	0.21
Japan	1.08	0.20
Indonesia	0.00	0.00
Other Asia	0.50	0.08
Total East Asia	1.83	1.23
World	9.39	7.18
East Asian Share (%)	19	17

Source: EPPA model's reference projections based on EIA (2006).

Table 7. Annual Real GDP Growth Rates in the Baseline Scenario (%).

	China, People's Rep. of	India	Japan	Indonesia	Other Asia	Other Regions	World
1997–1999	6.4	6.1	0.9	1.7	2.4	3.5	3.2
2000–2004	9.6	5.0	1.1	2.4	3.3	2.3	2.5
2005–2009	5.4	4.1	3.2	3.4	3.3	3.4	3.5
2010–2014	5.0	3.8	3.3	3.7	3.4	3.4	3.5
2015–2019	4.6	3.3	3.2	3.6	3.2	3.2	3.3
2020–2024	4.3	2.8	3.2	3.7	3.0	2.9	3.1

Table 8. Recent Annual Real GDP Growth Rate in China, India, Indonesia, and Japan (%).

Year	China, People's Rep. of	India	Indonesia	Japan
1997	6.9	7.8	4.7	0.6
1998	6.0	4.9	−13.1	−1.0
1999	6.2	6.6	0.8	0.9
2000	8.6	5.4	5.4	3.0
2001	8.1	4.4	3.8	−1.2
2002	8.9	5.8	4.5	0.1
2003	10.4	3.8	4.8	1.8
2004	12.7	8.5	5.1	2.3
2005	10.2	7.5	5.6	2.6

Source: Data for China for 1997–2004: NBSC (2005), for China for 2005: IMF (2006a); data for India: IMF (2007); data for Indonesia: IMF (2005, 2006b); data for Japan for 1997–2002: IEE (2004), for Japan for 2003–2005: IMF (2006c).

Note: China's growth reported by NBSC (2005) is 10.4% in 2003 and 12.7% in 2004 compared to 10.0% in 2003, 10.1% in 2004 reported by IMF (2006a).

If economic performance of the 2000–2005 period were sustained over the longer term, then economic growth would be much more rapid than in the baseline case.

Figure 3 (panels a–f) shows the resulting energy consumption by fuel type for the East Asian region in total and for the five locations separately. Renewables include hydroelectricity, solar and wind, and electricity from biomass and biomass liquids. Much non-commercial biomass currently used in many of these countries for cooking and home heating is not reported. Additional biofuels that are simulated in EPPA are commercial biofuels, primarily ethanol-based fuels that compete with petroleum products. Through the time horizon of this analysis (*i.e.* 2025), hydropower is the most significant renewable energy form, accounting for all renewables in 2000–2005 and around three quarters in 2010–2020. Some advanced biofuels begin to appear toward 2025 as oil prices rise.[3] Primary electricity (nuclear, hydro, and other renewable electricity) is reported in primary equivalent.

In the baseline, total energy use in the East Asian region is projected to increase from 124 to 219 EJ between 2005 and 2025, a 77% rise in 20 years. Of course, in the 20 years from 1980 to 2000, the region's energy use increased by 120% and so this is actually a slowing rate of growth. East Asian GDP is projected to grow by 105% in the baseline between 2005 and 2025. From these figures can be derived an implied aggregate energy-use elasticity for East Asia with respect to GDP, which is 0.74.

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[3] The EPPA model was designed to be simulated over 100 years and with a focus on greenhouse gas mitigation. In the longer term and under stringent climate policies, other renewables, especially biofuels, play a larger role.

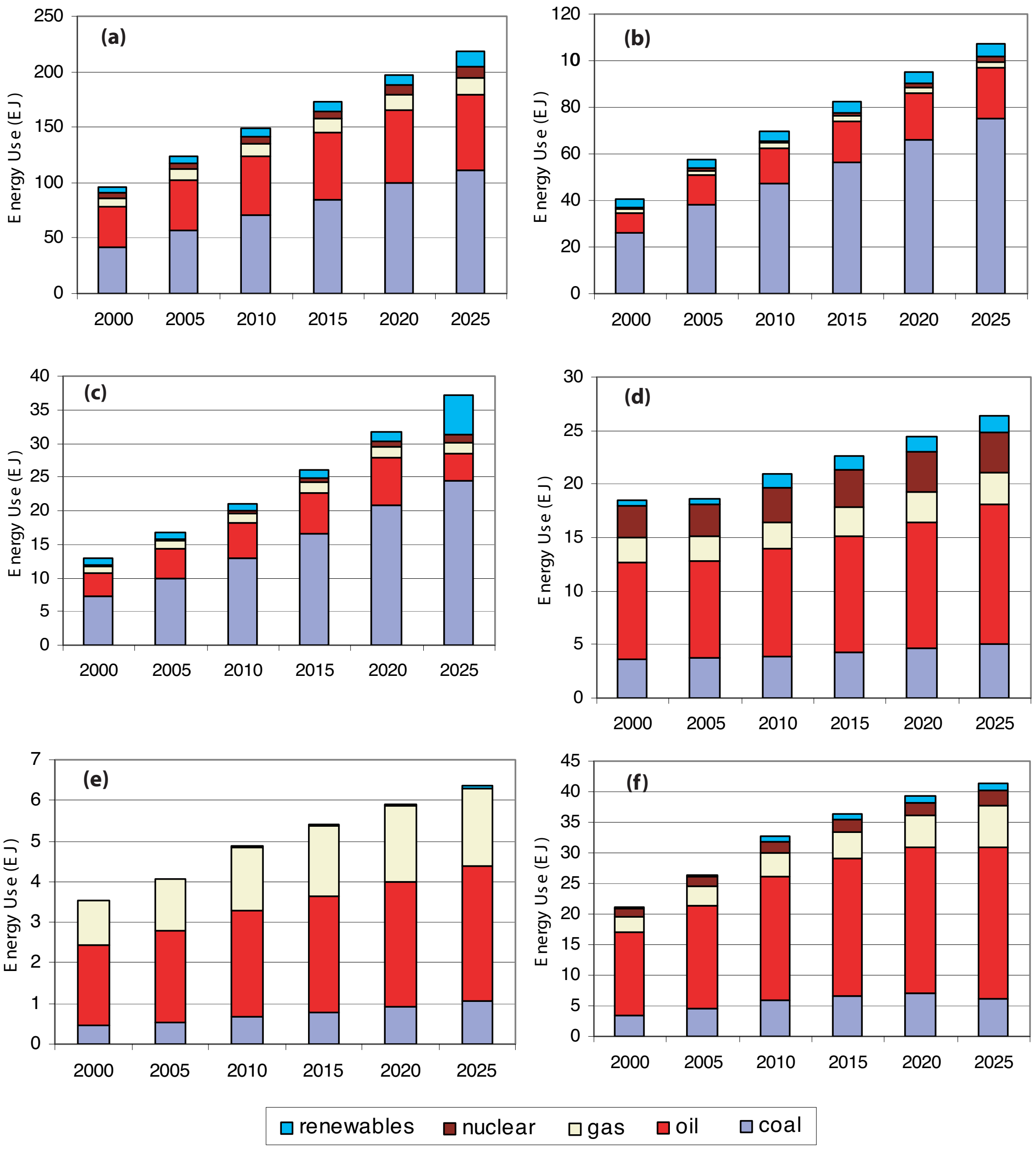

Figure 3. Energy Use in Baseline Scenario in East Asia (exajoules). **(a)** East Asia total, **(b)** China, People's Republic of, **(c)** India**, (d)** Japan, **(e)** Indonesia, and **(f)** Other Asia.

In this projection, energy use grows most rapidly in China and India, where it triples (or nearly so). In Indonesia and Other Asia, energy use doubles over the period. In Japan it rises by only about 45%. Given this increase in energy use and GDP growth, the income elasticity of energy demand across the East Asian region varies from 0.47 in Japan, 0.55 in China and Indonesia, 0.64 in Other Asia, to 1.23 in India. Adams and Shachmurove (2007) point out that a typical expectation is that energy elasticity in developing countries exceeds unity, in other words, energy consumption rises proportionately more rapidly than GDP. Of course, the actual experience of developing countries has varied as reflected in the historical changes in energy intensity discussed previously. In particular, until 5 years ago, the income elasticity of energy was considerably less than 1.0 in China.

With regard to fuels, all fuel use grows rapidly in China and India, whereas in the other locations oil and gas use grow more rapidly, as shown in Figure 3 (panels b–f). For the region as a whole, coal use expands more quickly because China and India are large coal users, and rapid growth there drives the overall regional pattern. One result is that the region's share of world coal consumption rises from 48% to 53% between 2005 and 2025, and of total energy from 28% to 32%, even as its share of oil and gas changes little (**Table 9**).

Among the forces in EPPA that affect overall energy efficiency and fuel demand are the sectoral composition and non-price changes in fuel demand. A leading influence on sectoral composition is the change in patterns of consumer demand with economic development. These sectoral shares are determined by many factors, including changes in relative factor prices, intermediate demand, final demand, and international trade. A CGE model like EPPA, which is based on CES functions, tends to be share preserving. As noted in Paltsev *et al*. (2005), additional adjustments are made from period to period to reflect the way that consumption is expected to change as per capita income increases. In addition, fuel shares for China households, which now often use much coal, are adjusted over time to switch to other fuels as incomes rise. In terms of production sectors, a vintaging structure in EPPA keeps some portion of capital fixed in a particular technology.

Fossil-fuel price indexes for the baseline scenario are given in **Table 10**, where 2005 is equal to 1.00. These are producer prices absent any excise taxes or trade and transport margins. The EPPA model determines relative prices, and the price projection for any particular year is most appropriately viewed as a 5-year average because the model simulates the economy in 5-year time steps. The EPPA model includes a sub-model for depletion of natural gas, oil, and coal on

Table 9. Energy Use in East Asia as a Share of World Energy Use (%).

	2005	2010	2015	2020	2025
Coal	0.48	0.50	0.53	0.53	0.53
Oil	0.26	0.27	0.28	0.28	0.27
Gas	0.11	0.11	0.11	0.11	0.12
Total Energy	0.28	0.29	0.31	0.32	0.32

Note: Nuclear, hydro, biomass, solar and wind use are included in the total energy figures.

Table 10. Fossil Fuel Price Indexes (2005 = 1).

Region	Fuel	2010	2015	2020	2025
China, People's Rep. of	Coal	1.05	1.10	1.15	1.21
	Gas	1.17	1.41	1.70	2.04
India	Coal	1.07	1.16	1.26	1.33
	Gas	1.25	1.62	2.13	2.58
Japan	Coal	1.05	1.09	1.14	1.18
	Gas	1.14	1.30	1.49	1.78
Indonesia	Coal	1.05	1.09	1.14	1.17
	Gas	1.16	1.34	1.59	2.05
Other Asia	Coal	1.04	1.08	1.12	1.16
	Gas	1.19	1.39	1.67	2.18
World	Crude oil	1.21	1.45	1.74	2.00

Note: The prices of coal and gas differ by country. Crude oil is a homogeneous good and so has a single world price.

the basis of supply and demand conditions, and so prices are endogenously determined as an interaction of demand and supply in regional and world markets. Coal and gas, as is the case with most goods in EPPA, are modeled as "Armington" goods, where domestic and imported goods are not perfect substitutes (Armington, 1969), and thus prices differ by country. However, crude oil is modeled as a homogenous good, giving a single world price.

Coal prices are projected to rise by about 20% by 2025, with the exception of India where prices are set to rise by 33%. The natural gas price increase is also the biggest in India, where it is projected to rise by nearly 150% compared with about 100% in the other locations in East Asia. Crude oil prices are projected to double. For a sense of actual fuel prices, the index values can be multiplied by the average 2002–2006 base prices ($40/barrel for oil, $5.40/thousand cubic feet for natural gas, $26.70/short ton for coal).[4] In this regard, the crude oil price is already substantially higher than the recent 5-year average.

Net imports of fossil fuels (in US dollars) by the five East Asian locations increase substantially in the projections. Coal and oil imports double, while natural gas imports triple, from 2000 to 2025 in dollar terms. But if one looks at them as energy trade deficits as a share of GDP, the model does not predict big changes. They amount to less than 1% of GDP in 2005–2025, except for oil imports to India (around 1.5% of GDP) and oil imports to Other Asia (around 3–4% of GDP). At the same time in the baseline scenario, the EPPA model projects that the net export surplus in manufacturing and services, as a share of GDP, will increase in 2005–2025 from 6.5% to 7.4% in China, from 3.7% to 4.9% in India, and from 7.7% to 12.8% in Other Asia. The net export surplus in these sectors in Japan is falling, but still outweighs an energy trade deficit there, while Indonesia continues to be an energy exporter over the period.

5. ALTERNATIVE SCENARIOS

The baseline scenario is one possible realization of future East Asian economic growth and energy use, and clearly such projections hold uncertainties. Several alternative scenarios are therefore constructed to represent these uncertainties and to help understand better how energy markets might affect energy use and economic growth in the region. An outline of the alternative scenarios is provided in **Table 11** with shorthand scenario titles.

Table 11. Illustrative Scenarios.

Name	Description
Baseline	Emissions Prediction and Policy Analysis model's reference
High growth	High economic growth in all East Asia
Low growth	Low economic growth in all East Asia
High growth, China alone	High economic growth in China only
Low growth, China alone	Low economic growth in China only
No energy efficiency gain, China	No improvement in energy efficiency in China
Low energy prices	Low energy (coal, oil and gas) prices
Gas trade markets	Regional trade in gas in three markets: Asia (Asia, former Soviet Union, Middle East, Australia), Europe (Europe and Africa), Americas (North and South America)

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[4] These are US average prices for 2002–2006 computed from DOE Energy Information Administration price data.

Economic growth is clearly one of the major drivers of energy demand and is an important uncertainty. Therefore, high and low economic growth scenarios are considered. Also, since China is emerging as such a large force in the region and the world, it is interesting to ask how different prospects there could affect the region. Consequently, two scenarios are created with different economic growth assumptions in China. In addition, as already noted, the last 5 years of China's experience show a switch to an increase in energy intensity. To consider this effect, a scenario is built in which the non-price-induced energy efficiency improvement in EPPA (which in the baseline was improving at 1% a year) is eliminated.

A scenario is considered where energy prices return to their approximate 2000 levels and are held there. Perhaps such lower energy prices are possible, but a major purpose of this scenario is to understand whether projected rising energy prices slow economic growth in the region.

Finally, a gas market scenario (in which a fully integrated regional gas market emerges) is motivated by the fact that the region has substantial gas resources, but its lack of pipelines and liquefied natural gas (LNG) facilities currently limits use, especially in countries like China and India. In this scenario it is assumed that broader regional markets in natural gas develop, implying that infrastructure impediments are overcome, and the large resources of gas in the region and from surrounding areas are made available for use in China, India, and other import-dependent countries in East Asia.

5.1 Effects of Economic Growth in East Asia and China, and China Energy Efficiency, on East Asian Energy Use

To construct different scenarios of GDP growth, ranges of historical growth are considered. With regard to China, the range of recent growth as shown in Table 8 has been wide, but for the last 5 years it has exceeded 10 % per year. Some researchers question China national statistics (see, for example, Zhang, 2003; Adams & Shachmurove, 2007) and note that China statistics might have underestimated GDP in the past, and that the reported economic growth (NBSC, 2005) in recent years might be higher than actual growth as the statistics catch up with the previous underreporting (Zhang, 2003). This claim is rejected by China authorities on the basis that high economic growth in China has been sustained for more than a decade. In recent years, India and Indonesia also show high economic growth rates. IMF (2006b, 2007) projects a sustained future economic growth in India and Indonesia at 6-7% per year. Japan has also shown an improved economic situation since 2003 and growth at more than 2%, which is slower than other dynamic Asian countries but a substantial improvement from its recent history.

The evidence would seem to suggest mostly higher economic growth than in the baseline; however, high- and low-growth cases are considered. In the high-growth case it is assumed that China grows at an annual average of 9.8% over 2005–2025, India at 8%, Indonesia and Other Asia grow at 6%, and Japan at 3.5%. In the low-growth case, China and India grow at an annual average of 3%, Indonesia and Other Asia at 2%, and Japan at 1%.

High growth in all East Asian locations lifts energy use to 430 EJ in 2025, while slow growth in East Asia leads to an increase to 170 EJ by 2025, compared with the baseline of about 220 EJ (**Figure 4**, panels a and b). The 430 EJ level is about 3.5 times as high as 2005 levels whereas

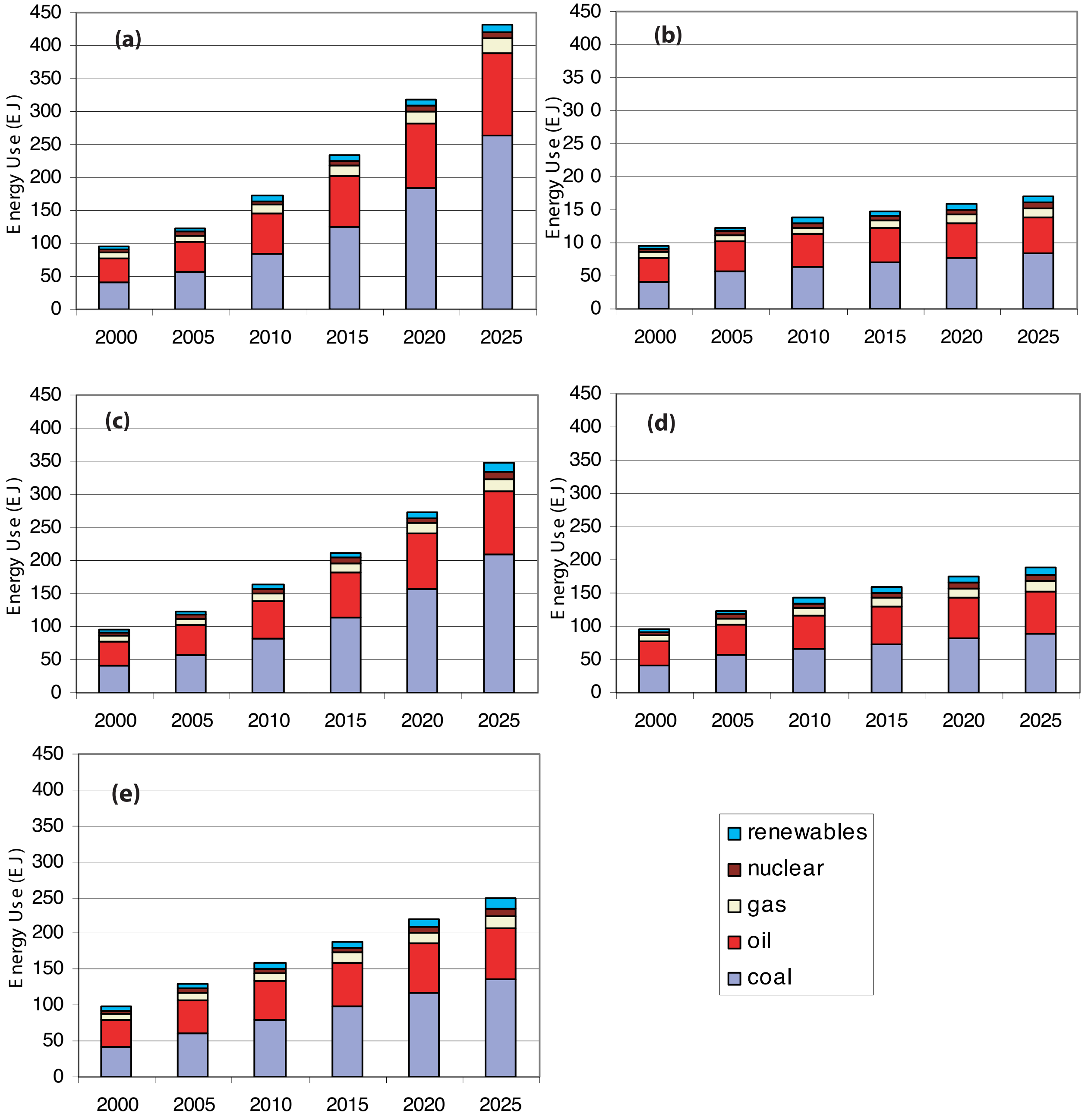

Figure 4. Energy use in East Asia under Scenarios of High And Low Growth, and No Energy Efficiency Gain in China (exajoules). High growth **(a)**, Low growth **(b)**, High growth, China alone **(c)**, Low growth, China alone **(d)**, No energy efficiency gain in China **(e)**.

the 170 EJ is about a two-fifths increase. Coal and oil use both grow substantially. China alone is a major factor in these differences. When varying GDP growth in China alone is simulated, energy use in 2025 for the entire region ranges from 350 EJ (high growth, China alone) to about 180 EJ (low growth, China alone) as shown in Figure 4, panels c and d. High growth in China alone would increase energy use by 140 EJ in 2025, nearly two thirds of the increase seen if all countries grow at the more rapid pace of the high-growth scenario.

Section 2 described historic trends for energy intensity in China and Other Asia. There are two factors that primarily affect energy intensity in the EPPA model. The first is an exogenous factor conventionally referred to as Autonomous Energy Efficiency Improvement (AEEI). AEEI reduces the energy required in each sector to produce the same amount of output, assuming that other things (such as energy prices) are unchanged. In an actual forward simulation of the model, "other things" change endogenously, and these changes also affect energy efficiency. Actual energy efficiency of production of each sector in forward simulations is thus a combination of the exogenous AEEI factor, and endogenous effects through changes in fuel and other prices. AEEI can thus be seen as a reduced-form parameterization of the evolution of non-price-induced changes in energy demand. It is often assumed that AEEI represents technical change, but it should be seen as broadly representing other changes such as in the structure of production within the aggregate sectors. (For more discussion about AEEI in the EPPA model, see Paltsev *et al.*, 2005 and Kasahara *et al*., 2007.)

As shown in Figure 4, panel e, with none of the energy efficiency gain in China, energy use in the region increases to 250 EJ, a 30 EJ increase from the baseline. While not as dramatic as the high-growth effect, this scenario may not provide a high bound on the energy-intensity effect. Even when the energy efficiency improvement is removed in China, energy intensity still falls by around 0.5% annually over the period because of price and structural changes (compared with an average reduction in energy intensity in 2005–2025 of around 1.5% in the baseline scenario). The effect on energy use is not as strong as if intensity actually rises, as has occurred over the past 5 years.

5.2 Effects of Low Energy Prices and Gas Trade Markets on Energy Use in East Asia

While EPPA simulates fuel prices as an interaction of supply and demand, it is structured such that one can set a price path and examine the implications for energy demand. To set the prices in this way, the model ignores resource constraints and assumes that all the fuel demanded at the given price is forthcoming. As a result, the regional energy supply projections and energy trade are not particularly meaningful because they may imply large fuel resources even though few resources are believed to exist. Thus this exercise is more useful for examining energy demand and the implications for economic growth of rising energy prices. If lower prices materialized, this would more likely result from some combination of reduced energy demand elsewhere in the world (perhaps in part because of stringent policies on greenhouse gas emissions reducing demand) or greater expansion of production in regions that are known to have large fuel resources (such as the Middle East, Russian Federation, or other countries of the Former Soviet Union).

In any case, as shown in **Figure 5**, panel a, if energy prices are stable rather than rising, total energy demand in East Asia is projected to increase to almost 250 EJ, whereas in the baseline, rising prices keep use to about 220 EJ. Since the baseline had oil and gas prices rising faster than coal, it is not surprising to see more of the increase in oil and gas use.

While the fact that economic growth leads to higher energy use is generally well recognized, the potential effect of energy prices on economic growth is not often modeled. The general

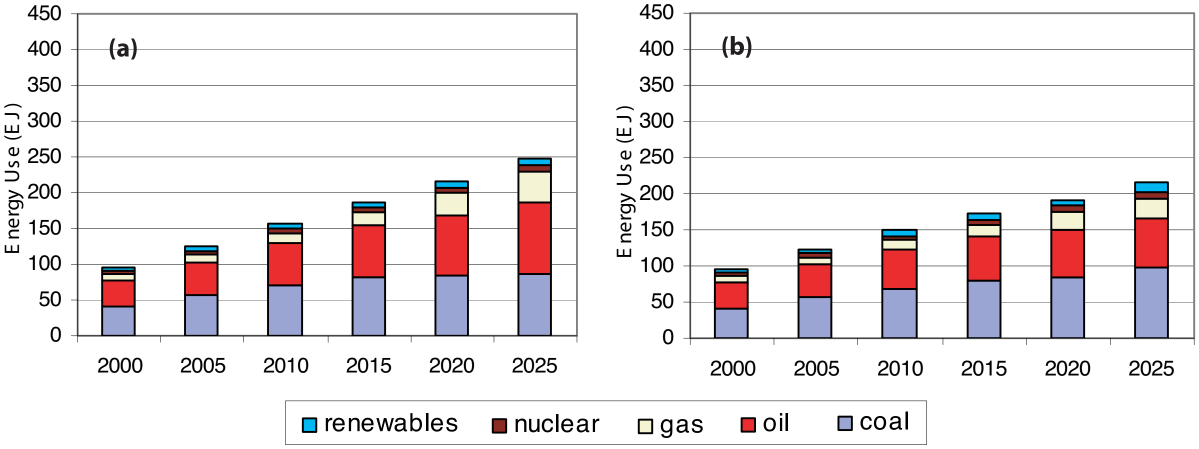

Figure 5. Energy use in East Asia in Scenarios of Low Energy Prices and Expanded Regional Gas Trade (exajoules). Low energy prices **(a)** and Regional gas trade **(b)**.

Table 12. Annual Real GDP Growth Rate in Baseline and Low-Energy Price Scenarios (%).

	China, People's Rep. of	India	Japan	Indonesia	Other Asia
Baseline					
2010	5.4	4.1	3.2	3.4	3.3
2015	5.0	3.8	3.3	3.7	3.4
2020	4.6	3.3	3.2	3.6	3.2
2025	4.3	2.8	3.2	3.7	3.0
Low Energy Prices					
2010	5.7	4.7	3.4	3.5	3.8
2015	5.2	4.3	3.4	3.8	3.8
2020	4.8	3.8	3.3	3.7	3.6
2025	4.5	3.4	3.4	3.9	3.4

equilibrium structure of the EPPA model provides a consistent framework for assessing these effects. **Table 12** shows that the energy price increases projected in the baseline would substantially slow economic growth compared with a case where fuel prices did not rise. The growth penalty is as much as 0.6% per year in India, about 0.4% per year in Other Asia, and about 0.2% per year in China, Indonesia, and Japan.[5]

As discussed above, natural gas markets in the baseline scenario are modeled such that international prices do not fully equalize, and therefore changes in domestic demand can have a larger effect on domestic prices. In the gas trade markets scenario the Armington specifications for natural gas are relaxed. The trade in gas is modeled in a similar fashion to trade in crude oil (which is a homogenous product with perfect substitution for imports across different regions of the world). In this scenario three regional markets are in fact assumed for natural gas, in each of which gas is a homogenous product: Asia (Asia, Former Soviet Union, Middle East, Australia and New Zealand), Europe (Europe and Africa), and Americas (North and South America).

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[5] Some caution is warranted in these calculations because of possible terms-of-trade effects that might stem from the location of the energy source, which, as discussed in the text, is not well resolved given the nature of the fuel price override in EPPA.

"Armington-type" trade between the three regional gas markets remains. The motivation for the regional markets is that pipelines can serve to link markets that are geographically close. Whether this result accurately describes emerging global gas markets depends on how fast LNG infrastructure and pipelines can be developed (especially whether terminals and pipelines will be built to keep pace with demand), and LNG production facilities can expand.

The main implication of a developing regional gas trade is that East Asia's gas use in 2025 expands from about 16 EJ in the baseline to about 28 EJ in the gas trade markets scenario. Most of this expansion displaces coal use, which falls from about 110 EJ to 100 EJ in 2025. Thus, it appears that gas penetration is somewhat limited by the Armington assumption and, if this is realistic, by limits on transportation. A more fully integrated regional gas market would lead to much more gas use in the region. However, even with this significant expansion of gas use, coal retains the largest share (by energy content) of energy used in the region.

5.3 Energy Prices in Alternative Scenarios

At the outset it was argued that the East Asian region was large and rapidly growing and so prospects there could affect energy markets globally. One way to measure East Asia's impact on energy markets is to examine energy prices. As noted previously, EPPA models a single world market for oil but national/regional markets for other fuels. Therefore, the impact on the world oil price is one direct measure of the region's effects on global energy markets. For coal and gas a stronger effect is expected within the region, but a more limited transmission of the effect is likely to other regions. **Table 13** gives prices for coal and gas in China and the world oil price under the alternative scenarios outlined above.

Table 13. Effects on Fossil Fuel Prices in China of Economic Growth, Energy Prices, Gas Markets, and Energy Efficiency (Index: 2005 = 1.00).

Scenario		**China Alone**			**East Asia**			
	Baseline	**High growth**	**Low growth**	**No Energy Efficiency**	**High growth**	**Low growth**	**Low energy prices**	**Gas trade**
Coal Price Index								
2005	1	1	1	1	1	1	1	1
2010	1.05	1.08	1.03	1.06	1.08	1.03	0.98	1.04
2015	1.1	1.19	1.06	1.13	1.2	1.05	0.98	1.08
2020	1.15	1.37	1.09	1.2	1.39	1.08	0.98	1.09
2025	1.21	1.71	1.12	1.29	1.74	1.1	0.98	1.16
Gas Price Index								
2005	1	1	1	1	1	1	1	1
2010	1.17	1.4	1.07	1.22	1.41	1.07	0.82	1.13
2015	1.41	2.08	1.18	1.54	2.1	1.17	0.82	1.28
2020	1.7	2.86	1.31	1.94	2.88	1.3	0.82	1.46
2025	2.04	3.26	1.47	2.43	3.29	1.46	0.82	1.65
Oil Price Index								
2005	1	1	1	1	1	1	1	1
2010	1.21	1.24	1.2	1.22	1.26	1.18	0.82	1.21
2015	1.45	1.53	1.43	1.46	1.6	1.39	0.82	1.45
2020	1.74	1.9	1.69	1.76	2.04	1.62	0.82	1.73
2025	2	2.23	1.96	2.02	2.4	1.89	0.82	2

Taking first the world oil price in Table 13, the price index for crude oil reaches 2.4 in the high-growth scenario, compared with 1.89 in the low-growth scenario, and 2.00 in the baseline. Crude oil has been selling in the \$60–70 range in 2006 and 2007. The baseline has it falling back from that level in the near term but rising to \$80 by 2025, given a base year crude price of \$40 per barrel. With high growth in East Asia, the price in 2025 is projected to approach \$100 a barrel; with low growth in East Asia, the price might reach only \$75. Thus in these simulations, growth prospects in East Asia could lead to a near-\$25 swing in the world oil price. Growth prospects in China alone could lead to about a \$10 swing in the global oil price. With no energy efficiency gain in China, the effect on oil prices is smaller. The low-price scenario arbitrarily sets energy prices at a low level by assumption.

Turning to the effects of alternative scenarios on coal and gas prices in China, also shown in Table 13, in general the impacts are larger than on the world oil price. This is expected because the Armington trade assumption means that the ability to substitute imported fuels for domestic production is limited. Thus, much more of the increased demand pressure falls on domestic markets. There is some spillover on prices in China as a result of varying conditions elsewhere in East Asia. For example, with high growth in China alone, China coal price index is 1.71 in 2025, but with high growth throughout East Asia, the coal price index in China rises to 1.74. These spillovers can result directly from effects in the own-fuel market (the coal price is affected by increased demand for coal due to higher economic growth) and from interactions among markets (the higher price of imported gas or oil may lead to a shift to greater use of domestic coal and an increase in the domestic price).

The effects of varying scenarios of East Asia and China growth on coal and gas markets outside East Asia are much smaller. For example, for most of the scenarios, the EPPA model projects no substantial effects on the European or US coal price indexes. The greatest impact on energy demand is the high-growth scenario, which sees about a 1% increase in coal prices in Europe and the US, and an increase in gas prices of 6% in Europe and about 4% in the US, relative to the baseline in 2025. Effects are much smaller in other cases. Thus, if this Armington representation of the fuel markets is realistic, the transmission of changes in East Asia to other regional markets is limited, with the major effect occurring in the crude oil market.

Also shown in Table 13 is the effect on prices of the development of regional gas trade markets. As expected, this reduces the price of gas in China fairly substantially because it makes available to China less expensive resources in the Russian Federation, other countries of the Former Soviet Union, the Middle East, and Indonesia. The effect also spills over into the coal market, with the price index declining from 1.21 in the baseline to 1.16. Increased gas trade has almost no effect on the price of crude oil. The price effects are not surprising given that the main effect of regional gas trade markets was to increase gas use at the expense of coal—and less coal demand means a lower price.

Not shown in the table but of some interest is the fact that the development of regional gas trade markets results in an increased price of gas in Europe of about 7%. If gas in the Middle East, Russian Federation, and other countries of the Former Soviet Union is readily accessible to East Asia, this increases competition for the fuel and makes gas less available to Europe, which has developed an extensive gas transportation network.

6. CONCLUSIONS

The economies of East Asia are growing rapidly and energy use in the region is becoming a substantial share of world energy demand. In the baseline scenario, energy use increases in East Asia from around 120 EJ in 2005 to around 220 EJ in 2025. Coal continues to play a leading role as an energy source in the region, especially in China and India, while oil and gas use is accelerated under different scenarios. For the region as a whole, coal use grows as a share of fuel use, but this is because China and India are growing more rapidly, and so their fuel consumption patterns increasingly dominate the regional pattern.

This paper has focused on energy scenarios with no particular attention to an increase in emissions of greenhouse gases and other pollutants. The environmental consequences of rapid economic and energy demand growth, while an important topic, is beyond its scope.

Alternative scenarios were developed to consider several specific questions including: How fast might energy demand grow in the East Asian region and how does such growth depend on key uncertainties? Do rising prices for energy affect growth in the region? Would growth in East Asia have a substantial effect on world energy markets? And, would development of regional gas markets have large effects on energy use and gas markets in other regions?

With regard to future energy demand growth, the most important single factor is the rate of economic growth. In the baseline scenario, annual GDP growth rates from 2005 to 2025 were approximately as follows: China 5%, India 3.5%, Indonesia 3.6%, Japan 3.2 %, and Other Asia 3.3%. In the high-growth scenario that extended rates seen in recent history, growth was substantially higher: China 9.8%, India 8%, Indonesia 6%, Japan 3.5 %, and Other Asia 6%. In this scenario, energy demand rises to 430 EJ in 2025. In the low-growth scenario, it rose to only 170 EJ compared with 220 EJ in the baseline. High growth in China alone could account for about two thirds of the increase.

The effects of higher energy prices on growth in the region were found to be substantial. If, instead of rising at the rates projected in the baseline, prices were to fall back to year 2000 levels, annual average growth rates in the region would be 0.2–0.6% a year higher. The biggest growth impact is on India, and the smallest on China, Japan, and Indonesia.

A substantial impact of East Asia’s energy demand growth on world oil markets was seen. Among scenarios of low and high demand growth in East Asia, the world oil price varied from about $75 to nearly $100 a barrel in 2025. Different growth prospects in China alone could cause a swing in the world oil price in 2025 of about $10 a barrel. The effects on other fuel markets were considerably less, reflecting the lack of complete integration of these markets, at least as seen in the EPPA model.

Finally, it was found that if regional gas markets developed better links between East Asia on the one hand and the Russian Federation and the Middle East on the other, gas use in the region could grow substantially more than in the baseline, possibly increasing by about 75%. This would occur mainly through switching of gas for coal. An interesting side effect of the development of gas markets is that they could lead to higher gas prices in Europe. In the simulation, European gas prices increased by about 7% with the development of regional trade because East Asian demand more effectively competed with that from Europe.

The above results depend on several aspects of the EPPA model structure and on particular input assumptions that greatly simplify the representation of economic structure and decision making. The EPPA model draws heavily on neoclassical economic theory. While this underpinning is a strength in some regards, the model fails to capture many economic rigidities that could lead to unemployment or misallocation of resources; nor does it capture regulatory and policy detail. Still, given the many assumptions that are necessary to model national and global economic systems, the precise numerical results are not as important as the insights into the general direction of changes in the economy, components of the energy system, and the approximate magnitude of the price effects seen under alternative assumptions.

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7. REFERENCES

Adams, F.G. & Y. Shachmurove, 2007. Modeling and forecasting energy consumption in China: Implications for Chinese energy demand and imports in 2020. *Energy Economics* (in press).

Altman, D., 2007. China growth challenges the world’s ability to adapt. *International Herald Tribune*, March 7, 2007.

Armington, P.S., 1969. A theory of demand for products distinguished by place of production. *International Monetary Fund Staff Papers*, **16**, 159-176.

Babiker, M.H., G.E. Metcalf and J. Reilly, 2003. Tax distortions and global climate policy. *Journal of Environmental Economics and Management*, **46**, 269-287.

Climate Change Science Program (CCSP), 2006. *CCSP Synthesis and Assessment Product 2.1, Part A: Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*, L. Clarke *et al*., U.S. Climate Change Science Program, Draft for CCSP Review, December 06, 2006.

Crompton, P. & Y. Wu, 2005. Energy consumption in China: past trends and future directions. *Energy Economics*, **27**, 195-208.

Dimaranan, B., and R. McDougall, 2002. *Global Trade, Assistance, and Production: The GTAP 5 Data Base.* Center for Global Trade Analysis, Purdue University, West Lafayette, Indiana.

Dimaranan, B., 2006. *Global Trade, Assistance, and Production: The GTAP 6 Data Base.* Center for Global Trade Analysis, Purdue University, West Lafayette, Indiana.

Energy Information Administration (EIA), 2006. *International Energy Outlook 2006.* Energy Information Administration, U.S. Department of Energy, Washington, DC.

Fisher-Vanden, K., G. Jefferson, H. Liu and Q. Tao, 2004. What is driving China’s decline in energy Intensity? *Resource and Energy Economics*, **26**, 77-97.

Fisher-Vanden, K., G. Jefferson, M. Jingkui and X. Jianyi, 2006. Technology development and energy productivity in China. *Energy Economics*, **28**, 690-705.

Hang, L., and M. Tu, 2007. The impacts of energy prices on energy intensity: Evidence from China. *Energy Policy*, **35**, 2978-2988.

Hertel, T. 1997, *Global Trade Analysis: Modeling and Applications.* Cambridge University Press, Cambridge, United Kingdom.

Institute of Energy Economics (IEE), 2004. *Handbook of Energy and Economics in Japan.* Tokyo.

International Energy Agency (IEA), 2005. *Energy Balances of Non-OECD Countries* (2005 edition). OECD/IEA, Paris.

International Monetary Fund (IMF), 2005. *Indonesia: Selected Issues.* IMF Staff Country Report No. 05/327, Washington, DC (http://www.imf.org/external/pubs/ft/scr/2005/cr05327.pdf).

International Monetary Fund (IMF), 2006a. *IMF Survey*, Vol. 35, No. 22. December 11, 2006, Washington, DC (http://www.imf.org/external/pubs/ft/survey/2006/121106.pdf).

International Monetary Fund (IMF), 2006b. *Indonesia: 2006 Article IV Consultations.* IMF Country Report No. 06/319, Washington, DC (http://www.imf.org/external/pubs/ft/scr/2006/cr06319.pdf).

International Monetary Fund (IMF), 2006c. *Japan: 2006 Article IV Consultations.* IMF Country Report No. 06/275, Washington, DC (http://www.imf.org/external/pubs/ft/scr/2006/cr06275.pdf).

International Monetary Fund (IMF), 2007. *India: Staff report for the Article IV Consultations.* IMF Country Report No. 07/63, Washington, DC (http://www.imf.org/external/pubs/ft/scr/2007/cr0763.pdf).

Jacoby, H.D., R.S. Eckhaus, A.D. Ellerman, R.G. Prinn, D.M. Reiner and Z. Yang, 1997. CO_2 emissions limits: economic adjustments and the distribution of burdens. *The Energy Journal,* **18**(3), 31-58.

Kasahara, S., S. Paltsev, J. Reilly, H. Jacoby and A.D. Ellerman, 2007. Climate Change Taxes and Energy Efficiency in Japan. *Environmental and Resource Economics,* **37**(2), 377-410.

Maddison, A., 2001. *The World Economy: A Millennial Perspective*. OECD, Paris.

National Bureau of Statistics of China (NBSC), 2005. *China Statistical Yearbook 2005.* China Statistics Press, Beijing.

Paltsev, S., H. Jacoby, J. Reilly, L. Viguier and M. Babiker, 2004. *Modeling the Transport Sector: The Role of Existing Fuel Taxes in Climate Policy*. MIT Joint Program on the Science and Policy of Global Change, Report 117, Cambridge, MA (http://mit.edu/globalchange/www/MITJPSPGC_Rpt117.pdf).

Paltsev, S., J. Reilly, H. Jacoby, R. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian, and M. Babiker, 2005. *The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4*. MIT Joint Program on the Science and Policy of Global Change, Report 125, Cambridge, MA. (http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt125.pdf).

Paltsev, S., J. Reilly, H. Jacoby, A. Gurgel, G. Metcalf, A. Sokolov, and J. Holak, 2007. *Assessment of US Cap-and-Trade Proposals*. MIT Joint Program on the Science and Policy of Global Change, Report 146, Cambridge, MA (http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt146.pdf).

Reilly, J., Prinn, R., J. Harnisch, J. Fitzmaurice, H. Jacoby, D. Kicklighter, J. Melillo, P. Stone, A. Sokolov and C. Wang. 1999. Multi-gas assessment of the Kyoto Protocol. *Nature,* **401**, 549-555.

Reilly, J. and S. Paltsev, 2006. European Greenhouse Gas Emissions Trading: A System in Transition. In: *Economic Modeling of Climate Change and Energy Policies,* M. De Miguel, X. Labandeira, B. Manzano (eds.), 2006, Edward Elgar Publishing, pp. 45-64.

Rutherford, T., 1995. *Demand Theory and General Equilibrium: An Intermediate Level Introduction to MPSGE.* GAMS Development Corporation, Washington, DC. (http://www.gams.com/solvers/mpsge/gentle.htm).

Sokolov, A.P., C.A. Schlosser, S. Dutkiewicz, S. Paltsev, D.W. Kicklighter, H.D. Jacoby, R.G. Prinn, C.E. Forest, J. Reilly, C. Wang, B. Felzer, M.C. Sarofim, J. Scott, P.H. Stone, J.M. Melillo, and J. Cohen, 2005. *The MIT Integrated Global System Model (IGSM) Version 2: Model Description and Baseline Evaluation.* MIT Joint Program on the Science and Policy of Global Change, Report 124, Cambridge, MA (http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt124.pdf).

United Nations (UN), 2001. *World Population Prospects: The 2000 Revision, Data in digital form.* Population Division, Department of Economic and Social Affairs.

Winters, L.A., and S. Yusuf, 2007. *Dancing with Giants: China, India, and the Global Economy.* The World Bank: Washington, DC and The Institute of Policy Studies: Singapore.

Zhang, Z., 2003. Why did the energy intensity fall in China's industrial sector in the 1990s? The relative importance of structural change and intensity change. *Energy Economics*, **25**, 625-638.

Zhao, X. and Y. Wu, 2007. Determinants of China's energy imports: An empirical analysis. *Energy Policy,* (in press).

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