# CHAPTER 4

## INDUSTRIAL ENERGY EFFICIENCY INDICATORS

### OVERVIEW

The industrial sector accounts for 35-40 percent of total final energy consumption in the APEC region.[8] Manufacturing was responsible for roughly 96.7 percent of total industrial energy consumption in 1997, the rest was consumed by mining and quarrying (2.0 percent), and construction (1.3 percent). Though a large consumer of energy, the industrial sector generated only 23.7 percent of total gross domestic product (GDP) in 1997 in the APEC region.

This chapter focuses on manufacturing, the largest consumer of energy in the industrial sector. Manufacturing includes iron and steel, pulp and paper, non-metallic minerals, non-ferrous metals, chemical and petrochemical, food and tobacco, textile and leather, machineries as well as other manufacturing industries. Energy consumption varies greatly among these manufacturing branches. The largest energy users by sub-sector are chemicals and petrochemicals, iron and steel, pulp and paper and non-metallic minerals such as cement. Fabricating industries such as textile, machineries and other manufacturing consume less energy [IEA, 1997].

The goal of this chapter is to construct energy indicators for the industrial sector and to examine the factors underlying energy consumption growth. For manufacturing, indicators have been calculated both in economic and physical terms wherever possible. Industries whose products are generally measured in metric tonnes like iron and steel, cement as well as pulp and paper were chosen for the construction of physical indicators. For other industries where the product mix was more heterogeneous, monetary indicators were constructed. To identify and evaluate factors driving intensity change, a parametric Divisia decomposition method was applied to overall manufacturing intensity.

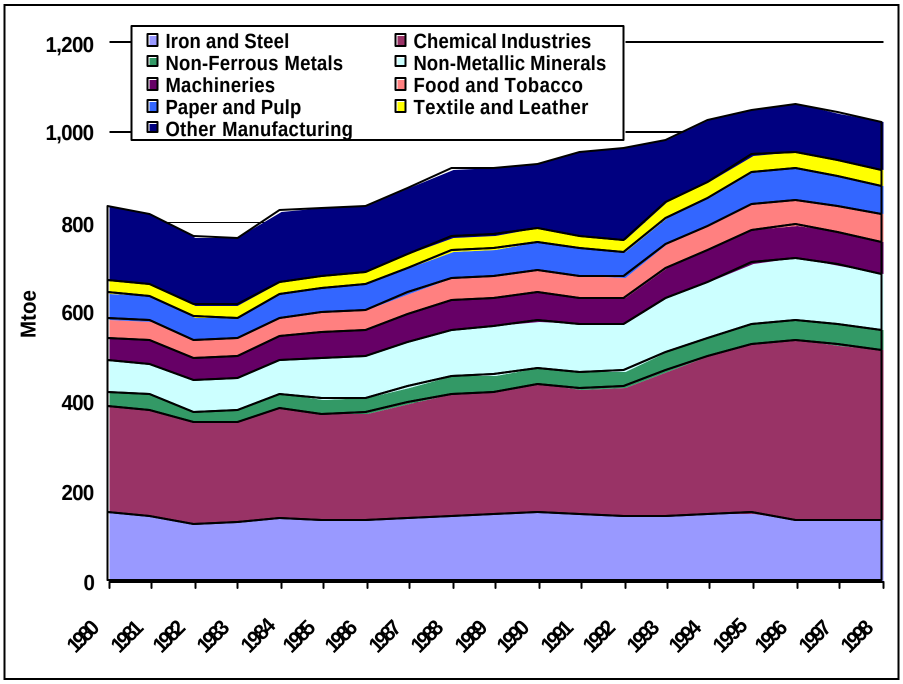
### MANUFACTURING ENERGY CONSUMPTION TRENDS

In the manufacturing sector, heat production is one of the most important uses for energy. Direct heat and steam are used for heating, treating, melting and smelting, ore agglomeration, lime and cement calcination, clay and brick firing and glass melting, curing and forming. Other important uses are machine drive and electrolytic processing. Non-process energy uses, which make up a small component of total consumption, include heating, ventilation, air-conditioning, lighting of industrial facilities and on-site transport [IEA, 1997].

Final energy consumption for manufacturing in APEC economies (except Russia) increased from 881 Mtoe in 1980 to about 1,043 Mtoe in 1998. The chemicals and petrochemicals sector was the leading energy consumer in manufacturing. Demand in this sector increased from 235 Mtoe in 1980 to 374 Mtoe in 1998 (Figure 9). Energy consumption by the iron and steel industry, the next largest energy consumer, fell from 153 Mtoe in 1980 to 133 Mtoe in 1998 (- 0.9 percent per year).

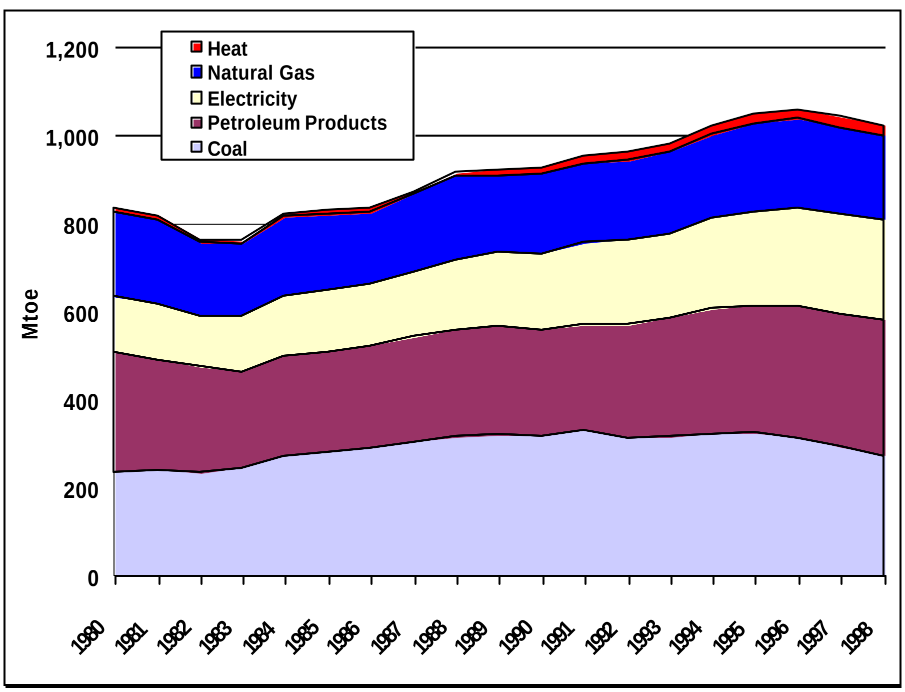
Coal has the highest share among the fuels used in the manufacturing sector (see Figure 10). Although consumption increased slightly over the study period, coal lost fuel share to electricity. With a growth rate of 3.4 percent per year, electricity increased its share of total energy from 14.4 percent in 1980 to 22.1 percent in 1998. Figure 10 is an aggregation of fuel use across the APEC region and may not be an accurate reflection of fuel mix in individual economies. The type of energy inputs consumed in each economy depends on fuel availability, price and industrial structure.

**Figure 9 Manufacturing Energy Consumption by Sub-sector***




Source APERC, 2000a *excludes Russia

**Figure 10 Manufacturing Energy Consumption by Fuel Type***




Source IEA, 2000a *excludes Russia

## ENERGY INTENSIVE INDUSTRIES

### IRON AND STEEL INDUSTRY

Final energy consumption by the iron and steel industry declined 13.0 percent over the study period. As the iron and steel sub-sector is a major consumer of energy, this large decline pulled down total consumption in the APEC region. However, while consumption fell over the period, iron and steel production increased by 28.6 percent from 1980 to 1997. China has played a large role in the observed trends for the iron and steel industry. China's final energy consumption declined by 15.7 percent over the study period, while production more than tripled. In 1998, with 115.6 million tonnes of production and a share of 23.4 percent, China surpassed Japan (22.1 percent) and the United States (21.2 percent) as the largest iron and steel producer in the APEC region. Other major steel producers include Russia and Korea.

### PULP AND PAPER INDUSTRY

Total final energy consumption by the pulp and paper industry increased by 21.6 percent over the study period while pulp and paper production grew more rapidly at 80.4 percent. The United States, the largest pulp and paper producer in the APEC region, had a large influence on observed production trends. In 1998 the United States was responsible for 40.4 percent of pulp and paper production, down from 54.6 percent in 1980. Over the study period, energy consumption in the United States declined by 13.2 percent while production rose by 33.4 percent.

### CEMENT INDUSTRY

In the APEC region, a 96.3 percent increase in final energy consumption by the cement industry was accompanied by a 177.5 percent increase in output over the period 1980 to 1995. China, the most important cement producer in APEC since 1982, largely influenced these results. In this economy, consumption rose three-fold while production increased almost six-fold over the period 1980 to 1995. China's share of APEC cement production increased from 24.7 percent in 1980 to 53.0 percent in 1998. Energy intensity in cement production in other APEC economies also fell.

## MANUFACTURING GROSS DOMESTIC PRODUCT

The growth rate of manufacturing output in monetary terms outpaced the growth rate of energy consumption in the APEC region (see Table 2). Collective manufacturing energy intensity in the APEC region has therefore been decreasing. This trend is best illustrated by China where manufacturing GDP grew 12.7 percent per year over the period 1987 to 1997 while final energy consumption (FEC) increased by only 1.5 percent per year.

As illustrated in Table 2, GDP in energy-intensive and less energy-intensive manufacturing industries grew more quickly than FEC in most economies implying improved productivity per unit of energy input. In Korea, New Zealand, Philippines, Russia and Thailand, the opposite trend is observed, energy consumption grew faster than GDP. In New Zealand, for example, manufacturing FEC grew 2.9 percent more quickly than GDP. Energy-intensive industries include iron and steel, non-ferrous metals, non-metallic minerals and chemical industries. All other manufacturing branches are classified as less energy-intensive industries.

**Table 2 Annual Growth Rates for Manufacturing GDP and FEC**

| Economy (Period) | Total Manufacturing | | Energy-Intensive | | Less Energy-Intensive | |
|---|---|---|---|---|---|---|
| | GDP | FEC | GDP | FEC | GDP | FEC |
| | | | percent | | | |
| AUS (80-96) | 1.4 | 1.3 | 2.4 | 1.4 | 1.2 | 0.9 |
| CDA (81-97) | 2.3 | 1.4 | 2.4 | 2.0 | 2.3 | 0.7 |
| PRC (87-97) | 12.7 | 1.5 | 10.0 | 1.9 | 14.7 | 0.2 |
| JPN (80-98) | 3.0 | 0.7 | 2.5 | 0.4 | 3.2 | 1.5 |
| ROK (84-96) | 10.0 | 10.7 | 10.6 | 15.3 | 9.7 | 4.5 |
| MEX (88-96) | 3.8 | 0.8 | 3.3 | -0.5 | 4.1 | 4.2 |
| NZ (80-97) | 1.6 | 4.5 | 2.5 | 10.9 | 1.4 | 0.3 |
| RP (80-98) | 1.5 | 3.1 | 0.4 | 4.0 | 1.9 | 2.6 |
| RUS (91-98) | -9.5 | -4.7 | -9.2 | -2.5 | -9.8 | -8.5 |
| CT (81-98) | 6.8 | 4.4 | 8.6 | 4.7 | 6.6 | 3.7 |
| THA (80-96) | 10.0 | 11.6 | 9.9 | 13.4 | 10.0 | 9.9 |
| USA (81-94) | 1.1 | -1.2 | 0.9 | -1.1 | 1.2 | -1.4 |

Note Derived from APERC, 2000a

## ENERGY INTENSITIES

### PHYSICAL INDICATORS

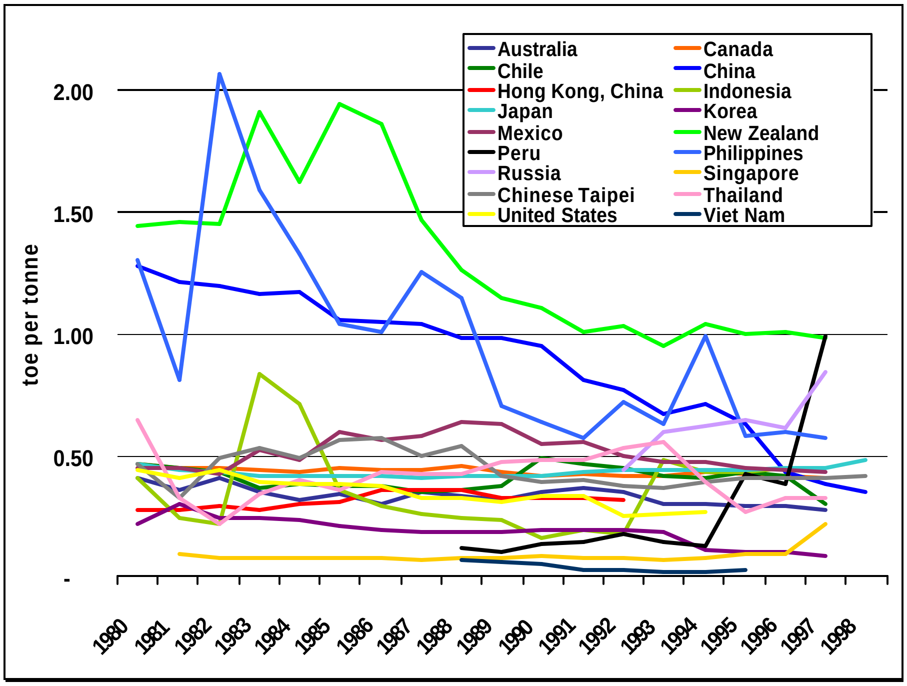
Physical indicators or specific energy consumption (energy consumed per unit of output) were constructed for three energy-intensive industries, iron and steel, pulp and paper and cement, where output was a reasonably homogeneous measurable product.

Physical indicators are better indicators of energy efficiency than economic indicators because physical indicators are not influenced by factors outside the production process such as prices and inflation. Moreover, economic indicators fail to reflect structural differences between economies or within an economy over time [Phylipsen, *et al*., 1998]. One drawback of this indicator is that it treats physical output as homogenous when the quality of product can vary.

#### IRON AND STEEL INDUSTRY

Despite similarities in iron and steel industry products, differences in energy intensities among the APEC region are still observed. Different technologies and steel production methods result in differences in required energy inputs per unit of output.

**Figure 11 Energy Intensities for Iron and Steel Production**




Source APERC, 2000a

A number of steps are involved in the production of steel. The first step is to reduce iron ore to pig iron or to sponge iron in a blast furnace using coke. Before it is processed in a blast furnace, the ore is usually shaped into pellets or turned into a powder by sintering. The pig iron from the blast furnace is then purified into steel in a Basic Oxygen Furnace (BOF), an Electric Arc Furnace (EAF) or by using the more traditional open-hearth method. Most of the world's steel supplies are produced using the BOF process. Finally, crude steel is moulded into ingots or directly cast into shapes such as beams or bars, it is then finished by rolling, pickling, coating or other treatment [IEA, 1991]. The method used to refine the pig iron into steel will also determine the energy content of steel. The open-hearth process requires more energy than EAF or the BOF, but can process more scrap iron than the BOF. In the APEC region, China and Russia use the open-hearth process. Some APEC member economies like Canada, Indonesia, Malaysia and Mexico process directly reduced iron.

Figure 11 shows the changes in energy intensities for iron and steel industries in the APEC region from 1980 to 1998. Overall, iron and steel intensities in the APEC region declined. China's energy intensity dropped from 1.28 toe per tonne in 1980 to 0.35 toe per tonne in 1998. In Japan, where energy intensity for iron and steel has been traditionally low, intensity hovered around 0.45-0.46 toe per tonne of steel during the study period. In New Zealand and the Philippines, energy intensities fluctuated sharply. Energy intensities moderately trended upwards in Peru and Russia. Viet Nam has the lowest energy intensity among APEC economies. The iron and steel industry in Viet Nam may not be involved in primary ore processing and may instead reprocess steel products.

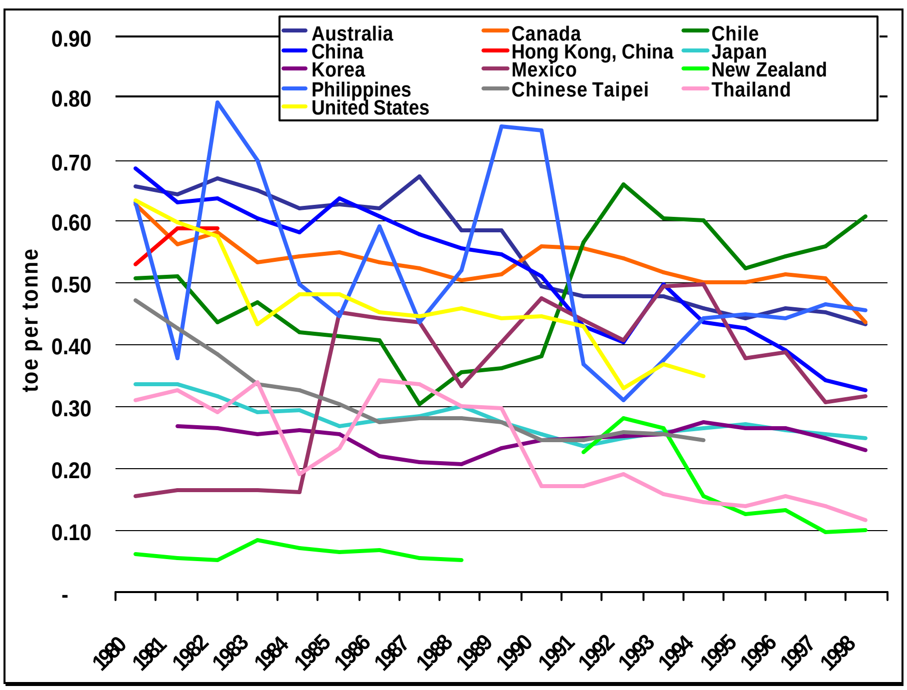
PULP AND PAPER INDUSTRY

To be able to fully understand the patterns of energy use in the pulp and paper industry, an examination of the production process is necessary. In the first step of the production process, wood is prepared then converted into pulp. Producing pulp or reducing wood to fibre is energy intensive and can be achieved through a mechanical process, a chemical process or a combination of the two. The pulp is bleached then formed into a mat of board, paper or pulp before being dried. Drying is also an energy intensive process.

The mechanical process for producing pulp uses electricity while the chemical process consumes thermal energy. In 1986, Canada and the United States used the chemical process for 75 percent of all pulp produced, mechanical pulping for about 20 percent and a combined process for the remaining 5 percent. In recent years, a process called thermo-mechanical has increased in popularity in both economies. This process is used to produce lower grade paper for newsprint. Recycled waste paper requires less energy to re-form than does virgin wood. Japan is a leader in using recycled paper to produce new products.

Figure 12 shows physical energy intensity for the pulp and paper sector in selected APEC economies. Energy intensity is declining in all economies except for Mexico where there was a sharp increase in 1985 and a moderate upward trend until the close of the period. There was a sharp increase in energy intensity of Chile's pulp and paper sector in 1991 but the following year it returned to its previous growth path.

**Figure 12 Energy Intensities for Pulp and Paper Production**

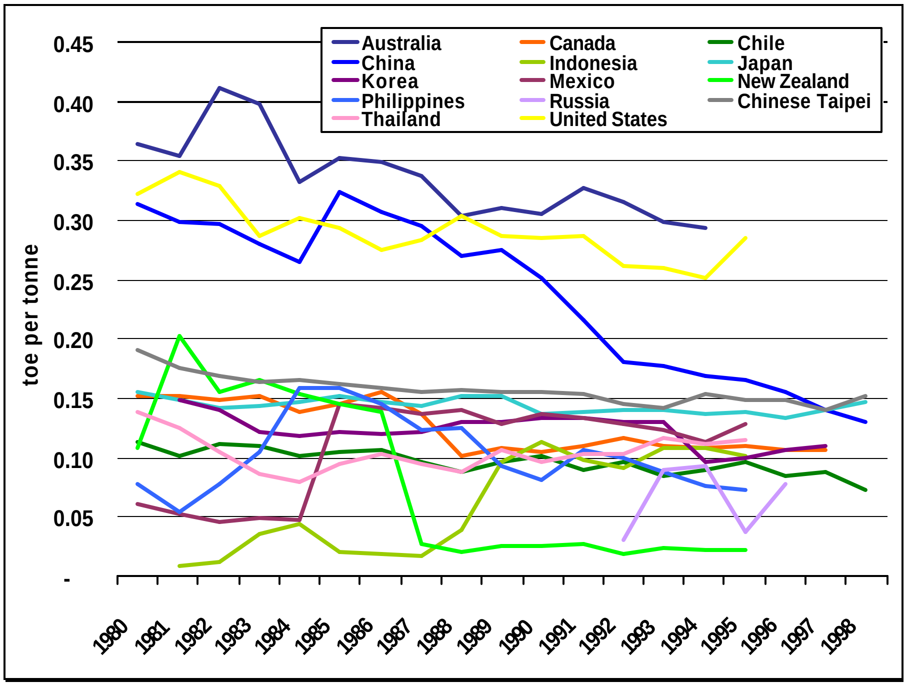



Source APERC, 2000a

## CEMENT INDUSTRY

Energy is a major input in cement production, it accounts for 20 to 50 percent of total production costs. Producing clinker, which is then ground into cement, is the most energy intensive process in cement production. Clinker can be produced using a wet process or a dry process, with variations (semi-wet and semi-dry). The wet process is more energy intensive because it requires large quantities of heat for pyro-processing. The dry process, using a long rotary kiln, requires less energy. Introducing pre-heaters to the kiln feed and adding pre-calciners in the dry process reduce the energy requirements in cement production. Most APEC economies use the dry process.

**Figure 13 Energy Intensities for Cement Production**




Source APERC, 2000a

As shown in Figure 13, in general, energy intensity declined in the APEC region over the period 1980 to 1998. For the ten APEC economies for which there are data, intensity fell from 0.12 toe per tonne in 1981 to 0.10 toe per tonne in 1995. Australia, USA and China have the highest specific energy consumption (SEC) levels ranging around 0.3 toe per tonne to 0.4 toe per tonne, considerably higher than most economies where SECs are between 0.05 toe per tonne and 0.2 toe per tonne. China however managed to decrease its SEC to 0.13 in 1998.

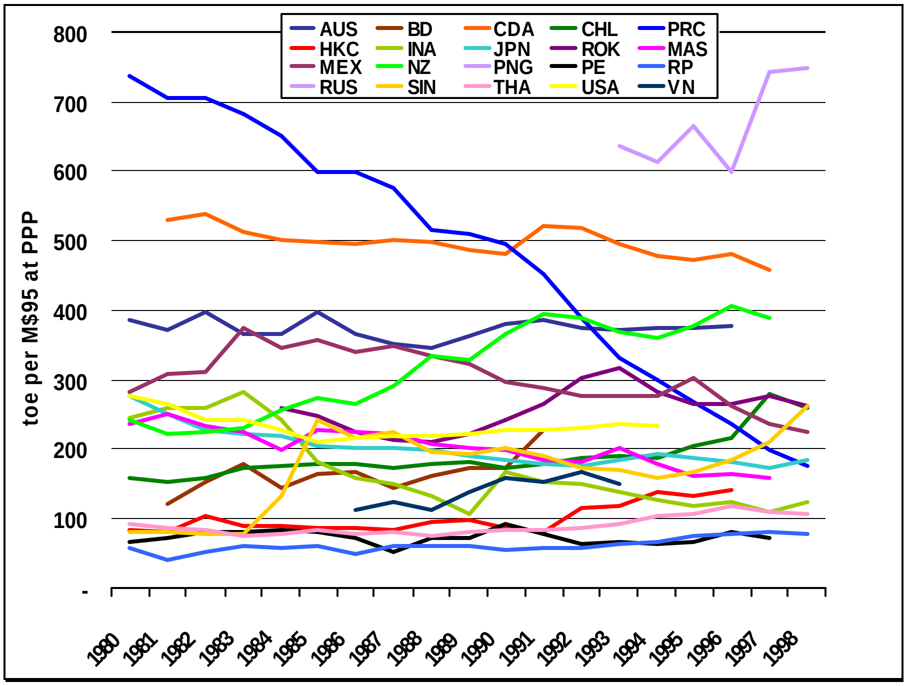
## ECONOMIC INDICATORS

Unlike iron and steel, cement and pulp and paper, the physical outputs of other manufacturing industries are more heterogeneous, therefore GDP data were used to construct energy indicators. All GDP data are presented in 1995 international dollars at purchasing power parity.[9] Results are shown in Figure 14.

Results show that China has the highest energy consumption per unit of output at more than 700 toe per M$95 at PPP[10] of GDP in 1980. This however dropped to less than 200 toe per M$95 at PPP in 1998. Russia had an energy intensity of about 186 toe per M$95 at PPP in 1994 but this increased to 492 toe per M$95 at PPP in 1998. Brunei Darussalam had the lowest energy intensity due to its small manufacturing base.

The seven OECD APEC member economies had energy intensities ranging from 183 toe per M$95 at PPP for Japan, to 457 toe per M$95 at PPP for Canada.

**Figure 14 Final Energy Intensity for Manufacturing**




Source APERC, 2000a

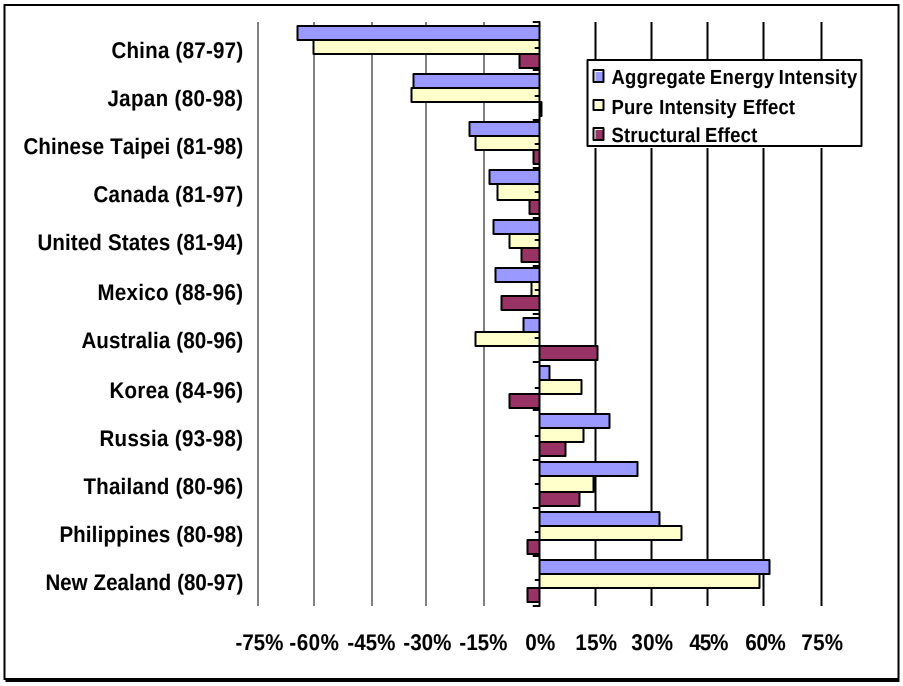
Developing economies in Southeast Asia and Latin America had lower energy intensities, about 100 toe per M$95 at PPP, compared to the developed economies in the APEC region.

## DECOMPOSITION ANALYSIS OF CHANGES IN ENERGY INTENSITIES

Decomposition analysis was carried out for only 12 of the 21 APEC economies using the Divisia parametric technique. There was inadequate disaggregated energy consumption and GDP data for the nine remaining economies. Results for the economies with good disaggregated data are presented in Figure 15.

Energy intensity was decomposed into a structure effect and a pure intensity effect. The structure effect measures changes in intensity, which were induced by changes in the composition of manufacturing sub-sectors. Economies producing large amounts of energy-intensive products like iron and steel, non-ferrous metals and cement are expected to consume more energy per unit of output than economies with structures favouring less energy-intensive industries like electronics and textile industries. In general, if the structure effect is positive, the GDP share of energy intensive industries has increased compared with the base year. If the structure effect is negative, then energy intensive industries have a smaller share of GDP output than in the base year. The pure intensity effect measures improvements in energy efficiency, changes in technology, fuel mix changes as well as any other factor which is not related to activity or structure. If this effect is positive, then energy use per unit of GDP has increased which may imply worsening energy efficiency. A negative pure intensity effect points to improvements in energy use per unit of GDP.

**Figure 15 Decomposition Results for Manufacturing Energy Intensities**[11]




Note Derived from APERC, 2000a

CHINA

China's aggregate energy intensity has decreased by - 64.6 percent from 1987 to 1997. Of this decline, - 5.2 percent can be attributed to the structure effect while - 60.2 percent was attributed to the pure intensity effect. Further, the energy intensities of energy-intensive industries such as iron and steel (from 1.28 toe per tonne in 1980 to 0.35 toe per tonne in 1997), cement (from 0.31 toe per tonne to 0.13 toe per tonne) as well as pulp and paper (from 0.68 toe per tonne to 0.33 toe per tonne) have significantly declined. All manufacturing branches in China reduced their energy intensities from - 43 percent (chemical and petrochemical industries) to - 70 percent (machinery) during the 1987 to 1997 period.

The structure effect is largely due to growth in the less energy intensive machinery and transport equipment industry. This sub-sector's share of total manufacturing GDP increased from 13.3 percent in 1987 to 24.5 percent in 1997. Further, this traditionally less intensive manufacturing branch reduced its specific energy consumption (SEC) from 329.6 toe per M$95 at PPP in 1987 to 65.3 toe per M$95 at PPP in 1997.

JAPAN

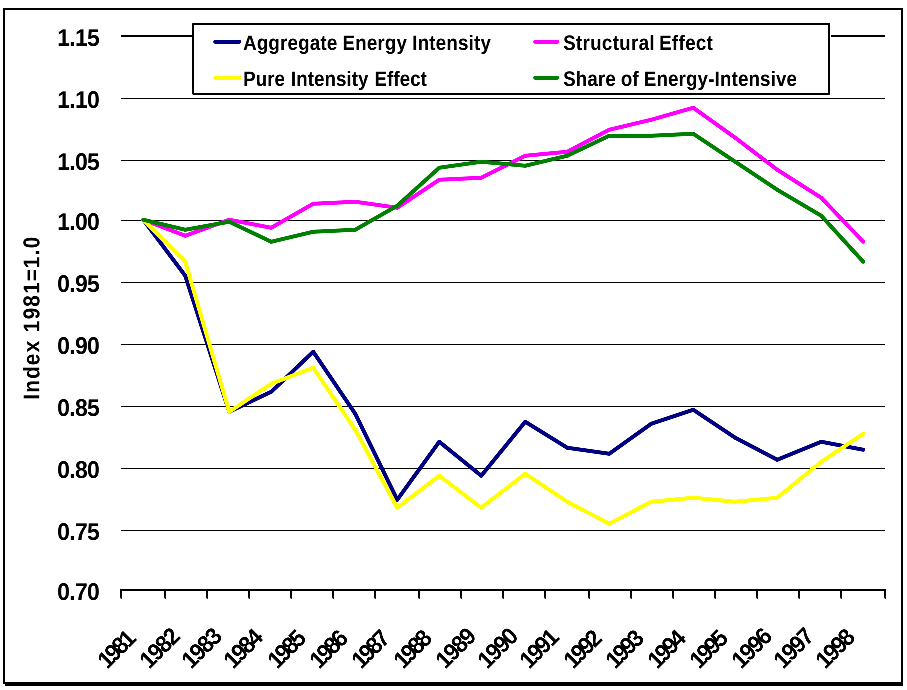
Aggregate final energy intensity in Japan declined by - 33.9 percent from 1980 to 1998. Growth in manufacturing GDP of 3.0 percent per year surpassed the 0.7 percent growth in final energy consumption. The pure intensity effect was - 34.2 percent. The decline in the final energy intensities of the energy-intensive industries such as iron and steel (- 27 percent), non-metallic minerals (- 32 percent), chemicals (- 52 percent) as well as pulp and paper (- 48 percent) contributed to this result. The pure intensity effect would have been larger if it had not been offset by increases in the intensities of less energy intensive sectors such as machinery (44 percent), food, beverages and tobacco (15 percent) and textiles, leather and clothing industries (5 percent). The structure effect was small at 0.5 percent.

CHINESE TAIPEI

The aggregate energy intensity of Chinese Taipei decreased by - 18.6 percent from 1981 to 1998. It was above the 1980 level from 1987 to 1996 due to an increase in the share of energy-intensive industries. The structure effect, not pure intensity pushed up aggregate energy intensity in this economy (see Figure 16). When the share of energy-intensive industries declined in 1997 and 1998, the gap between aggregate and pure intensity narrowed. The shift to less energy-intensive industries or a negative structure effect resulted in a - 1.7 percent reduction in energy intensity, the pure energy intensity effect was much larger at - 17.5 percent.

The pure energy intensity effect was influenced by declining SECs in three energy-intensive industries, iron and steel, cement and pulp and paper industries, which fell by - 0.05 toe per tonne, - 0.04 toe per tonne and - 0.22 toe per tonne, respectively.

**Figure 16 Decomposition of Manufacturing Intensity for Chinese Taipei**




Note Derived from APERC, 2000a

CANADA

Canada's manufacturing industry is the most energy-intensive among the OECD APEC economies. From 1981 to 1997, Canada realised a - 13.4 percent decline in aggregate energy intensity where pure intensity and structure effects accounted for - 11.1 percent and - 2.6 percent, respectively. Large declines in the energy intensities of the non-ferrous and chemical industries likely contributed to the observed intensity effect. Moreover, the SECs of iron and steel, cement and pulp and paper industries declined by - 0.06 toe per tonne, - 0.04 toe per tonne and - 0.21 toe per tonne, respectively.

UNITED STATES OF AMERICA

Aggregate energy intensity in the United States decreased from 275.5 toe per M$95 at PPP in 1980 to 232.8 toe per M$95 at PPP in 1994 for an aggregate energy intensity reduction of - 12.2 percent. The pure intensity effect was responsible for - 8.2 percent while the structure effect accounted for - 4.5 percent. The pure energy intensity effect was derived from declines in SECs for iron and steel (- 0.17 toe per tonne), cement (- 0.03 toe per tonne) and pulp and paper (- 0.28 toe per tonne) industries over the study period. Structural changes resulted from reductions in the share of energy intensive industries, iron and steel industry (- 3 percent), non-metallic minerals (- 1 percent) and pulp and paper industries (- 2 percent) and the increase in the share of machinery (11 percent), a less energy intensive industry.

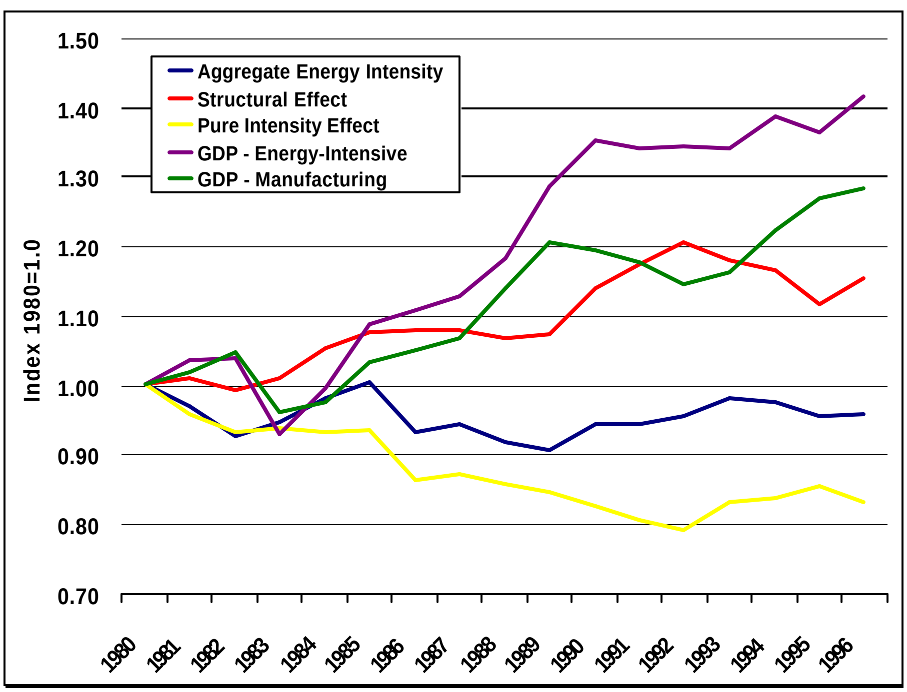
MEXICO

Aggregate energy intensity in Mexico fell by - 11.8 percent over the study period. In this economy, the structure effect was responsible for a - 10.0 percent decline in intensity or a shift to less energy intensive manufacturing branches. Likewise, pure energy intensity, declined by - 2.1 percent. In contrast, the SECs increased for the pulp and paper (0.17 toe per tonne) and cement (0.07 toe per tonne) industries over the study period.

AUSTRALIA

In Australia, the structure and pure intensity effects offset each other at 15.2 percent and -16.9 percent, respectively. Energy intensive sectors namely non-ferrous (from 4 percent to 7 percent) and chemicals (from 6 percent to 8 percent), increased their shares of total manufacturing GDP from 1980 to 1996. However, the energy intensities of individual branches decreased sharply resulting in an aggregate energy intensity improvement of 4.2 percent (see Figure 17). The pure energy intensity effect was likely influenced by the - 0.13 toe per tonne, - 0.07 toe per tonne and - 0.23 toe per tonne decreases in the SECs of the iron and steel, cement as well as pulp and paper industries.

**Figure 17 Decomposition of Manufacturing Intensity for Australia**




Note Derived from APERC, 2000a

As shown in Figure 17, GDP for energy-intensive industries grew quickly relative to total manufacturing resulting in a positive structure effect.

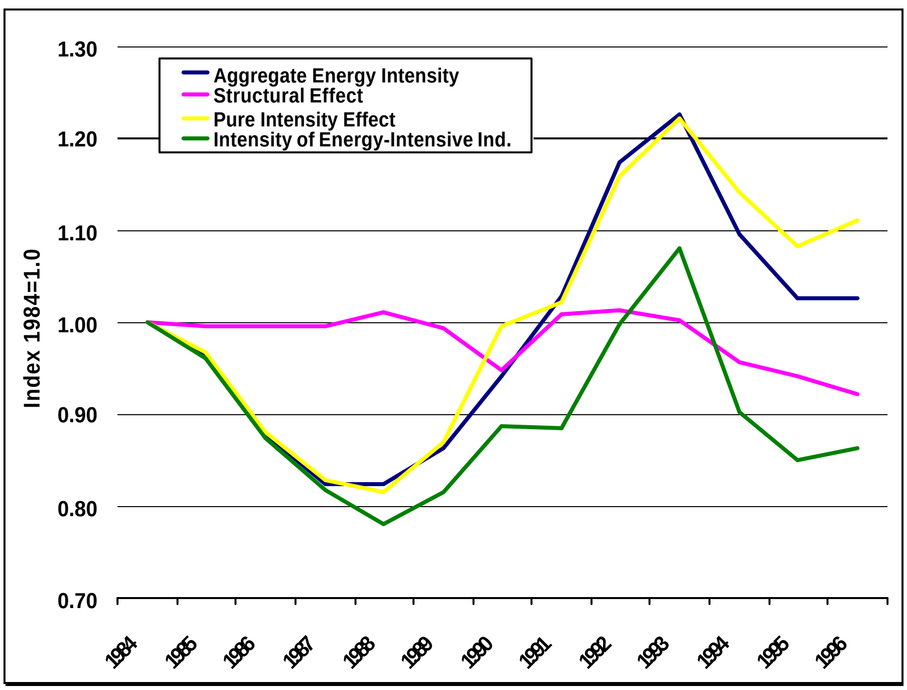
REPUBLIC OF KOREA

Aggregate energy intensity in Korea trended downward from 1984 to 1992. Intensity changed direction after 1992 and by 1996, it had surpassed the 1980 level. Overall, aggregate energy intensity in Korea increased by 9.6 percent. The structure effect was -4.2 percent while the pure energy intensity effect was measured at 11.4 percent.

Over the study period, there has been a shift towards less energy-intensive industries. Machinery increased its share of total manufacturing GDP by 16 percent from 1984 to 1996. The declines in the SECs of the iron and steel industry of - 0.12 toe per tonne and the cement industry of - 0.01 toe per tonne failed to pull down the pure energy intensity effect.

Figure 18 shows energy intensity decomposition results for Korea. There were rapid increases in aggregate energy intensity from 1988 to 1993, which occurred in tandem with rising energy intensities in energy-intensive industries. When energy intensities in these industries sharply fell in 1994, there was a corresponding sharp decline in the aggregate energy intensity.

**Figure 18 Decomposition of Manufacturing Intensity for Korea**




Note Derived from APERC, 2000a

THAILAND

Thailand's economy has been growing quickly over the period 1980 to 1996. Manufacturing GDP increased by an annual rate of 10 percent while energy consumption increased by 11.6 percent. Decomposition analysis showed that aggregate energy intensity increased by 26.5 percent with the structure effect accounting for 10.7 percent and the pure energy intensity effect for 14.5 percent. Except for the pulp and paper industry, which reduced energy intensity by 2.2 percent, energy intensity increased in all other manufacturing branches. Thailand's economy experienced a long period of prosperity which was abbreviated by the Asian Financial Crisis of 1997.

### PHILIPPINES

From 1980 to 1998, aggregate energy intensity in the Philippines rose by 32.2 percent. According to decomposition analysis, the structure effect accounted for - 3.2 percent while the pure intensity effect was 37.9 percent. The pure intensity effect, mainly increases in the energy intensities of individual manufacturing branches, was the main driver of this result. Initially, manufacturing structure shifted to less energy-intensive industries but this trend reversed and by 1997, the industrial structure had reverted back to the 1980 structure. In 1998 however, a shift to less-energy intensive industries was observed. A recession induced by the Asian Financial Crisis in 1997, may have led to a decline in production by energy-intensive sectors.

### RUSSIA

The aggregate energy intensity of Russia increased by 35.6 percent. The pure energy intensity effect accounted for 24.7 percent of the aggregate energy intensity while the structure effect made up 9.6 percent. Except for the food and tobacco industry, energy intensity increased in all manufacturing branches.

In terms of SECs, energy consumption in the iron and steel industry jumped from 0.44 toe per tonne in 1992 to 0.84 toe per tonne in 1997. Cement industry increased by 0.05 toe per tonne, while pulp and paper decreased by - 1.17 toe per tonne.

### NEW ZEALAND

Overall, manufacturing energy intensity in New Zealand increased by 61.2 percent from 1980 to 1997. The pure intensity effect was 43.7 percent while the structure effect was - 4.8 percent. Total manufacturing energy consumption increased by 4.5 percent per year while GDP increased by only 1.6 percent. Except for the non-metallic minerals and food and tobacco industries, energy intensities in all other manufacturing branches increased from 1980 levels. The negative structure effect implies a shift towards less energy intensive industries.

On the basis of SEC, New Zealand's iron and steel and cement industries made significant improvements in energy intensities. The SEC of the iron and steel industry decreased by - 0.47 toe per tonne while that of the cement industry declined by - 0.09 toe per tonne.

## MINING AND QUARRYING: OVERVIEW

Though a small component of industrial energy consumption in the APEC region, mining and quarrying is an important industry in some APEC economies. In the Philippines, for example, this industry accounted for 22 percent of industrial energy consumption in 1998. In Indonesia, Thailand and Viet Nam these shares were 10 percent, 12 percent and 18 percent, respectively. The mining and quarrying industry involves the extraction of oil, coal, natural gas and mineral resources such as iron ore, gold, silver, copper, zinc, lead and aluminium.

Many economies do not collect separate energy and GDP information for this sub-sector. Due to this lack of data, energy intensities for only 12 of the 21 APEC economies could be calculated. Some of the economies left out of this analysis are important mining and quarrying producers. For instance, neither energy consumption nor GDP data is available for the oil and natural gas exporting economies of Malaysia and Brunei. China, with a large coal industry and significant deposits of metallic and non-metallic minerals has a large mining and quarrying sector, but no separate GDP data is available for this segment. The analysis presented in this section is therefore incomplete.

The structure of mining industries varies from economy to economy. In order to make meaningful comparisons across economies, disaggregated data for all mining sub-sectors is required. Since this sort of detailed GDP data is not available, aggregate mining and quarrying intensities are calculated, but no decomposition into structure and pure intensity effects is attempted. Table 3 provides a cross-section of mining production in selected APEC economies.

**Table 3 Production of Minerals in 1996**

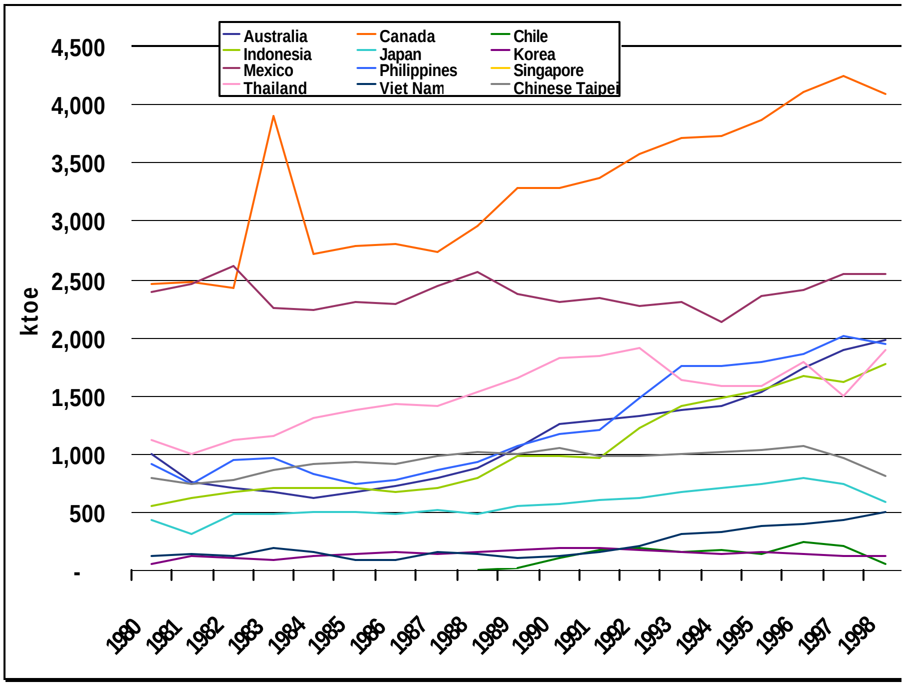
| Economy | Aluminium | Copper[1] | Gold | Lead | Nickel | Silver | Zinc | Tin |
|---|---|---|---|---|---|---|---|---|
| | | | thousand metric tonnes | | | | | |
| Australia | 1,366 | 314 | 0.29 | 231 | 73 | 1.02 | 326 | |
| Canada | 2,283 | 559 | 0.17 | 305 | 127 | 1.31 | 716 | 4 |
| Chile | | 1,712 | 0.05 | | | 1.13 | | |
| Indonesia | 221 | | 0.07 | | 9 | 0.23 | | 2 |
| Japan | 17 | 1,251 | | 285 | 130 | 0.09 | 599 | 27 |
| Korea | | 244 | | 140 | | | 287 | 11 |
| Mexico | 62 | 198 | 0.02 | 228 | | 2.50 | 223 | 3 |
| Philippines | | 156 | | 17 | | 0.03 | | |
| Chinese Taipei | 62 | | | 36 | | | | 7 |
| Thailand | | | | 20 | | | 72 | 6 |
| percent APEC | 46.4 | 64.9 | 55.2 | 58.3 | 42.8 | 73.6 | 52.8 | 61.0 |

Source World Metal Statistics Yearbook 1997, World Bureau of Metal Statistics.
Note [1] Refers to production of refined products and not to fine copper equivalent (copper content).

The mining and quarrying sector in Canada has the highest final energy consumption among the 12 economies reported. Canada is a large oil and gas exporter and one of APEC's largest producers of metals like aluminium, copper and zinc (see Table 3 and Figure 19). Mexico, which is also an oil and gas exporter, is second while the Philippines and Australia are third.

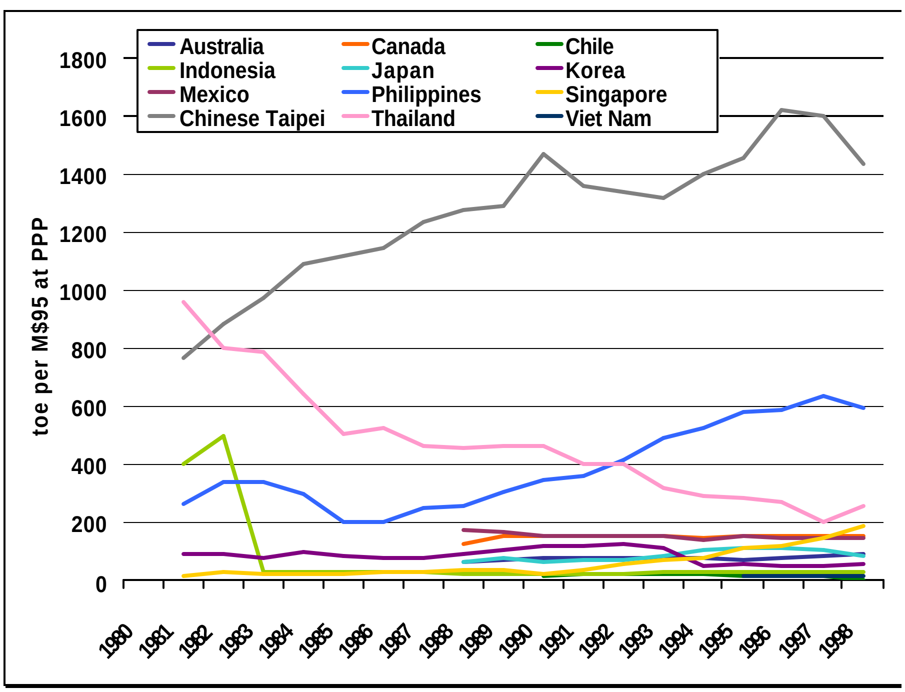
Chinese Taipei had the highest mining and quarrying energy intensity among the 12 economies (see Figure 20). However, this is not conclusive as the GDP used in the calculation was based on exchange rates and not on PPP. After Chinese Taipei, the Philippines is the most energy-intensive mining economy at 600 toe per M$95 at PPP. Thailand is third at about 260 toe per M$95 at PPP. The remaining 9 economies have energy intensities less than 200 toe per M$95 at PPP. Again, in view of the absence of more disaggregated data, no conclusion could be deduced from the calculated energy intensities. Mining some types of minerals is more energy-intensive than others and the structure of mining sub-sectors may have a significant impact on aggregate energy intensity. The absence of information on the mix of mining and quarrying products makes cross-economy comparisons impossible.

**Figure 19 Mining and Quarrying Final Energy Consumption**




Source APERC, 2000a

**Figure 20 Mining and Quarrying Energy Intensity by Mining and Quarrying GDP**




Source APERC, 2000a

## INDUSTRIAL CARBON DIOXIDE EMISSIONS

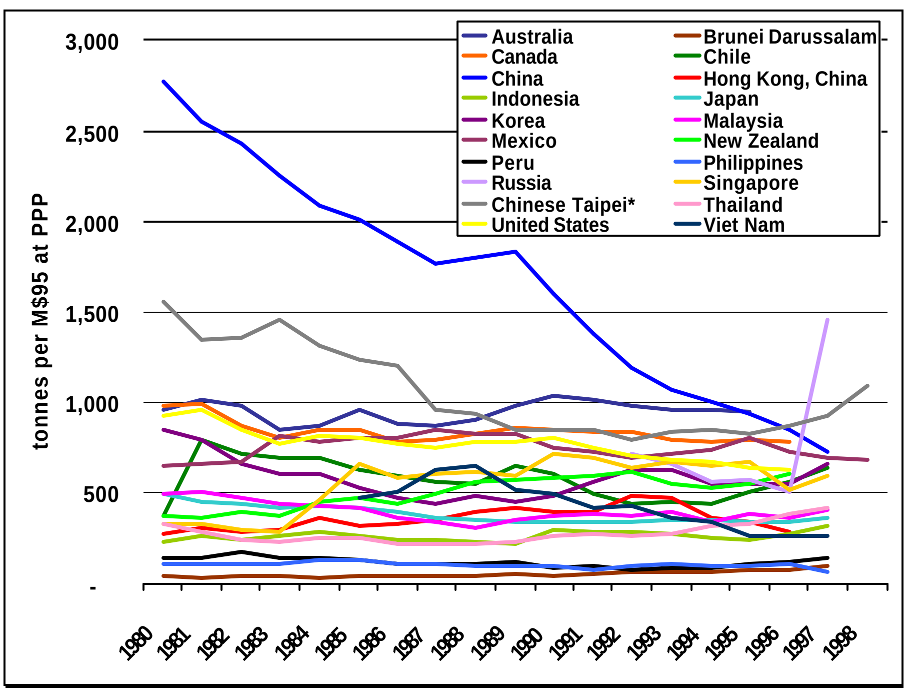
As the industrial sector expanded during the study period, energy consumption and $CO_2$ emissions increased. Though GDP expanded at an average annual rate of 4.3 percent, energy use and $CO_2$ grew more slowly at 0.9 percent and 1.9 percent per year, respectively.

China's industrial sector is the biggest emitter of $CO_2$ in the APEC region, accounting for 33.4 percent of the APEC total or 1,536 million tonnes in 1998. The USA was next with 27.9 percent and 1,282 million tonnes. Russia was a distant third at 10.3 percent and 473 million tonnes of emissions.

In terms of $CO_2$ emissions per unit of industrial GDP or carbon intensity, at the beginning of the period, China had the highest intensity at 2,766 tonnes per unit of GDP, but this figure declined to 724 tonnes by 1997 (Figure 21). Russia has become the most $CO_2$-intensive economy in 1998 at 1,456 tonnes per unit of GDP. Chinese Taipei's carbon intensity is the second highest in APEC. However, in the absence of PPP data, GDP in Chinese Taipei was converted using exchange rates and may not be directly comparable to other economies.

On average, $CO_2$ intensities in APEC industries declined by 24.6 percent from 1980 to 1995. Over the study period, at the secondary level, economies have been substituting away from coal towards other fossil fuels with lower carbon contents. Coal's contribution to the energy mix in industry fell from 77.8 percent in 1980 to 67.2 percent in 1997. Moreover, there have been sharp declines in energy intensities in some of the larger energy consuming economies. These factors have contributed to the decline in overall carbon intensity in the APEC region.

**Figure 21 Industrial Carbon Dioxide Intensity by Industrial GDP**




Source APERC, 2000a; IEA, 1998

Note In the absence of PPP data, Chinese Taipei's GDP was based on exchange rates.

Rapid economic growth, however, led to increases in energy consumption and higher carbon intensities in some APEC economies over the study period. Carbon intensities grew by 2.1 times in Brunei Darussalam, Russia (2.0), Singapore (1.8), Chile (1.7), New Zealand (1.6), Indonesia (1.4), and Thailand (1.3). Carbon dioxide intensities in three other economies, HKC, Mexico and Peru increased minimally. Since these economies are relatively small, they had little impact on the overall downward trend in intensities observed across the APEC region.

## CONCLUSIONS

Collective manufacturing energy productivity in the APEC region has been improving since 1980. Manufacturing GDP has been increasing more quickly than energy consumption in most economies. This trend is particularly striking in developing economies like China and Chinese Taipei. The large declines in pure intensity imply significant energy efficiency improvements over the study period.

In Korea, New Zealand, the Philippines, Russia and Thailand, however, aggregate energy intensities have been increasing. In industrialising economies such as Korea (0.9 percent per year) and Thailand (0.9 percent), pure intensity has been growing, but relatively slowly compared to intensities in the services and transportation sectors.

Energy intensity can be decomposed into structure and pure energy intensity effects. An upward or downward trend does not necessarily mean an economy is using energy less or more efficiently. Structural changes may be playing a role in observed trends. Other factors, such as technology changes and fuel mix effects, which are captured in the pure intensity effect, cannot be isolated due to inadequate data. A more vigorous data collection is required to improve the quality of data for individual manufacturing branches. Such output and energy consumption data would permit a more detailed analysis of key industrial branches.

In most economies, physical and monetary indicators for energy intensive industries move together or at least in the same direction. In some economies, such as Mexico and New Zealand, no apparent relationship could be established between the two indicators. Additional investigation is required to explain this apparent contradiction. In theory, SEC is a better indicator than is a monetary-based intensity. To decompose the SEC intensity, however, would require more detailed disaggregated data and these data are simply not available.

# CHAPTER 5

## TRANSPORTATION ENERGY EFFICIENCY INDICATORS

### OVERVIEW

The transportation sector comprises all activities related to the movement of passengers and freight. There are four different modes of transportation: road, air, rail and navigation.[12, 13]

In 1998, the transportation sector in all APEC economies consumed nearly 1 Gtoe of energy.[14] This sector accounted for nearly 30 percent of total final energy consumption, second only to industry [IEA, 2000a]. This sector is also one of the fastest growing, both in developed and developing economies. These factors, in addition to associated problems of congestion, local air pollution and GHG emissions, explain why transportation is attracting significant attention from policy-makers.

Energy consumption in transportation can be influenced by a variety of economic, social and political factors including technology, lifestyle changes, government policy, urban planning and others. Analysis of transportation issues is therefore particularly complex, especially when designing and assessing policies to alter energy consumption patterns.

This chapter presents energy consumption trends and associated indicators for the APEC transport sector, with a discussion of some of the driving forces behind them. Given its relative importance in terms of energy consumption, this analysis focuses mainly on road transportation. Though important in many economies, non-motorised transport and international transport were not included due to lack of information.

### ENERGY CONSUMPTION TRENDS

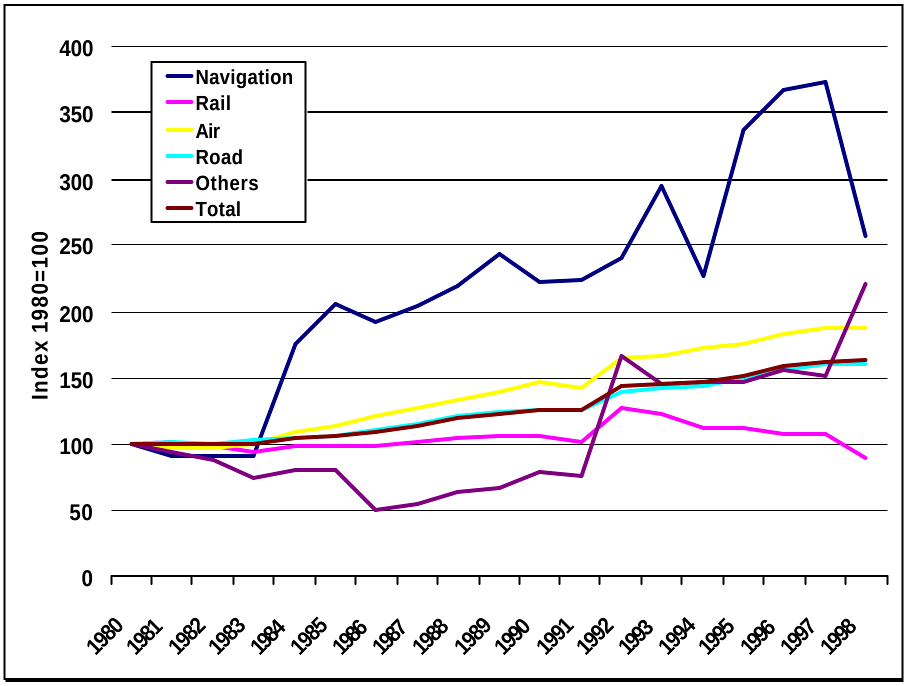
#### AGGREGATE MODAL TRENDS

In the period 1980 to 1998, total energy consumption for transport in the APEC region grew at an average annual rate of 2.8 percent, reaching nearly 1 Gtoe by the end of the period. As Figure 22 shows, internal navigation and air transport have experienced the fastest growth. Consumption by the rail sector, however, was fairly flat until 1991 when Russian data were added. The downward trend after 1992 is due mainly to declining demand in Russia.

Road transportation is the dominant mode in this sector. It accounted for 77 percent of the 1998 APEC total, a figure that has been fairly stable during the period of analysis. Air transport was responsible for 13 percent, rail for 3 percent, navigation for 1 percent and other uses for 6 percent [IEA, 2000a]. The modal shares cited are an APEC average and may not be representative of all economies in the region.

The road sector can be broken down further into energy consumption for passenger travel and for freight. Due to data limitations, energy consumption for these two sub-categories is unavailable for APEC as a whole; however, data from selected economies show that passenger travel accounts for almost two-thirds of road consumption (the figure is nearly 60 percent in Canada [NRCan, 2000] and 64 percent in Japan [EDMC, 2000], both in 1998).

**Figure 22 Transport Energy Consumption Growth by Mode**




Source IEA, 2000a

## AGGREGATE ENERGY MIX TRENDS

Gasoline is the main fuel used in transport, with nearly a 60 percent share in 1998 (see Figure 23). Diesel, however, is gaining share at the expense of gasoline. Its share of total consumption increased from approximately 20 percent to 25 percent during the study period. An increase in the stock of large trucks for use in the freight sector, is behind this shift to diesel [IEA, 1997].

Aviation fuel (mainly jet kerosene) is in third place at 13 percent, after motor gasoline and diesel. Natural gas, used mainly in cars and buses, increased its market share in the latter part of the period securing fourth place by 1998. Electricity, used mainly in rail transport, accounts for approximately 1 percent.

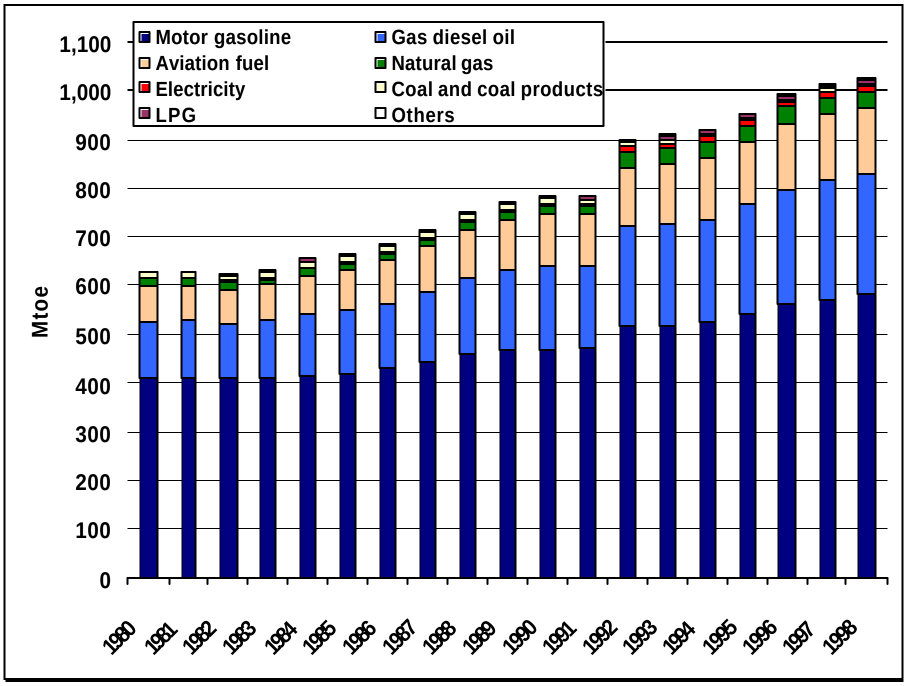
Russia uses the broadest range of transportation fuels - albeit the less common ones account for a lower percentage of the total.

## GLOBAL TRENDS BY ECONOMY

### TRANSPORT ENERGY CONSUMPTION

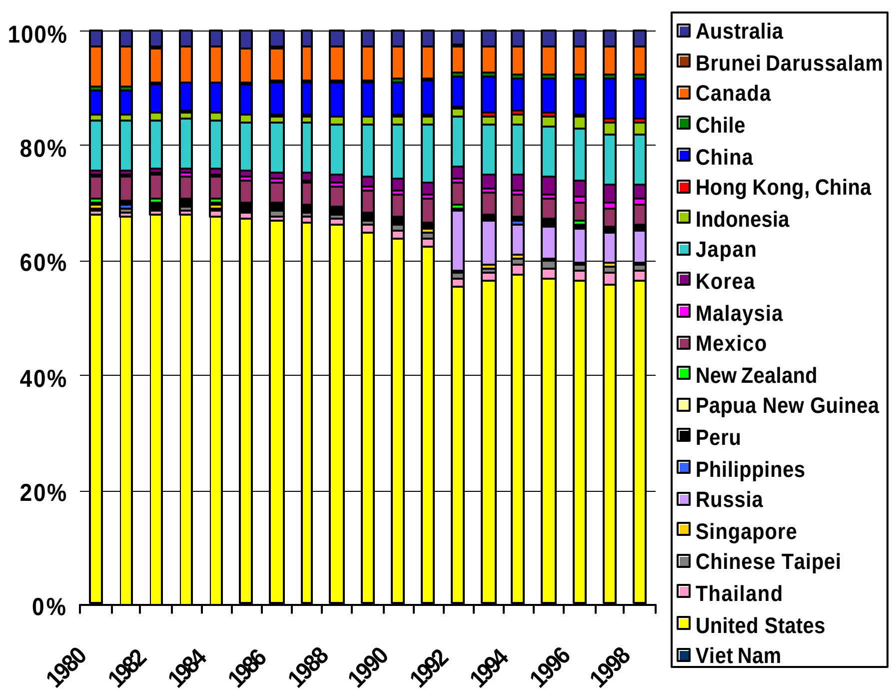
The United States accounts for a significant, but generally declining, percentage of transport energy consumption among APEC economies (see Figure 24). At the beginning of the 1980s, its share was nearly 68 percent, falling to 64 percent by 1990, and further declining to around 55 percent after 1992 when Russian data are included. As the figure below shows, in 1998 Japan was the second most important transport energy consumer in APEC, with a 9 percent share for most of the period. China was in third place, with a 7 percent share. As in other sectors, Russia, in fourth place with 5 percent, shows a significant reduction in its energy consumption during the period where data are available (1992-1998).

## Figure 23 Transport Energy Consumption by Fuel




Source APERC, 2000a

## Figure 24 Transport Energy Consumption Share by Economy

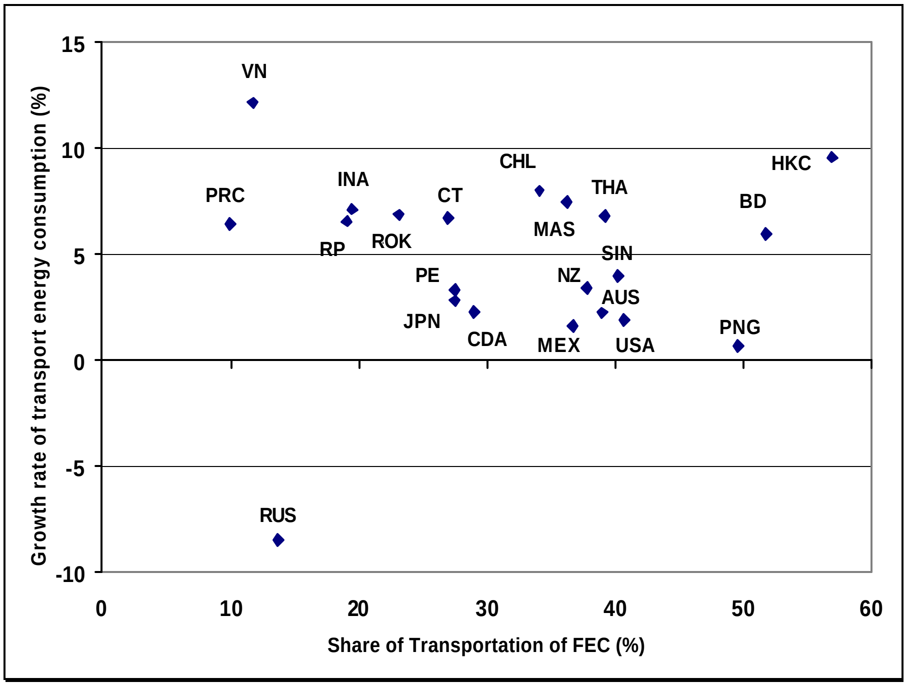



Source APERC, 2000a

## IMPORTANCE OF TRANSPORTATION IN FINAL ENERGY CONSUMPTION

As can be inferred from Figure 24, energy consumption growth rates are different for each APEC economy. When average annual growth rates for the period 1990-1998 are plotted against the transportation share of total final energy consumption (in 1998), distinct groups can be identified (see Figure 25).

**Figure 25 Transportation Share (1998) and Transportation Energy Consumption (1980-98)**




Source APERC, 2000a

Note Due to data limitations, Russia's annual average growth rate was calculated for the period 1992-1998.

China and Viet Nam form the first group, where energy consumed in transportation accounts for a comparatively low share in final energy consumption. However, this sector is growing very quickly in both economies; Viet Nam (12.2 percent per annum on average for the period) had the highest growth rate in APEC. Therefore, provided that current high growth rates persist, this sector will play an increasingly important role in both economies.

The Chinese situation is particularly relevant. China is currently the third largest energy consumer in transportation after the US and Japan. Consumption, however, is growing at double the rate of these more mature economies. If 1990-1998 growth rates were to be maintained for these three economies, then China could surpass Japan in transport energy consumption as early as 2005-2006, and perhaps reach US consumption levels by 2045-2046.

Economies where transportation makes up 20-40 percent of final energy consumption can also be grouped together. Two sub-groups can be identified: (a) those economies with a high annual growth rate, in the range of 6 to 8 percent (Chile, Indonesia, Korea, Malaysia, the Philippines, Chinese Taipei and Thailand), and; (b) those economies with a growth rate of less than 4 percent (Australia, Canada, Japan, Mexico, New Zealand, Peru, Singapore and the United States).

Brunei Darussalam, HKC[15] and Papua New Guinea make up a third group where transportation is the single most important energy consuming sector. Though their individual situations may differ, changes in consumption levels have a significant impact on overall energy demand in these economies. Brunei Darussalam and HKC exhibit some of the highest growth rates in the region, while Papua New Guinea has one of the lowest. As an oil producer and exporter, Brunei Darussalam may be better able to cope with rapidly increasing fuel demand than Hong Kong, China which imports all of its oil.

Finally, Russia falls into a category of its own. The share of transport energy consumption is among the lowest in APEC, and as with other sectors in this economy, consumption is falling quickly (at an - 8.5 percent yearly average for the period 1992-1998).

## PER CAPITA TRANSPORT ENERGY CONSUMPTION

Population-weighted average per capita transportation energy consumption in APEC in 1997 was approximately 450 toe per thousand people. In that year, the United States had the highest consumption per capita at 2,315 toe per thousand people, while Papua New Guinea had the lowest at 49 toe per thousand inhabitants or a difference of 48 times. Figures 26 and 27 show the evolution of this indicator during the study period.

Similar patterns in energy consumption per capita in North American economies are particularly noticeable. Economic cycles, technological developments, regulations and lifestyles in the United States appear to have a decisive influence on neighbouring economies, particularly Canada.

Energy per capita grew quickly in Korea and Chinese Taipei. Since 1980, this indicator has nearly tripled in both economies. Except for a sharp drop in consumption in 1998, probably the result of the 1997 financial crisis, Korea appears to be asymptotically approaching the Japanese level of energy per capita.

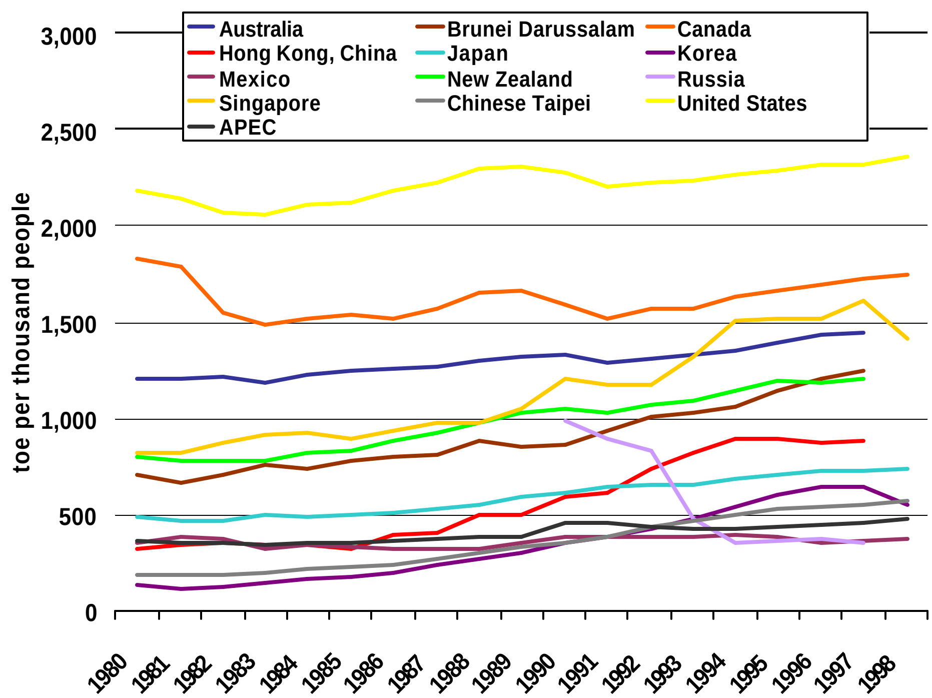
In Singapore, energy consumption per thousand people doubled between 1980 and 1997. Like Korea, this indicator declined in 1998 due to the impact of the 1997 financial crisis. In 1993, Singapore displaced Australia as the third highest consumer of energy per capita.

Transportation energy per capita in Chile, Malaysia and Thailand grew by 1.9, 2.4 and 3.9 times respectively, during the period. In this second group of economies, this indicator rapidly approached the APEC average. A recession in Chile in the early 1980s explains a moderate decline in energy use per capita during this same period.

Though China was the third most important transportation energy consumer in 1997, it had the third lowest per capita consumption level in the region at 60 toe per thousand people. At approximately 13 percent of the APEC average, the level of this indicator signals considerable growth potential for the transportation sector in China.

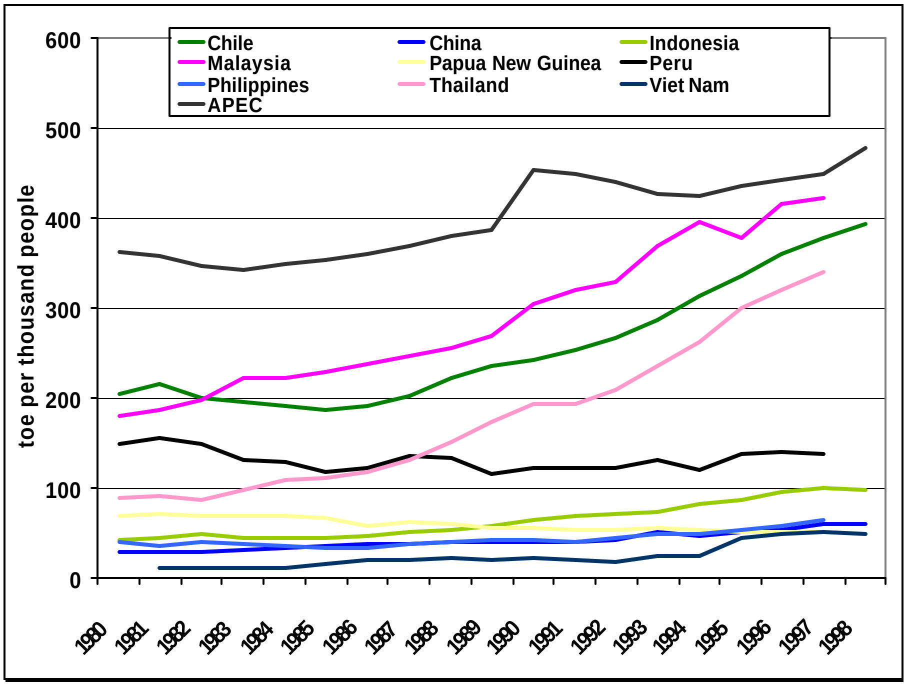
Only four APEC economies had lower per capita consumption levels in 1997/98 than in 1980. In Canada, reductions from 1980 to 1983 were significant, however these declines were almost completely offset by increases during the 1990s. Russia's indicator fell by almost 65 percent in the first half of the 1990s, but stabilised in the final years of the study period. Energy per capita in Peru drifted downwards until 1994, but trended upwards in the last few years of the study period. In Papua New Guinea, the energy indicator at the end of the period was only 70 percent of the 1980 level.

**Figure 26 Transport Energy Consumption per capita, Group 1**




Source APERC, 2000a

**Figure 27 Transport Energy Consumption per capita, Group 2**




Source APERC, 2000a

## TRANSPORT ENERGY INTENSITY

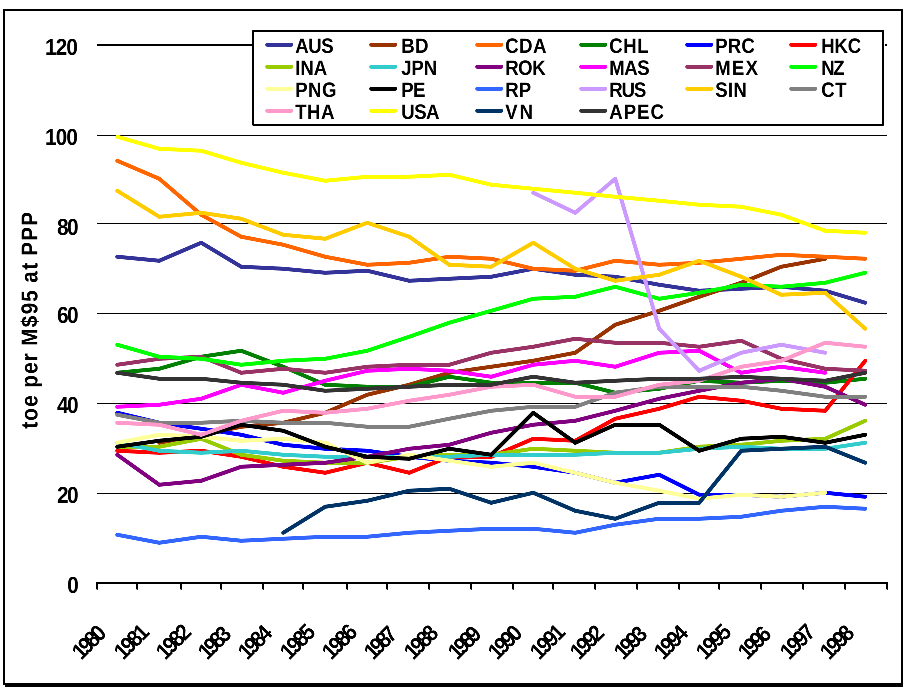
### AGGREGATE INTENSITY

There is a narrower range of values among APEC economies for transport energy intensity or transport energy consumption per unit of GDP at PPP values,[16] than for per capita energy consumption. In 1998, the ratio of the highest and lowest per capita indicators among APEC economies was approximately 48, while a similar ratio for GDP intensity was 4.7. The highest consumption per unit of GDP was in the United States, and the lowest was in the Philippines.

Figures 26 and 27 showed how per capita transport energy consumption trends are, in general, growing or stabilising at high values. Transport energy intensities of GDP, however, seem generally to be converging to the APEC average, a value of around 47 toe per M$95 of GDP at PPP[17] (see Figure 28).

There are however notable exceptions. Canada, New Zealand and the US seem to be stabilising at a higher value, around 75 toe per M$95 at PPP. On the other end, Japan, which has the lowest transport energy intensity of APEC developed economies, has maintained an intensity of 30 toe per M$95 at PPP during most of the study period, though it has been increasing since 1997. A similar trend is evident in Peru, though with bigger fluctuations. Brunei has more than doubled the value of this indicator, reaching Canadian levels at the end of the period but showing no signs of deceleration. If current trends are maintained, Brunei could surpass the United States in 2000-2001 as the largest consumer of transportation energy per unit of GDP in APEC. Another notable exception is China, where energy intensity ended the period at half its starting value. Papua New Guinea also exhibited a downward trend.

**Figure 28 Transport Energy Intensity by Total GDP**




Source APERC, 2000a

## DECOMPOSITION ANALYSIS

The goal of previous sections was to illustrate general trends in intensity using aggregated data for all economies. At this level, few conclusions can be made with respect to energy efficiency. In this section, transportation energy consumption will be decomposed into its key drivers: activity, structure and pure energy intensity. The following analysis focuses on road transportation, particularly passenger travel, since it accounts for a major share of transport energy consumption. As mentioned in the introduction to this chapter, many technical and non-technical factors influence energy consumption in this sector, making analysis work more difficult. Furthermore, due to data limitations, only a few drivers can be isolated for analysis purposes. Many relevant factors are masked by data aggregation.

It must be noted that these factors are not independent of each other [IEA, 1997]. A typical example is the rebound effect, where an increased efficiency or cheaper fuel prices make driving less expensive and may lead to increases in activity levels. Further, if driving conditions become congested, drivers may look to alternatives such as public transportation to make their commutes less difficult. If the traffic problem becomes severe enough, a structural change in the transportation infrastructure favouring more public transportation may result. Traffic congestion can also lead to a deterioration in on-road fuel economy.

### ACTIVITY

A first-order driver of energy consumption in transport is the level of activity. *Ceteris paribus*, if people travel more or more freight is transported, then energy consumption rises. To gain insight into the drivers behind changes in activity levels, basic questions must be asked: Why do people travel? Why is freight transported? What is the impact on activity levels? The answers to these questions are theoretically simple, but may prove very difficult to quantify in practice.

If data is available, activity can be measured in passenger-km for travel and tonne-km for freight. These units have several virtues, but also some drawbacks. For example, they correctly address the unit to be transported, and include the distance it is moved. They also control for load factors, which results in a more accurate comparison of energy consumption between different transportation modes. Since they are based on estimation, a major drawback of these units is the possibility of a non-negligible margin of error. Moreover, data is scarce as few economies calculate passenger-km and tonne-km. In this study, to work around data problems, several proxies for measuring activity are used.

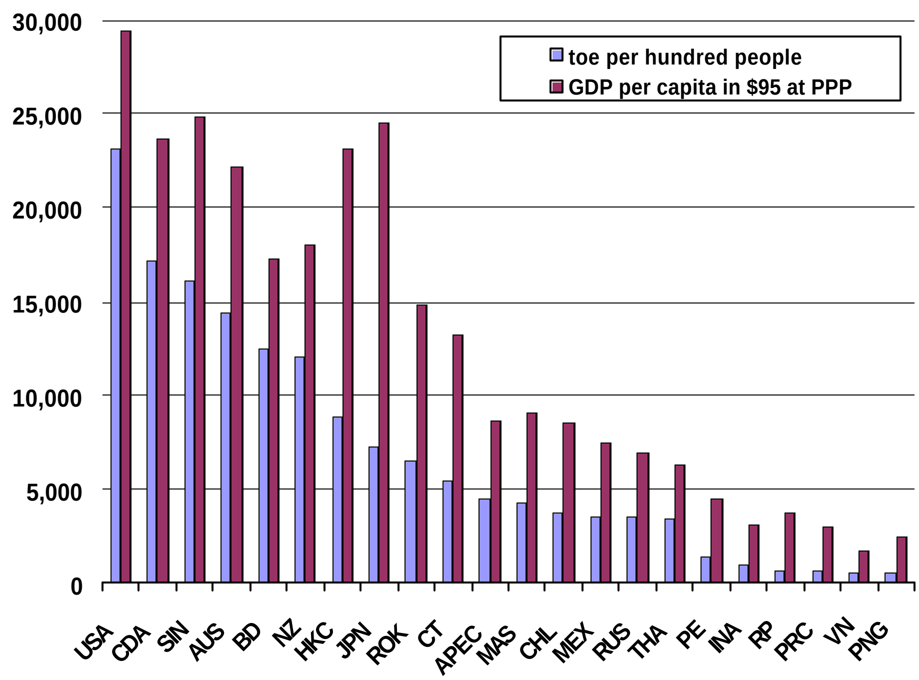
#### ECONOMIC DRIVERS

Economic activity appears to be correlated with transport activity, and, *ceteris paribus*, with energy consumption. Due to data limitations, for many economies, road transportation cannot be separated into its passenger and freight components. This is unfortunate because different activity measures are relevant for each component. Since energy consumption by the passenger component is more closely related to the household sector, income per capita is often considered an appropriate economic driver. That is, if disposable income rises, then people tend to purchase more and bigger cars and/or use them more. Additional recreational trips and trips to procure more goods and services may explain the increase in transportation activity levels. The freight component is more closely linked with overall industrial production levels and is therefore associated with industrial GDP. Increased economic activity is positively correlated with higher freight activity levels because, when the economy is strong, the demand for intermediate and final goods is higher. Since these passenger and freight components are aggregated, neither measure of economic activity will adequately capture energy movements.

*GDP per capita*

Figure 29 plots per capita energy consumption and per capita GDP at PPP for all APEC economies in 1997, ordered with respect to the first variable. As can be seen, the positive relationship between these two variables holds for most economies. There are however two exceptions, namely HKC and Japan, which indicate that, though this relationship is important, there are other variables that influence consumption levels.

**Figure 29 Income and Transport Energy Consumption per capita in 1997**



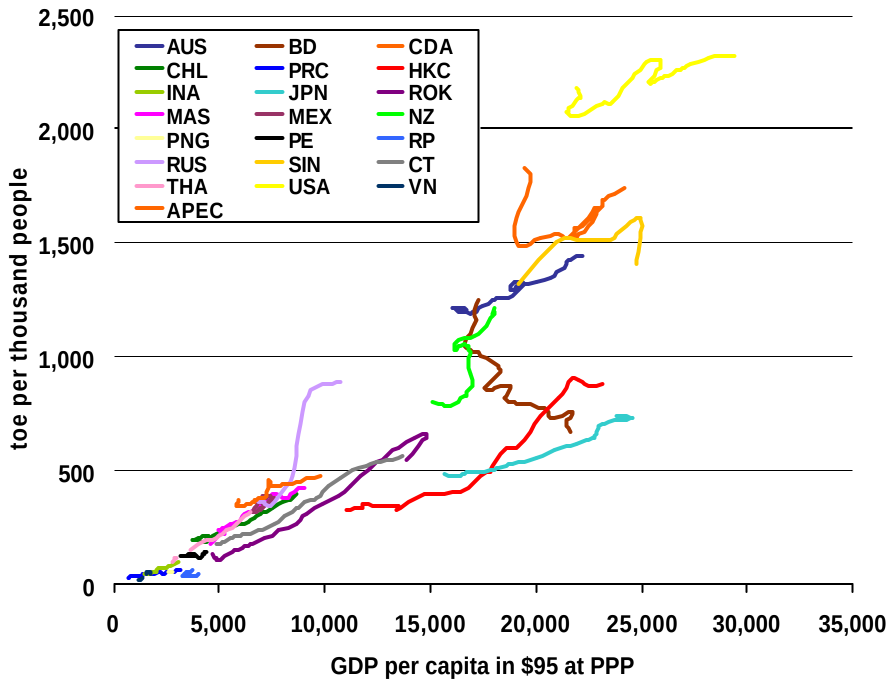

Source APERC, 2000a

The time series for the period 1980-1998 also shows a correlation between income and energy consumption variables (see Figure 30). In Brunei, unlike in other economies, per capita GDP (in PPP terms) fell for most of the period though per capita energy consumption continued to increase sharply.

In Figure 30, at low values of per capita GDP, the dispersion in energy consumption between economies is quite low, perhaps implying a cross-economy relationship between these income and energy consumption indicators. It is interesting to note how the economic turndown in Russia has put it on the same growth path as developing economies.

At higher levels of per capita GDP however, the dispersion in energy consumption levels increases considerably. The United States has the highest energy consumption level and Japan has the lowest among developed economies. Though income contributes to higher energy consumption within an economy, once income passes a certain level, it ceases to be meaningful when comparing economies. Clearly, other variables start to play an important role.

**Figure 30 GDP per capita and Transport Energy Consumption per capita**




Source APERC, 2000a

*Car Ownership Per Capita*

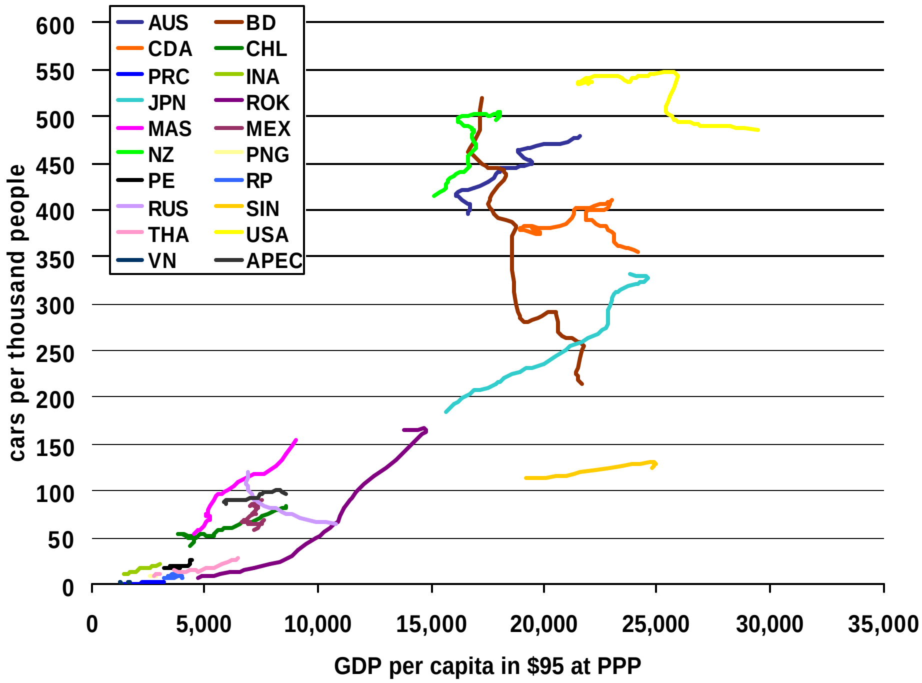
Passenger transportation by cars is the most important driver of road transport energy demand. It is therefore relevant to analyse the relationship between economic development and car ownership. As illustrated in Figure 31, in general, car ownership increases with per capita GDP. However, in some high-income economies like Brunei, Canada and the US, and in medium income ones like Mexico and Russia, this relationship is not always clear. In Brunei, per capita GDP fell by 20 percent during the period, but per capita car ownership increased by almost 2.4 times. The expected link between car ownership and income is observed in Canada and the US until 1989. A recession in the early 1990s led to a contraction in per capita car ownership. Though incomes recovered, car ownership per capita continued to decline to the end of the study period. The growing popularity of light-duty trucks (such as minivans and sport utility vehicles) as a substitute for conventional cars in both economies during the 1990s might explain the apparent deviation from established trends. In Canada and the US, car ownership per capita may be falling but passenger vehicle (cars and light trucks) ownership is increasing quickly.

In Mexico, per capita GDP increased by approximately 10 percent between 1980 and 1998 while car ownership rose by almost 60 percent. In Brunei and Russia, where a significant decrease in per capita GDP was accompanied by an increase in car ownership.

Korea had by far the quickest growth in per capita car ownership. While GDP per capita tripled, car ownership per capita increased 24 times. This impressive growth distanced Korea from other developing economies and put it on a growth path similar to the one in Japan (see Figure 31).

From 1988 to 1993, China had the lowest per capita car ownership in APEC. Viet Nam took over the lowest spot in 1994. Between 1988 and 1998 car ownership per capita in China increased 13 times while income increased more slowly, doubling over this period. The ratio between car ownership per

**Figure 31 Car Ownership per capita and GDP per capita**




Source APERC, 2000a

capita in China and the economy with the highest car ownership value fell from almost 3,950 times in 1988 (with respect to the US) to 280 times in 1998 (with respect to Brunei). The gap between car ownership in China and the APEC average has also reduced significantly, from 660 times in 1988 to nearly 62 times in 1997. If growth rates for income and car ownership in China stay at current levels, it may soon surpass Japan as APEC's second highest transport energy consumer.

*Passenger Vehicle Usage*

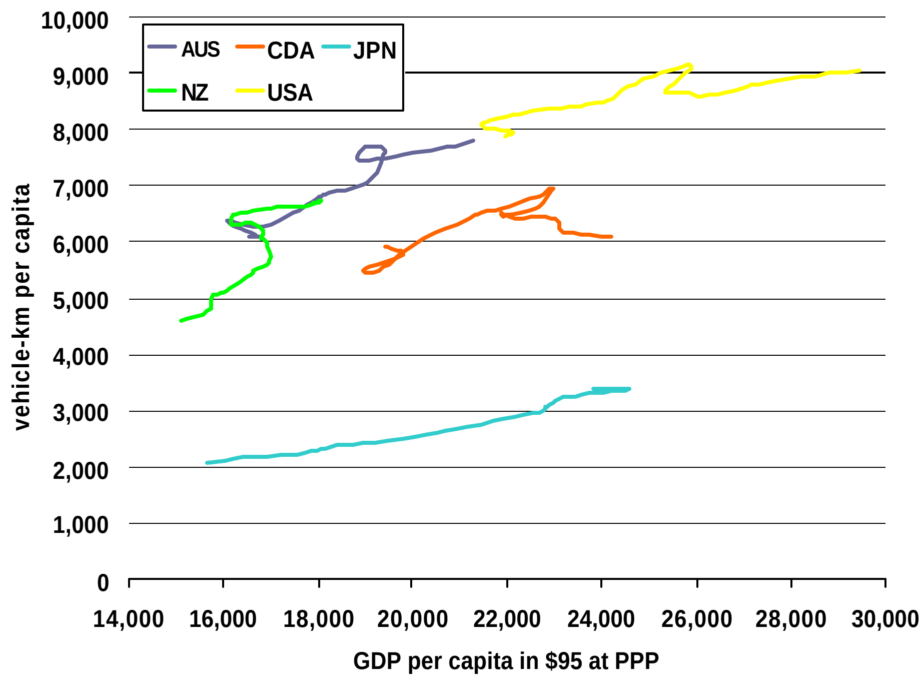
Vehicle usage, measured as vehicle-km per capita, is also positively correlated with economic activity, measured as per capita GDP at PPP. This is shown in Figure 32.

Vehicle usage rates in three economies, namely Australia, New Zealand and the United States, seem to be following a similar path. Canada and especially Japan, however, are following lower paths. In the case of Canada, falling per capita car ownership may account for the lower level of activity (see Figure 31). For Japan, with traditionally low per capita car ownership, car usage may be less intensive due to lifestyle differences and other factors. As can be seen in Figure 33, Japan is the only developed APEC economy for which annual distances driven per car are falling. Increased congestion may be contributing to this decline [IEA, 1997].

*Freight Activity*

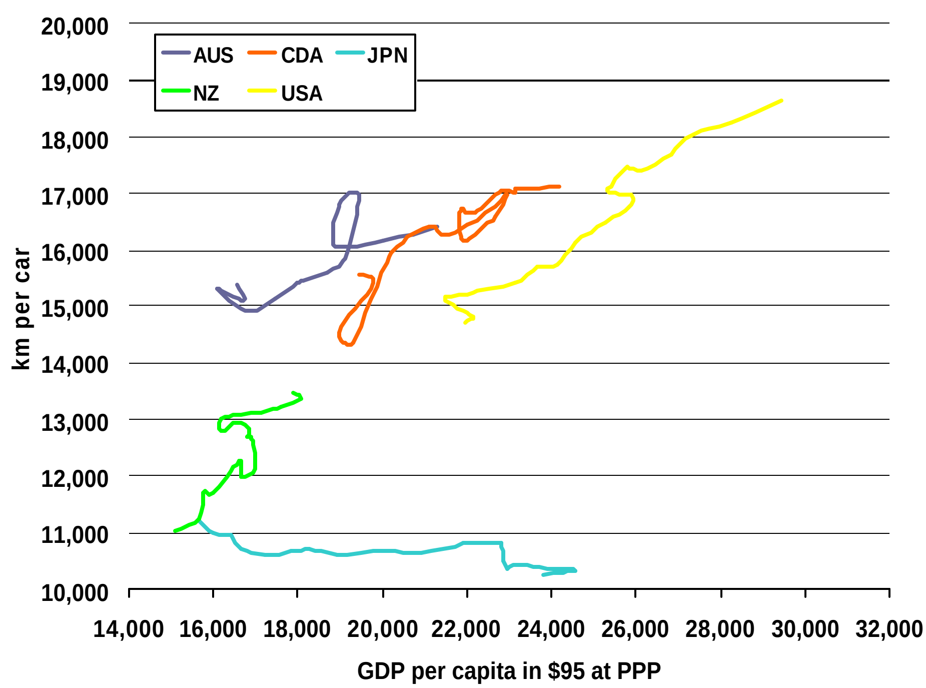
Freight activity, measured as tonne-km, has been increasing in most APEC economies (see Figure 34). Of the economies graphed, Korea showed the largest increase. A sharp decline in 1998 may have been due to the Asian Financial Crisis in 1997. As shown in Figure 35, tonne-km per unit of industrial value added at PPP for developed economies appears to be rising. This means that freight activity is growing more quickly than industrial value added. The only exceptions are New Zealand, which shows a declining

**Figure 32 Vehicle-km per capita and GDP per capita**



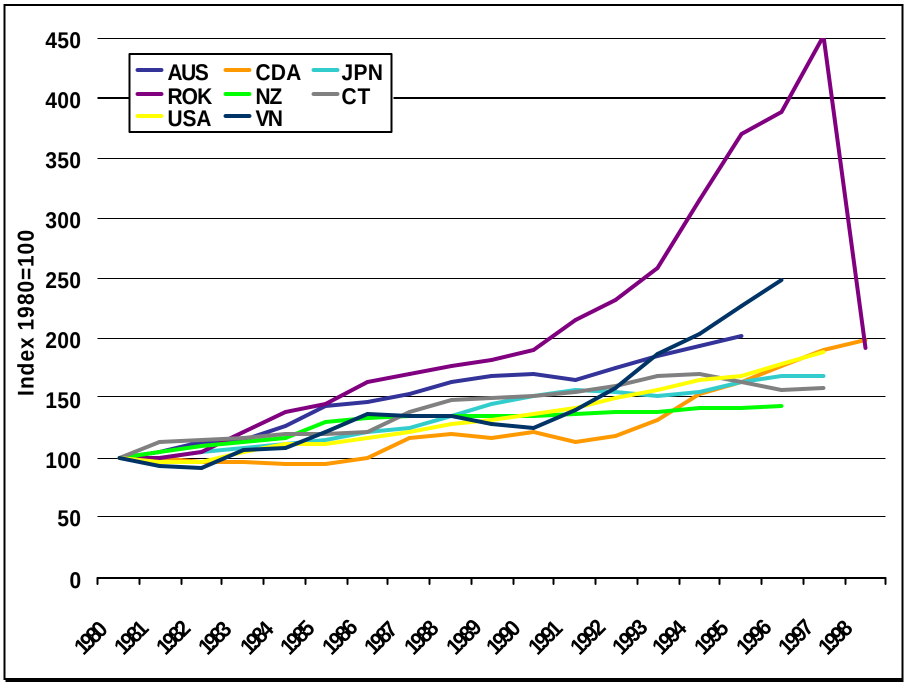

Source APERC, 2000a

**Figure 33 Annual Distance Travelled per Car and GDP per capita**



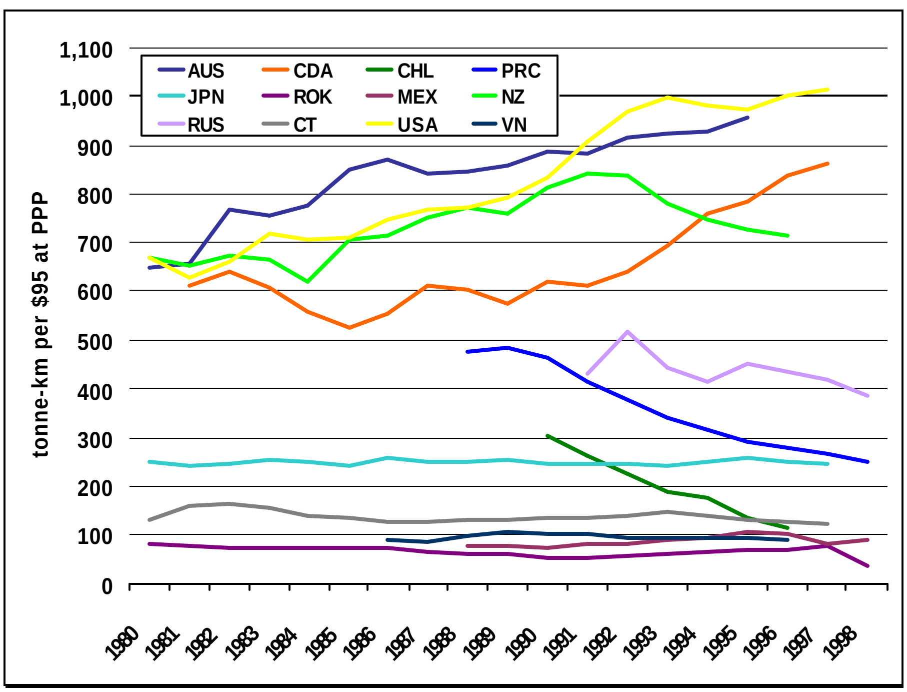

Source APERC, 2000a

**Figure 34 Goods Transported by Road in tonne-km**




Source APERC, 2000a

**Figure 35 Freight Intensity by Industrial GDP**




Source APERC, 2000a

trend starting in 1991, and Japan, which maintained a stable lower value during the study period. On the other hand, all of the APEC developing economies for which there were data show stable or declining trends for this indicator. In particular, Chile and China show significant decreases in tonne-km per unit of industrial GDP. In the case of Chile, transport of goods in 1996 decreased to almost 57 percent of its 1991 value, while industrial value added increased by 40 percent. In China, both transport activity and industrial value added increased, but GDP rose at double the rate of activity.

### OTHER DRIVERS

Non-economic factors can also affect transport activity and thus energy consumption in this sector. Such factors include congestion, urban planning, availability of services, work practices, policies, consumer preferences and others. In this study, there was insufficient information available to derive causal quantitative relationships.

As seen previously in the case of Japan, increased congestion can lead to a reduction in the activity of certain modes, possibly favouring other less energy-intensive ones like subways.

Urban planning and the availability of services can have a significant impact on the number, length and mode of trips. If workplaces, supermarkets, stores, banks, facilities (such as educational, health, government and entertainment), and others are planned together with residential developments, then the need for long motorised trips can be reduced. If distances are short, then non-motorised modes such as bicycles and walking become feasible. The availability of services can even eliminate the need to make trips at all. Services offered through the Internet and telephone (shopping, bank transactions and information retrieval) are prime examples. Telecommuting and other work-at-home arrangements may reduce the need for commuting.

Government policy can also affect energy consumption levels in transport. Since the structure of the transport sector has a decisive influence on energy consumption levels, policies that favour public over motorised private transport can significantly reduce intensity levels. Policies can also influence behaviour, for example special lanes for cars with a certain minimum occupancy may encourage higher load factors.

Consumer preferences can also significantly affect energy consumption. After the oil crises, cars became smaller in size and less powerful. However, when fuel prices moderated, preferences changed and consumers again demanded bigger and more powerful vehicles, partially offsetting the previous improvements in fuel economy [IEA, 1997]. As noted earlier, light trucks have become popular as passenger vehicles in economies like Canada and the US. This trend has had a measurable effect on energy consumption patterns.

Consumers often fail to consider energy efficiency when choosing a mode of transportation. They tend to place a higher value on comfort and convenience than on reducing energy consumption. Travelling from point A to B in a packed subway has lower energy consumption per passenger-km than commuting in a private car along an uncongested road yet when given a choice, consumers will often choose a private car.

Management practices can affect freight energy consumption. For example, just-in-time supply practices in manufacturing reduced on-site inventories and increased daily transport activity.

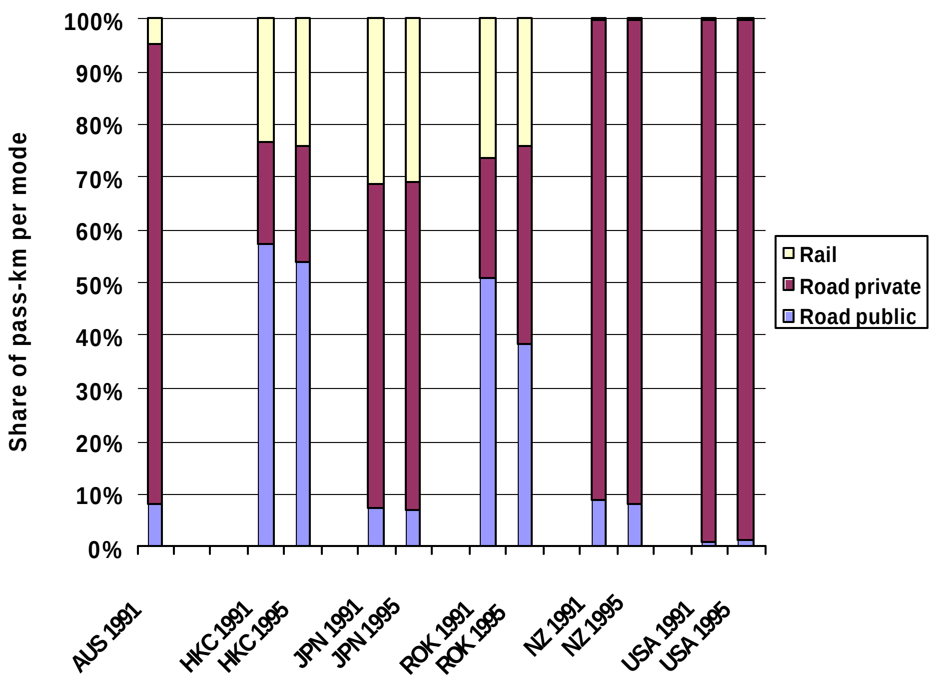
## STRUCTURE

Several modes, each with different characteristics, are available for the transport of passengers and freight. In this section we analyse the various structures among APEC economies and their effect on energy consumption.

### STRUCTURE OF SURFACE TRANSPORTATION

As shown in Figure 36, the structure of the transportation sector, measured in terms of passenger-km per mode, varies across APEC economies. In the United States, surface transportation is dominated by private cars. Private cars are the most energy-intensive surface mode available (see next section). Hong Kong, China represents the other extreme, where road public transport and rail transport are responsible for a large share of passenger travel. Both of these modes are considerably less energy intensive than cars. An even higher percentage of passenger-km, nearly 30 percent, are devoted to rail in Japan. Public road transportation, however, has a very small share of passenger-km.

**Figure 36 Surface Travel by Mode, 1991 and 1995**




Source Data for Australia, HKC, Japan, Korea and the US was taken from IRF, 1996 while that for New Zealand came from EECA, 2000.

These structural differences partially explain variation in transport energy intensities. If, for example, Japan had the same structure for surface passenger transportation (that is, excluding air travel and internal navigation) as the United States, then the energy consumption level in Japan would be approximately 45 percent higher. In the case of New Zealand, with a similar structure as the US, the increase would only be around 5 percent. In general (see Figure 26), economies with the highest per capita energy consumption correspond to those with largest shares of private transportation.

Figure 36 also shows the changes in structure for each economy between 1991 and 1995. In Hong Kong, China, the share of road private transportation and rail, to a lesser degree, increased at the expense of road public transportation. Japan and New Zealand maintained a fairly stable structure during this 5-

year period. In the case of Japan, there was a slight increase in road private transport at the expense of both rail and road public transport. Korea shows the biggest structural change of the economies graphed, where private road transportation significantly increased its share at the expense of road public transportation. This shift towards a more energy intensive mode helps partially explain the high growth rates of energy consumption in this economy. Among this group of economies, the US is the only one that shows an increase in the share of road public transportation, although in 1995 it still accounted for less than 2 percent of the total passenger-km in surface travel.

### STRUCTURE OF PASSENGER ROAD VEHICLES

With respect to road transportation, differences in vehicle stocks also give insight into transport energy intensity levels among APEC economies. The following table shows the evolution of vehicle stock composition for selected economies, in percentage, between 1980 and 1997.

**Table 4 Structure of Transportation Vehicle Stocks**

| | 1980 | | | | | 1997 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Economy | Cars | Light Road Vehicles | Motor-cycles | Trucks | Buses | Cars | Light Road Vehicles | Motor-cycles | Trucks | Buses |
| | percent | | | | | | | | | |
| Australia[1] | 77.4 | 12.6 | 3.7 | 5.9 | 0.3 | 78.8 | 14.4 | 2.7 | 3.8 | 0.4 |
| Canada | 70.5 | 15.8 | 3.5 | 9.7 | 0.5 | 62.6 | 29.1 | 1.9 | 5.9 | 0.5 |
| Chile | 63.7 | 17.7 | 5.4 | 10.3 | 2.9 | 62.9 | 26.7 | 1.8 | 6.7 | 1.8 |
| China | | | | | | 5.3 | | 61.7 | 16.8 | 16.2 |
| Indonesia[2,3] | | | | | | 26.2 | | 60.9 | 8.6 | 4.3 |
| Japan | 49.5 | 15.4 | 2.3 | 32.3 | 0.5 | 49.5 | 21.7 | 3.6 | 24.9 | 0.2 |
| Korea[2] | 34.7 | | 29.1 | 30.5 | 5.7 | 58.8 | | 19.7 | 16.0 | 5.5 |
| Malaysia[2] | | | | | | 38.8 | | 50.4 | 10.3 | 0.5 |
| Mexico[2] | | | | | | 67.3 | | 1.5 | 30.3 | 1.0 |
| New Zealand | 75.8 | 9.9 | 7.3 | 6.8 | 0.1 | | | | | |
| Peru[4] | | | | | | 60.4 | 24.3 | | 10.9 | 4.4 |
| Philippines[5] | 31.6 | 36.3 | 18.6 | 11.8 | 1.8 | 23.3 | 37.3 | 29.8 | 8.6 | 1.0 |
| Singapore[2] | | | | | | 58.8 | | 19.3 | 20.8 | 1.6 |
| Thailand[2,3] | | | | | | 10.1 | | 62.2 | 17.3 | 10.4 |
| USA | 75.3 | 17.3 | 3.5 | 3.6 | 0.3 | 61.3 | 33.2 | 1.8 | 3.3 | 0.3 |

Notes 1) The figures correspond to 1980 and 1995.
2) No data concerning light road vehicles was available.
3) The figures correspond to 1996.
4) No data concerning motorcycles was available.
5) The figures correspond to 1981 and 1997.

Source APERC, 2000a

A trend observed in most economies is the increasing share of light-duty trucks. In many economies these vehicles are used for private passenger transportation like cars. In economies such as Canada, Chile, and the United States, the share of light trucks nearly doubled during the study period, reaching approximately 30 percent of total vehicle stock. The Philippines, at 37 percent, has the highest share of this type of vehicles among the economies tabulated. This share has remained stable through the study period and includes the "Jeepneys" which are used for public transportation.

As noted earlier, car ownership has grown very quickly in Korea. Cars accounted for 59 percent of all vehicles in 1997. In Korea, the classification for car is thought to include light duty trucks. Therefore, part of the increase in car ownership may be attributable to light road vehicles.

Noteworthy in Table 4 is also the high percentage of motorcycles (including three-wheelers) in some Asian economies such as China, Indonesia, Malaysia and Thailand. In these economies, motorcycles may be more attractive than cars because they are more mobile in heavy traffic and they are significantly less

**Table 5 Structure of Vehicle Stocks Normalised to SEC for Cars**

| | 1980 | | | | | 1997 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Economy | Cars | Light Road Vehicles | Motor-cycles | Trucks | Buses | Cars | Light Road Vehicles | Motor-cycles | Trucks | Buses |
| | | | | | percent | | | | | |
| Australia[1] | 68.6 | 14.5 | 0.3 | 15.8 | 0.8 | 71.4 | 17.0 | 0.2 | 10.2 | 1.1 |
| Canada | 57.8 | 16.9 | 0.3 | 23.8 | 1.3 | 52.2 | 31.6 | 0.2 | 14.8 | 1.3 |
| Chile | 50.3 | 18.2 | 0.4 | 24.3 | 6.9 | 51.0 | 28.2 | 0.1 | 16.2 | 4.5 |
| China | | | | | | 4.8 | | 5.6 | 45.6 | 44.0 |
| Indonesia[2,3] | | | | | | 37.0 | | 8.6 | 36.3 | 18.1 |
| Japan | 29.5 | 11.9 | 0.1 | 57.6 | 0.8 | 32.2 | 18.4 | 0.2 | 48.7 | 0.5 |
| Korea[2] | 23.7 | | 2.0 | 62.6 | 11.7 | 46.9 | | 1.6 | 38.3 | 13.3 |
| Malaysia[2] | | | | | | 50.8 | | 6.6 | 40.6 | 2.0 |
| Mexico[2] | | | | | | 41.7 | | 0.1 | 56.4 | 1.8 |
| New Zealand | 68.7 | 11.7 | 0.7 | 18.6 | 0.3 | | | | | |
| Peru[4] | | | | | | 43.8 | 22.9 | | 23.7 | 9.6 |
| Philippines[5] | 26.1 | 38.9 | 1.5 | 29.1 | 4.4 | 22.5 | 46.8 | 2.9 | 24.9 | 2.9 |
| Singapore[2] | | | | | | 45.8 | | 1.5 | 48.9 | 3.8 |
| Thailand[2,3] | | | | | | 10.1 | | 6.2 | 52.2 | 31.5 |
| USA | 68.6 | 20.4 | 0.3 | 9.8 | 0.9 | 53.0 | 37.3 | 0.2 | 8.7 | 0.8 |

Notes 1) The figures correspond to 1980 and 1995.
2) No data concerning light road vehicles was available.
3) The figures correspond to 1996.
4) No data concerning motorcycles was available.
5) The figures correspond to 1981 and 1997.

Source APERC, 2000a

expensive. In many economies, motorcycles are used not only for private travel but for delivery and taxi services as well.

Energy consumption by vehicle type, both on a per vehicle and per passenger-km or tonne-km basis, varies considerably. In order to account for the influence of structure on energy consumption, the stock of light road vehicles, motorcycles, buses and trucks was normalised to account for differences in energy consumption per type of vehicle. For light trucks and motorcycles, the ratio of annual specific energy consumption relative to cars was used. For buses and trucks, due to the absence of data, the normalising factor was the ratio of fuel economies (that is, litres of fuel required to travel 100 km).[18]

These are rough proxies, which in the absence of better data, can give a first order estimation of the impact of changes in the structure of vehicle stock on energy consumption. The types of vehicles that contribute most to energy consumption are highlighted by this rough estimate.

After converting vehicle stocks to a “car equivalent,” as expected, the weight of motorcycles fell considerably, and that of trucks and buses rose. Table 5, which can be compared with Table 4, illustrates these differences.

## ENERGY EFFICIENCY

Of the three components of transport energy consumption analysed in this study, energy efficiency, taken in a strictly technological sense, probably shows the least variability among economies. Since there are relatively few vehicle manufacturers worldwide, similar models and brands can be found in many economies. These cars feature similar technological developments in aerodynamics, engine controls and other areas.

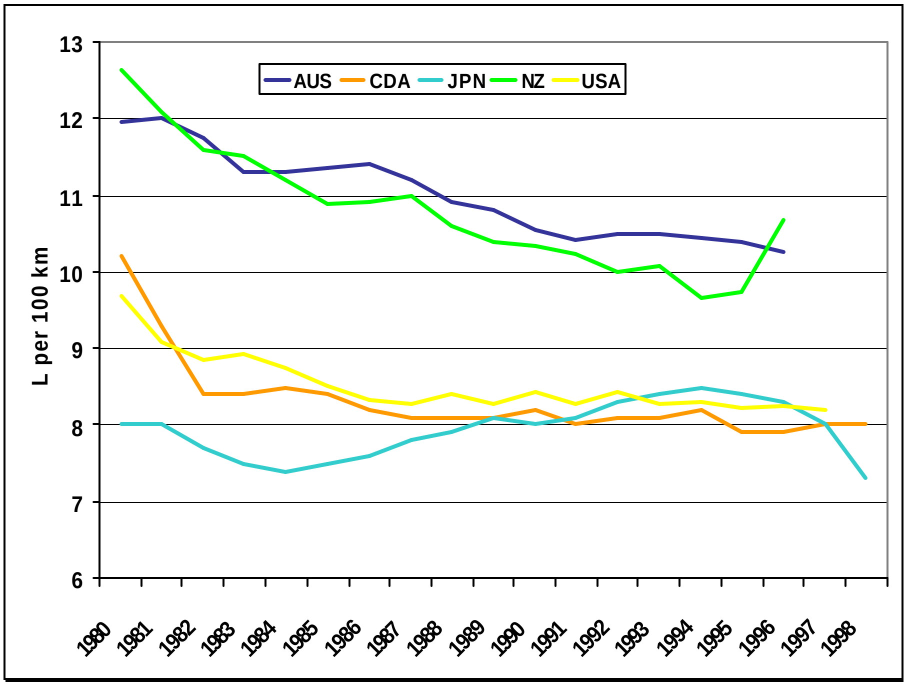
Japan and the United States have fuel efficiency standards for transportation vehicles (see Chapter 8). Since these economies dominate the car manufacturing and export markets, importing economies from the APEC region also benefit from these standards.

Figure 37 shows the evolution of fuel economy for new cars, expressed as litres of fuel required to travel 100 km, for selected economies. Fuel efficiency for new cars declined by approximately 20 percent during the study period in Australia, Canada, New Zealand and the United States. The strongest improvements were observed in the 1980s immediately following the energy crisis. In the latter half of the period, particularly in Canada and the US, improvements in fuel economy moderated. One new technology, the hybrid-electric vehicle, which is reputed to be twice as efficient as a conventional vehicle with similar performance features, has recently been introduced to car markets in Japan and the United States. If this technology takes hold, it has the potential to improve fleet fuel economy substantially.

Since vehicle vintage and stock mix are different in each economy, average fleet fuel efficiency varies across the APEC region. Just as transportation structure by mode or type of vehicle can affect overall energy consumption in an economy, so can the age profile of the car stock. In general, as demonstrated in Figure 37, a vehicle manufactured in 1998 is more energy efficient than a vehicle produced in 1980. If the car stock is more heavily weighted towards older cars, *ceteris paribus*, energy consumption by that stock of cars will be higher. Moreover, when a car is taken out of service, it is often replaced with a new car. Since new cars tend to be more energy efficient, the shorter the service life of a car, the more quickly average fleet fuel efficiency will improve. In recognition of this fact, governments in some economies offer car owners cash grants to retire vehicles older than 10-15 years.

Observed trends in fuel economy were similar in Australia and New Zealand on one hand, and in Canada and the US on the other. This may reflect similarities in vehicle availability and car preference in both pairs of economies. Figure 37 further suggests that Australia and the US purchase larger and/or

**Figure 37 Specific Consumption of New Cars (test value)**




Source APERC, 2000a

more powerful cars than their neighbours. Trends in fuel economy have been much more variable in Japan than in the other four economies graphed. During the first half of the 1980s, fuel economy fell by 7.5 percent, then it rose by almost 15 percent to 1994 before falling again.

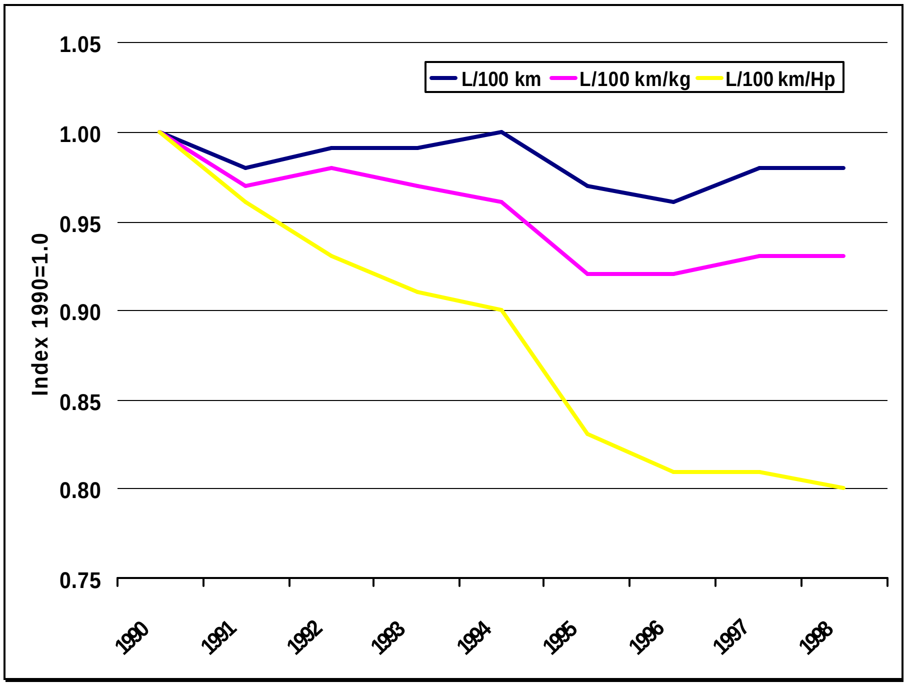
Figure 38 shows a number of fuel efficiency indicators for new vehicles in Canada during the 1990s. Though traditional fuel efficiency per 100 km, illustrated by the top line, has been flat, energy consumption per kilogram of car weight and by energy horsepower have declined dramatically. Overall fuel efficiency has made few gains because technological efficiency improvements have been traded off for performance features such as additional weight and power. If cars had not become heavier or more powerful than they had been in 1990, fuel economies would be significantly lower than current observed values [OEE, 2000]. Similarly, in Europe, diesel engine vehicles have been promoted as a more energy efficient alternative to gasoline engine vehicles. However, consumers have offset any efficiency gains from using diesel-powered vehicles by choosing larger cars and driving more [IEA, 1997].

The variable trends in fuel economy observed in Japan in Figure 37 do not necessarily imply a deterioration in energy efficiency levels. As demonstrated in Figure 38, traditionally-used fuel economy indicators fail to fully reflect the trade offs between efficiency improvements and other car features.

## DECOMPOSITION OF TRANSPORT ENERGY CONSUMPTION FOR JAPAN

The above sections dealt mainly with a qualitative discussion of the drivers behind transport energy consumption, supported by available data. Decomposition methods, which are significantly more rigorous, can be used to quantitatively determine the effect of activity, structure and pure energy efficiency on energy consumption. These methods require disaggregated data which is available in only a few APEC economies.

**Figure 38 New Car Fuel Economy in Canada, Normalised for Weight and Power**



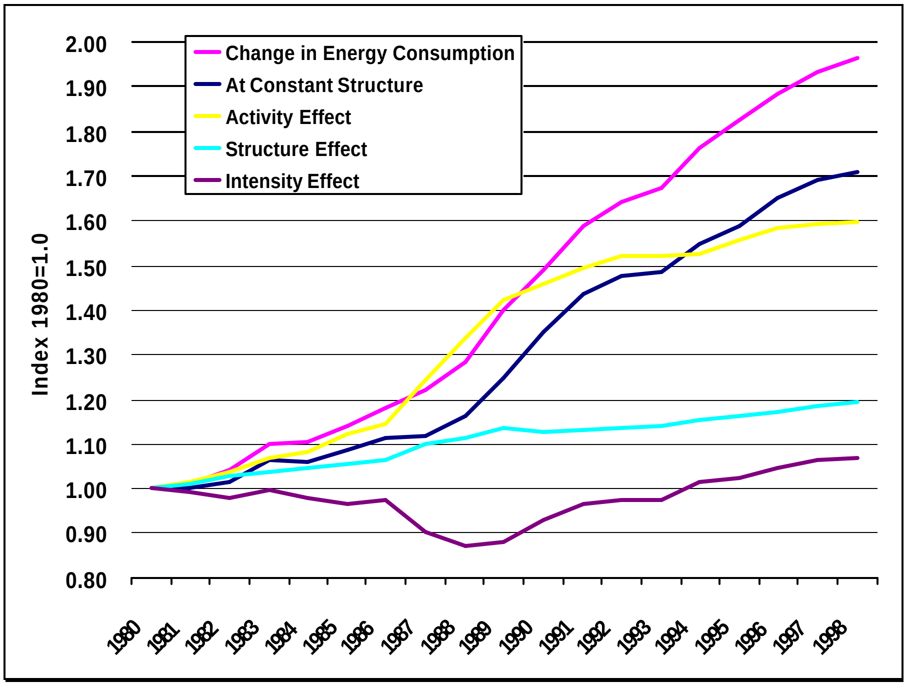

Source OEE, 2000

To illustrate the decomposition technique, in this section travel and freight energy consumption in Japan are decomposed using the Laspeyres method. For passenger vehicles, the activity variable is defined as passenger-km, the structure effect refers to mode of passenger transport and pure intensity is measured as toe per passenger-km. For freight, activity is defined as tonne-km, structure refers to mode (road, air, rail or marine) and intensity is presented as toe per tonne-km. Graphical results showing the relative importance of each driver are presented in Figure 39 and Figure 40.

Figure 39 shows that an increase in activity has been the major driver behind the growth in travel energy consumption. As seen earlier, changes in structure, namely increased use of cars, raised energy consumption by shifting passenger-km activity from less to more energy intensive modes. For most of the period, advances in pure energy efficiency offset upward pressure from the activity and structure effects. However, after the middle of the 1990s, fuel economy also contributed to higher energy consumption levels.

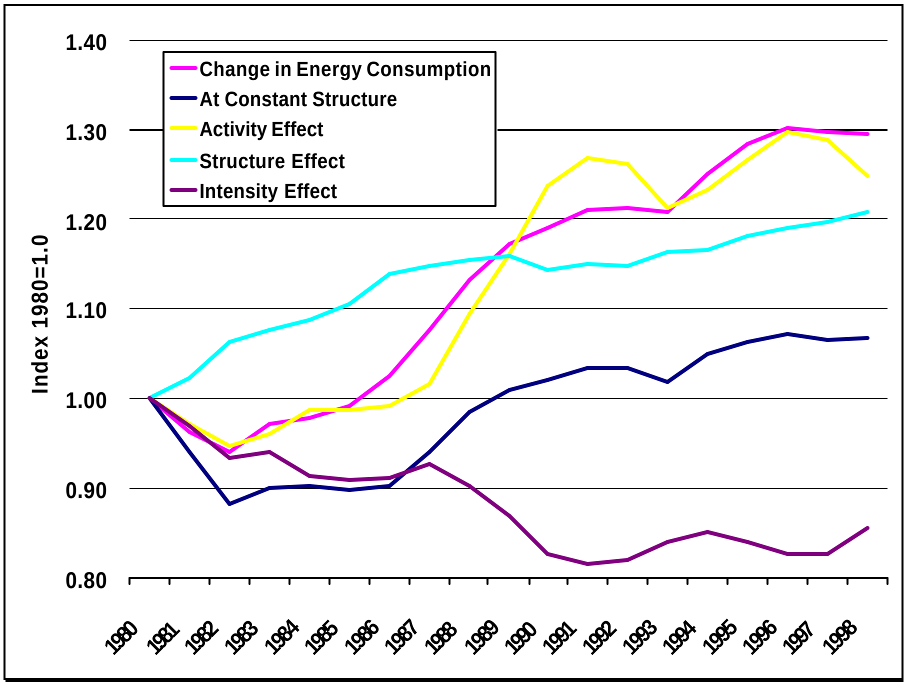
In the freight sector, activity was the most important factor in higher levels of energy consumption, followed by a change in structure (see Figure 40). Over the study period, trucks have increased their share of freight transport in Japan. Unlike in the travel sector, pure energy efficiency has helped to offset energy consumption growth during the study period.

**Figure 39 Decomposition of Passenger Travel Energy Consumption in Japan**




Note Derived from EDMC, 2000

**Figure 40 Decomposition of Freight Transport Energy Consumption in Japan**




Note Derived from EDMC, 2000

## TRANSPORTATION CARBON DIOXIDE EMISSIONS

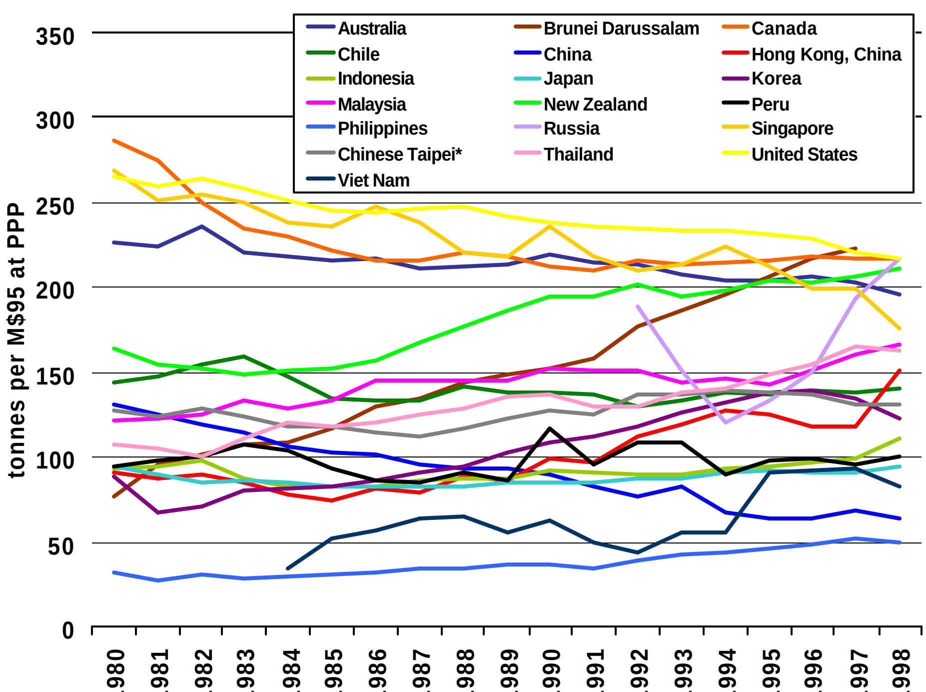
The APEC transport sector emitted 3,247 Mt of $CO_2$ in 1998, including the emissions derived from electricity generation. The United States was responsible for 54.8 percent of this total, followed by Japan with 8.8 percent and China with 7.7 percent. The carbon shares of these economies correspond to their shares of total transport energy consumption.

Overall emissions increased by 65 percent for the study period (or 54 percent increase if Russian emissions, for which data is available only since 1992, are not included). Though the growth rates for energy consumption in the US and Japan are significantly lower than in developing economies, these two APEC members accounted for over half of the increase in $CO_2$ (excluding Russian data) in the Asia-Pacific region.

$CO_2$ emissions in all APEC economies except Russia were increasing over the study period while intensities with respect to GDP showed a mix of results (see Figure 41). $CO_2$ intensities in Australia, Canada, Chile, China, Mexico, Singapore and the US all fell. China, with an intensity reduction of - 51.6 percent for the period, showed the largest decline. On the other extreme, carbon intensities in Brunei grew by nearly 190 percent during the period 1980-1997. Viet Nam was next with a 141 percent increase in intensity since 1984. Brunei also has the highest $CO_2$ intensity in APEC, with 223 tonnes per M$95 at PPP in 1997, followed by APEC's developed economies.

Fossil fuels dominate the energy mix in the transportation sector. Minor shifts to less carbon-intensive propane or natural gas powered vehicles have reduced carbon intensity slightly.

**Figure 41 Transportation Carbon Dioxide Intensity by Total GDP**




Source APERC, 2000a; IEA, 1998

## CONCLUSIONS

Transportation accounts for a major share of final energy consumption in most APEC economies. Despite improvements in vehicle efficiency, especially following the energy crises of the 1970s, transportation energy consumption is one of the fastest growing end use sectors in most APEC economies. The analyses presented in this chapter provide insight into the reasons behind the observed trends.

Available data show a strong correlation between income and car ownership as well as income and kilometres travelled per vehicle. Car ownership levels have been increasing quickly in developing economies such as China, Korea, Indonesia, Malaysia and Thailand. Already, severe traffic congestion and air quality problems are well documented in large cities like Bangkok, Jakarta and Seoul. GDP per capita in these developing economies is still very low compared to OECD economies and as standards of living improve, problems related to transportation can only be expected to get worse. Moreover, since more than 90 percent of fuel used in this sector is derived from oil, strong growth in the transportation sector will likely lead to increased dependence on oil imports in many APEC economies.

As discussed earlier, due to the complexity of factors affecting energy consumption in transportation, there is no easy solution to problems caused by rapid growth in this sector. Choices by individual consumers about what transportation mode they use and how many trips they make are key determinants of energy consumption levels. In making these decisions, consumers rarely factor in the energy efficiency implications of their choices. Therefore, since transportation-related problems, particularly in developing economies, are not going away, policy-makers need to be thinking ahead. Careful urban planning, for example, can reduce the number of trips people need to take. Adequate public transportation infrastructure, both road and rail, give commuters a choice other than private road transportation and can alleviate traffic congestion problems. As was previously discussed, structural differences in transportation infrastructure have a large impact on energy intensity levels among APEC economies. In the US, private transportation dominates passenger travel and results in a higher energy intensity than in Hong Kong, China where public rail transportation is the dominant mode.

Indicators calculated with data at higher aggregation levels provide only general information. To address each economy’s unique situation and challenges, detailed data by mode on vehicle stocks, direct activity measures such as passenger-km and tonne-km and energy efficiency measures for the vehicles in that stock are necessary in order to produce useful analysis for policy development purposes. To facilitate this work, a significant effort in data collection is therefore required in many, particularly developing, economies. Given the importance of the transportation sector in terms of current energy consumption and the potential for future expansion, investment in data collection and analysis could help policy-makers to develop focused effective programmes that achieve government objectives.

# CHAPTER 6

## SERVICES ENERGY EFFICIENCY INDICATORS

### OVERVIEW

The services sector is the most diverse and least understood of the four major end use sectors. It includes wholesale and retail trade; restaurants and hotels; transport,[19] storage and communications; financial institutions, insurance, real estate; community/social and personal services; government services; as well as anything that does not fall into another end use category. These sub-sectors have little in common save that most of the energy consumed is buildings-related. Though this sector makes up from 40-60 percent of total GDP in most economies (57 percent in APEC in 1997), it is often neglected as a target for energy policy and detailed data collection because it is responsible for only 3-17 percent of total final energy consumption (9 percent in APEC in 1997). Another issue is that data collection in this heterogeneous sector is expensive. Governments have instead chosen to focus their efforts on more energy intensive sectors such as the industrial sector.

The purpose of this chapter is to construct a set of energy efficiency indicators for the services sector in APEC economies, to evaluate the quality of these indicators and to discuss how to improve them. This chapter also identifies the key drivers of energy consumption in the services sector over the study period, 1980-1998.

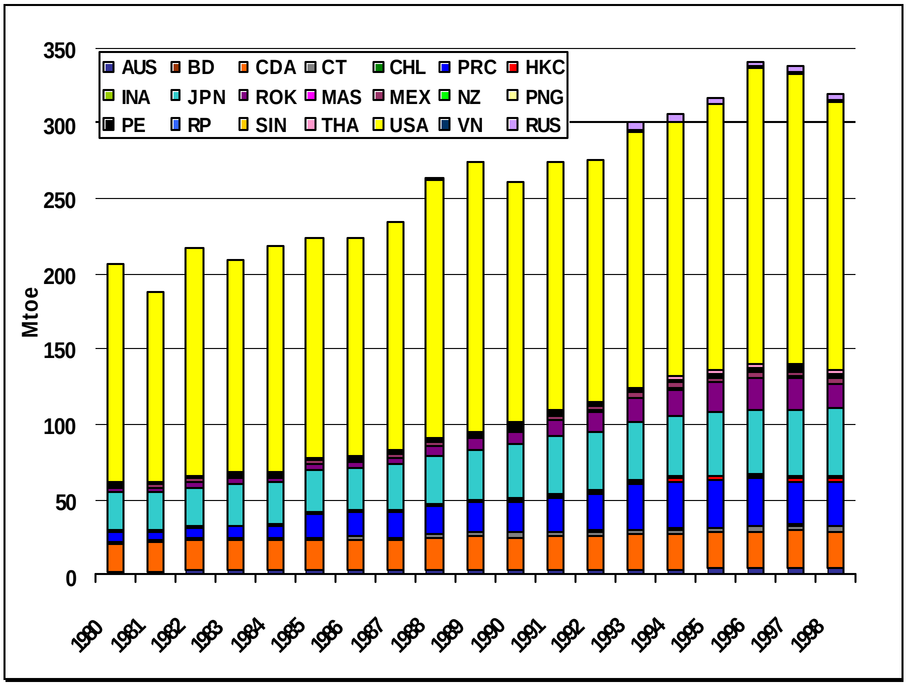
### ENERGY CONSUMPTION TRENDS

In 1997,[20] services sectors across the APEC region consumed 341 Mtoe (see Figure 42). The United States was by far the largest contributor to services energy consumption with 56 percent of the APEC total. Energy consumption by this sector has been growing rapidly, particularly in Asia. From 1980 to 1998, China's consumption for services increased by 4.5 times, Malaysia's 5.1 times, Indonesia's by 6.6 times, Korea's by 6.6 times and Thailand's by 6.9 times. Russian data is only available after 1992.

There is a sharp contrast in energy consumption trends between developed economies (including Australia, Canada, Japan, New Zealand and the United States) and developing economies (including Indonesia, Korea, Malaysia and Thailand) (see Figure 43). The absolute levels of growth for service sector final energy consumption (FEC) were significantly higher in developing economies, 5-12 percent per year compared with 1-4 percent per year in developed ones. Moreover, services FEC growth in industrialising economies outpaced services GDP as well as overall FEC over the study period. This rapid energy growth is particularly evident from 1987 to 1997. A trend observed in both developed and developing economies is robust growth in electricity consumption. Over the study period, electricity was the main contributor to FEC growth in almost all APEC economies.

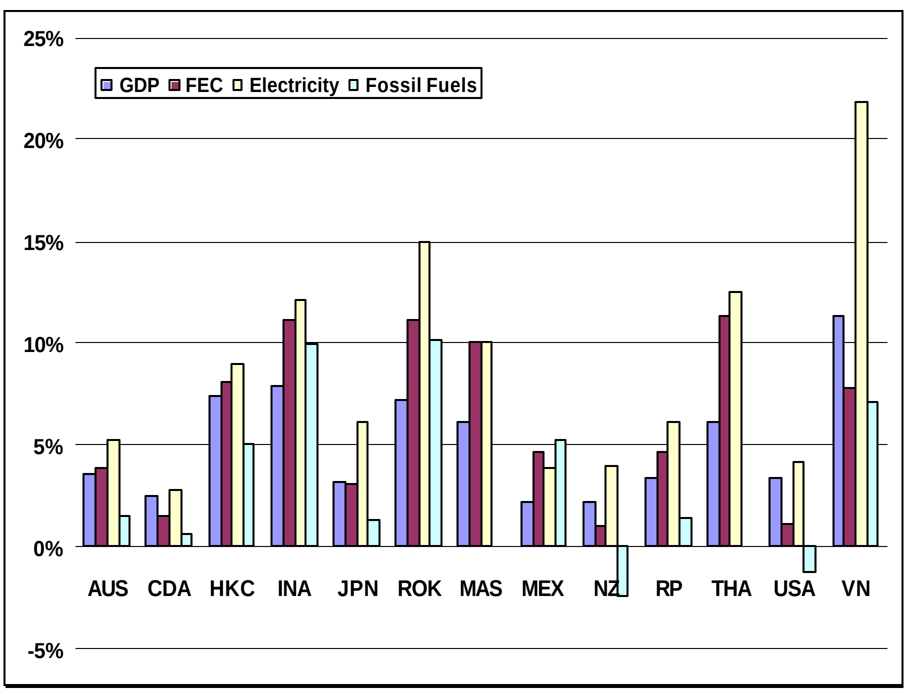
Energy in the commercial building sector is used for space conditioning, ventilation, lighting, water heating, cooking, refrigeration, office equipment and other uses. The type of end use is often fuel specific. Fossil fuels are favoured for space and water heating (light fuel oil and natural gas) as well as cooking (natural gas and propane). Electricity is more versatile. Air conditioning, lighting, office equipment, elevators/lifts, escalators and ventilation equipment use electricity almost exclusively. While electricity can be used for heating and cooking, it tends to be more expensive than fossil fuels. Figure 44 shows end uses and fuel mix for selected APEC economies located in different climate zones. Canada represents a northern climate with a harsh winter, Hong Kong, China represents a temperate climate with some temperature variation among seasons and the Philippines is considered tropical with warm year-

**Figure 42 Services Energy Consumption**




Source APERC, 2000a

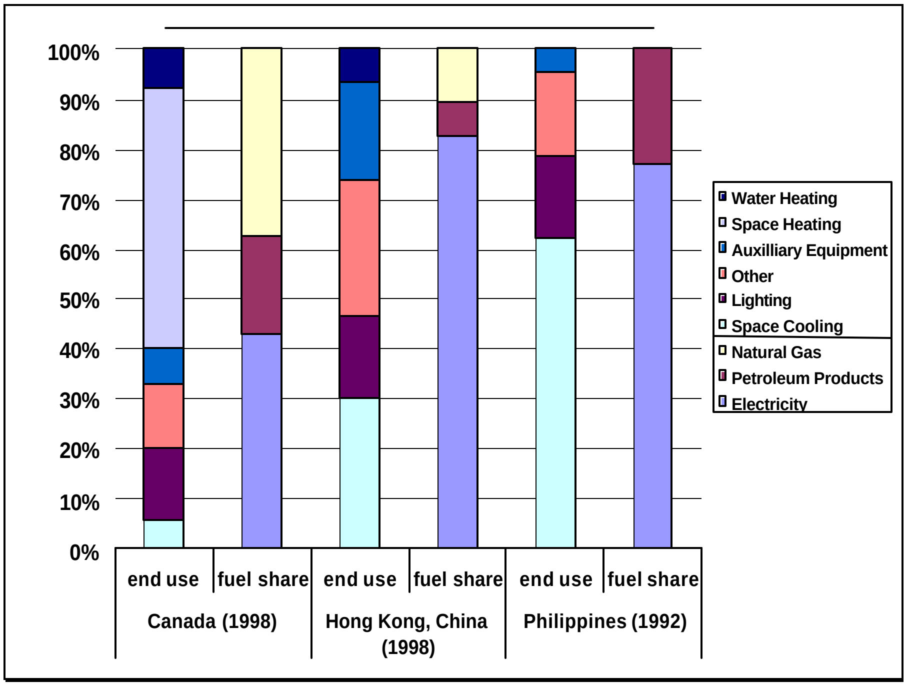
**Figure 43 Average Annual Growth Rates for Selected Service Sector Variables**




Source APERC, 2000a

Note In Thailand, some fossil fuels are used in the early 1980s, but this value falls to zero, therefore the growth rate for fuels has been excluded.

**Figure 44 Services End Use and Fuel Shares for Different Climates**




Source OEE, 1999; EMSD, 2000; Anunciacion, 1994; APERC, 2000a

round temperatures. In all three of these climate zones, space conditioning accounts for 30-60 percent of energy consumption and is the dominant end use in the buildings sector. However, since tropical climates use space conditioning for cooling, the fuel mix in these economies is heavily weighted towards electricity. In climates with colder winters where energy is used for heating, there is a marked preference for fossil fuels.

In economies at low levels of economic development, the relationships described in the previous paragraph do not hold. In Indonesia and Viet Nam where climates are tropical, fossil fuels dominate the fuel mix at 43 percent and 88 percent respectively in 1998. Low incomes and limited access to electricity help explain this bias towards fossil fuels. Only 56 percent of households in Indonesia had access to electricity in 1998. In warm climates, fossil fuels such as propane are typically used for cooking and, if electricity is unavailable, for lighting (kerosene) too. Moreover, when incomes are low, the bulk of energy is used for cooking and lighting. In urban areas, if electricity supplies are unpredictable, hotels, shopping malls and hospitals which require stable supplies, may invest in diesel powered generators. On-site generation would make electricity demand appear as fossil fuel demand. As income levels rise and rates of electrification increase, a fuel mix resembling the Philippines should emerge in these economies.

## ENERGY INTENSITY

Measures of energy intensity highlight energy trends and can provide valuable insight into energy consumption patterns within and across economies. GDP and floorspace are direct and employment is an indirect measure of activity in the services sector. These indicators are used to normalise energy consumption for analysis purposes. Intensities vary over time due to changing energy efficiency practices, structure, climatic variations and the like. Across economies, for the same reasons, intensities are not directly comparable, but they do highlight some interesting trends in energy use. Each measure of intensity has different strengths and weaknesses. Therefore, to derive a more complete picture, intensities constructed using GDP, floorspace and employment should be considered together when analysing energy consumption in the services sector. This section examines general trends in energy intensity in APEC economies and compares the different measures available. A more detailed analysis about the end use factors behind the observed changes in these broader measures of energy intensity will be discussed in the next section, *Decomposing Energy Consumption*.

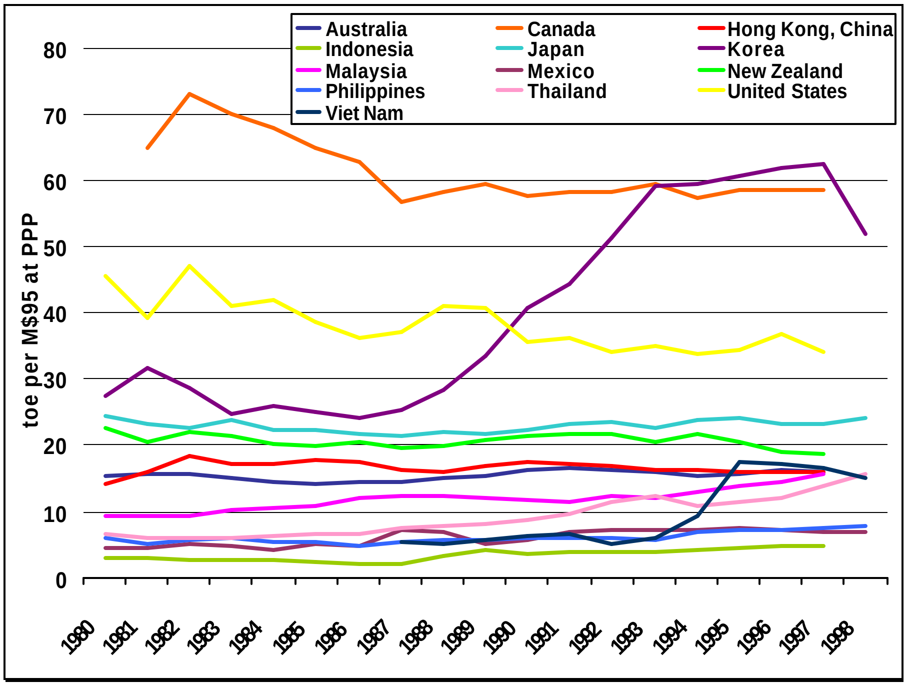
Brunei Darussalam, Papua New Guinea, Peru and Russia were not included in this analysis because of inadequate data. Chile, China and Singapore were also excluded due to irregularities in the IEA energy data for services. For Chinese Taipei, PPP GDP data is not available. When services GDP was converted to US dollars for this economy, there were inconsistencies in the data series. Overall, 13 APEC economies were examined in this analysis.

GDP measures output in the services sector. Since energy is an input in production, it tends to be correlated with GDP. However, GDP is affected by productivity improvements in factors other than energy. As illustrated in Figure 45, in general, energy consumption per unit of GDP is much higher in developed than in developing economies. Colder climates and fuel mix effects (due to conversion losses, it takes more than 1 ktoe of natural gas or fuel oil to produce 1 ktoe of useful energy) partially explain why intensities in Canada and Korea are significantly higher than in other economies. In developed economies energy per unit of GDP is flat or gently trending downward while intensities in many developing economies such as Korea, Indonesia, Malaysia, Thailand and Viet Nam, have been increasing rapidly at 3-9 percent per year. In Korea, for example, intensity more than doubled, growing from 27 toe per M$95 at PPP[21] in 1980 to 62 toe per M$95 at PPP in 1997. Rising incomes and improved standards of living in developing economies partially explain these sharp increases in energy consumption. In developing economies, services energy consumption has been growing at almost double the rate of services GDP (see Figure 43).

Employment is an input in the production process. It is correlated with energy consumption for office equipment and hot water usage [Krackeler *et al.*, 1999]. These uses, however, account for only 10-20 percent of overall energy demand in services. A clear advantage of this indicator is that service sector employment data or a reasonable proxy, are available for most APEC economies. In Figure 46, trends in energy per worker indicators are similar to those observed for energy per unit of GDP: intensities for developed economies are higher and usually trending downwards whereas those for developing economies are at lower levels, but are rising quickly. There are some differences as well. The gap between intensities for developed and developing economies such as Indonesia, Malaysia, Mexico, Philippines, Thailand and Viet Nam, is much more pronounced for this indicator. This implies that production methods in industrialising economies are more labour intensive. Whereas energy per unit of GDP is flat, energy per worker is rising in Australia, HKC[22] and Japan. This implies that fewer workers are required to produce a unit of output. Therefore, either labour is becoming more productive or firms are substituting away from labour towards another factor which has become more productive.

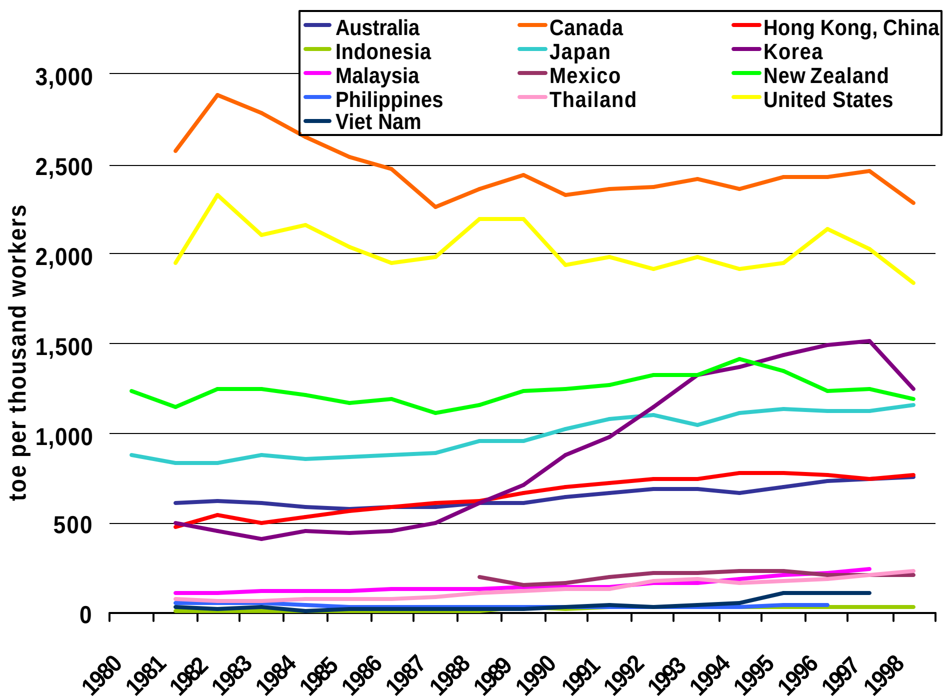
Floorspace, like employment, is an input into services production. It is more strongly correlated with energy consumption than employment because it is related to end uses such as space conditioning and lighting [Krackeler *et al.*, 1999]. Floorspace data, however, is only available for a handful of APEC economies (see Figure 47). In Canada, energy per unit of floorspace fell sharply in the early 1980s and flattened out through the 1990s. This trend is also evident in energy per unit of GDP and energy per worker. These indicators imply that energy is being used more efficiently in the services sector in Canada. In the United States, all three intensities appear to be trending downwards too. Again, this implies more efficient use of resources. In contrast, while GDP and floorspace intensities for Japan are flat, energy per worker is trending upwards. Such trends suggest that there are fewer workers per unit of floorspace and that firms are substituting away from labour towards floorspace. In New Zealand, energy intensity for all three indicators has been flat over most of the study period; however, since 1994, each of these indicators has started to decline suggesting some efficiency gains.

**Figure 45 Services Energy Intensity by Services GDP**



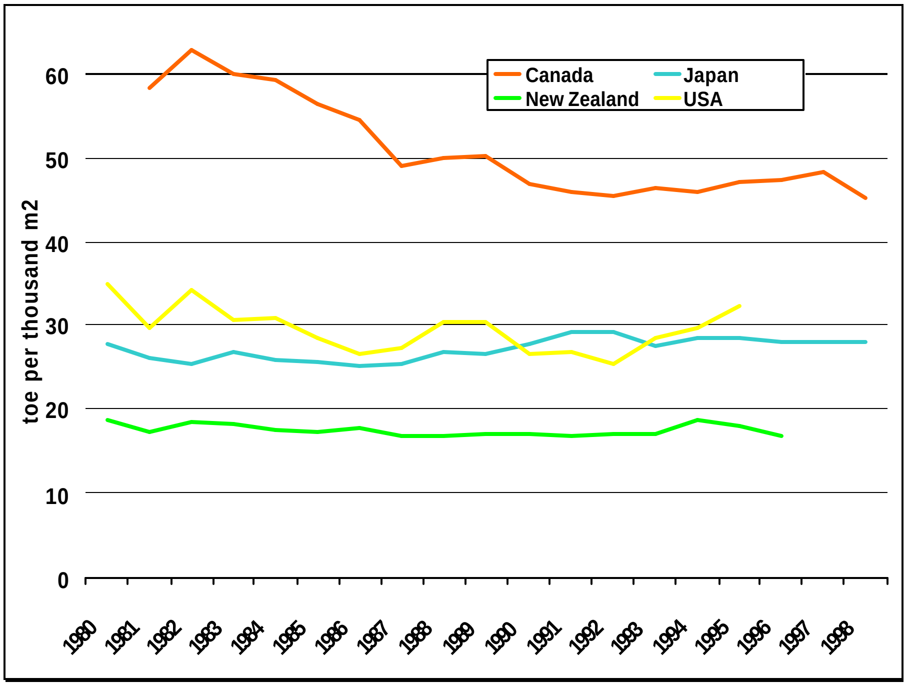

Source APERC, 2000a

**Figure 46 Services Energy Intensity by Service Worker**




Source APERC, 2000a

**Figure 47 Services Energy Intensity by Floorspace**




Source APERC, 2000a

As discussed earlier, energy intensity is not necessarily a measure of energy efficiency. Other factors such as sub-sectoral make-up and weather, which have little to do with energy efficiency, may cause energy intensities to rise or fall. To more accurately assess the impact of energy efficiency on changes in energy consumption, overall energy intensity should be refined to remove components not related to efficiency. Two methods of decomposition are applied in the next section, *Decomposing Energy Consumption*.

## DECOMPOSING ENERGY CONSUMPTION

### INTRODUCTION

The main drivers of energy consumption in the services sector are activity, structure, weather and intensity. To decompose growth in energy consumption into its components, two factorisation methods were applied to data from APEC economies. Both techniques use a fixed-year Laspeyres index in order to evaluate changes over time in the drivers of energy consumption. Separate indexes with a base-year of 1990 have been built for final energy consumption as well as for the activity, structure, weather and intensity effects.[23]

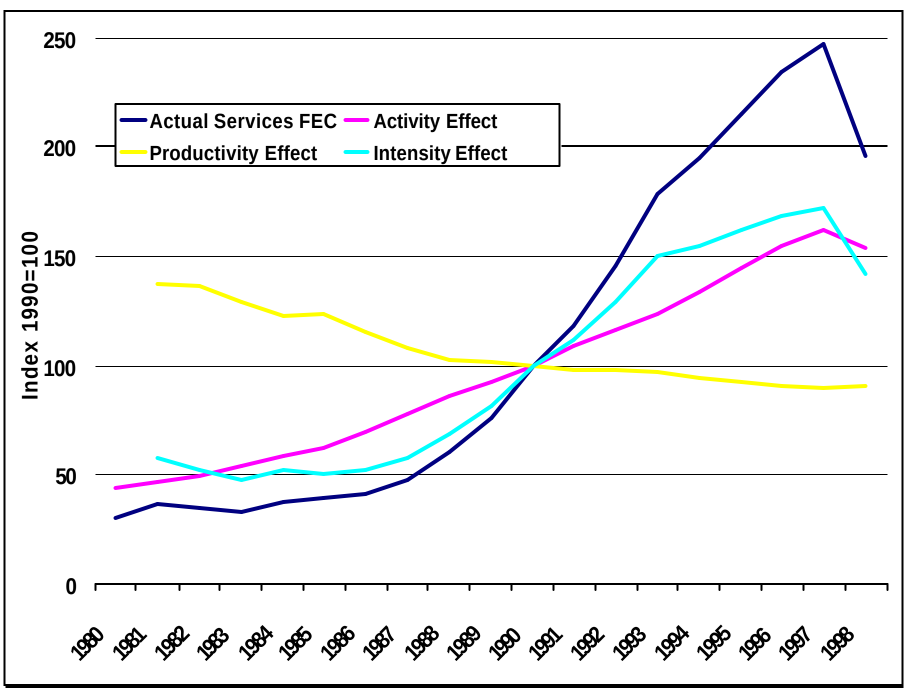
In the first factorisation method, services sector GDP at purchasing power parity is the activity driver. The second term is a measure of labour productivity in the services sector; that is, how many workers are required to produce a unit of services GDP. Energy intensity is measured using energy consumption per worker. As noted in the section on *Energy Intensity*, employment is less strongly correlated with energy consumption than is floorspace; however, employment data is more readily available. This model was applied to 13 APEC economies: Australia, Canada, HKC, Indonesia, Japan, Korea, Malaysia, Mexico, New Zealand, the Philippines, Thailand, the United States and Viet Nam. It should be noted that energy intensity has been adjusted for improvements in labour productivity but not for climatic variations or changes in the composition of sub-sectors.

The second factorisation method is more rigorous. Floor space, not GDP or employment, is the activity driver. The structure effect is measured by each sub-sector's share of total floor area. This indicator gives insight into how the composition of the sector is changing over time and what impact this may have on energy consumption. The weather effect measures the impact of deviations from normal weather patterns on overall energy consumption.[24] The intensity effect measures energy (adjusted to reflect weather) per unit of floor area for each sub-sector. Due to these adjustments for variations in weather and changes in sub-sector composition, the intensity measure in this factorisation method is considered to be a better representation of energy efficiency than the intensity in factorisation method 1. Since most economies do not collect the detailed data required for this analysis, this technique was applied to only 3 APEC economies: Canada, Japan and the United States.

## RESULTS

Figure 48 shows the decomposition results for Korea using factorisation method 1. Over the study period, energy consumption in Korea increased 6.6 times or 10.5 percent per year. The activity effect was an important driver of energy consumption growth through the period, but after 1990, the energy intensity effect surpassed activity as the key growth factor. The impact of the intensity effect has been particularly important in developing economies where increases in energy use per worker are related to rising standards of living and the adoption of modern business practices rather than deteriorating energy efficiency. Since quality of life is starting at much lower levels, strong economic growth will have a larger impact on observed energy consumption than in industrialised economies. In Korea, energy per worker has been increasing, but so has the level of output produced by each worker. Strong FEC growth was accompanied by robust improvements, about 3.4 percent per annum in the 1980s, in labour productivity (workers per unit of GDP). These increases moderated in the 1990s.

**Figure 48 Services Method 1, Energy Decomposition Results for Korea**




Note Derived from APERC, 2000a

Table 6 shows the average yearly impact of activity, labour productivity and energy intensity on service sector energy consumption for 13 APEC economies. The decomposition results for Korea are similar to those observed in developing economies such as Indonesia, Malaysia, Thailand and Viet Nam. FEC growth has been much slower in developed economies. Though increases in energy per worker have played a role in higher consumption levels, the activity effect is the most important driver for these economies. Improvements in labour productivity helped to offset the activity and intensity effects in all economies save the Philippines.

**Table 6 Results of Factorisation Method 1 for the Services Sector**

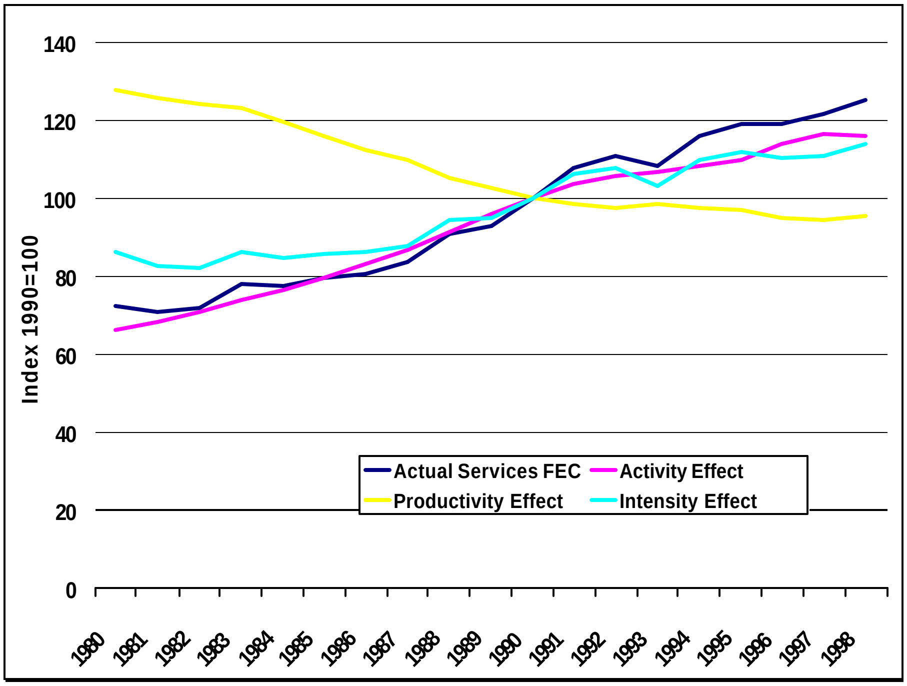
| Average Annual Growth Rates | Coverage | Actual FEC | Activity Effect | Productivity Effect | Energy Intensity Effect |
|---|---|---|---|---|---|
| | | | | percent | |
| Australia | 1981-1997 | 3.9 | 3.7 | -1.0 | 1.2 |
| Canada | 1981-1997 | 1.8 | 2.5 | -0.4 | -0.2 |
| Hong Kong, China | 1981-1997 | 7.3 | 7.3 | -2.7 | 2.8 |
| Indonesia | 1981-1997 | 10.9 | 7.7 | -2.4 | 5.6 |
| Japan | 1980-1998 | 3.1 | 3.1 | -1.6 | 1.6 |
| Korea | 1981-1998 | 10.5 | 7.3 | -2.4 | 5.5 |
| Malaysia | 1981-1997 | 10.0 | 6.4 | -1.8 | 4.4 |
| Mexico | 1988-1998 | 3.3 | 3.2 | -0.3 | 0.5 |
| New Zealand | 1980-1997 | 1.1 | 1.5 | -1.2 | 0.1 |
| Philippines | 1981-1996 | 5.7 | 3.4 | 4.7 | -2.3 |
| Thailand | 1981-1998 | 12.2 | 6.1 | -1.1 | 6.9 |
| United States | 1981-1997 | 2.6 | 3.6 | -1.2 | 0.2 |
| Viet Nam | 1987-1997 | 25.1 | 11.8 | -6.8 | 20.1 |

Note Derived from APERC, 2000a

Figure 49 and Figure 50 show decomposition results for Japan using method 1 and method 2. FEC is, of course the same in both methods. However, in method 1, GDP is growing more slowly than floorspace. Labour productivity improvements were robust in the 1980s but have slowed significantly in the 1990s. Slower productivity improvement has likely contributed to slower GDP growth during the 1990s. In method 2, changes in the structure of the service sector had little impact on energy consumption. Since the mid-1980s energy intensity measured as energy per worker has been steadily increasing. Intensity in method 1 has not been adjusted for weather effects and this may be contributing to the upward trend in intensities in parts of the 1980s and 1990s. Weather from 1983-85 and from 1993-94 was colder relative to 1990. In the 1990s while floorspace intensity was flat after 1993, labour intensity has been trending upwards. This implies that the number of workers per unit of floorspace is falling.

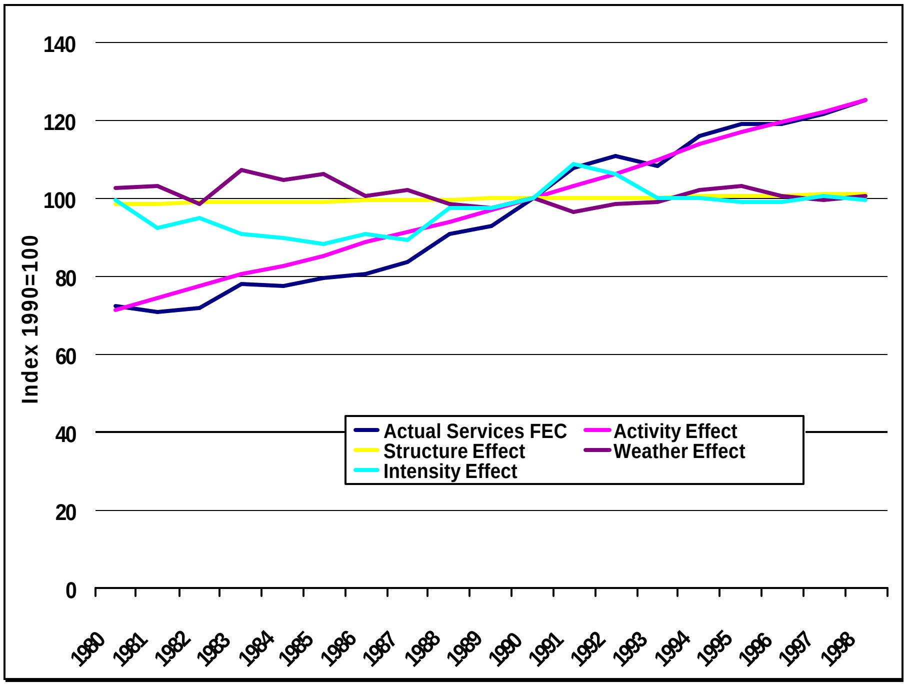
Findings for the second factorisation method are presented in Table 7. As in the first factorisation method, the activity effect (measured in floorspace instead of GDP) was the most important driver of final energy consumption growth. On a year-to-year basis, deviations from normal weather patterns caused large swings in FEC consumption. The structure effect or changes in the composition of sub-

**Figure 49 Services Method 1, Energy Decomposition Results for Japan**




Note Derived from APERC, 2000a

**Figure 50 Services Method 2, Energy Decomposition Results for Japan**




Note Derived from EDMC, 2000

sectors proved to be of minor significance in Canada and Japan and of moderate significance in the United States. Different trends in weather-adjusted intensity were observed in these three economies.

**Table 7 Results of Factorisation Method 2 for the Services Sector**

| Average Annual Growth Rate | Coverage | Actual FEC | Activity Effect | Structure Effect | Weather Effect | Intensity Effect |
|---|---|---|---|---|---|---|
| | | | | percent | | |
| Canada | 1981-1998 | 1.4 | 3.1 | 0.1 | -0.1 | -1.4 |
| Japan | 1980-1998 | 3.1 | 3.2 | 0.2 | -0.1 | 0.0 |
| USA | 1989-1995 | -0.3 | -0.7 | 1.0 | -0.1 | -0.7 |

Note Derived from OEE, 1999; EDMC, 2000; EIA, 1999a

### ACTIVITY EFFECT

In 13 APEC economies, the average growth rate of real GDP at purchasing power parity was 3.7 percent per year over the period 1981-1997.[25] Though Australia, Canada, Japan, New Zealand and the United States make up the bulk of total GDP, these economies have activity growth rates at the average or lower. Except for Mexico, which suffered a serious recession in 1982-83 and a currency devaluation in 1995, and the Philippines which had a major recession in 1984-85 and power shortages from 1990-93, developing economies have experienced GDP growth of 1.5 or 2 times the yearly APEC average over the study period.

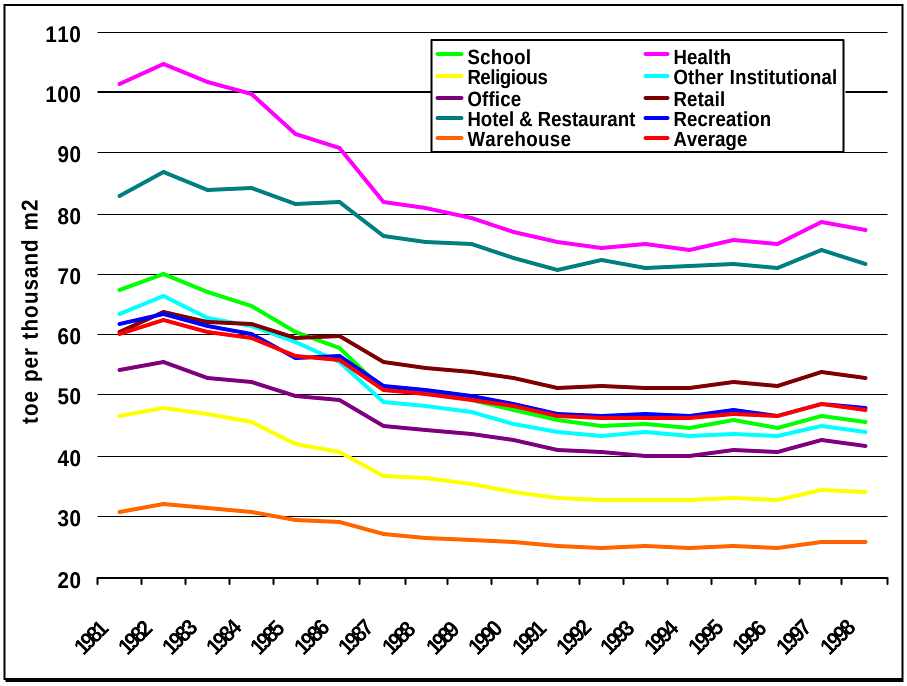
Floorspace was chosen as the activity driver in the second factorisation for several reasons. The bulk of end use energy consumption, space conditioning and lighting, is strongly correlated with the amount of floor area in place. Moreover, since GDP is more responsive to fluctuations in business cycles than floorspace, GDP may “exaggerate” the impact of economic contractions on energy consumption. As well, though GDP and floor area exhibit similar growth patterns, due to the long lead-time for planning and construction, there can be a considerable lag between a slowdown in GDP and slowdown in floorspace construction. In Canada, the OEE estimates this lag to be about three years [OEE, 2000]. In Canada, Japan and the US, the activity effect measured by average growth in floorspace is similar to the rate recorded for GDP.

### STRUCTURE EFFECT

The productivity effect is a simplified method of measuring the structure effect when disaggregated sub-sectoral floorspace and energy data are unavailable. The productivity effect measured in units of GDP (a proxy for floorspace) per worker helped to offset energy consumption growth in all economies except for the Philippines. Energy rationing in the Philippines in the early 1990s likely contributed to a worsening in labour productivity as firms were forced to substitute away from capital and energy towards labour in order to maintain production levels. In Indonesia, Japan, Korea and Thailand productivity improvements were very rapid in the 1980s but have slowed or flattened out in the 1990s. Hong Kong, China has enjoyed robust productivity improvements over the entire study period whereas Australia, New Zealand, Malaysia and Viet Nam have demonstrated strong gains since 1990. Canada’s and the United States’ productivity improvement have been slow but steady over the period. End use data for the US is unavailable after 1995. These years should show strong improvements in US labour productivity (see page 24).

A true structure effect was constructed in the second factorisation method for Canada, Japan and the United States using floorspace data broken out by sub-sector. Energy consumption patterns for main end uses vary across sub-sectors; therefore, the mix of these sub-sectors can influence overall energy consumption. Figure 51 shows weather adjusted energy intensities for different service sub-sectors in Canada. In general, hospitals, restaurants and hotels and retail shopping malls are the most energy intensive sub-sectors while warehouses, with minimal space heating requirements, are the least energy intensive.

**Figure 51 Weather Adjusted Services Intensities by Sub-sector in Canada**

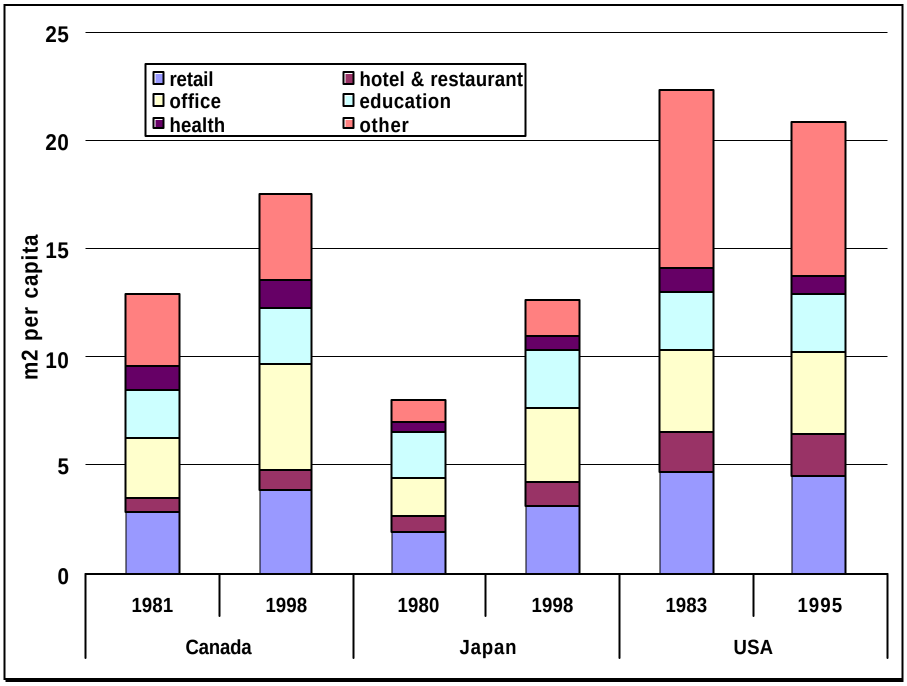



Source OEE, 1999

Figure 52 shows the composition of the service sector by unit of floorspace per capita in Canada, Japan and the United States. Though the absolute levels are different, these economies have similar structures. The largest sub-sectors are retail and office space, which together make up about 40-50 percent of total floorspace. Though most sub-sector floorspace shifts were minor, in Canada and Japan, education lost floorspace share to offices. However, the energy intensities for these two sub-sectors are similar and the structure effect was marginal in these two economies. The structure effect appears to have played a larger role in energy consumption growth in the United States. In the US, data was only available from 1989-1995 and since floorspace, sub-sector and end use energy data came from surveys (1989, 1992 and 1995) which are subject to sampling error, intensity is quite variable. Floorspace share for energy intensities for sub-sectors such as hospitals and food service increased sharply from 1992 to 1995 which resulted in a moderate increase in energy consumption.

Within each sub-sector other factors can impact on energy consumption in the services sector. The vintage or age of the building can affect consumption levels. Newer buildings tend to consume less energy per square metre than older buildings. The size of the building also plays a role. Larger buildings tend to consume less energy per square metre than smaller buildings. Building utilisation levels are also important. Buildings such as hospitals are occupied continuously while hockey arenas are used much less intensively. There is very little data on the utilisation levels or physical characteristics of the building

**Figure 52 Services Floorspace per capita**




Source OEE, 1999; EDMC, 2000; EIA, 1999a

types for each economy [IEA, 1997]. The United States is the only economy that collects detailed data of this kind.

The impact of a true structure effect on services energy consumption in developing economies is unclear. Typically, in the earlier stages of economic development, most floorspace is devoted to restaurants, schools and hospitals. As an economy becomes more affluent, there is an increased demand for hotels, office space, shopping malls and entertainment complexes. Few APEC economies collect detailed information on commercial floor space, energy consumption by end use or by individual sub-sectors in the services sector, so it is difficult to calculate indicators and to examine long-term trends in the service sector. This is an area that requires better data and additional study.

## WEATHER EFFECT

In the second factorisation method, energy for space heating and cooling was adjusted to reflect “normal” or average weather in the economies studied: Canada, Japan and the United States. Unlike the other effects, the weather effect for each year is independent of the weather effect in previous years. Since weather varies randomly, the average yearly contribution of the “weather effect” presented in Table 7 is a bit misleading because it compares only the impact of weather in the initial year with the weather effect in the final year.

Figure 50 shows the decomposition for Japan and year-to-year deviations due to weather. In some years, it has pushed up FEC as much as 5-7 percent. In Canada, it is not uncommon for weather to contribute 3-5 percent to FEC for a given year. The three economies for which a weather effect was calculated have cold northern or northern temperate climates and the findings here may not be applicable to warm temperate or tropical climates.

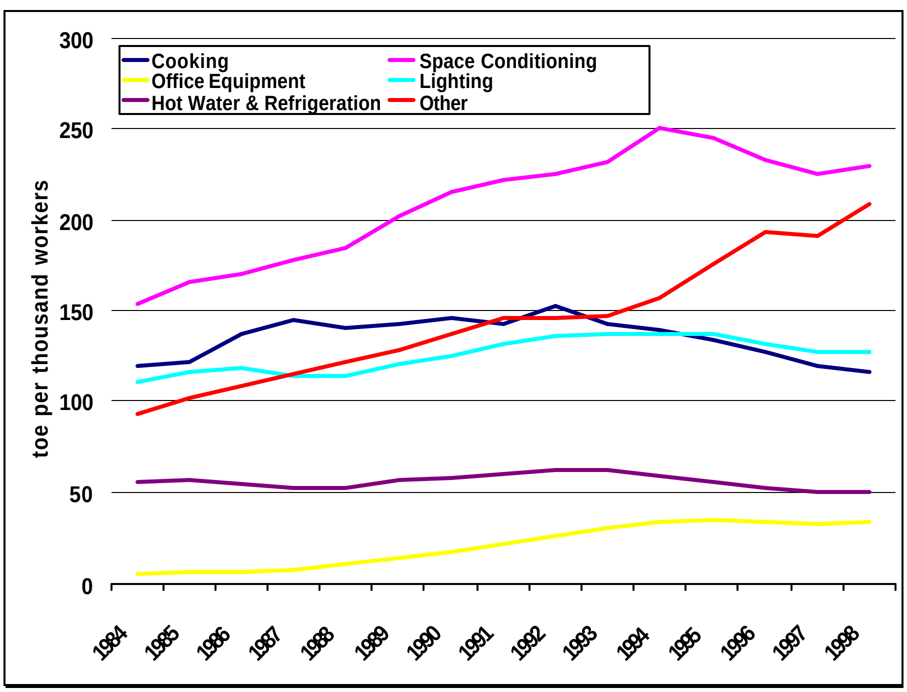
Many economies have meteorological agencies which collect temperature data, but few calculate heating and cooling degree day information. Even fewer economies estimate the amount of energy used for heating and cooling purposes. This poses challenges for evaluating the impact of weather on energy consumption, particularly in developing economies.

### INTENSITY EFFECT

In the first factorisation method, the intensity effect is measured by the amount of service sector energy per service worker. This factor is a catch-all and includes technical changes in energy efficiency, improvements in living and working standards, changes in the composition of sub-sectors, weather effects and fuel mix effects. Due to the hodgepodge of components making up this indicator, it is very difficult to interpret the results.

In developing economies, intensity is almost as important as the activity effect in driving energy consumption growth. The lack of adjustments for weather and structure may play a minor role in this upward trend, poor energy efficiency practices in many of these economies is also a contributing factor; however, improved living and working standards are likely the key drivers in the intensity effect. As industrialising economies develop and incomes rise, the demand for modern office space increases, as does the consumer's appetite for shopping and entertainment complexes. These types of modern buildings are better lit and provide a higher level of service (air conditioning, more escalators and elevators) than traditional buildings and as a result, consume more energy per unit of floorspace. Data from Hong Kong, China lends support to this hypothesis. Though few would consider Hong Kong, China a "developing" economy today, in the early 1980s this economy still had some of the traits of an industrialising economy. Therefore, data from Hong Kong, China provides insight into the transition process from a developing to a more mature economy.

**Figure 53 Services End Use Intensities in Hong Kong, China by Service Worker**




Source EMSD, 2000; APERC, 2000a

Energy consumption per worker (floorspace data was not available) in Hong Kong, China is illustrated for each end use in Figure 53. From 1984-1994, energy per worker for the largest end use, space conditioning mostly air conditioning, increased by 63 percent. Lighting intensity rose by 23 percent. Comprehensive building codes and the introduction of an energy audits programme in 1993 may have contributed to declining intensities for lighting and space conditioning after 1994. "Other" energy consumption which may refer to uses such as escalators, lifts/elevators and streetlighting, more than doubled from 1984 to 1998. Though only a small component of overall consumption, energy per worker for office equipment jumped seven-fold over this same period.

In developed economies the intensity effect has contributed to rising energy consumption but not to the degree seen in industrialising economies. Upward trends in developed economies for energy per worker are likely due to the rapid penetration of office equipment such as computers, faxes, photocopiers and printers, since the late 1980s. In the United States, for example, between 1992 and 1995 the number of personal computers and terminals increased by 45 percent while PCs and terminals per worker increased by 32 percent [EIA, 1999b]. In their most recent forecast to 2020, the EIA estimated that while floorspace would grow by only 1.3 percent per year, energy for computers and other office equipment such as fax machines and photocopiers, was projected to grow 4.5 percent and 3.5 percent per year, respectively [EIA, 2000].

The second factorisation method separates out structure and weather effects. The resulting intensity effect (weather adjusted energy per unit of floorspace) is therefore a purer measure of technical and behavioural energy efficiency changes. In Canada, energy per unit of floorspace fell sharply in the early 1980s and flattened out through the 1990s. These intensity improvements resulted from improved energy conservation and efficiency practices following the energy crisis in the 1970s. A recession in the early 1990s and weak economic growth to 1997 contributed to slower adoption of energy efficient technologies during the 1990s.

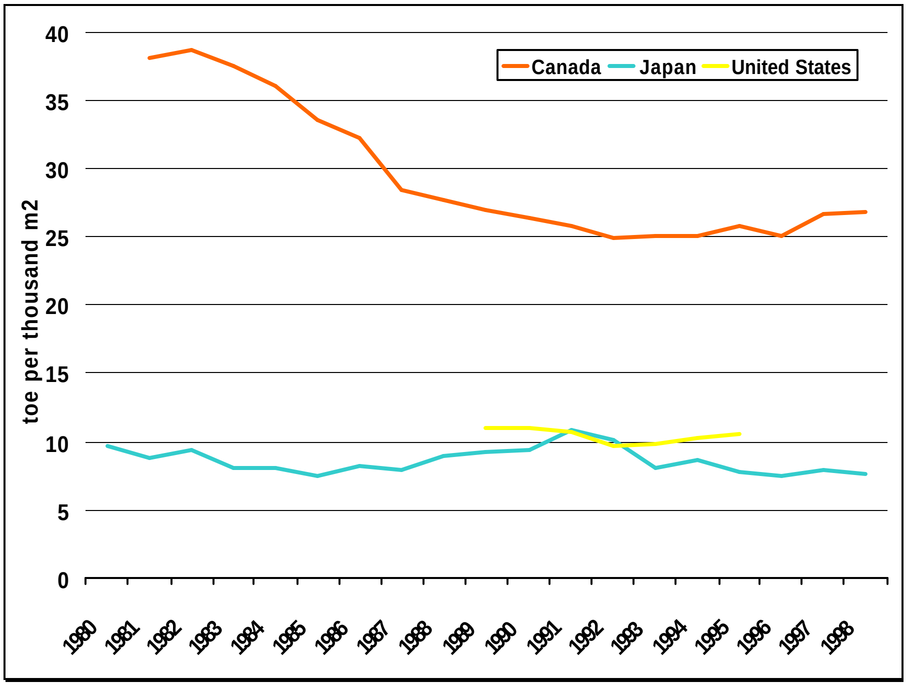
In Japan, energy intensity improved in the late 1980s, then worsened, before flattening out in the 1990s at its 1980 level. The impact of intensity on overall energy consumption was therefore neutral. The period of worsening intensity, 1987-1992, corresponds with a time of rapid economic growth dubbed the "bubble economy." Falling vacancy rates during these years contributed to the increase in energy use per unit of floorspace observed.

In the United States, end use data is only available from 1989 to 1995. Coinciding with a severe recession in 1990-1992, weather adjusted energy use per square metre fell sharply in the United States. This decline was likely caused by higher vacancy rates during the recession rather than improved energy efficiency performance. When a building is vacant, energy consumption is lower. Intensity levels returned to 1989 levels in 1995. From this small sample of data which includes a period of recession, it is difficult to draw conclusions about energy intensity trends in the United States.

By studying end use data, it is possible to identify where energy efficiency gains have been made. In Canada, space heating is responsible for more than 50 percent of service energy consumption and was the key driver of efficiency improvements over the study period. After the energy crisis, buildings were designed with more insulation, better windows and more energy efficient boilers and furnaces. Figure 54 shows weather adjusted energy consumption for space heating per unit of floorspace. From 1981 to 1990 energy consumption for space heating declined by about 30 percent. If end use data for this period was available for the United States, it would likely show similar trends. In the 1990s efficiency improvements flattened out in Canada as lower energy prices reduced incentives for further efficiency improvements and slower economic growth reduced the rate of floorspace additions (new buildings are more energy efficient than older buildings).

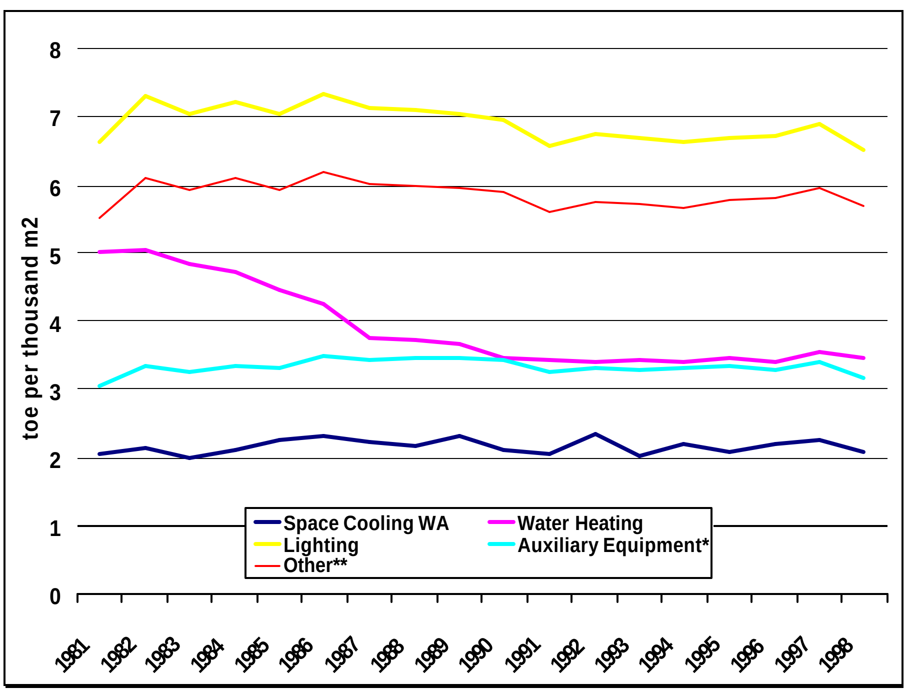
In Japan, where energy is much more expensive, space heating energy per unit of floorspace showed only moderate improvement over the study period. Incentives to reduce energy consumption and

**Figure 54 Weather Adjusted Services Space Heating Energy Intensity by Floorspace**




Source OEE, 1999; EDMC, 2000; EIA, various years

**Figure 55 Canada, Other Services End Use Intensities by Floorspace**



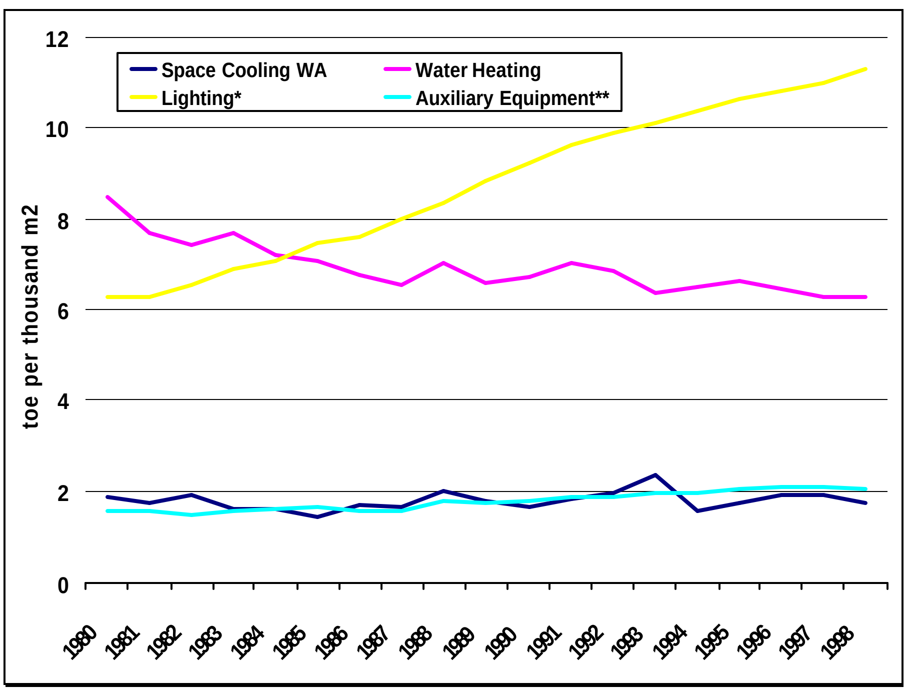

Source OEE. 1999 * includes cooking, refrigeration and office equipment. ** includes ventilation, escalators and other miscellaneous uses. WA= weather adjusted.

improve efficiency were strong in Japan long before the energy crisis and conservation measures may have been exhausted before the study period. Space heating is one of the most important end uses in Japan and is responsible for 24 percent of end use consumption.

In Canada, other end uses have also, to a lesser degree than space heating, contributed to the improvements in energy intensity (see Figure 55). Water heating intensity improvements mirrored those observed in space heating. Energy per unit of floorspace fell 31 percent between 1981 and 1990 due to the installation of more efficient water heaters. There has been some improvement in lighting and "other" energy consumption (ventilation, escalators, elevators and the like) since 1990. Increased use of building control systems to regulate lighting and space conditioning systems and mandated performance standards for lighting products and motors in the United States and Canada contributed to these efficiency gains. The intensity for auxiliary equipment (including energy for cooking and for office equipment) is flat throughout the period. This result is surprising since between 1990 and 1995 sales of personal computers in Canada grew by 107 percent, workstations grew by 199 percent, laser printers by 320 percent and fax machines by 98 percent [OEE, 2000]. Moreover, each year these products become more powerful and are equipped with new features. Power management equipment, which reduces energy consumption during periods when the product is not in use, and which is now standard in personal computers and some printers and photocopiers, may be offsetting this expected energy consumption growth. Another possible explanation is that other end uses, such as cooking, which are grouped with office equipment in the data collection process, may be masking the expected upward trend.

In Japan, for data collection purposes, lighting, office equipment, ventilation, elevators, escalators and other electric equipment are grouped together into one category called "lighting and power." This category has been the most important contributor to overall energy intensity. Over the study period, lighting per unit of floorspace increased by almost 80 percent (3.3 percent per year). The increased

**Figure 56 Japan, Other Services End Use Intensities by Floorspace**




Source EDMC, 2000 * includes lighting, office equipment, ventilation, escalators, elevators ** includes cooking.

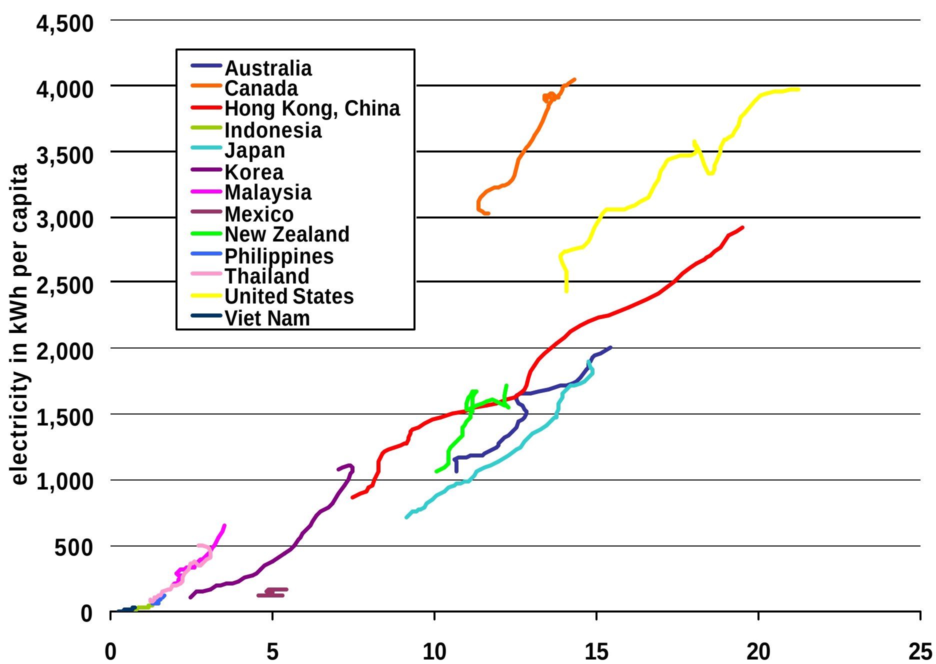
WA= weather adjusted.

penetration of office equipment as well as more intensive use of existing equipment contributed to higher levels of energy intensity in the services sector. In recent years, lighting and power has surpassed space heating as the most important end use in Japan. Energy per unit of floorspace for cooking was also drifting upwards during this period. Water heating accounts for 22 percent of FEC in Japan. A 26 percent reduction in water heating energy intensity during the study period helped to offset the upward trend in overall energy per unit of floorspace. As in Canada, weather adjusted space cooling energy intensity was relatively flat over the study period despite reports of increased penetration of air conditioning equipment. New cooling equipment is more energy efficient than older units. As this older equipment is retired, the net result may be slower growth in cooling intensity. Initially, overall improvements in energy intensity in Japan were derived from falling intensities for space heating. More intensive use of existing floorspace during the "bubble economy" led to increased energy consumption. During the 1990s, rising end use intensities for lighting and power have been offset by falling space and water heating intensities. Aggregate intensity levels in Japan therefore flatten out after 1992.

## THE PIVOTAL ROLE OF ELECTRICITY

Electricity use appears to be an indirect indicator of affluence. In all APEC economies, regardless of development status, when services GDP per capita is plotted against services electricity consumption per capita, a strong positive correlation between the two indicators is observed during the study period (Figure 57). In warm temperate and tropical climates, such a relationship is not surprising. As demonstrated in the section *Energy Consumption Trends*, in these economies, electricity consumption makes up 80 percent or higher of total energy consumption in the services sector. However, a similar pattern is also observed in economies, developed and industrialising, with cooler climates, because major end uses such as space cooling, lighting, ventilation, refrigeration and office equipment, which improve the standards of living and working, are powered almost exclusively by electricity.

**Figure 57 Electricity per capita and Services GDP per capita**

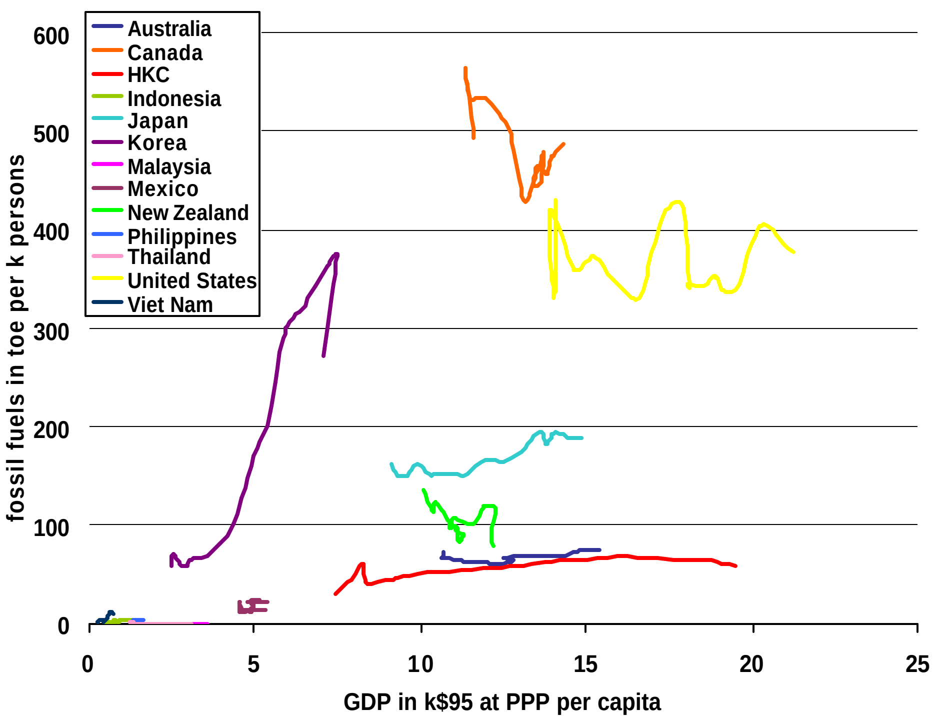



Source APERC, 2000a

Rising standards of living appear to be driving rapid growth in electricity consumption. In developed economies such as Japan and the United States from 1981 to 1997, service GDP per capita increased 1.5 and 1.6 times, respectively. For economies like Indonesia, Korea, Thailand and Viet Nam, income grew by 2.7, 3.0, 2.4 and 2.5 times, respectively over the same period. However, incomes and overall wealth in developing economies are starting at much lower levels than in industrialised economies. Since consumers are purchasing equipment for the first time rather than replacing or upgrading what they have, rising incomes will have a much larger impact on energy consumption levels than in developed economies. Moreover, incomes are still very low in economies such as Indonesia, Malaysia, Mexico, Philippines, Thailand and Viet Nam and there is still much room for income and in tandem, electricity consumption growth.

Except in the case of Korea, the correlation between per capita income and fossil fuels in 13 APEC economies appears quite weak (see Figure 58). Korea has a climate with cold winters; therefore, space heating is an important end use. This observed link between income and fossil fuel consumption may be short term. It is likely that many buildings in Korea have not yet achieved an acceptable minimum level of space heating service. Once this level is reached, the relationship between income and fossil fuel consumption should weaken. In Canada, an economy with a colder climate than Korea, fossil fuel consumption relative to income has actually begun to decline due to improved efficiency measures.

**Figure 58 Fossil Fuels per capita and Services GDP per capita**




Source APERC, 2000a

## SERVICES CARBON DIOXIDE EMISSIONS

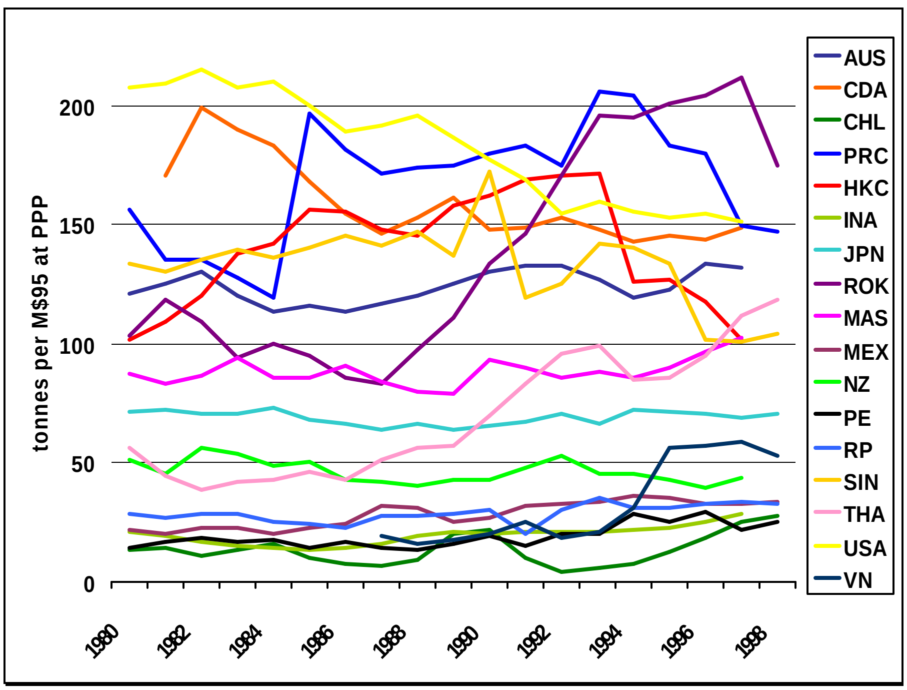
Carbon dioxide emissions related to energy use in the services sector was calculated using IEA emissions factors. The total reported takes into account full cycle emissions; that is, it includes emissions produced during the electricity generation process.

The United States is by far, the largest emitter of carbon dioxide in the APEC region. It was responsible for 62 percent or 898 Mt of service sector emissions in 1998. China was the next largest emitter at 11 percent or 163 Mt and Japan was in third place with 9 percent or 131 Mt of carbon dioxide. Overall $CO_2$ emissions in the APEC region have increased by two-thirds during the study period growing from 875 Mt in 1980 to 1,451 Mt in 1998.

Carbon intensities and energy intensities show similar patterns. In developing economies, carbon intensities are increasing while in industrialised economies, carbon intensities are flat or declining. In the United States tonnes of $CO_2$ per unit of services GDP fell from 208 tonnes per M$95 at PPP in 1980 to 151 tonnes per M$95 at PPP in 1997, a decline of -1.9 percent per year. In Thailand carbon intensities rose 4.3 percent per year, increasing from 56 tonnes per M$95 at PPP in 1980 to 118 tonnes per M$95 at PPP in 1998.

Energy mix plays an important role in carbon intensities. Space heating, which strongly favours fossil fuel use, is responsible for more than half of services end use consumption in economies such as Canada, China and Korea. As would be expected, higher carbon intensities are observed in these economies. In the Philippines and Thailand where electricity is responsible for more than 80 percent of energy consumption in the services sector, the method of electricity generation is very important in determining carbon intensity. If an economy uses a lot of coal or fuel oil to produce electricity, its carbon intensity will be higher than an economy which relies on low carbon options such as geothermal or hydro. Electricity generated from high-carbon fuels may explain why Malaysia and Thailand, both with tropical climates, have higher carbon intensities than Japan and New Zealand.

**Figure 59 Services Carbon Dioxide Intensities by Services GDP**




Source APERC, 2000a; IEA, 1998

## CONCLUSIONS

As indicated at the outset, the services sector contains a large variety of sub-sectors and building types with very different requirements for end uses such as space conditioning, lighting, water heating, cooking and the like. Analysing aggregate indicators such as services FEC per worker or unit of GDP provide general information about energy consumption in the sector as a whole but give very little insight into energy efficiency. Except for a handful of APEC economies, the best energy intensity indicator that could be constructed was energy per worker. This indicator was not adjusted for structure or weather effects. Further analysis of this intensity was impossible because few economies collect more detailed service sector data. To make meaningful conclusions, better data on building types, floorspace and end use services broken out by building type are required. Examining trends at a sub-sectoral and end use level help to identify energy consumption patterns and provide ideas for effective energy policy to improve efficiency. Though there is still room for improvement, data from Canada, Japan and the US show what sort of energy efficiency analysis is possible with good data.

Regardless of the data constraints, several interesting results have come from this analysis. Energy consumption in services is growing quickly, particularly in developing economies. Electricity consumption is driving this growth. Based on end use data for a few economies and fuel shares information, the drivers of electricity growth in industrialising economies appear to be air conditioning use and to a lesser degree the penetration of office equipment. These roles are inversed in developed economies.

Electricity consumption is strongly correlated with services GDP per capita and as standards of living increase, consumption of this fuel is expected to grow rapidly. The choice of fuels to generate that electricity will have a large impact on carbon dioxide intensities, particularly in developing economies. If coal or fuel oil is used, carbon intensities will increase. If low carbon sources such as hydro or geothermal are exploited, then the environmental impact will be lower.

Given the energy dependence of many of Asia’s largest economies, the rising cost of energy and air quality issues in some of Asia’s largest cities, understanding the drivers behind energy consumption growth and monitoring efficiency trends is important for achieving sustainable levels of energy consumption. The need is particularly urgent in developing economies where growth has been extremely rapid. This simple analysis reveals a few areas where energy policies and regulation may be very effective. Of course, these are general ideas, specific policies must be tailored to each economy’s unique situation. Since lighting and space conditioning cover 80 percent of energy consumption in most economies, implementing building codes which regulate the energy efficiency of the building envelop as well as lighting and space conditioning levels would be particularly effective in reducing the rates of electricity consumption growth. Regulating minimum levels of efficiency for air conditioners, lighting products and office equipment would also help to reduce consumption levels. There is a cost to higher standards but slower rates of energy consumption, especially when energy supplies are imported and air quality is a concern, will help ease the transition from a developing to a more industrialised economy.

# CHAPTER 7

## RESIDENTIAL ENERGY EFFICIENCY INDICATORS

### OVERVIEW

The residential sector accounted for approximately 20 percent of final energy consumption (FEC) in the APEC region. Residential share was highest in Russia at 33 percent and lowest in Singapore at 5 percent in 1997.

In the residential sector energy is used for space conditioning, water heating, cooking, lighting and household appliances and electronics. The sector includes four types of dwellings: private homes, rented homes, apartments/flats and mobile homes. Lodging such as hotels and motels, is included in the services sector. [26]

This chapter analyses trends in residential energy consumption in the APEC region over the period 1980 to 1998. It also examines energy efficiency trends in selected APEC economies. The data presented is mainly collected from international sources, such as the WB, IEA and ADB but wherever possible, data has been supplemented by economy sources.[27]

### ENERGY CONSUMPTION TRENDS

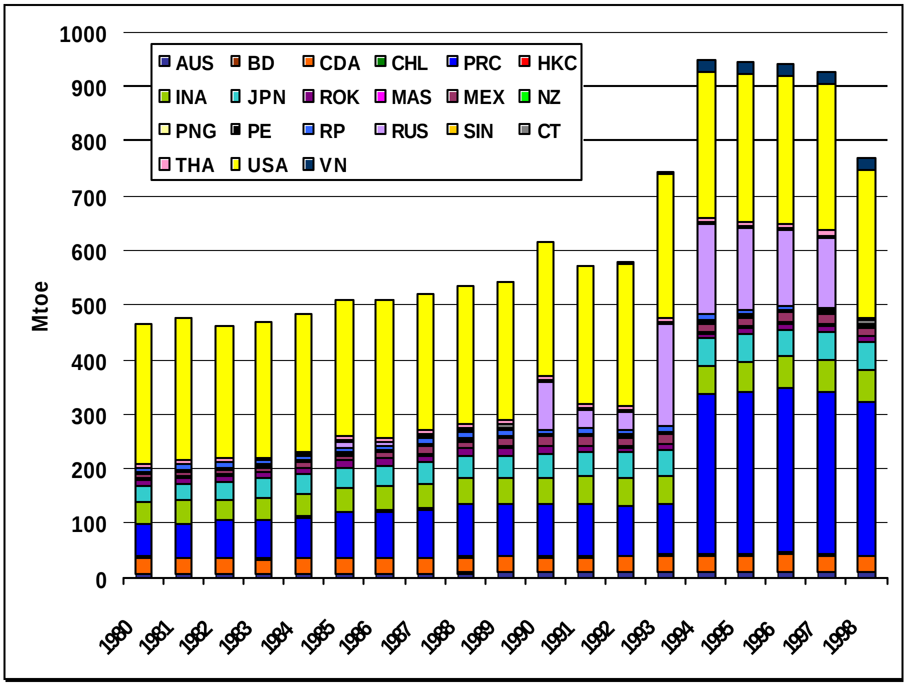
Final energy consumption in the residential sector was 926 Mtoe in the APEC region in 1997. China accounted for the largest share of the APEC total at 32 percent, followed by the United States with 29 percent.[28] Figure 60 shows residential energy consumption over the study period. Russian data is not available until 1992 and is quite variable. China and Viet Nam also have data problems. The IEA reports biomass or traditional fuels for these economies only after 1993 and the result is a large jump in energy consumption. Residential energy consumption has been increasing relatively slowly compared to other end use sectors. Over the period 1987 to 1997 household energy use in the APEC region increased by 2.8 percent[29] per year, while total FEC grew by 3.9 percent.

In general, the household sector in developing economies grew at a faster pace than in developed economies. Viet Nam posted the highest growth rate in the APEC region at 6.5 percent over the period from 1980 to 1998.[30] Among OECD members, Japan had the most robust growth at 2.8 percent per year.

Figure 61 shows fuel shares in the residential sector for economies in the APEC region. Biomass and non-commercial fuels dominate the fuel mix in many developing economies. In Viet Nam, traditional fuels accounted for more than 90 percent of total household energy use in 1998 and for approximately 77 percent in China. Biomass is used extensively in rural areas because incomes are low and because the infrastructure for distributing other fuels such as natural gas or fuel oil, is underdeveloped. In urban areas where incomes are low and access to other fuels is limited, coal is also an important fuel. Like biomass, indoor use of coal leads to poor air quality. As per capita income increases, households substitute cleaner more expensive fuels such as propane for cooking and water heating, and traditional fuel use begins to decline. In the case of Korea, household coal consumption fell 28 percent between 1994 and 1998. Coal use in China by the residential sector declined 8 percent from 1988 to 1998.

Due to the extensive infrastructure required, natural gas consumption is higher in developed economies than it is in developing economies. Natural gas has captured a large share of fuel

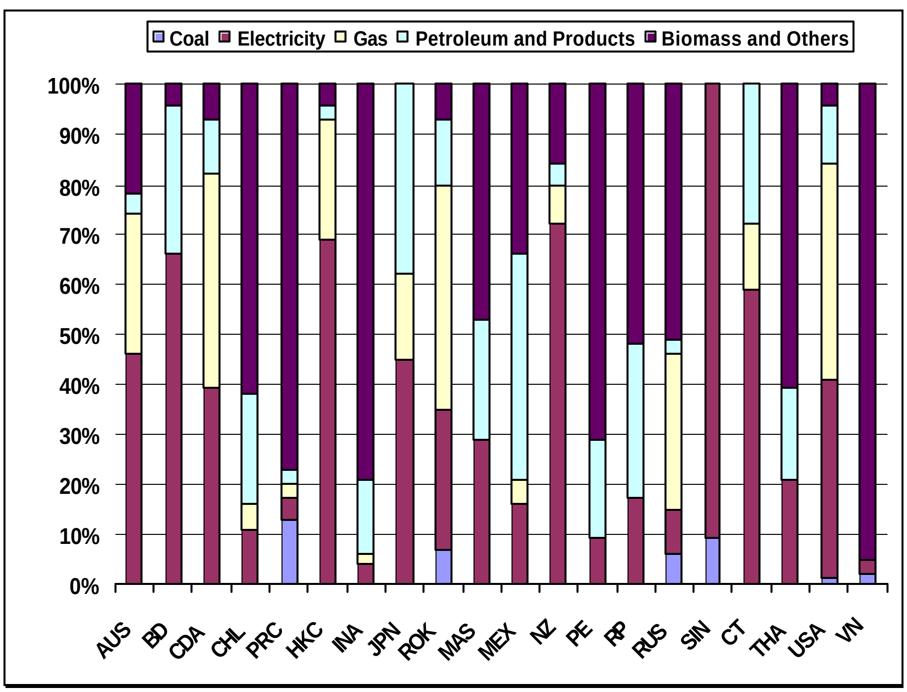
## Figure 60 Energy Consumption in the Residential Sector




Source APERC, 2000a

Note Includes traditional energy

## Figure 61 Energy Mix in the Residential Sector, 1998

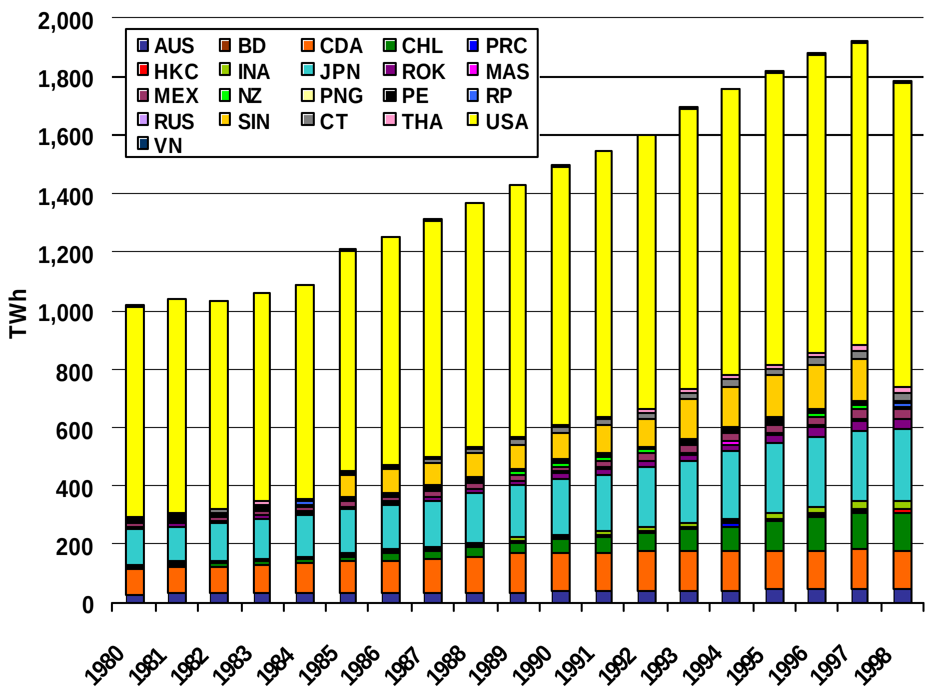



Source IEA, 2000a

consumption in Canada, Korea and the United States, where it is popular for space heating.

Electricity is widely used by all the member economies. Electricity made up 18 percent of total household energy consumption in 1997. As shown in Figure 62, electricity consumption in the APEC region grew by 3.8 percent per year over the study period, reaching 1,922 TWh in 1997. The United States, at 54 percent, was responsible for the largest share of APEC electricity consumption. Over the study period, consumption in the US grew by 2.0 percent per year. China led APEC economies with the fastest growth rate, 15.1 percent per year, for electricity consumption. Chinese consumption reached 133 TWh in 1998. Improvements to power infrastructure and the penetration of electric appliances facilitated this rapid growth.

**Figure 62 Electricity Consumption in the Residential Sector**




Source APERC, 2000a

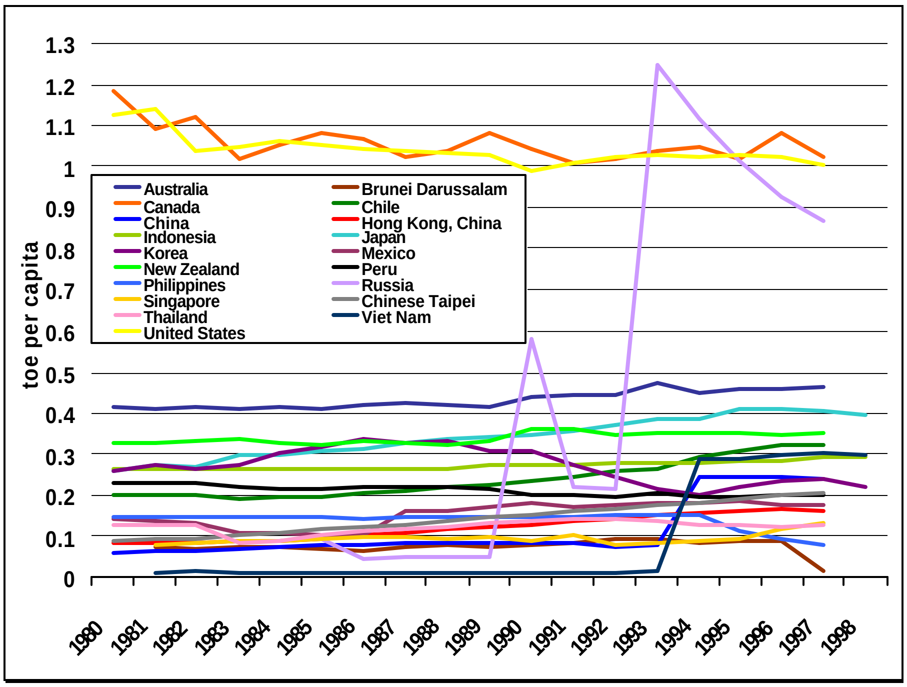
## ENERGY INTENSITY

In general, improvements in energy efficiency are achieved when the same level of service is provided using fewer energy inputs. Energy intensity or energy normalised by a physical indicator, does not necessarily provide a good measure of energy efficiency over time. Observed changes in this indicator can be due to factors such as climate, demographic changes, lifestyle changes and access to energy supplies, which have little to do with energy efficiency per se. Each available indicator has its strengths and weaknesses; therefore, to get a complete picture of the sector, these indicators should be considered together. The availability of data is also a problem in constructing energy efficiency indicators for the residential sector. Many economies do not collect data on the number of households, the size of living area or the end uses for energy. This lack of data reduces the number of indicators that can be constructed and limits a policy-maker's ability to monitor energy efficiency changes.

### TOTAL ENERGY CONSUMPTION PER CAPITA

Figure 63 shows residential energy consumption per capita across the APEC region. Though energy per capita is drifting upwards in most economies, there is a large gap in absolute intensity levels between developing and developed economies. Energy per capita use per household was significantly higher in the United States and Canada than in other APEC economies. Both of these economies have substantial space heating requirements, more than half of total energy is devoted to this end use. Unlike with electricity, it takes more than 1 ktoe of fossil fuels to produce 1 ktoe of useful energy for space heating. Fossil fuels for space heating may inflate the observed energy indicator.

**Figure 63 Residential Energy Consumption per capita**




Source APERC, 2000a

Energy consumption per capita in Korea declined significantly in the early 1990s, but has since trended upwards. This observed downward trend may be related to fuel switching. Households have been substituting away from coal towards more expensive, but cleaner-burning fuel oil, natural gas and propane for space heating, water heating and cooking [Ishiguro and Akiyama, 1995]. Further, new stoves have higher thermal efficiencies than older coal-burning equipment resulting in a decline in the amount of input energy required by households [Ishiguro and Akiyama, 1995]. Japan showed the strongest growth trends among developed economies. Larger dwelling sizes and further penetration of electric appliances explain this strong growth. As discussed previously, the inclusion of traditional fuels for China and Viet Nam after 1994 caused total energy to jump substantially and has distorted observed intensity levels.

### DRIVERS OF ENERGY CONSUMPTION

The most important drivers of energy consumption are activity, structure, weather and energy intensity. Even if intensity is adjusted for structure and weather effects, it is still a catch-all and is influenced by fuel switching, quality of life as well as energy efficiency improvements and conservation.

Given data constraints, only a limited amount of decomposition analysis is possible in the residential sector. By examining these key factors, it is possible to explain some of the trends observed in energy intensity in the household sector over the study period.

## ACTIVITY

In the residential sector, activity can be measured by several indicators: population, households and floor area.

### POPULATION

Population is an indirect driver of energy use. The total APEC population was 2.4 billion in 1997 with an average growth rate of 1.3 percent over the period from 1980 to 1997. At 2.7 percent per year, Malaysia had the strongest growth rate among APEC economies. China had the largest share of population in the APEC region at approximately 50 percent and maintained an annual growth rate of 1.3 percent. Across the Asia-Pacific region population growth averaged around 1.1 percent per year over the period 1990-1997, slower than the 1.4 percent observed at the beginning of the study period, 1980-1990.

The age distribution of a population may also influence energy consumption. It is theorised that energy consumption is lower among certain segments of the population, particularly those over 50 years old. Many people in this age group have smaller households (their children have grown up) and their incomes are lower (they are starting to retire); therefore, it is hypothesised that energy consumption by this age group is lower relative to other age segments. In recent years, in economies such as China and Japan the average age of the population has been rapidly increasing as older segments of the population grow more quickly than the younger segments. The ageing of the population is also expected to become an issue in developed economies such as Canada and the USA as 2010 approaches and baby boomers (the generation born after the second world war) begin to retire.

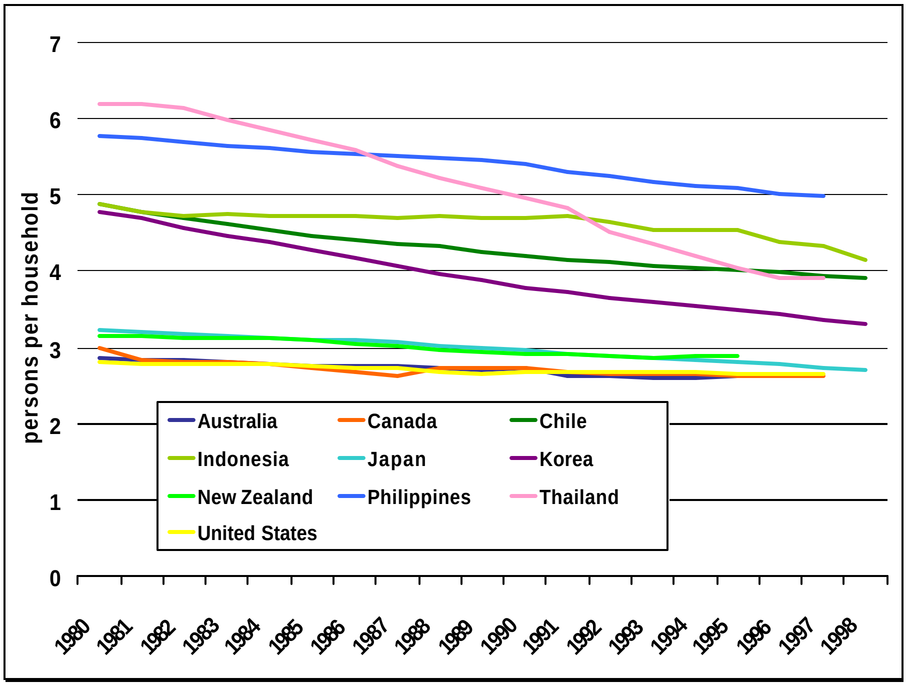
### HOUSEHOLDS

The number of households also influences residential energy consumption. Each new household requires a housing unit and each housing unit, regardless of occupancy level, requires a certain level of energy service for space conditioning and lighting. The number of households increased in all APEC economies. In general, in Asian economies the number of households grew faster than in other regions. Thailand had the quickest growth rate for households over the study period with 4.3 percent per year.

Though the number of households has been on the rise, the size of each household has been declining across the APEC region (see Figure 64). In Thailand, though the number of households is growing quickly, the size of each household fell 37 percent over the study period. The gap in size between developed and developing economies has been narrowing and appears to be converging at about 3 people per household. The drop in family size reduces energy consumption for cooking, water heating and some electric appliances, but has little effect on the largest end use for the housing unit, space conditioning.

The type of residence occupied by a household also affects energy consumption levels. Residential buildings are comprised of single-family dwellings, including detached, semi-detached houses, mobile homes; and multiple-family dwellings, such as apartment blocks [IEA, 1997]. The single-family dwelling is the most energy-intensive housing type.

**Figure 64 Household Size**




Source APERC, 2000a

In Canada and the United States, single-family dwellings make up more than 70 percent of dwelling stocks and this share is increasing. In Japan, due to the scarcity of land, urbanisation has led to a move from single-family dwellings to apartments. This pattern has been repeated in developing economies in Asia. The trend towards apartments instead of single-family dwellings does not necessarily mean a reduction in energy consumption. Energy infrastructure in rural areas is often less developed than in urban areas. Since the cost of energy is higher and supplies are less reliable, consumption per household tends to be lower in rural than in urban areas.

Construction materials and the age profile of the building stock also affect energy consumption per dwelling. Wood-framed homes consume less heating fuel than brick-framed ones. In general, older buildings consume more energy for space conditioning than do new buildings. Due to the cost of housing, it can take many years for the housing stock to turnover. In Canada, according to a survey done in 1997, 16.5 percent of existing housing floorspace was built before 1946 [OEE, 2000].

FLOOR SPACE

Unlike population and households, floor space is a direct indicator of energy consumption. Energy demand for space conditioning and lighting, about 70 percent of end use energy consumption, is directly correlated with the amount of floor area in place. Floorspace data, however, is only available for a few economies. According to available data, space area per capita seems to increase over the time. However, the gap between economies is still large. Floor area per capita in the United States is 1.9 times higher than Japan and 4.6 times higher than in China (see Table 9).

**Table 8 Proportion of Total Households in Urban Areas**

| | 1980 | 1985 | 1990 | 1995 | 1997 |
|---|---|---|---|---|---|
| Australia | 0.86 | 0.85 | 0.85 | 0.85 | 0.85 |
| Brunei | | 0.62 | 0.66 | 0.69 | 0.70 |
| Canada | 0.52 | 0.52 | 0.58 | 0.65 | 0.66 |
| China | | | 0.26 | 0.29 | 0.30 |
| Chile | 0.81 | 0.83 | 0.83 | 0.84 | 0.84 |
| Korea | 0.57 | 0.65 | 0.74 | 0.81 | 0.83 |
| Malaysia | 0.42 | 0.46 | 0.50 | 0.54 | 0.55 |
| Mexico | 0.66 | 0.70 | 0.73 | 0.73 | 0.74 |
| New Zealand | 0.83 | 0.84 | 0.85 | 0.86 | 0.86 |
| PNG | 0.13 | 0.14 | 0.15 | 0.16 | 0.17 |
| Peru | 0.65 | 0.67 | 0.69 | 0.71 | 0.72 |
| Philippines | 0.37 | 0.43 | 0.49 | 0.54 | 0.56 |
| Singapore | | 1.00 | 1.00 | 1.00 | 1.00 |
| Russia | 0.70 | 0.72 | 0.74 | 0.76 | 0.77 |
| Thailand | 0.17 | 0.18 | 0.19 | 0.20 | 0.21 |
| USA | 0.74 | | 0.75 | | |
| Viet Nam | 0.19 | 0.20 | 0.20 | 0.19 | 0.20 |

Source APERC, 2000a

**Table 9 Residential Floor Area per capita**

| | 1980 | 1983 | 1984 | 1987 | 1988 | 1990 | 1993 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | (square metres) | | | | |
| US[31] | 60.0 | | 58.6 | 61.9 | | 64.9 | 67.3 | 60.4 | |
| Japan | | 25.0 | | | 27.2 | | 30.0 | | 32.4 |
| China | | | | | 9.3 | 9.9 | 11.0 | 13.0 | 13.6 |

Source EIA, various years; Statistics Bureau and Statistics Center of Japan, 2000; State Statistical Bureau of PRC, 1999.

## STRUCTURE

Structure is defined as the percentage of energy used for different end uses. End use intensities for space conditioning, lighting, water heating, cooking and appliances vary across APEC economies. Cross-economy comparisons of these end use intensities are questionable because differences do not stem just from energy efficiency performance. Climate, level of economic development and local preferences also affect the level of energy intensity. Few economies collect detailed energy consumption data for end use purposes so only two broad categories of end uses will be examined: energy for space heating and captive electricity uses.

### ENERGY CONSUMPTION FOR SPACE HEATING PER HOUSEHOLD

According to data collected for 6 APEC economies, space heating is the largest end use in the residential sector (see Table 10). It accounted for 27 to 59 percent of end use consumption in 1997. As would be expected, economies with colder climates had larger space heating shares. Over the study period, space heating share fell in all economies except for Russia.

**Table 10 Share of Residential Energy Consumption for Space Heating**

| | 1980 | 1985 | 1990 | 1993 | 1995 | 1997 |
|---|---|---|---|---|---|---|
| | | | percent | | | |
| Australia | 55 | 51 | 52 | 51 | 51 | |
| Canada | 67 | 62 | 58 | 59 | 59 | 59 |
| Japan | 29 | 31 | 28 | 28 | 29 | 27 |
| New Zealand | 33 | 44 | 40 | 30 | 32 | |
| Russia | | | | 36 | 46 | 53 |
| USA | 56 | 56 | 52 | 53 | 52 | 51 |

Source APERC, 2000a

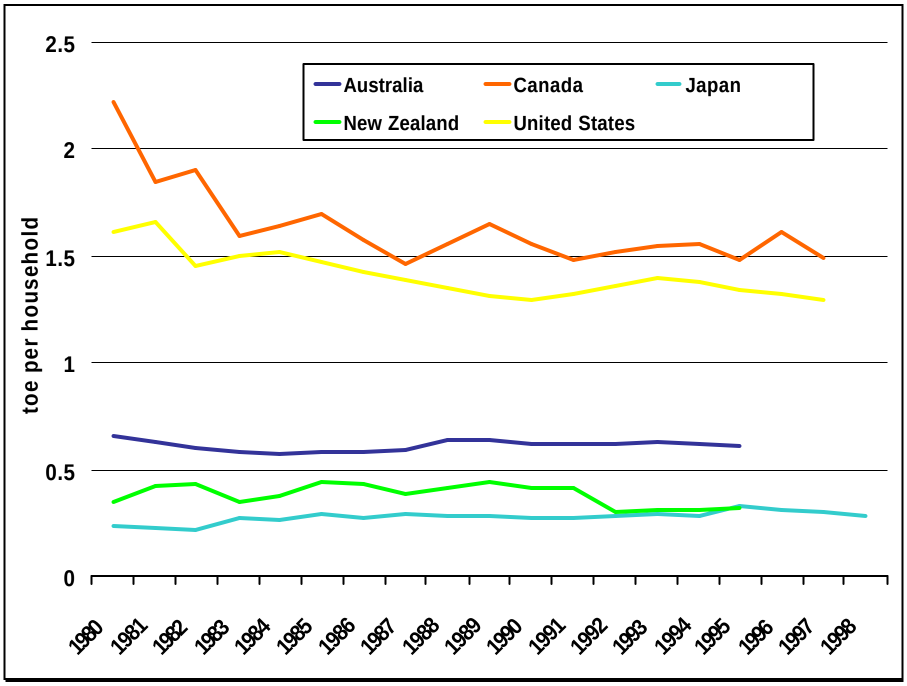
Climate plays a significant role in influencing energy consumption patterns. To normalise data within an economy, space heating and space cooling energy needs to be adjusted for normal weather patterns in that economy. This adjustment smooths out year-to-year variations in space conditioning energy consumption and makes it easier to identify reductions in energy consumption due to efficiency improvements. In order to facilitate cross-economy comparisons, energy for space conditioning purposes in all economies should be adjusted for an average "regional" weather pattern. Due to data constraints, this adjustment was not attempted.

Figure 65 and Figure 66 show energy use per household for space heating unadjusted and adjusted for each economy's normal weather patterns.[32] Data is only available for a few economies. Over the study period, even after adjusting for weather, space heating intensity in Canada and the United States declined by 23 percent and 17 percent, respectively. In the early 1980s, after the energy crisis, buildings were designed with more insulation, better windows and more efficient space heating equipment was installed. All of these changes helped to reduce space heating requirements in these economies. This same intensity increased by 55 percent in Japan over the same period.

### ELECTRICITY CONSUMPTION PER CAPITA FOR CAPTIVE USES

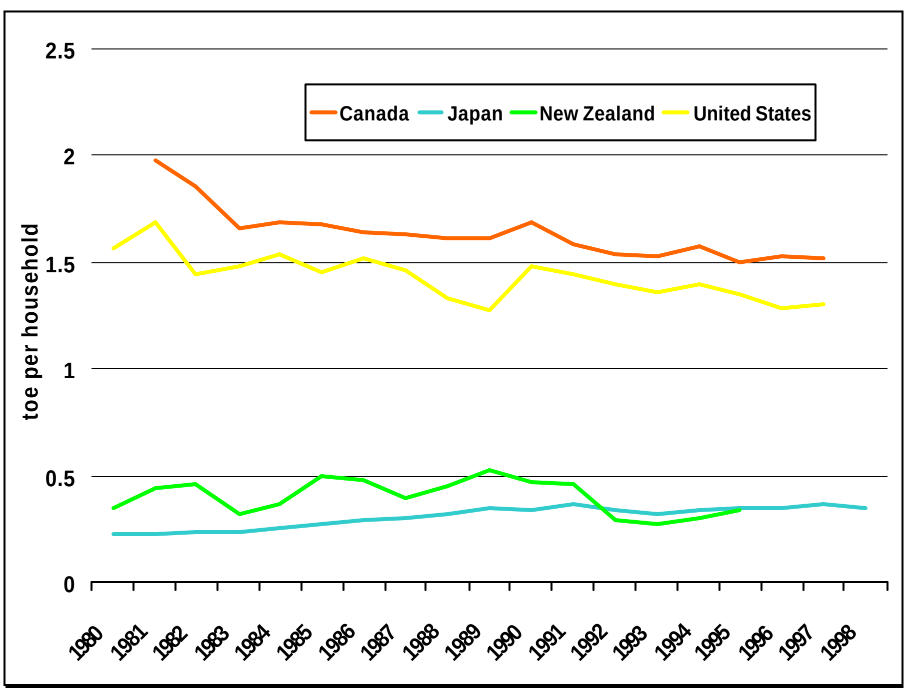
Electricity is used for a variety of purposes in the household sector including space conditioning, lighting and electric appliances. In colder climates, space heating intensity is the dominant end use; however, in milder climates where space heating needs are minimal, electricity intensity is more important. As illustrated in Figure 67, electricity per capita increased in all APEC economies except Russia. Canada and the United States had much higher energy per capita use than other APEC economies. However, strong growth rates were observed in developing economies. In Viet Nam this intensity increased quickly at 11.1 percent per year over the study period.

**Figure 65 Energy Use for Space Heating per Household without Climatic Correction**



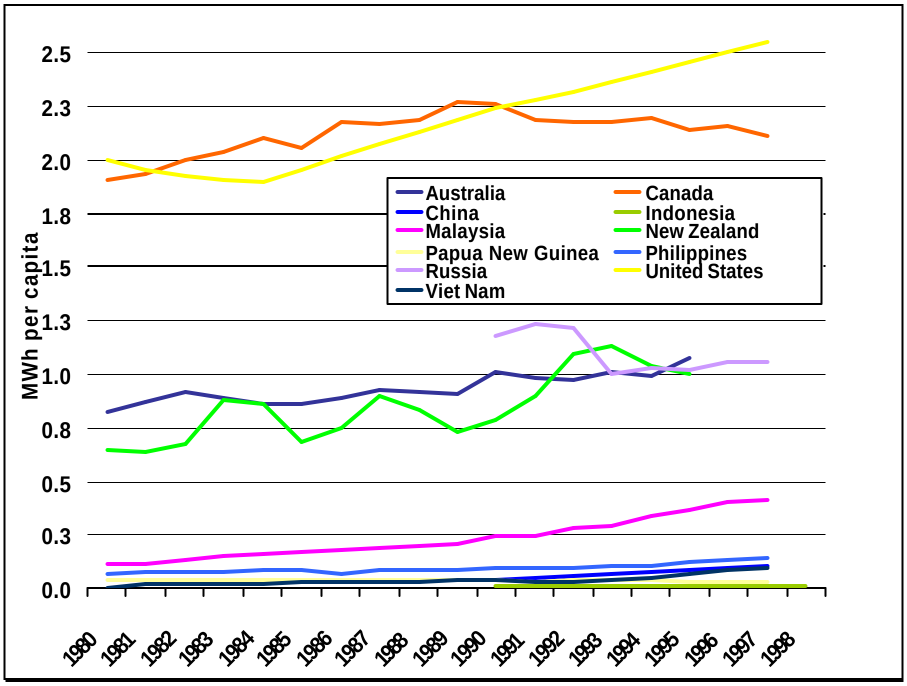

Source APERC, 2000a

**Figure 66 Energy Use for Space Heating per Household with Climatic Correction**




Source EDMC, 2000; EIA, various years; OEE, 1999

**Figure 67 Electricity Consumption per capita for Captive Uses**




Source APERC, 2000a

Due to the diversity of uses for electricity, without detailed end use energy data for the residential sector, it is difficult to attribute rapid electricity use to a particular source. Increasing standards of living are likely driving these rapid increases in developing economies. Table 11 shows ownership rates for electric appliances in China. Between 1985 and 1998, ownership levels for refrigerators and colour televisions per 100 households increased by 12 and 6 times, respectively. The rapid penetration of

**Table 11 Urban Household Electric Appliances in China**

| | 1985 | 1990 | 1994 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|
| | (Number of units per 100 households) | | | | | |
| Electric Fan | 74 | 136 | 154 | 168 | 166 | 168 |
| Washing Machine | 48 | 78 | 87 | 90 | 89 | 91 |
| Refrigerator | 7 | 42 | 62 | 70 | 73 | 76 |
| Colour TV | 17 | 59 | 86 | 94 | 100 | 105 |
| Video Disc Player | | | | | 8 | 16 |
| Tape Recorder | 41 | 70 | 73 | 73 | 57 | 58 |
| Air Conditioner | | | 5 | | | 20 |
| Electric Cooking Appliances | | | 75 | | | 96 |

Source State Statistical Bureau of PRC, 1995 and 1999 electric appliances in developing economies, such as China, is likely contributing to growing per capita electricity use. It is uncertain if the energy intensity of each appliance is also increasing. Though the quality of electronic equipment has improved and new items are more powerful and have more options, over the same period, energy saving features have been incorporated into new appliances.

In economies with mild or tropical climates, the use of air conditioners is increasing. In China, the number of air conditioners per 100 households quadrupled between 1994 and 1998. Air conditioners for cooling are expected to be a key source of electricity growth in the future.

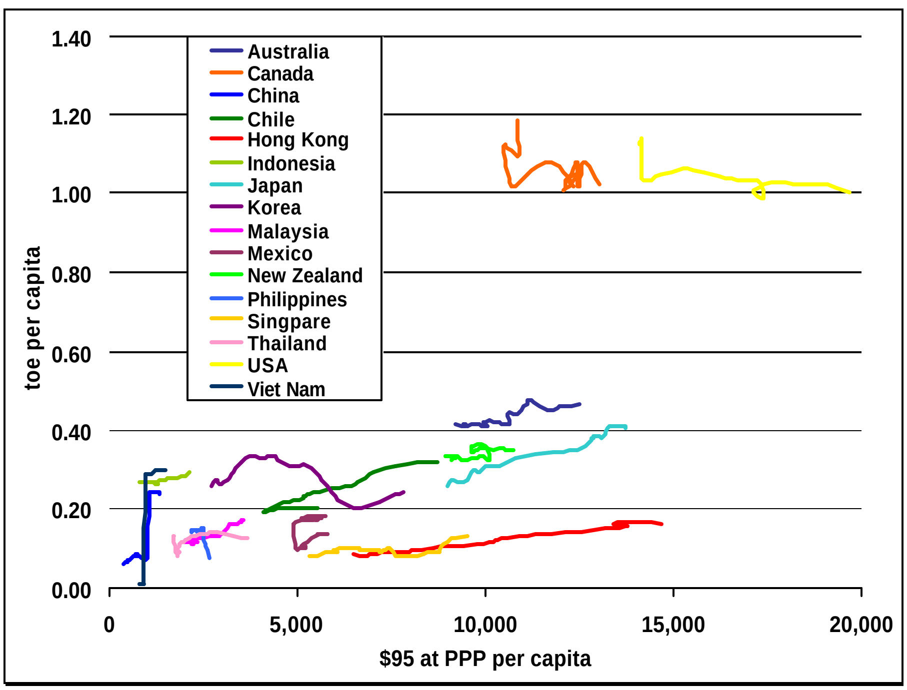
## ENERGY INTENSITY

Even after structural changes and weather effects have been accounted for, energy intensity is not necessarily an accurate indicator of energy efficiency improvements. Fuel switching and rising standards of living and other sub-structural changes affect intensity and may not be adequately documented at higher levels of aggregation such as energy use per capita.

### PERSONAL CONSUMPTION EXPENDITURES

Income per capita is a key driver of energy consumption per capita (see Figure 68). This correlation is particularly strong at low levels of income. Reinhard Haas and Lee Schipper have found that income elasticity for energy consumption is higher than price elasticity. Energy demand, however, is responsive to the highest historical price [Hass and Schipper, 1998]. In developing economies, many households have a low standard of living. As incomes rise, individuals purchase items to increase their levels of comfort. Since they are purchasing this equipment for the first time rather than replacing existing

**Figure 68 Personal Expenditures per capita and Residential Energy per capita**




Source APERC, 2000a

equipment, energy consumption begins to rise sharply in these economies. Canada and the United States have the highest incomes and highest energy per capita use in the APEC region; however, in these economies, the relationship between income and energy consumption has started to reverse direction. This decline in energy use as income rises implies energy efficiency improvements. Given the income gap between developed and developing economies and the link between income growth and energy use, there exists strong potential for significant energy intensity growth in developing economies in the future.

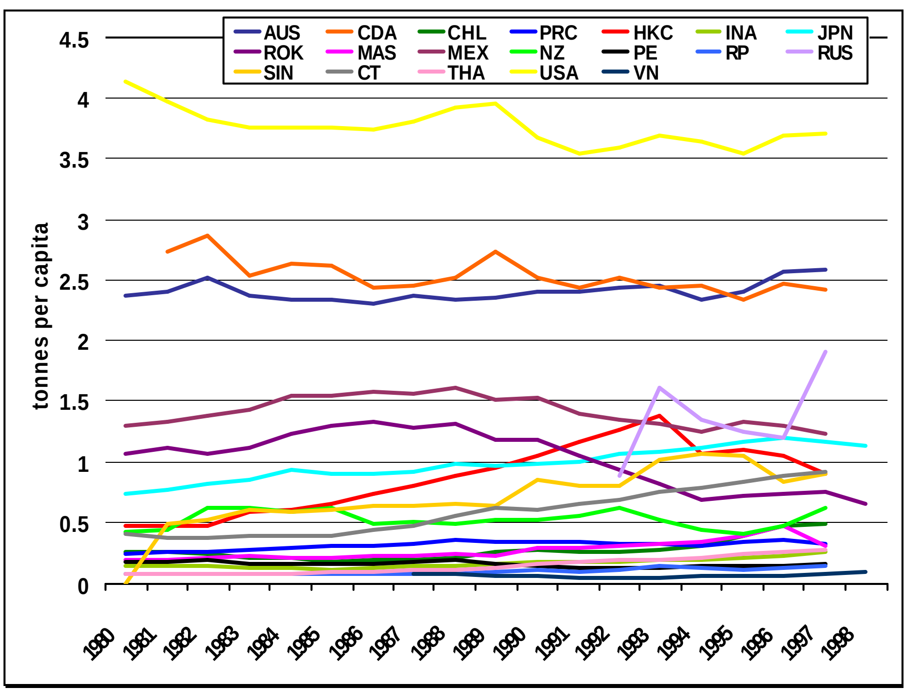
## RESIDENTIAL CARBON DIOXIDE EMISSIONS

$CO_2$ emissions are directly related with energy consumption. As with energy consumption, the United States has the highest level of carbon dioxide emissions at 48 percent of the APEC total in 1998, followed by China with 18 percent.

Except for Canada, Korea, Peru and the United States, carbon dioxide intensities per capita increased in APEC economies. In Chile, HKC, Indonesia, Singapore and Chinese Taipei, $CO_2$ intensities grew by 4-5 percent per year over the study period. In Thailand, intensities rose 8 percent per year.

As shown in Figure 69, the gap between developed and developing economies is quite large. According to the Intergovernmental Panel on Climate Change (IPCC), $CO_2$ emissions from biomass used as fuels should be excluded from total emissions figures. Since biomass accounts for 50-90 percent of energy use in the residential sector of many APEC economies, this assumption biases downwards $CO_2$ intensities.

**Figure 69 Residential Carbon Dioxide Intensity per capita**




Source APERC, 2000a; IEA, 1998

## CONCLUSIONS

Energy in the residential sector is used for a variety of purposes. Analysing aggregate indicators such as residential energy use per capita provides little information about energy efficiency. In order to evaluate energy efficiency progress for APEC economies, more data on end uses, the stock of household equipment and buildings and the efficiency levels of these stocks are required. Analysis in this chapter does shed light on key drivers of consumption growth in the residential sector and provides some ideas for policy development.

Most APEC economies experienced rapid economic growth during the study period. Higher incomes and improvements in energy services have resulted in more energy use in the residential sector. The rapid penetration of household appliances in many Asian developing economies has pushed up electricity consumption and this trend will continue in the future. There is large potential for space cooling in economies with tropical or warm temperate climates and sales of this equipment are already increasing. Smaller families and rapid growth in population and the number of households are also driving future consumption growth.

Higher standards of living do not always result in more energy use. In many developing economies, the dominant fuel is biomass. When incomes rise, households switch to more expensive but better quality fuels and equipment. More efficient fuel-based cooking and heating equipment, as in the case of Korea, resulted in a decline in energy consumption in the household sector, at least in the short-run. This bodes well for energy intensity but badly for carbon dioxide intensity. As standards of living improve and carbon-based fuels are substituted for biomass, carbon dioxide intensities should also be expected to increase in developing economies. This fuel switching effect will have more of an impact in China and Korea where space heating is a large component of energy use.

Current and future rapid growth in the residential sector provides a unique opportunity for developing economies. The stock of equipment accumulated today will affect energy consumption in the residential sector for years to come. Buildings, as discussed earlier in this chapter, stay in the capital stock for 40 to 50 years. Therefore, measures such as mandatory building codes, minimum efficiency standards for household appliances and lighting systems can be particularly effective in reducing energy consumption levels for the long-term.

# CHAPTER 8

## ENERGY EFFICIENCY POLICIES

### OVERVIEW

Government agencies, non-profit organisations and the energy sector have used a variety of instruments and programmes to reduce energy consumption, to improve energy efficiency and to mitigate carbon emissions. These measures are implemented in different ways depending on the end use sector (transportation, industrial and buildings). Moreover, a variety of programmes have been used by different economies to achieve these goals. In this chapter the main policy instruments that have been used to initiate energy efficiency and conservation programmes are discussed.

The purpose of energy efficiency programmes and initiatives is to reduce barriers to energy efficiency which exist in the market place. If a programme is effective, the market penetration of a targeted product or service will increase and policy goals such as reducing energy consumption or emissions will be achieved.

This chapter provides the reader with general policy information and illustrates how these policies have been implemented in various APEC economies. Intensities calculated in sectoral chapters for each economy have not been evaluated to assess the importance of energy efficiency programmes in place. Though documenting the impact of these programmes on energy intensity levels is beyond the scope of this report, comparing the sources of consumption growth in an economy with current programmes could highlight areas for policy assessment and possible development.

APERC has been working with ADEME to document energy efficiency and conservation policies currently being used by APEC economies. A separate report will be promulgated with ADEME that outlines these policies. Appendix A contains a summary of initial findings from the ADEME/APERC policy survey.

Before individual policies are outlined, several macro issues will be discussed such as market barriers, high “first” cost, demand side management, and electric industry restructuring.

### MARKET BARRIERS

Energy efficient products and services have not always achieved acceptance in the market-place due to a variety of market barriers. A market barrier exists if factors, other than price, discourage a consumer from purchasing the product in question. Lack of information about energy efficient products is an easy to understand barrier - consumers will not buy a product if they do not know it exists. Another barrier is a lack of concern over energy conservation. In most economies, energy prices are low enough that consumers place little value on energy saving features.

In the commercial and industrial sectors, as in the residential market, a basic lack of information prevents the penetration of energy efficient goods and services. Unless businesses are trained in energy management, have experienced high-energy bills, or are confronted with environmental regulation, energy efficiency is not a primary concern. Though businesses may be aware of energy saving opportunities and may actually conduct economic analysis based on a corporate investment rate, they may choose not to proceed with the project for other reasons.

Decision makers are concerned about a range of factors. Some questions they might ask about an untried energy efficient product or service include: Will the alternative product be durable? Will customer support be sufficient? Will the product be compatible with my existing system? Will there be special maintenance requirements or will my technicians need special training? Will it really save as much as it promises? How can I pay the higher purchase price, even if it saves me money in the long term? There is an element of risk in buying a different product or using a different technique. Since reliability and continuity are important in running a profitable business, in many cases, it is easier for the decision maker to buy the typical market product or to build the structure using established techniques rather than to try something new. At the same time, the decision maker may be convinced that the high efficiency product or practice would be the best decision, but other barriers such as lack of financing, procurement rules and unfavourable tax systems, can prevent the decision maker from buying the more efficient product.

This discussion demonstrates some of the non-price barriers that can limit the penetration of energy efficient products. The goal of energy efficiency policy is to minimise these barriers and encourage the adoption of energy efficient products and services. In developing a policy strategy for encouraging energy efficiency, it is beneficial for economies to examine the experiences of other APEC members. In APEC economies, many approaches for achieving energy conservation goals have been tried. By using the lessons learned from these policy experiments, an economy can design a more effective package of measures for achieving energy efficiency goals.

## HIGH “FIRST” COST

Consumers often do not realise that less efficient typical products with low initial costs have higher operating costs than energy efficient alternatives. To ultimately determine which product is less expensive, a simple analysis can be used to calculate a payback period. By taking the difference in price between the typical unit and the energy efficient product and dividing it by the annual energy savings resulting from use of the energy efficient product, the consumer can determine how long it takes to recoup the investment made in a more energy efficient product. In some instances, it may take one year or less to recover the cost difference.

A better method of assessment is to consider the life cycle cost or net present value of the product. In this approach, the initial purchase price of the product is added to a time series of energy costs, discounted by the appropriate discount rate. The option with the lowest life cycle cost, or greatest net present value, is the preferred option.

The determination of an appropriate discount rate can be difficult. The purchase of an energy efficient product can be considered an investment. Therefore, discount rates can be viewed as the next best alternative, or opportunity cost, for the money invested. The interest rate on a savings bank account might be an appropriate discount rate (approximately 0-7 percent) or if, the consumer is purchasing equipment on credit, the loan rates offered by banks or credit cards (approximately 7-22 percent) may be more suitable. The problem is that numerous market studies have shown that consumers generally use implicit discount rates that are much higher than these ranges. Consumers seem to place a higher value on initial purchase prices than on life cycle cost savings. High observed discount rates may vary significantly depending on the types of products being considered, available information, cultural differences, usage habits and energy rates.

The discussion above generally refers to the comparison of two products that are identical except for energy efficiency. In reality, often the energy efficient product is in some way different from the product normally used. The consumer may, therefore, perceive a risk associated with purchasing this high efficiency product. This inherent risk may partially explain high consumer implicit discount rates. Studies have shown, however, that even when nearly identical products offer the same performance, appearance, reliability, and brand, consumers still consider the initial purchase price more important than lower operating or energy costs over time. In light of these preferences, mandatory policies are considered to be more effective than policies aimed at influencing consumer choice.

## DEMAND SIDE MANAGEMENT / MARKET TRANSFORMATION

Demand Side Management (DSM) activity has been used for many years by utilities. The goal of DSM is to reduce demand through a variety of energy efficiency and conservation programmes. The avoided or deferred capital investment is used to fund the programmes. If it costs less to reduce demand through efficiency or conservation measures than to construct additional generation capacity, DSM is preferable.

Recently, in several world economies the term "Market Transformation" (MT) has been widely used and promoted. The concept is generally the same as DSM, except that Market Transformation programmes often target opportunities with much larger potential savings than DSM and these programmes are evaluated and scrutinised more rigorously. The concept of MT is intuitive or self-explanatory from the name. The programmes are intended to have a lasting effect in the market or to result in a transformation of market characteristics. Previously, a specified amount of generation was avoided at an estimated cost. Long lasting effects were not the primary objectives of the project. However, it is believed by some, that DSM and MT are really the same thing, except that Market Transformation is "fresher" and is not associated with previous DSM problems.

## MANAGING PEAK LOAD ELECTRICITY DEMAND

As a part of DSM, utilities have promoted a variety of programmes to shift demand from peak to off-peak periods. These programmes are highly valued by utilities because they allow for a more uniform demand profile and increase system reliability. For areas with peak demand problems, or where reliability of the power system is in question, the best policies or programmes would be ones that reduce overall demand while directly reducing peak demand. For example, in many APEC economies with warm climates, the demand profile peaks in the late afternoon. Policies that encourage or mandate high efficiency air conditioning systems would reduce peak loads and decrease overall energy demand. With appropriate economic analysis and planning, the installation of high efficiency air-conditioning, despite the initial investment, could reduce operating costs and increase net profits for the end user (utility customer).

Peak demand programmes are funded by the avoided cost of building additional generation capacity. Programmes that avoid peak demand rather than reduce overall demand should be used with caution. If peak demand levels are triggering "black outs," then such programmes should be considered. However, if the demand avoidance programme is just smoothing the usage factor of an inefficient power plant, then other options should be considered. Building a more efficient power plant may be a better solution both in terms of reducing costs and environmental impact.

Electric industry restructuring has also encouraged the use of Distributed Generation (DG) technologies. DG reduces costs and emissions because electricity is generated close to the point of use and distribution losses are minimised. Frequently, DG technologies are connected to the power grid. These interconnections allow the business or consumer to sell power back to the electric grid. Some distributed generation technologies use renewable energy sources. Examples include solar photovoltaic, wind power, small hydropower and biomass. Low polluting power sources include the use of gas micro turbines and fuel cells where waste heat is utilised to achieve system efficiencies of up to 80 percent [Valenti, 2000]. DG is discussed in detail in APERC's report *Sustainable Electricity Supply Options for the APEC Region -the Emerging Importance of New and Renewable Electricity Supply Options* [APERC, 2001]. The use of DG can alleviate electric-peak demand problems by utilising new highly efficient and non-polluting technologies.

**ELECTRICITY INDUSTRY RESTRUCTURING**

The goal of electricity restructuring is to generate and deliver electricity more efficiently, resulting in lower electricity prices to end users. In several economies it is generally believed that electric industry restructuring will lead to lower industrial prices, but possibly higher residential prices. Electric industry restructuring is not only lowering prices, it is also changing the role of the "utility." Traditionally, the utility generated the electricity, transmitted it to the locality, and provided customer service. Now, with electric industry restructuring, these roles are being performed by different entities each with their own perspectives, objectives, and market conditions. For more information on the electrical industry restructuring, please see APERC report, *Electricity Sector Deregulation in the APEC Region* [APERC, 2000b].

There has been much debate over whether electricity restructuring has added or reduced market barriers to the wider adoption of energy efficient practices. On the negative side, lower energy prices make the use of highly efficient products and services less cost effective. As well, a more efficient electric supply sector with numerous entities makes the implementation of energy demand improvements more difficult to coordinate.

Restructuring has also led to some positive developments. In the United States many of the states implementing electric industry restructuring programmes have created public benefit funds. These funds collect revenue from "wires charges" (usually around US$0.001 to US$0.004 per kWh) and use the money to fund energy efficiency programmes, low-income weatherisation (see Appendix C - Energy Audits), renewable energy incentives, and research and development [NASEO, 1999]. Thus far, over US$1.6 billion has been made available for these programmes. There are concerns that this large source of funding will only exist for a relatively short period of time. Although California has completed its second round of restructuring, the collection of "wires charges" will continue for 10 more years. These revenues will continue to fund energy efficiency, renewable energy, and energy conservation programmes [CEC, 2000].

## POLICIES

There are a variety of market-based policy mechanisms to promote energy efficiency and conservation. Policies range from passive programmes such as labelling schemes that attempt to influence the consumer at the retail outlet to aggressive financial incentive and procurement strategies. Tax incentives can also be used. The overall objective of these policies is to encourage manufacturers to produce and consumers to buy, high efficiency products. These strategies are applied to many energy consuming goods and products including appliances, heating equipment, homes, buildings, windows, electronics, automobiles and factories.

For energy efficiency programmes to be effective, policy-makers must set out clear objectives for the initiative and take into account market characteristics when designing the policy. If market conditions are not appropriately assessed and taken into consideration, the efficiency initiative may not succeed. Outlining an evaluation criterion before the programme is introduced to the market is also good practice. By determining measures for success in advance, policy-makers are more inclined to streamline their programmes before implementation. Moreover, if the policy measure is effective, having decided on a criterion in advance lends more credibility to evaluation results. Thorough assessment of current policies using good data is important because it provides ideas for future programme design and improvement. For example, if a voluntary agreement does not achieve what was intended, evaluation results can bolster support for the introduction of a regulatory programme.

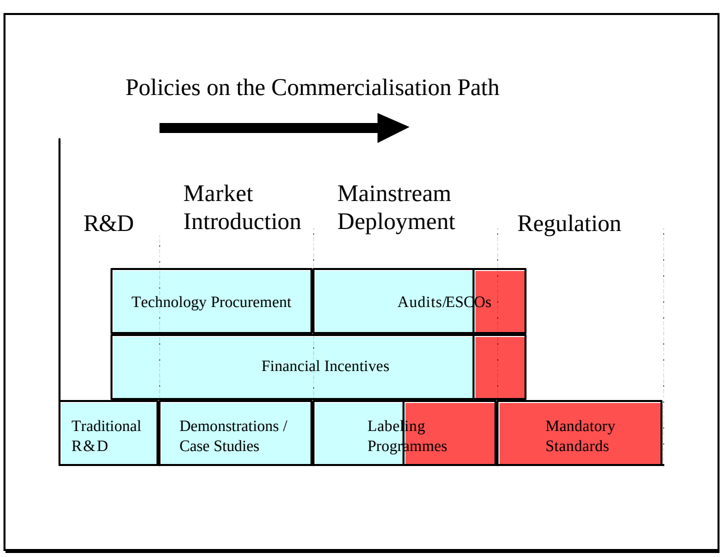
Mandatory energy efficiency policies are the most effective. If manufacturers or importers do not meet the requirements, standards, or policies outlined by the law, they may face legal or financial penalties. These programmes, if enforced, reach 100 percent of the market and have lasting effects. However, introducing mandatory regulations is sometimes controversial and may take many years to implement. Government or opposition parties, manufacturers and consumers have sometimes objected to these types of restrictions. Some argue that mandatory regulations facilitate technological innovation and improve the competitiveness of domestic industry while others argue that regulations force expensive, unnecessary upgrades to factories and reduce profits.

Market-based programmes are less controversial than mandatory policies, but are often less effective. These programmes are only in place for a limited amount of time. Therefore, if these initiatives succeed in reducing energy consumption and increasing the availability of high efficiency products, once the programme expires these achievements may not last. Market transformation initiatives can be effective in the long term, but there is no mechanism to prevent the market from reverting back to previous buying patterns.

A broad unified portfolio of programmes should be implemented by policy organisations. Many people believe that successful market-based programmes help lead or "smooth" the way for mandatory programmes. Others believe that market-based programmes promote the most efficient products or services whereas mandatory programmes eliminate the least efficient products or services from the market. Although these opinions may differ, it is generally agreed that a combination of policies, applied appropriately, will achieve the best overall result.

Figure 70 shows the "commercialisation path." New products and technologies are conceptualised and developed in the research and development stage, then introduced to the market for the first time.

**Figure 70 Commercialisation Path and Policy Mechanisms**




Note Adapted from US DOE Emerging Technologies Program [DOE, 2000a]

If the product gains market acceptance, it moves to the next stage "mainstream deployment." Once the market becomes familiar with the product, there may be less opposition to the last stage of the path, mandatory regulation. Programmes can be implemented at any stage of the commercialisation path to reduce market barriers to energy efficient products. In this chapter, policies will be presented in the same general order outlined in Figure 70.

### COMMERCIALISATION OF PRODUCTS / TECHNOLOGY PROCUREMENT

Research and development (R&D) activity by private parties and supported by governments can lead to the introduction of new technologies for commercial use. These new products can be incremental improvements to existing technologies such as improvements to the internal combustion engine for gasoline-powered vehicles, or they can be fundamentally new products that offer "step function" improvements such as the introduction of electric vehicles. R&D is expensive and may not be practical in some developing economies. R&D advances in more developed economies can benefit the entire APEC region through technology transfer. Due to the complexity of this policy mechanism, only a limited discussion is provided.

However, there is a relatively new market-based mechanism that may be utilised by most economies. It is called technology procurement and it can be used to commercialise new, highly efficient products. This interactive mechanism uses buyer demand to specify requirements for future products that address customer's needs (requirements other than energy) along with a specification for improved energy efficiency performance. Using a facilitator or public entity as a catalyst, draft specifications are widely circulated for comment and possible revision by manufacturers and consumers. The final specification is used in a procurement competition that may, or may not include a guaranteed purchase of a certain number of products. However, if a buyer is not committed to a certain purchase, then at least potential

**TECHNOLOGY PROCUREMENT BY THE INTERNATIONAL ENERGY AGENCY (IEA)**

**Figure 71 EU Class "A" Labelled Dryer**

Source NOVEM/Van Holsteijn en Kemna BV, 2000

The use of technology procurement began approximately 10 to 15 years ago to commercialise energy-efficient products by the Swedish National Energy Administration. The Swedish activity resulted in the initiation of high efficiency windows, lighting and electronics [Harris, 1995]. The Swedish activity also prompted the International Energy Agency to conduct a multinational project under the Demand Side Management Agreement. The project, Annex III, resulted in the completion of several pilot procurements with many different economies. From APEC, Korea and the United States directly participated in the Annex. A final summary report of the project can be downloaded from the internet at http://www.eren.doe.gov/buildings/emergingtech/pdfs/ieademand.pdf. Figure 71 shows the world's most efficient dryer, EU Class "A" Labelled Dryer. This product was the result of the IEA pilot procurement.

buyers are identified usually through some type of "intent to consider" letter. If the potential market identified by the procurement mechanism is large, then the likelihood that manufacturers will develop new products for the competition increases.

Manufacturers are given a certain amount of development lead-time and are asked to develop products meeting the specified requirements. Products are evaluated for compliance with the specifications and in accordance with evaluation criteria to establish the competition winner or winners. Winning manufacturers sell their products directly to the buyers without the facilitator's or public entity's direct involvement. This strategy increases or accelerates the commercialisation process of high efficiency products, while reducing manufacturer risk in bringing new products to market. In addition, since consumer interests were considered before the product was designed, it is expected to have more success in the market-place. This strategy is usually combined with promotional activity to ensure the winning products are highly visible [Ledbetter, 2000]. The box in the previous page provides an example of a technology procurement project that was conducted by the International Energy Agency.

## DEMONSTRATIONS AND CASE STUDIES

A common policy is the use of demonstrations and case studies to showcase highly efficient technologies and products. By increasing general awareness, it is believed that reluctance to adopt cutting edge technologies can be reduced. Case studies and demonstrations usually include detailed evaluations to show consumer benefits, product performance, energy and environmental impacts, along with an economic analysis. Evaluations should also include lessons learned so that problem areas can be addressed. Many projects are economically and technically viable, and demonstration showcases illustrate possible ways to apply the technologies.

Some technology projects are not necessarily intended for mainstream adoption. The primary purpose is to demonstrate that advanced technology products or practices can be successfully applied. A project may incorporate all of the latest technologies into a demonstration home or building to the point where the additional measures offer diminishing returns. The overall net effect is that the building is extremely efficient and therefore demonstrates what can be done technically. The intent of these demonstrations is not to get builders to install all of the high efficiency measures, but rather to get publicity about the technological options available. Though the projects may not be economically viable, the publicity gained may lead to further research and development that will lower the cost of the technology in the future.

These projects increase public awareness and may increase demand for the products. Increased sales may eventually allow manufacturers to exploit economies of scale and to reduce production costs further. Demonstration projects usually receive public or utility funding and facilitate partnerships with the product manufacturers and customers receiving the new technology.

The following project is an example of a case study. The City of Kaliningrad in Russia has worked with the Nordic Environment Finance Corporation to showcase six building renovations. The first major completion included the installation of insulation to the walls, roof, and ground floor in accordance with current building codes and highly efficient lighting (using only 40 percent of the energy) in a school. The completion was officially celebrated on July 4, 1999. Other project sites include the Kaliningrad City Hall and some apartment buildings. The primary challenge of the project was to establish and demonstrate how a revolving fund can work to finance such improvement projects [NEEG, 2000]. A revolving fund is a pool of resources from which an organisation can borrow in order to implement energy efficiency upgrades. The "loan" is repaid from energy savings that result from the improvements.

One method of increasing publicity for demonstration buildings is to conduct an award competition.

Award competitions have been used for a variety of activities including energy efficiency programmes, manufacturing partners, utility partners, or demonstration buildings. Award competitions usually have a detailed nomination process including applicable guidelines, objective evaluation criteria and judges. The winner or winners are usually provided with prestigious awards and receive significant publicity. An example of an awards competition is the Association of Southeast Asian Nations' (ASEAN) Best Practices Competition for Energy Efficiency in Buildings. Numerous entries were submitted representing several of the APEC economies including Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam. All of the entries were impressive and included advanced features such as building designs to reduce energy consumption through passive cooling, luminaries with day-light sensor activated dimmable electronic ballasts, advanced thermal envelopes, various shading designs, state-of-the-art energy management, advanced space conditioning equipment, and automated maintenance controls. The types of buildings included office buildings, multifamily residential units, hotels, and schools. Singapore's Revenue House won the first ASEAN Energy Award [ASEAN Centre for Energy, 2000].

## INCENTIVE PROGRAMMES

A widely used strategy is to provide incentives for the purchase of highly efficient products. The purpose of the incentive is to encourage the decision maker to buy more efficient products. Most incentives are financial and reduce the initial purchase price of the product, a key barrier discussed at the beginning of the chapter. Incentives come in many forms, can be applied to a wide range of products and are funded in a variety of ways. Examples of common incentives include product rebates, tax credits, elimination of sales taxes and preferred financing. Less common incentives may include small gifts, special services (for example, free delivery), or other unique promotions. Incentives are applicable to homes, buildings, factories, all types of equipment, and may include much larger items such as alternative fuelled vehicles.

Funding for incentives comes primarily from government agencies or from electric, gas or water utility companies. Government tax revenues may support these programmes because energy conservation is a public policy goal and it is believed that these programmes will generate long-term benefits for the economy by reducing energy costs. Programmes initiated by utilities, however, are funded by the avoided cost of developing additional generation capacity that would have been required to meet forecasted demand levels.

Incentive programmes are usually marketed to consumers through public service announcements, point of purchase signage and through a broad range of innovative techniques to get the attention of potential buyers. Utilities may directly market to their large commercial, industrial, or municipal customers, as well as to their residential customers through "bill stuffers." Some rate payers may object to incentive programmes because, though they contribute to the cost of the programme, they may not benefit directly. Other consumers may feel there are better uses for their taxes than conservation programmes.

The following are a few examples of incentive programmes:

- National Resources Canada's Commercial Building Incentive Programme for high efficiency building practices. Financial incentives up to CDA$80,000 (US$54,054 WB1998) are provided for buildings that consume 25 percent less energy than a national model building code. The programme will remain in effect until March 2004 [NRCan, 2000].

- Alternate Fuelled Vehicles (AFV) which include electric, hybrid electric with gasoline, compressed natural gas, liquid propane gas, or possibly in the near future, fuel cell vehicles are eligible for incentives such as reduced sales or value added taxes, tax credits (annual taxes such as income), reduced or exemptions from registration fees, or other incentives. AFVs also qualify for reduced fuel taxes, reduced off-peak electric recharging rates, and may receive special incentives such as the operator's right to use special "high occupancy vehicle" lanes [ADEME/APERC, 2000].

- Singapore offers accelerated depreciation incentives for energy efficient equipment. Thus, businesses can reduce their overall tax burdens by purchasing more efficient equipment [ADEME/APERC, 2000].

## LABELLING PROGRAMMES

There are a variety of labelling strategies in APEC economies. Labelling programmes provide consumers with energy efficiency information about the product before they make the purchase. The purpose of labels is to differentiate products based on levels of efficiency. Some labels only offer a designation indicating that the product satisfies a particular criteria or efficiency level. Other labels include the efficiency level or energy consumption (usually depicted as annual energy consumption), and may compare factors such as energy price, usage habits, and capacity of the equipment. They may also provide typical annual cost estimates for energy consumption at average energy prices and average usage habits. Some labels also have sophisticated designations, graphics, charts, and other designs to convey information to the buyer.

There have been evaluations of various label designs and suggestions for improvements. Generally, labelling programmes are effective in conveying information to buyers. How buyers react, however, depends on many factors. Therefore, it is hard to make generalisations about the overall effectiveness of labelling programmes in increasing sales of high efficiency products. Results vary significantly based on label design, product types, energy prices, cultural differences, purchase premiums and product availability.

Labels also can affect the manufacturing sector. For example, manufacturers may be "embarrassed" if they do not offer at least some high efficiency products. Most of the labelling programmes are mandatory and will be discussed below, however there are several voluntary label programmes currently being promoted.

**Figure 72 Thailand Voluntary Label**


Source Energy Efficient Strategies, Australia, 2001

For example, Thailand has a voluntary labelling programme for refrigerators and air conditioners that started in 1995 and 1996, respectively. Using a scale of one to five, the label categorises each product relative to the average. Category one represents efficiency values that are at least 30 percent less than the average efficiency value. Similarly, category two represents efficiencies 15 to 30 percent less than average, category three represents efficiencies that range from 15 percent below average to 10 percent above average, category four represents efficiencies that range from 10 to 25 percent above average, and category five represents efficiencies that are at least 25 percent greater than the average efficiency value. Figure 72 is an example of the label. The label also shows consumers the average energy consumption per year (kWh/year) and the average electricity price per year (Baht/year). Since this is a voluntary programme, manufacturers have chosen not to label any products in categories one or two.

A recent independent evaluation of the programme concluded that the programme was having a positive impact in the market place. For refrigerators, the number of category five refrigerators increased significantly, from approximately 12 to 97 percent of the labelled products. Category three represented less than one percent of the labelled products, while overall labelled products represented about 92 percent of the overall sales. In addition, the survey showed that a majority of manufacturers believed that the programme had a significant influence on the market and their manufacturing choices. The results for air conditioners were not as compelling due to some irregularities in Thailand's air conditioning market, but showed very positive results overall [Na Phuket and Prijyanonda, 2000].

The US ENERGY STAR® programme, jointly administered by the US Department of Energy and US Environmental Protection Agency, is another voluntary labelling programme. For a product to earn the ENERGY STAR® label it must satisfy an established specification or criteria. For products that have a minimum energy performance standards (MEPS) requirement, the product must be a certain percentage more efficient than the minimum standard in order to earn an ENERGY STAR® designation. For products without MEPS, the specification will detail how a product complies, such as a specified test protocol along with maximum energy consumption requirements.

The ENERGY STAR® label is widely used on numerous products in the US economy. These products include appliances, heating and cooling equipment, building materials such as insulation and roofing, home electronics, office equipment, windows, and others. The label is placed on products such as computers, televisions and VCRs in the factory. Since many of these products are manufactured outside of the US and exported to other economies, ENERGY STAR® labelled products are starting to penetrate markets around the world. Currently, Australia, the European Commission, Japan, New Zealand, Chinese Taipei and the United States promote ENERGY STAR® products in their respective economies.

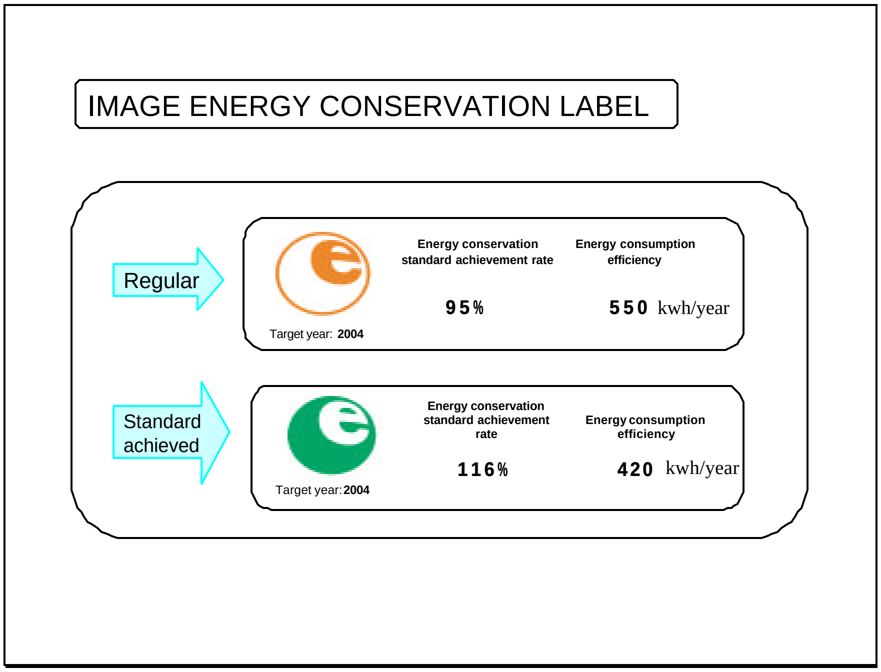
**Figure 73 US Voluntary ENERGY STAR® Label**

Source D&R International, 2000

Though limited evaluation has been done, sales and manufacturing data have been very positive. ENERGY STAR® products have transformed the market for some types of equipment. For example, over 87 percent of video cassette recorder (VCR) sales in the US are ENERGY STAR® compliant. This shift in the market has resulted in a significant (up to 70 percent) reduction in stand-by losses (energy that is being consumed while the product is not being used or while the product is turned off) for VCRs. Standby power represents the overwhelming majority of energy consumption for VCRs [EPA, 2000]. Figure 73 shows an example of the ENERGY STAR® label.

One last example of a voluntary labelling programme is Japan's top runner programme. The goal of this label is to promote the early adoption of products which will exceed future standards. In addition to showing basic energy consumption, the label will also show the rate of efficiency relative to the future standard. So for example, a highly efficient product may be 120 percent more efficient than the future standard level, three or four years before the standard will take effect. At the same time, an inefficient product may be 80 percent of the level only one year before the standard takes effect. Figure 74 shows a sample of the Japanese top runner label.

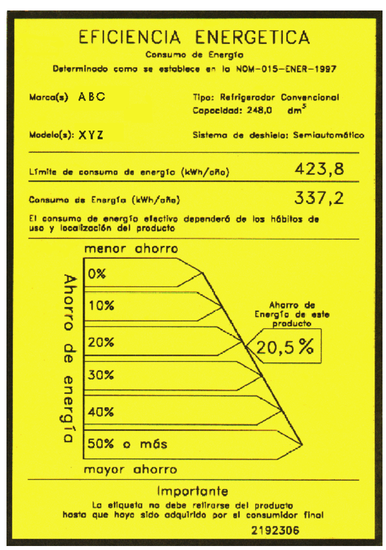
**Figure 74 Japan's Top Runner Programme Label**




Source METI, 2001

Numerous economies in APEC have or are planning to implement mandatory labelling programmes. Figure 75 shows a sample of Mexico's mandatory label. The programmes require manufacturers to mark their products with some type of label that shows its efficiency, energy consumption, and/or comparison of efficiency or consumption relative to other products on the market. Table 12 shows a status of the mandatory labelling programmes in APEC economies.

**Figure 75 Mexico's Mandatory Energy Efficiency Label**




Source Energy Efficient Strategies, Australia, 2001

The labelling programmes and several other policies discussed above use a detailed testing protocol that can be highly technical. The testing protocol or procedure establishes the "ruler" against which a particular product is rated. Test protocols vary across the APEC region. The APEC Steering Group on Energy Standards (SGES) has worked on this issue and produced a comprehensive report, *Review of Energy Efficiency Test Standards and Regulations in APEC Member Economies* [SGES, 1999]. This report highlights the complexities of comparing test results across APEC economies and makes suggestions to improve the level of standardisation within the APEC region. Differences in test protocols among APEC economies can impede trade. For example, compliance with the MEPS of an export economy may not be readily known, and thus the product will not be marketed even though it may have passed the MEPS requirement.

**Table 12 Status of APEC Economies Using Mandatory Labelling Programmes**

| Mandatory Labelling Programmes in Place | | Planning Mandatory Labelling Programmes |
|---|---|---|
| Australia | New Zealand | Indonesia |
| Canada | Philippines | Malaysia |
| Korea | Chinese Taipei | Papua New Guinea |
| Mexico | USA | Peru |
| | | Viet Nam |

Source ADEME/APERC, 2000

## ENERGY AUDITS AND ENERGY SERVICE COMPANIES

Energy audits involve the assessment of a factory, building or residence to determine the condition of the energy consuming equipment and the building structure. Energy conservation measures or replacement of old equipment with highly efficient equipment are often recommended. Estimated energy and economic savings from the upgrades are also assessed. Appendix C discusses energy audits in detail and shows examples from the following APEC economies: Australia, Korea, Thailand and the USA.

Audits can be funded by government agencies, utilities, non-profit organisations or the building owner. Possible problems encountered with audits are that the energy auditor may not be adequately trained, the recommendations made by the auditor may be too expensive or too unrealistic to implement, or the building owner may simply choose to ignore the energy conservation upgrades proposed in the audit.

An Energy Service Company (ESCO) is sometimes employed to conduct and implement audits through an energy service contract. ESCOs work with potential clients to develop a performance contract that specifies a particular upgrade or set of upgrades to a building or factory. For example, a particular contract may include the installation of high efficiency T-8 fluorescent lamps and electronic ballasts, high efficiency motors, and pipe insulation. The ESCO guarantees a specified amount or percentage of energy savings and the energy savings from the upgrades are split between the client and the ESCO. Energy saving verification is usually conducted to ensure compliance with the contract.

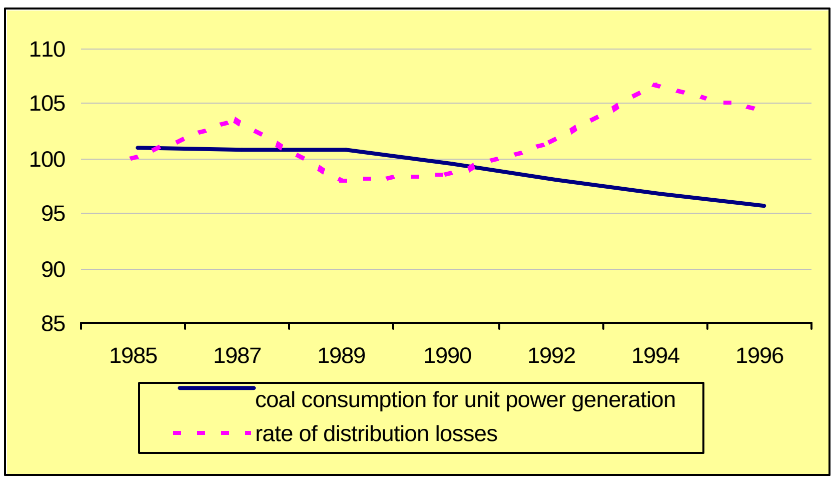
Associated with energy audits is the possibility of replacing existing equipment with new, highly efficient equipment. Until this point, most of the policy mechanisms discussed involved the purchasing of new equipment or products to replace failed products. Before early replacement can be considered, it must be demonstrated that significant energy saving potential exists or this strategy may not be cost effective. A basic "time value of money" cash flow analysis with salvage life considerations is considered to be a reasonable approach. If the new highly efficient product can be financed using the existing stream of funds normally used for energy expenses, then the normal future capital expense for equipment replacement can be avoided. As a result of the immediate purchase of the more efficient product, no additional funds are required to finance the installation or to replace the old equipment. Using such financing mechanisms for energy efficiency measures can reduce requirements for capital equipment replacement funds.

**CHINA POWER SYSTEM UPGRADE**

Along with rapid economic growth, the power sector in China experienced rapid development over the last two decades. Electricity production increased significantly, at an average growth rate of 9.2 percent, during the period 1985 to 1996 [SDPC, 1997]. At the same time, China invested heavily in highly efficient generation equipment. As shown in the figure below, coal consumption for unit power generation declined through the 1990s. China also plans to close small and/or outdated power plants to improve efficiency further.

Power distribution losses increase the amount of electricity consumption. The macro power grid was improved along with new power plant implementation, but the local end use distribution grid was not updated. To improve the situation, China launched a national programme in 1998, focusing on end use distribution grid update for both urban and rural grids. China invested around US$30 billion in the project, targeting electricity transformation line update and early equipment replacements, such as transformers and switching components [Li Jianji, 2000].

**Figure 76 Energy Efficiency Index in the Power Sector (Index 1985 = 100)**




Source SDPC, 1997

**VOLUNTARY AGREEMENTS**

A fairly common policy is the establishment of voluntary agreements. These vary significantly in their objectives, methodology, and overall perspective. However, the common theme is that government or efficiency advocates usually work with industry or businesses to voluntarily agree to some type of efficiency improvement, policy or practice. Businesses like the positive publicity they get from these agreements. Governments like these agreements because they are much easier to implement than other policies. However, some people have been critical of this policy because results are not always achieved. For a voluntary agreement to be successful it should include a reporting mechanism to monitor the progress of the initiative and independent verification of results.

The European Commission (EC) has a voluntary programme to reduce the consumption of standby power used in portable AC/DC power supplies. These power supplies are used for a wide range of products including lap top computers and wireless telephones. The programme is called the Code of Conduct and specifies that external power supplies must not exceed a certain amount of power when the charging is complete. Currently, standby power losses of 3 to 10 watts are common in many products. Under the programme, losses of one watt are permitted and this level will be reduced to 0.3 W - 0.75 W (based on the power rating of the supply) by 2005.

The programme has been fairly successful. More than 10 companies, including IBM, have agreed to meet the requirements. IBM has stated that all AC/DC power supply sales worldwide, not just in Europe, will meet the EC Code of Conduct [EC, 2001].

## EQUIPMENT STANDARDS

The most widely used mandatory policy is the adoption of minimum energy performance standards (MEPS) for industrial, commercial and consumer products. If a domestic manufacturer or an importer tries to sell a product which does not meet the requirements set out in the MEPS, it will usually face legal or financial penalties. Standards have been applied to the full range of energy consuming devices such as space conditioning equipment, appliances, lighting, motors, electronics, and automobiles. Table 13 shows the status of the APEC economies that are currently using, or are planning MEPS programmes.

**Table 13 Status of APEC Economies Using Minimum Energy Performance Standards**

| MEPS Programmes in Place | | Planning MEPS |
|---|---|---|
| Australia | Mexico | Indonesia |
| Canada | Philippines | Malaysia |
| Japan | Chinese Taipei | Papua New Guinea |
| Korea | USA | Peru |
| | | Viet Nam |

Source ADEME/APERC, 2000

The main components of a MEPS programme include performance criteria, test protocol, effective dates (which allow for manufacturer lead-time), and possibly a mechanism to review or adjust the performance criteria for future levels. Manufacturers usually oppose MEPS because they are concerned about unnecessary regulation. Others argue that mandatory regulations facilitate technological innovation and improve the competitiveness of domestic industry. MEPS can be very effective in reducing energy consumption. Please see the box on the following page for an example of MEPS in practice. In the United States, refrigerator standards have been amended several times since 1990.

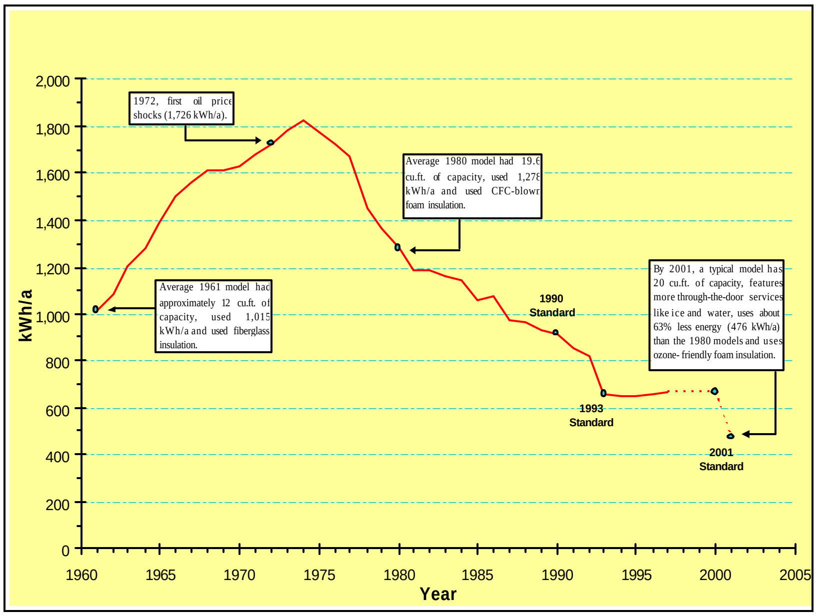
Australia has an interesting MEPS programme. Australia found that manufacturer opposition to MEPS programmes led to on-going delays, analysis, debate and eventually stagnation. Therefore, Australia designed a programme which requires domestic manufacturers to produce products which satisfy the world's best available performance standards. One of the stated benefits of the programme is that it will make Australia's manufacturers and products globally competitive. This programme ensures that Australian manufacturers offer energy efficient products comparable to the best in the world to domestic consumers. The programme is flexible and allows for additional lead-time if warranted [Holt *et al.*, 2000].

A key advantage of a MEPS programme is that once a level becomes effective, all future sales must meet or exceed that level. Eventually with the natural attrition of product replacements, over a period of time, the entire stock of a particular product is replaced. In reference to the US example in the box, the third standard for refrigerators will soon start replacing units that were originally sold in accordance with the first refrigerator standard. Therefore, the entire stock of refrigerators is starting to be replaced with more efficient products for the second time.

### US REFRIGERATOR MINIMUM ENERGY PERFORMANCE STANDARDS (MEPS)

The USA MEPS programme was initiated in the 1970s and had the first standards promulgated in the late 1980s. The most aggressive and successful succession of standards for one product in the world has been the USA refrigerator standards. Mandatory standards have been established for 1990, 1993, and 2001. The average new refrigerator in July of 2001 will consume approximately 26 percent of the energy used by a refrigerator in 1974.

**Figure 77 Average Energy Consumption for New Refrigerators**




Source LBNL, 2000

### INDUSTRIAL STANDARDS

Some economies have regulations for the industrial sector. These regulations may stipulate requirements for energy managers, reporting of energy consumption, and an overall conservation plan. Often, an industry is benchmarked and a plan is made outlining energy efficiency and conservation measures to be installed over a period of one year or more. There are regulations in the following APEC economies: Australia, Japan, and Korea.

The Energy Conservation Law in Japan, enacted in 1979, outlines a very aggressive industrial programme. The law categorises each factory based on the amount of energy it consumes. It further specifies detailed energy consumption targets for each category which must be met by energy managers. Energy consumption and detailed plans need to be submitted every year with an overall goal to reduce energy intensity by more than one percent per year on average. Japan's industrial sector is the least energy intensive in the world. While Japan's manufacturing GDP has more than doubled in the last 25 years, the total energy consumption for its industrial sector has remained almost constant [EDMC, 2000].

### TRANSPORTATION STANDARDS

Some economies have regulations regarding minimum efficiencies for personal vehicles, automobiles and light-weight trucks. These regulations are expressed as distance per consumption of fuel (km/L) or fuel consumption per specified distance (L/100 km). The regulations may be based on a fleet average for the manufacturer, by a particular weight class or engine size. Currently, only Japan and the USA have regulations for personal vehicles in the APEC region. However, due to the close integration of the automobile industries in Canada and the USA, voluntary guidelines in Canada closely adhere to the USA standard.

These standards have been extremely effective. For example, in the USA the average efficiency of new automobiles was 5.5 km/L in 1974 during the energy crisis. Corporate Average Fuel Economy (CAFE) standards, implemented in the late 1970s, mandated improvements in fuel efficiency for new vehicles through 1985. With CAFE standards, efficiencies for new automobiles improved from 5.5 km/L in 1974 to 9.8 km/L in 1980 or by approximately 88 percent in six years. CAFE standards have not been materially increased since 1985. In 1998, the average fleet efficiency was only 10.5 km/L, or around six percent higher than in 1980.

In the USA, the issue of increasing CAFE standards has been a highly debated issue in the US Congress. In 1994, the US Department of Transportation initiated a rulemaking to increase the CAFE standard by publishing a Notice of Proposed Rulemaking. However, since then, due to manufacturer and political concerns, the US Congress has refused to approve funding to continue the process of improving vehicle efficiency standards [Bamberger, 2000].

Another concern in Canada and the United States is the growing popularity of light-weight trucks, namely sport utility vehicles and mini-vans. Though CAFE standards have remained unchanged since 1985, the overall average efficiency of new personal vehicles in Canada and the United States is deteriorating because the share of light-weight trucks in new vehicle sales has increased significantly since the late 1980s. For example, in Canada light-weight truck sales as a percentage of private passenger vehicle sales increased from around 20 percent in the early 1980s to 44 percent by 1998 [OEE, 1999].

In Japan, a new amendment to the energy conservation law was issued in 1999 which established new performance standards for automobiles and trucks. These standards will go into effect in 2005 for diesel powered vehicles and in 2010 for gasoline powered vehicles. It is expected that the efficiency of new automobiles in Japan will increase by 15 percent by 2005 and by 23 percent by 2010 [ECCJ, 1999]. Japan's Top Runner Programme will also promote the early adoption of these standards (see section on *Labelling Programmes*).

## BUILDING CODES

Building codes for service buildings and residential dwellings are implemented as either a mandatory or market based policy. Building codes usually establish prescriptive or performance based requirements for the building shell, or thermal envelope. This can include specifications for insulation, windows, doors, and foundations. Some building codes include equipment requirements while others leave this to MEPS programmes. Performance requirements usually allow for trade-offs by the builder or developer while meeting an overall performance achievement. Therefore, the builder can make various choices in meeting the required specification, such as the installation of very efficient windows and/or more insulation. Table 14 shows the status of the building code programmes in various APEC economies.

Building codes can be very effective, especially if they are mandatory. One concern with building codes is that they are more difficult to enforce than MEPS or labelling programmes. For example, with MEPS and labelling programmes the products are being built in factories and distributed in the market. Manufacturers, retailers, consumers, and others have ready access to the product and can therefore assess compliance. Building codes are sometimes difficult to enforce. Construction projects are taking place at numerous locations and at different times. Building inspectors are few and they cannot oversee all stages of construction. Moreover, problems in construction are sometimes not evident for many years. Despite compliance problems, building codes have improved building practices. In the USA, voluntary building codes promote the latest technologies while mandatory building codes ensure minimum requirements are met. This strategy has led to the construction of homes which are significantly more efficient than just 10 or 15 years ago [DOE, 2001].

**Table 14 Status of APEC Economies Using Building Code Programmes**

| APEC Economy | Service Buildings (Commercial) | Residential Buildings (Dwellings) |
|---|---|---|
| Australia | Mandatory | Mandatory |
| Canada | Mandatory | Mandatory |
| Chile | Mandatory | |
| Hong Kong, China | Mandatory | |
| Indonesia | Voluntary | |
| Japan | Mandatory | Mandatory |
| Korea | Mandatory | Mandatory |
| Malaysia | Planned Voluntary | |
| Mexico | Planned Mandatory 2001 | Planned Mandatory 2001 |
| New Zealand | Mandatory | Mandatory |
| Papua New Guinea | Mandatory | Mandatory |
| Peru | Voluntary | Voluntary |
| Philippines | Mandatory | |
| Russia | Mandatory | Mandatory |
| Chinese Taipei | Mandatory | |
| USA | Voluntary/Mandatory | Voluntary/Mandatory |
| Viet Nam | Planned | Planned |

Source ADEME/APERC, 2000

## CONCLUSIONS

In this chapter a variety of energy efficiency and conservation policies have been discussed. Though many policies are in place, there is significant room for expansion in most economies. The most developed economies tend to have a broader range of policies; however, developing economies such as Indonesia, Malaysia, Papua New Guinea, Peru, and Viet Nam are planning to adopt MEPS and mandatory labelling programmes.

Further work by APEC's SGES on testing protocols and ways to harmonise or establish algorithms for test procedures among APEC economies should enable developing economies to implement these programmes more easily. Further harmonisation of testing, rating, and joint implementation of programmes such as the ENERGY STAR® programme can lead to greater efficiencies of programme administration and increase the effectiveness of existing programmes.

An area that is of significant concern is the transportation sector. Although several economies offer incentives for the purchase of alternative fuelled vehicles and may have reduced taxes on more environmentally friendly fuels, only Japan is addressing fuel efficiencies for conventional diesel and gasoline fuelled vehicles. Other APEC economies should consider adopting mandatory policies to increase the energy efficiency of all personal vehicles. Since alternative vehicles make up only a small portion of the transportation market, attention must be paid to conventional vehicles as well.

Potential for further collaboration between APEC and other world economies should be explored. Significant lessons have been learned by policy administrators in various economies and other economies could learn from these experiences. Greater cooperation within the region may reduce the cost and improve the success rate of new policies. For example, if Australia's new MEPS programme which challenges domestic manufacturers to meet the world's most aggressive standards is successful, then APEC economies with MEPS programmes may consider such an approach.

# CHAPTER 9

# CONCLUSIONS

## METHODOLOGICAL ISSUES

This study is an extension of APERC's report *Energy Efficiency Indicators for Industry in the APEC Region*, published in March 2000. It is part of a long-term effort to improve energy efficiency - a component of a sustainable energy system - in APEC member economies.

Energy consumption trends have numerous underlying factors, only one of which is energy efficiency. Consequently, increases or decreases in aggregate energy intensities (time series for one economy), or differences in their absolute levels (comparison between economies), do not necessarily mean that energy efficiency has improved or worsened in one economy, or that one economy is more energy efficient than another. Nevertheless, energy intensities provide useful information on the evolution of energy consumption.

In this report a set of indicators was constructed for all major macroeconomic sectors, highlighting the main drivers behind energy consumption and energy efficiency trends. The general methodology is a top-down analysis of monetary-based indicators with supplementary indicators in the industrial, services and transportation sectors.

Energy intensities can serve as proxies for energy efficiency levels, provided that factors not related to efficiency have been removed. Several analytical tools are available to isolate structure and pure intensity effects. Pure intensity is only a good measure of energy efficiency if the aggregate intensity from which it was derived, was calculated using detailed, disaggregated data. At higher levels of aggregation much of the recorded pure intensity effect is actually sub-structural effect. For example, in this report, whole economy energy intensity is decomposed into structure and pure intensity effects. At such a high level of aggregation, pure intensity is still a poor measure of energy efficiency in the economy. It fails to capture structural shifts towards more energy-intensive sub-sectors in the industrial sector or increases in the amount of energy consumed by household appliances in the residential sector.

Aggregate intensity was decomposed into structure and pure intensity effects in the industrial sector. In services and transportation, total energy was decomposed into activity, structure and pure intensity effects. Taking into account structural change at the sub-sectoral level improves the quality of pure intensity as a measure of energy efficiency. However, due to data constraints, structural change within sub-sectors is not taken into account. In the iron and steel industry, for example, energy intensity is falling. Is it declining because of the adoption of new technologies or because of improved management practices? Without more detailed data, these questions go unanswered. The collection of detailed data for analysis purposes should be a priority for APEC economies.

## KEY FINDINGS

This study shows that data is already available in most APEC economies for at least a first order analysis of energy consumption trends in all major macroeconomic sectors and opens the door to further more detailed analysis. Sectoral analysis also provides insight into the sources of energy consumption growth in APEC economies.

Growth in energy consumption, particularly in industrialising Asia, is being driven by rising incomes and higher standards of living. Income and energy use levels in economies such as China, Indonesia and Viet Nam are still very low compared to OECD economies and even compared to the APEC average. Therefore, energy consumption growth in Asia, excluding Japan, will continue at a brisk pace for many years to come. Sharp increases in energy use can pose many problems for developing economies. Energy combustion leads to increased levels of air and water pollution. For economies that do not have large reserves of energy resources, security of supply becomes an important issue as dependence on energy imports increases. In recent years, APEC has been promoting energy efficiency as a way of reducing or minimising energy consumption without sacrificing quality of life in the Asia-Pacific region.

The most developed economies tend to have the broadest range of energy efficiency policies. In industrialising economies, this area of policy development is still quite new and there are many sectors which would benefit from policy attention. The potential benefits of early action on energy efficiency could be substantial. Stocks of appliances and office equipment need to be replaced every 3-10 years. The working life of a car is 10-15 years. A new building will remain in use for as long as 40-50 years after it is constructed. Therefore, the choices made today concerning what equipment is purchased and how buildings are constructed will affect energy consumption levels for years to come. Rapid penetration of energy-using equipment provides a unique energy policy opportunity for developing economies. Implementing policies such as building codes and minimum efficiency standards at a time when stocks of energy-using equipment are accumulating rapidly could have a significant impact on future energy consumption growth rates.

Energy efficiency measures, particularly mandatory policies, can be very controversial. Firms believe regulation will reduce their profits and citizens are concerned policy initiatives may compromise rising standards of living. Proponents of conservation measures argue the opposite. They claim standards will force domestic industry to be more competitive and that more efficient use of energy will improve air and water quality. For consumers, more efficient products often result in increased disposable income, because less money is spent on utility bills, despite a higher purchase price.

Sectoral chapters have highlighted some interesting developments. Transportation is a sector of particular concern. In many economies it is already a large component of FEC, comparable to industry, and it is growing very quickly. In Korea and Viet Nam, energy consumption for transportation increased 7-fold between 1981 and 1997. In Thailand consumption grew 5-fold. In China and Indonesia, two of the most populous economies in APEC, energy consumption for transportation approximately tripled during the same period. Moreover, except for some fiscal incentives promoting the use of alternative-fuelled vehicles, there are few energy efficiency policies in place to offset future consumption growth. Only Japan and the United States have minimum energy efficiency standards in place for car manufacturers. Due to its current status as a major energy consuming sector and the potential for rapid future growth, energy efficiency policies aimed at reducing consumption in transportation should be a priority in APEC economies.

The services sector, with energy consumption growth rates comparable to transportation should receive more policy attention. However, it accounts for less than 5 percent of FEC in some economies and addressing consumption growth in this sector is less urgent than for transportation.

The industrial and residential sectors are also important consumers of energy; however, consumption growth in these sectors is much slower. Traditionally, policy-makers have paid close attention to industry. In most economies, industrial is the largest end use sector. Moreover, since each factory is a large consumer of energy and the whole manufacturing process usually occurs in one place, it is easier for governments to implement energy efficiency initiatives and monitor compliance. One of the most effective energy efficiency measures tried in APEC economies has been the application of industrial standards. Under this type of mandatory programme, an industry is benchmarked and a plan for implementing energy efficiency and conservation measures over a period of one year or more is outlined.

Japan has achieved intensity improvement of 1 percent per year under such a programme.

The importance of the residential sector varies from economy to economy. It is often neglected as a target for conservation initiatives because there are literally millions of users and each household consumes only a small amount of energy. It is therefore difficult to coordinate effective policy. Many policy measures that would be effective in the services sector including building codes and minimum efficiency standards for equipment, could easily be extended to the residential sector too. Therefore, implementing measures in the services sector, may pave the way for similar programmes for the residential sector.

The policies outlined in *Chapter 8: Energy Efficiency Policies* provide programme ideas for reducing consumption growth. APEC economies have used a wide range of energy efficiency policies and measures to minimise energy consumption. Of course, any slate of policy initiatives must be tailored to the unique situation of each economy. However, governments considering policy actions may be able to learn valuable lessons from the policy experiences of other APEC economies. The use of cost-effective policies can lead to increased wealth for an economy through the reduction of wasted resources.

To assist APEC economies in their own work on energy efficiency, the EEI database and information on successful energy efficiency policies and programmes should be shared with energy efficiency agencies and experts around the APEC region. Strategies for evaluating the impact of energy efficiency programmes are beyond the scope of this report and are an area for additional study. One method, which has not been explored in this report, is to use efficiency indicators to monitor the progress of conservation programmes. This is an area that should be addressed in future research.

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## Endnotes

1 HKC refers to Hong Kong, China.

2 Residential energy is excluded from this discussion due to irregularities in residential energy data in China and Viet Nam. The inclusion of biomass and traditional energy in the data series for these economies causes a significant jump in energy consumption.

3 Russian data is excluded in the calculation of this APEC growth rate as reliable data are only available after 1990.

4 For more information on the concept of international 1995 dollars at purchasing power parity, please see *Chapter 2: Methodology*.

5 HKC refers to Hong Kong, China.

6 Please see *Chapter 2: Methodology* for a more detailed discussion of the multiplicative Divisia decomposition method.

7 GDP generated by freight transportation is included in services GDP. A disaggregation of services GDP was not available for all APEC economies.

8 Russian data is not available until 1993; therefore, this economy is not included in the APEC totals cited in this chapter.

9 For more information on the unit 1995 international dollar at purchasing power parity, please see *Chapter 2: Methodology*.

10 M$95 at PPP stands for millions of 1995 international dollars at PPP. See *Chapter 2: Methodology* for more information on this unit.

11 The Divisia parametric technique was used for decomposition. The aggregate intensity can be calculated by multiplying, not adding, the structural and pure intensity effects presented in Figure 15.

12 According to the classification used by the IEA - main source of energy data used in this chapter - internal navigation "includes small craft and coastal vessels not purchasing their bunker requirements under international marine bunker contracts. Fuel used for ocean, coastal and inland fishing is included in agriculture." [IEA, 2000a]

13 Pipeline transportation, which in 1998 accounted for 3.4 percent of transport energy consumption in the APEC region [IEA, 2000a] -more than rail transportation- is not considered separately in this analysis due to a lack of data.

14 Transportation in the APEC region accounts for nearly 15 percent of the world's total final energy consumption, and roughly 60 percent of the world's transport energy consumption.

15 HKC refers to Hong Kong, China.

16 GDP at purchasing power parity was unavailable for Chinese Taipei. As a proxy, local currency GDP was converted to 1995 US$ using an exchange rate.

17 M$95 at PPP stands for millions of 1995 international dollars at purchasing power parity.

18 Based on data provided by some economies, the ratios of specific energy consumption with respect to cars used to normalise vehicle stocks were 1.3 for light road vehicles and 0.1 for motorcycles. In the case of trucks and buses, a factor of 3 was used, based on fuel economies of approximately 30 litres of fuel per 100 km for trucks and buses, and of 10 litres/100 km for cars.

19 Transport refers to supporting and auxiliary transport activities (for example, terminal facilities for freight) and activities of travel agencies.

20 1997 was chosen as the most recent representative year because energy data is not available for some economies in 1998.

21 M$95 at PPP stands for millions of 1995 international dollars at purchasing power parity. See *Chapter 2: Methodology* for more information on this unit.

22 HKC refers to Hong Kong, China.

23 For additional information on the two chosen factorisation methods, please consult *Chapter 2: Methodology*.

24 The weather adjustment adjusts energy for normal weather patterns in that particular economy, it does not normalise for differences in weather patterns across economies.

25 A growth rate was calculated for the period 1981-1997, because data is missing for many economies in 1980 and 1998.

26 Please see *Chapter 6: Energy Efficiency Indicators in the Services Sector* for additional information.

27 Please see *Chapter 2: Methodology* for additional detail on data sources.

28 Traditional energy was included in the totals for China and Viet Nam starting in 1994.

29 Excludes traditional energy for China and Viet Nam.

30 Excludes traditional energy.

31 In the 1997 RECS only the heated floor space was estimated using regression analysis. Therefore, the 1997 estimate will be lower than the 1993 RECS estimate. Prior 1997 estimates include all the floor area of the housing unit that is enclosed from the weather.

32 For additional information on the weather adjustment please see *Chapter 2: Methodology*.

33 Fuel cell vehicles have received a significant amount of media attention and several companies have developed demonstration vehicles. Market introduction is expected in 2003 or 2004.

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# APPENDIX A

## ADEME / APERC SURVEY SUMMARY OF ENERGY EFFICIENCY POLICIES IN APEC ECONOMIES

**Table 15 Fiscal Measures for Automobiles**

| | Purchase Tax | Annual Registration Tax | Incentives for Car Scrapping | Incentives for Clean/Efficient Cars |
|---|---|---|---|---|
| Australia | | | P | |
| Canada | ● | ● | ● | |
| Chile | | ● | | |
| Hong Kong, China | ● | ● | ● | ● |
| Indonesia | P | | | |
| Japan | ● | ● | T | ● |
| Korea | ● | ● | | |
| Malaysia | ● | ● | | |
| Mexico | ● | | | |
| New Zealand | | | | |
| Philippines | | ● | | |
| Peru | | | | |
| PNG | | ● | | |
| Russia | | ● | | |
| Chinese Taipei | ● | ● | ● | ● |
| USA[1] | | | | ● |
| Viet Nam | | | | |

●: Policy in place

P: Policy planned

T: Policy terminated

**Table 16 Energy Audits**

| | Dwellings | Commercial Buildings | Public Buildings | Industry |
|---|---|---|---|---|
| Australia | M | M, P | M | M, P |
| Canada | V | P | V | |
| Hong Kong, China | | F | | |
| Indonesia | | T | T | T |
| Japan | | F | F | F |
| Korea | | P | M | C |
| Malaysia | | | F | F |
| Mexico | | | | |
| Peru | F | F | F | F |
| Philippines | | Fee | F | Fee |
| PNG | | | F | P |
| Russia | | | M, C | M |
| Chinese Taipei | | F, M | F, M | F, M |
| USA | F/FEE | FEE | M | V |
| Viet Nam | | | | P |

M: mandatory; V: voluntary; F: free for the consumers; P: partly paid by consumers; C: condition for receiving a subsidy; T: terminated
Indonesia: 1994-1998, free for the consumer (identification study)
Viet Nam: for companies consuming > 500 toe per year

## OTHER ENERGY EFFICIENCY MEASURES

Economy Abbreviations: AUS: Australia; CDA: Canada; CHL: Chile; HKC: Hong Kong, China; INA: Indonesia; JPN: Japan; ROK: Republic of Korea; MEX: Mexico; NZ: New Zealand; RP: The Republic of the Philippines; RUS: The Russian Federation; CT: Chinese Taipei; VN: Viet Nam; US: United States of America.

### Table 17 Other Energy Efficiency Measures

| | Industry | Service Buildings | Households | Transport |
|---|---|---|---|---|
| Regulation on: | | | | |
| - Consumption reporting | JPN, ROK, RP, RUS, CT | JPN, ROK, RP, RUS, CT | | RP, CT, US |
| - Energy managers | JPN , RUS, CT | JPN , RUS, CT | | CT |
| - Energy saving plan | AUS, INA, JPN, ROK, RP, RUS, CT, | AUS, CDA, INA, JPN, ROK, RP, RUS, CT | AUS | AUS, INA, RP |
| - Heat metering | JPN, RUS, CT | JPN, RUS | | |
| - Maintenance | AUS, JPN RUS, CT | AUS, JPN, RUS, CT | AUS | AUS, CT |
| Investment subsidies | AUS, HKC, JPN, CT, US | AUS, CDA, HKC, JPN, CT, US | AUS, CT, CT | AUS, CDA, CT, US |
| Soft loans | CHL, ROK, MEX, RP, RUS, CT, US, VN | ROK, MEX, RP, RUS, CT, US | ROK, MEX, US | ROK, MEX, CT, US |
| Tax credit or tax deduction | CDA, ROK, CT | ROK, CT | ROK | CDA, ROK, US |
| Accelerate depreciation | JPN, CT | JPN, CT | JPN | |
| Sectoral agreements | CDA, CHL, ROK, NZ, RP | CDA, NZ, RP, US | RP, US | CDA, NZ, RP, US |
| Tax reduction[2] | ROK, US, VN | ROK, US | ROK, US | US |
| Information programmes on: | | | | |
| - Best practices | AUS, CDA, MEX, NZ, RUS, US, VN | AUS, CDA, HKC, MEX, NZ, RP, RUS, US | AUS, CDA, HKC, JPN, MEX, NZ, US | AUS, CDA, HKC, MEX, NZ, US |
| - Comparative information | CDA, NZ, RUS, CT, US, VN | CDA, NZ, US, RUS | CDA, MEX, NZ, RUS, US | CDA, NZ, RUS, CT, US |

## Endnotes

1 There exist programmes of purchase tax, annual registration tax in some States.

2 Taxes which may be reduced include value added (VAT), goods and services (GST) and import taxes.

# APPENDIX B

## ENERGY EFFICIENCY STATUS BY ECONOMY[1]

### AUSTRALIA

Final energy intensity by GDP in Australia declined from 162 toe per M$95 at PPP in 1980 to 133 toe per M$95 at PPP in 1998.

The responsibility for improving energy efficiency in Australia is shared by the Commonwealth Government of Australia and the State governments. The Federal government has worked to coordinate a consistent economy-wide approach. The bulk of end use efficiency programmes, however, are under the responsibility of state and territory governments. Electric utilities have also implemented demand side management or energy saving programmes aimed at all sectors of the economy including industry.

The National Greenhouse Response Strategy (NGRS) provides the main framework for Australia's approach to addressing greenhouse gas emissions. Energy efficiency initiatives are a part of this strategy. Under NGRS' current five-year plan (1997-2001), governments introduced minimum energy performance standards in 1999 for a limited number of domestic electrical appliances including refrigerators, freezers and electric storage water heaters. An economy-wide mandatory building code for commercial buildings was introduced in 1998. Under the NGRS, mandatory labelling for major household appliances is being developed in cooperation with industry.

Most energy efficiency programmes in Australia are information-based or voluntary initiatives. Some examples include government sponsored training programmes, advisory services, audit programmes, publicity campaigns and voluntary commitments with industry. To set an example, all levels of government are implementing initiatives to reduce energy consumption in their operations.

**Table 18 Summary of Energy Efficiency Programmes in Australia**

| Types of Energy Efficiency Initiatives | Industrial | Transportation | Commercial | Residential |
|---|---|---|---|---|
| Voluntary Commitments | X | | X | X |
| Product Efficiency Standards | | | | X |
| Product Labelling | | | | X |
| Information | X | | X | X |

Source ADEME/APERC, 2000

## BRUNEI DARUSSALAM

Final energy consumption in Brunei Darussalam increased 7 percent per year from 1980 to 1997. Economic growth, however, remained stable during this same period. Energy intensity in Brunei by total GDP increased from 40 toe per M$95 at PPP in 1980 to 112 toe per M$95 at PPP in 1998. Energy per capita grew from 1.2 toe in 1980 to 2.1 toe in 1998. Population growth, at 2.9 percent per year through the 1990s, and increasing standards of living have been driving energy consumption growth.

In 1980, the transportation sector consumed 69 percent of FEC in Brunei Darussalam, industry accounted for 16 percent and residential / commercial made up 15 percent. In 1998, the share of energy consumed by the residential / commercial sector more than doubled to 32 percent while the industrial sector remained unchanged at 16 percent. The share of transportation sector fell to 51 percent.

The 5-year National Development Plan promotes the sustainable development and use of natural resources. Conservation plays an important role in achieving these goals.

## CANADA

Aggregate intensity in Canada fell from 255 toe per M$95 at PPP in 1980 to 202 toe per M$95 at PPP in 1998, a decline of - 20.8 percent.

Canada is one of the most energy intensive economies in APEC. Energy intensity in all end use sectors has been declining during the study period. Intensities in the industrial and commercial sectors fell - 15.5 and - 10.0 percent during the study period. In the industrial sector intensity improvements in energy intensive industries such as pulp and paper, iron and steel, non-ferrous metals, chemicals and cement have contributed to the downward trend in aggregate pure intensity. In commercial and residential sectors, large declines in space heating intensity in the early 1980s were the major contributor to observed intensity reductions. In transportation, energy per capita decreased slightly from 1,826 toe per thousand people in 1980 to 1,744 toe per thousand people in 1998. Transportation energy per unit of industrial GDP has also fallen.

The Federal Department of Natural Resources (NRCan) is responsible for formulating and implementing energy policy in areas of federal jurisdiction. The Office of Energy Efficiency (OEE) implements NRCan's energy efficiency initiatives and distributes information about energy efficiency. The CANMET Energy Technology Branch works with industry on the research and development of energy efficient technologies. Provincial and regional governments, utilities and non-governmental organisations have also implemented energy efficiency initiatives of their own.

Most of the energy efficiency initiatives in Canada support research and development or are voluntary or information based. There are a few programmes that offer monetary incentives. Currently, there are mandatory building codes in all provinces and minimum energy efficiency standards have been established for 33 products including residential appliances, electric motors and lighting. See Table 19 for a summary of the types of energy efficiency programmes in place in Canada.

**Table 19 Summary of Energy Efficiency Programmes in Canada**

| Types of Energy Efficiency Initiatives | Industrial | Transportation | Commercial | Residential |
|---|---|---|---|---|
| Voluntary Commitments | X | X | X | X |
| Product Efficiency Standards | X | | X | X |
| Product Labelling | | X | X | X |
| Information | X | X | X | X |

Source ADEME/APERC, 2000

## CHILE

Aggregate energy intensity by GDP decreased slightly from 108 toe per M$95 at PPP in 1980 to 105 toe per M$95 at PPP in 1998. Final energy consumption and GDP increased at about 5 percent per annum during this period.

Transport sector energy intensity by GDP was flat at around 45 toe per M$95 at PPP during the study period. In the manufacturing sector however, intensity increased by more than 65 percent. A similar trend was noted in the residential sector, where per capita energy consumption increased by 61 percent.

The National Energy Commission (CNE) is responsible for developing and implementing energy efficiency policy in Chile. Energy efficiency research and promotion has also been undertaken by the University of Chile, some NGOs, as well as by the Economic Commission for Latin America and the Caribbean (ECLAC).

The bulk of the energy efficiency initiatives in Chile encourage voluntary actions through information campaigns, energy audits, and technical and financial assistance. In the mining sector, particularly in the state copper company, CODELCO, energy efficiency initiatives have been linked to reductions in both cost and GHG emissions. In the residential sector, the building code has been recently modified to incorporate thermal efficiency requirements for new buildings. Almost 70 percent of the inefficient incandescent and mercury streetlights have been replaced with high-pressure sodium vapour ones [CNE, 2001; ADEME/APERC, 2000].

## CHINA

In China, GDP based energy intensity for the whole economy was about 340 toe per M$95 at PPP in 1980, this was the highest intensity in the APEC region. Intensity declined - 6.1 percent per year over the study period and dropped to 112 toe per M$95 at PPP by 1998.

Energy consumption in China has increased rapidly since 1980. Energy intensity declined significantly in the industrial sector due to a structural shift from high energy intensity industries to low intensity industries. Technology improvements and more efficient use of energy also helped to reduce energy intensity. On the other hand, along with the personal income increases, energy intensity in the transportation and residential sectors rose steadily during the study period.

The Energy Efficiency Department of the State Economic and Trading Commission is in charge of energy-related regulation and policy development. The China Certification Centre for Energy Conservation Products and the China National Institute of Standardisation are responsible for verifying that new products meet established energy standards. The China Energy Conversation Company invests in energy efficiency related projects.

As a national policy, the Chinese government promotes new technologies usage and encourages energy efficiency improvements. In 1998, China launched a national programme aimed at updating electricity end use distribution grids in both urban and rural areas. This programme will reduce the amount of electricity lost through the transmission process. Energy standards for some electric appliances such as television sets, refrigerators, air conditioners and the like, are also being introduced.

## HONG KONG, CHINA

During the study period, energy intensity in Hong Kong, China grew from 58 toe per M$95 at PPP in 1980 to 77 toe per M$95 at PPP in 1998, an increase of nearly 35 percent. With only a small industrial sector, Hong Kong, China has one of the lowest energy intensities in APEC. Economic development in this economy has been driven by the services sector.

In both the manufacturing and transport sectors, energy intensity by GDP increased by nearly 70 percent over the study period. Per capita energy consumption in the residential sector also grew by more than 90 percent for the study period. While services energy intensity by GDP has been fairly stable, energy intensity per worker in this sector has risen by nearly 60 percent from 1981 to 1998.

The implementation and coordination of energy efficiency programmes is the responsibility of the Energy Efficiency Office of the Electrical and Mechanical Services Department, HKSAR Government. Energy efficiency is part of the work of the Environment and Food Bureau.

"Increase Efficiency in Energy Use" is Hong Kong, China's national programme for energy efficiency. It is considered a "key area to achieve the Government's policy objective to improve HKC's urban, rural and marine environment, conserving natural heritage, and optimising the use of resources and goods so as to reduce pollution and waste [ADEME/APERC, 2000]."

Most energy efficiency programmes in Hong Kong, China are voluntary. Labelling programmes started in 1995, with the "Hong Kong Voluntary Energy Efficiency Labelling Scheme for Household Refrigeration Appliances" (revised in 1999). These voluntary labelling schemes have also been applied to washing machines (1997), air conditioners (1996, revised in 2000), compact fluorescent lamps (1998), electric clothes dryers (1999), electric storage water heaters (2000) and photocopiers (2000). In the transportation sector, subsidies are provided for electric cars (exemption from first registration tax), as well as to scrap old cars. There is also an information programme on energy efficiency for cars.

Only service buildings have mandatory thermal efficiency standards. Energy audits in dwellings, commercial buildings and industry are also voluntary. The Government pays for audits in public buildings. There are also a variety of information programmes on energy efficiency for commercial and residential buildings. A code of practice and guidelines for the commercial and residential buildings, set minimum efficiency standards and provide advice on best practices concerning lighting, air conditioning, electrical and lift/escalator installations. The codes of practice are implemented by means of a voluntary registration scheme. A demand-side management programme for non-residential sectors started in July 2000. It provides rebates for new installations of efficient lighting. A similar programme for the residential sector is being planned.

In Hong Kong, China, plans are being made to develop energy consumption indicators and benchmarks for certain selected commercial and transport energy consuming groups.

## INDONESIA

Energy consumption, driven by strong economic growth, grew rapidly in Indonesia during the study period. FEC increased 2.6 times going from 21.1 Mtoe in 1980 to 55.2 Mtoe in 1998. Though it is still very low compared to developed economies, energy consumption per capita in Indonesia doubled from 0.14 toe in 1980 to 0.27 toe in 1998. At 56 percent in 1998, electrification rates in Indonesia are low compared to its neighbours Malaysia and the Philippines. Despite a lack of access to electricity services, electricity demand increased by around 14 percent per year during the 1990s. Even with the Asian Financial Crisis in 1997, which severely checked economic growth in Indonesia, electricity demand still increased by 5 percent in that year.

Whole economy energy intensity by GDP increased slightly from 71 toe per M$95 at PPP in 1980 to 76 toe per M$95 in 1998. Over the study period, the Indonesian economy has shifted away from agriculture towards industry. In 1980, the household sector was responsible for 34 per cent of FEC, industry and transportation consumed 32 percent and 29 percent respectively. In 1998, the breakdown of end use sectors changed substantially. The transportation sector jumped to 36 percent of FEC, industry also made up 36 percent and the residential sector fell to 22 percent of consumption.

The Directorate General of Electricity and Energy Development, a government agency, is responsible for national energy conservation programmes. Energy conservation became a priority with the release of Presidential Decree No. 43/1991 in 1970. This decree encouraged energy efficiency improvements in all energy using sectors. Government, non-government as well as private sector companies such as PT KONEBA have tried to promote energy conservation practices through promotional campaigns, training and guidance, pilot phase projects, workshops, seminars, award programmes and other initiatives. Despite these efforts, there are few energy conservation regulations, measures and policies which encourage energy conservation in Indonesia. Other barriers to energy efficiency improvements in Indonesia include relatively low energy prices and a lack of awareness about energy efficient products and processes.

## JAPAN

Aggregate intensity in Japan fell from 109 toe per M$95 at PPP in 1980 to 92 toe per M$95 at PPP, a decline of about - 15.6 percent.

There has been mixed results in energy efficiency performance across sectors. In the industrial sector, energy intensity fell by - 33 percent from 1980-1998. Energy intensities have sharply declined in energy-intensive industries such as iron and steel (- 27 percent), non-metallic minerals (- 32 percent), chemicals (- 52 percent) as well as pulp and paper (- 48 percent), contributing to a lower aggregate intensity. Energy intensity in the commercial sector has been flat through the study period. Building owners may have fully exploited energy saving potential during the energy crisis in the 1970s. In the residential sector, consumption per capita increased by more than 50 percent. Similarly, in the transportation sector, energy use per capita jumped from 481 toe per thousand people in 1980 to 736 toe per thousand people in 1998. Transportation energy intensity by industrial GDP has been flat since the early 1990s.

Under the supervision of the Ministry of Economy, Trade and Industry (METI), the Energy Conservation Center, Japan (ECCJ) promotes energy efficiency and conservation in the residential, commercial, industrial and transportation sectors in Japan. The ECCJ conducts audits, runs publicity campaigns, disseminates information on energy-saving products and conducts training and education programmes on energy efficiency.

In Japan, the 1993 Energy Conservation Law and the revised Energy Conservation Law of 1998 promote energy conservation measures by offering subsidies and low interest loans to building and factory owners who voluntarily invest in energy efficient systems and equipment. Moreover, designated factories are required to hire a certified energy manager, submit an energy rationalisation plan and report energy consumption levels to the government each year. The law is administered by METI. These conservation laws also established standards for improved energy efficiency for certain products and made energy efficiency labelling mandatory.

In Japan, a new amendment to the conservation law was issued in 1999 which established new performance standards for automobiles and trucks. These standards will go into effect in 2005 for diesel powered vehicles and in 2010 for gasoline powered vehicles. It is expected that the fuel efficiency of new automobiles in Japan will increase by 15 percent by 2005 and by 23 percent by 2010 [ECCJ, 1999].

Table 20 provides a summary of energy efficiency programmes in Japan.

**Table 20 Summary of Energy Efficiency Programmes in Japan**

| Types of Energy Efficiency Initiatives | Industrial | Transportation | Commercial | Residential |
|---|---|---|---|---|
| Energy Controls | X | | | |
| Fiscal/Financial Measures | X | | X | |
| Voluntary Commitments | X | X | X | X |
| Product Efficiency Standards | | X | X | X |
| Product Labelling | | X | X | X |

Source ADEME/APERC, 2000

## REPUBLIC OF KOREA

Republic of Korea's final energy intensity by GDP has increased from 127 toe per M$95 at PPP in 1980 to 152 toe per M$95 at PPP in 1998.

Energy intensity in the manufacturing sector, despite some ups and downs, rose slightly from 257 toe per M$95 at PPP in 1984 to 262 toe per M$95 at PPP in 1998. Improvements in standards of living and quality of life have led to sharp increases in energy intensities in other sectors. In the services sector, energy intensity jumped from 27 toe per M$95 at PPP in 1980 to 52 toe per M$95 at PPP. In transportation energy consumption per thousand people quadrupled from 133 toe per thousand people in 1980 to 547 toe in 1998.

Energy efficiency programmes in Korea are managed by the Korea Energy Management Corporation which is part of the Ministry of Commerce, Industry and Energy. Energy efficiency priorities in Korea were outlined in the Second National Energy Utilisation Plan (NEUP) [ADEME/APERC, 2000]. The main objective of the plan is to reduce energy consumption by 10 percent relative to estimated demand levels in 2003. The plan went into effect in 1999 and aims to achieve its goals by 2003. The NEUP includes thermal energy efficiency standards for new buildings, both residential and commercial. There is also an energy audit programme for both commercial and public buildings and for industrial buildings and equipment.

Energy efficiency standards and a labelling programme for household electrical appliances have been in place since 1992. Refrigerators, lighting products and air conditioners currently carry labels. This labelling programme will be extended to gas boilers in 2001 and dishwashers and electric water heaters in 2002. Efficiency standards were set for incandescent bulb in 1997 and those for fluorescent lighting systems including ballast and lamp came into effect in 2000. By 2001, standards for appliances such as refrigerators, washing machines, air conditioners and domestic gas boilers will come into effect.

Other efficiency measures in Korea include requirements for consumption reporting and preparation of energy saving plans for industrial and commercial buildings; provision of soft loans, tax breaks and credits for energy efficient equipment and measures; and information dissemination on best practices and energy efficiency measures. Moreover, research and development (R&D), demonstration and dissemination of technologies on energy and mineral resources, commercialisation and diffusion of higher-efficiency energy appliances and climate change mitigation efforts are also being pursued in Korea [Government of Korea, 1997].

## MALAYSIA

In Malaysia, final energy intensity by total GDP rose from 88 toe per M$95 at PPP in 1980 to 129 toe per M$95 at PPP in 1998. Intensity increased by 47 percent over the study period.

Energy intensity in the manufacturing sector declined from 233 toe per M$95 at PPP in 1980 to 157 toe per M$95 at PPP in 1997, a drop of - 33 percent. In contrast, services energy intensity rose from 9 toe per M$95 at PPP in 1980 to 15 toe per M$95 at PPP in 1997. Transportation energy per capita was the fastest growing end use sector. Intensity more than doubled over the period, rising from 179 toe per thousand people in 1980 to 423 toe per thousand people in 1997.

Two government agencies are involved in energy efficiency programmes, the Malaysia Energy Centre and the Ministry of Energy, Communications and Multimedia. Other institutions such as universities and research groups also work towards improving energy efficiency in Malaysia.

Energy efficiency programmes in Malaysia are targeted at the industrial and commercial sectors. In the industrial sector, the Malaysian Industrial Energy Efficiency Improvement Programme (MIEEIP) which began in 2000, aims to reduce energy consumption by 10 percent over a four year period [ADEME/APERC, 2000]. In the commercial sector, voluntary thermal energy efficiency targets have been set for overall thermal transfer value (OTTV) and roof thermal transfer value (RTTV) in buildings. Energy audits are being conducted in industrial and public buildings and there are plans to audit commercial buildings in the future. A labelling programme for Malaysia is currently in the planning stages.

## MEXICO

In Mexico, aggregate energy intensity by GDP decreased from 116 to 105 toe per M$95 at PPP or a 9.5 percent reduction during the study period. In the manufacturing sector, intensity declined by 21 percent, falling from 283 to 224 toe per M$95 at PPP. Transportation intensity hovered around 50 toe per M$95 at PPP during the study period. In the residential sector, per capita energy consumption increased by 25 percent from 1980 to 1997.

The National Commission for Energy Conservation (CONAE) is responsible for implementing and coordinating energy efficiency programmes. Other institutions dealing with energy efficiency programmes include the Electricity Savings Trust (FIDE), as well as other public and private entities.

There is no general national energy efficiency programme with official objectives in Mexico. There are however several national programmes such as the Electricity Sector Savings Programme (PAESE) and the Daylight Time Savings Programme. Several efficiency measures are mandatory, such as (a) thermal efficiency standards for new dwellings and service buildings; and (b) labels and standards for refrigerators, washing machines and air conditioners. Other measures include soft loans for major end use sectors, technical assistance and information programmes on best practice [ADEME / APERC, 2000; Secretaría de Energía, 2000].

Incentive and market transformation programmes provide economic incentives to users that acquire and install high efficiency equipment. These programmes have been geared to residential lighting and the productive sectors. Supply-side programmes include the promotion of cogeneration and renewable energy.

## NEW ZEALAND

Final energy intensity by total GDP in New Zealand rose from 125 toe per M$95 at PPP in 1980 to 159 toe per M$95 at PPP in 1998.

The Energy Efficiency and Conservation Authority (EECA) is mandated to promote, educate, facilitate and coordinate energy efficiency issues and programmes in New Zealand. The Ministry for the Environment oversees the EECA.

New Zealand has a mandatory building code with thermal efficiency standards which apply to new construction and renovations. Minimum efficiency performance standards for household electrical appliances are about to become law. At this time, there are no legislated statutory targets for energy efficiency programmes, though the Energy Efficiency and Conservation Act 2000 promotes mandatory energy efficiency targets. A National Energy Efficiency and Conservation Strategy is expected in April 2001.

## PAPUA NEW GUINEA

In Papua New Guinea, energy intensity by total GDP fell from 60 toe per M$95 at PPP in 1980 to 52 toe per M$95 at PPP in 1998.

The government is currently considering a National Energy Policy Statement (NEPS). This statement pledges to minimise energy consumption and to use energy more efficiently so long as the economic and social well-being of Papua New Guineans is not affected. Currently there are no legislated or statutory targets for energy efficiency programmes. There are, however, plans to introduce statutory requirements once the NEPS has been approved.

The Energy Division under the Ministry of Petroleum and Energy is mandated to promote, educate, facilitate and coordinate energy efficiency issues and programmes. The Building Board deals with building codes, the National Institute of Science and Industrial Technology tests appliances while the Office of Environment and Conservation handles environmental issues.

There is a building code in Papua New Guinea that applies to all new construction and renovations. The government is considering a plan to apply the voluntary US ENERGY STAR® label to household electrical appliances.

## PERU

In Peru, aggregate energy intensity by GDP hovered around 65 toe per M$95 at PPP during the study period. Manufacturing intensity, at 71 toe per M$95 at PPP in 1997 increased by 5 percent since 1980, though there were substantial year-to-year variations. Transport intensity rose by nearly 8 percent, ending at 33 toe per M$95 at PPP in 1998. In the residential sector, however, per capita energy consumption decreased by 12 percent.

The Ministry of Energy and Mines (MEM) is responsible for implementing and coordinating energy efficiency programmes. Since 1995, MEM has promoted an information campaign called the "Energy Savings Project" which aims to reduce peak electricity consumption in dwellings by changing consumer behaviour and providing information about efficient equipment. In September 2000, the "Law for the Promotion of Energy Efficient Use" was enacted. This law declares the promotion of energy efficiency to be of national interest so as to ensure energy supply, protect customers, promote economic competitiveness and reduce the environmental impact of energy use [ADEME/APERC, 2000].

Thermal efficiency standards for new dwellings and service buildings are voluntary. Audits have been conducted free of charge in dwellings, commercial and public buildings, as well as in industry. Energy efficiency labelling and standards for household electrical appliances are required by the new law and will soon be implemented.

## PHILIPPINES

Final energy intensity in the Philippines rose slightly from 45 toe per M$95 at PPP in 1980 to 52 toe per M$95 at PPP in 1998.

In the Philippines, energy intensities across end use sectors have been increasing. In the industrial sector, manufacturing intensity increased from 58 toe per M$95 at PPP in 1980 to 77 toe per M$95 at PPP in 1998. Services intensity increased during the study period rising from 6 toe per M$95 at PPP in 1980 to 8 toe per M$95 at PPP in 1998. Transportation per capita increased from 40 toe per thousand people in 1980 to 63 toe per thousand people in 1997. Higher standards of living have contributed to increased levels of energy consumption in the Philippines.

The Department of Energy is the national agency responsible for energy efficiency programmes. The Energy Efficiency Division (EED) under the Energy Utilization Management Bureau designs and implements these programmes [ADEME/APERC, 2000]. Two non-government bodies, the Energy Management Association of the Philippines (ENMAP) and the Energy Development Utilization Foundation, Inc. (EDUFI) are also involved in energy efficiency programmes.

In the Philippines, there are specific energy efficiency programmes for each of the energy-consuming sectors. Programmes in place for the industrial sector include energy audits, special financing for energy conservation projects, power patrol and energy certification of industrial fans and blowers. System loss reduction, heat rate improvement of power plants and demand-side management are some of the programmes available to the electricity sector. Programmes for the residential and commercial sector are energy efficiency labelling of appliances such as room air-conditioners and refrigerators and freezers, and lamp ballast efficiency standards. The Power Patrol Programme provides information on energy efficient practices to all sectors and has been in operation since 1993. A similar programme for the transport sector, the Road Transport Patrol was started in 1998. In addition, vehicle efficiency standards and testing protocols for motor vehicles are currently in place in the Philippines.

## RUSSIA

Due to economic recession in the 1990s energy consumption dropped by 25 percent while economic activity measured as GDP in 1995 values at PPP, fell by about 35 percent.

At 269 toe per M$95 at PPP in 1998, Russia had the highest final energy intensity in APEC. A cold climate and heavy industries using inefficient technology account for this high level of energy use. The industrial structure in Russia changed very little during the 1990s due to a lack of investment.

Total energy savings potential in Russia is estimated to be 310-370 Mtoe. The industrial sector is thought to have a savings potential of 110-133 Mtoe, transportation at 29-34 Mtoe, agriculture at 20 Mtoe, services at 52-58 Mtoe and the energy upstream sector at 104-127 Mtoe [Shakhin, 2000].

The federal law “On Energy Conservation” was enacted in 1996. Infrastructure for energy efficiency management exists at the federal, regional and local levels. There is a Federal Energy Ministry; a Federal Energy Commission; 6 regional and 74 local departments inside a framework of State energy Supervision; 20 non-budget regional funds and more than 20 centres and institutes for energy efficiency.

The Federal Programme “Energy Conservation in Russia” (1998-2005) is currently being implemented. The programme covers all types of energy savings, structural and technological, in different economic sectors. The goal of the programme is to achieve energy savings of 240-280 Mtoe and a 13.5 percent decline in GDP energy intensity by 2020. The funding for this programme will come from the federal budget, regional budgets, energy efficiency funds and commercial credits.

## SINGAPORE

Singapore’s GDP energy intensity increased from about 118 toe per M$95 at PPP in 1980 to 127 toe per M$95 at PPP in 1998. Both energy consumption and GDP grew about 7 percent per year during the 1990s. During the same period, energy per capita increased to 3.5 toe per capita in 1998 from 1.3 toe per capita in 1980 or at a rate of 5.5 percent per annum.

In 1980, transportation accounted for 44 percent of FEC and was the largest end use sector in Singapore. In 1998, the residential and commercial sectors accounted for 36 per cent of the total final energy consumption while transportation and industry made up 34 percent and 30 percent, respectively.

In 1979, the government introduced stringent building codes regulating energy efficiency in new buildings. Air-conditioned buildings were required to be energy efficient in design, use of materials as well as lighting and other electrical fixtures. Overall heat gain in new construction could not exceed a certain limit (45 Watts per square metre). Building designers were permitted to adjust architectural shape, orientation, size of windows and/or wall materials in order to meet these requirements.

The Public Utility Board is responsible for national energy conservation programmes in Singapore. The Board has actively promoted and encouraged the efficient use of energy in the industrial and commercial sectors. It has conducted 141 energy audits at various industrial and commercial facilities. This programme has identified upgrades worth 41.8 million kWh per year. Besides audits, the government periodically holds Energy Management Training Courses.

## CHINESE TAIPEI

Energy intensity in Chinese Taipei fell from 198 toe per million US$95 in 1980 to 136 toe per million US$95 (the World Bank does not produce PPP estimates for this economy). Intensity declined by about - 3 percent in the 1980s and more slowly at about - 1 percent in the 1990s.

The government in Chinese Taipei has set goals to improve total energy efficiency by 1.2 percent per year from 1997 to 2010 and 1.0 percent per year from 2010 to 2020. The plan is expected to save about 18 Mtoe by 2010, and 39 Mtoe by 2020 [ADEME/APERC, 2000].

To achieve these goals, Chinese Taipei has implemented a "Comprehensive Plan for the Conservation of Energy and the Promotion of Energy Efficiency." If energy utilisation by an energy consumer reaches a certain level, the owner of the facilities must report energy utilisation levels to the government, establish an energy audit system, and submit a conservation plan with energy targets. Chinese Taipei has mandatory performance standards for all energy using equipment, including motor vehicles. It also has energy conservation standards for new buildings. To encourage investment in high-efficiency equipment and facilities, the government offers accelerated depreciation, investment tax credits and low-interest loans.

Chinese Taipei also promotes voluntary action through public information campaigns, compiling teaching materials for schools and sponsoring training programmes on energy conservation. The government offers technical conservation services such as energy audits, advisory services, technology transfer and voluntary commitments with industry. See Table 21 for a summary of energy efficiency programmes in Chinese Taipei.

**Table 21 Summary of Energy Efficiency Programmes in Chinese Taipei**

| Types of Energy Efficiency Initiatives | Industrial | Transportation | Commercial | Residential |
|---|---|---|---|---|
| Energy Controls | X | | X | |
| Fiscal/Financial Incentives | X | | X | |
| Voluntary Commitments | X | | | |
| Product Efficiency Standards | X | X | X | X |
| Product Labelling | | | | |
| Information | X | X | X | X |

Source ADEME/APERC, 2000

## THAILAND

In Thailand, final energy intensity by GDP grew from 85 toe per M$95 at PPP in 1980 to 111 toe per M$95 at PPP in 1998, an increase of 31 percent.

In the industrial sector, manufacturing energy intensity increased slightly from 93 toe per M$95 at PPP in 1980 to 107 toe per M$95 at PPP in 1998. These increases were small compared to services intensity which grew from 7 toe per M$95 at PPP in 1980 to 16 toe per M$95 at PPP in 1998. Transportation energy per capita almost quadrupled rising from 86 toe per thousand people in 1980 to

342 toe per thousand people in 1997. Rapid economic growth and rising standards of living have greatly increased energy consumption levels in Thailand.

Energy efficiency and conservation programmes in Thailand are designed and implemented by the Department of Energy Development and Promotion (DEDP) and the National Energy Policy Office (NEPO). The Electricity Generating Authority in Thailand (EGAT) implements demand-side management programmes.

In Thailand, the Energy Conservation and Promotion Act was passed in 1992. The Energy Conservation Programme for Thailand, including an energy efficiency strategy, was laid out in this act. Thailand has introduced a variety of energy efficiency programmes including public awareness campaigns, energy labelling for household appliances, energy standards for energy-consuming equipment, promotion of energy efficiency in government buildings, energy audits and the formulation of energy conservation plans for commercial and industrial facilities.

## UNITED STATES OF AMERICA

The USA is the largest consumer of energy in both the APEC region and the world. Energy intensity in the United States fell from 210 toe per M$95 at PPP in 1980 to 137 toe per M$95 at PPP in 1998, a decline of **-** 53 percent.

Due to the importance of energy in the US economy, there are extensive programmes of energy efficiency policies. The US has the longest running MEPS programme. Recent successes include the promulgation of more stringent minimum energy efficiency standards for a variety of products, such as refrigerators, fluorescent lighting ballasts and clothes washers. Virtually all sectors have established research and development (R&D) programmes that are helping to bring new technologies to the USA and world market. There are many technology transfer or deployment programmes to encourage consumers and businesses to adopt high efficiency technologies more quickly than they otherwise would. There are numerous technology roadmaps with industry that help establish a strategy to bring more efficient practices, technologies, and products to industrial and the buildings sectors. The voluntary ENERGY STAR® labelling programme, which is well known in the US market, is being adopted by other economies around the world.

There are a large number of energy efficiency initiatives in all sectors and they are summarised in Table 22. Additional information on conservation programmes in the USA can be accessed on the main energy efficiency web site maintained by the US DOE Office of Energy Efficiency and Renewable Energy, http://www.eren.doe.gov.

**Table 22 Summary of Energy Efficiency Programmes in the USA**

| | Industrial | Transportation | Residential | Commercial | Renewable |
|---|---|---|---|---|---|
| R&D | X | X | X | X | X |
| Deployment / Labelling | X | X | X | X | X |
| Industry Roadmap | X | | X | X | |
| Regulation | | X | X | X | X |

## VIET NAM

Energy consumption in Viet Nam increased by 4 percent per year during the 1990s. At the same time, energy intensity by total GDP rose slightly from 51 toe per M$95 at PPP in 1990 to 57 toe per M$95 at PPP in 1998. Viet Nam has one of the lowest levels of energy intensity in the APEC region. Over the study period, the economic structure of Viet Nam has become more energy-intensive, but at the same time, this economy has enjoyed significant energy efficiency improvements (- 0.7 percent per year).

The government's 5-year plan (1996-2000) aims to reduce total final energy consumption by 8-10 percent (equal to 1.2-1.5 Mtoe) and to maintain GDP energy intensity at 1996 levels. Reducing peak power demand by 150-200 MW through demand side management programmes is another goal outlined in the plan.

Investment in energy efficiency products and technologies is encouraged through tax exemptions or reductions. The government also encourages technology transfer with OECD economies.

The Ministry of Science, Technology and Environment (MOSTE) is responsible for energy conservation programmes in Viet Nam. Under the supervision of MOSTE, the Project Office for Energy Conservation and Efficiency designs and implements energy efficiency programmes.

In the industrial sector, potential energy savings have been identified in the cement industry (- 50 percent), ceramics industry (- 35 percent), coal-fired power generation (- 25 percent) and boilers replacement (- 50 percent) [MOSTE, 1998]. The government plans to implement mandatory energy audits for utilities which consume more than 500 ktoe per year.

## Endnotes

1 Unless otherwise specified, the energy intensity cited is the same one which appears in *Chapter 3: Macroeconomic Energy Efficiency Indicators*. That is, final energy consumption excluding the residential and non-energy sectors divided by total GDP.

# APPENDIX C

## ENERGY AUDITS

### INTRODUCTION

Energy audits involve the assessment of a factory, building or residence to determine the condition of the energy consuming equipment and the building structure. The fundamental purpose of the audit is to identify areas where energy efficiency and conservation improvements can be made that will be cost effective and will result in significant energy savings.

The energy auditor inspects the condition, age, efficiency, fuel source, performance, usage habits, and other parameters of the equipment used. The auditor also inspects the thermal envelope of the structure including the types and amount of insulation, windows, doors, and basic configurations. The audits may also assess the fuel sources being used and may propose alternatives. The auditor may even suggest that certain non-essential equipment be curtailed during periods of peak demand. Depending on the price structure, implementing these upgrades can result in significant economic savings for the firm. Many of these improvements may also have non-energy benefits such as improved comfort, enhanced safety, quieter operation, reduced waste and pollution, and improved productivity.

Energy audits are often funded by government agencies or by utility service companies.[1] These programmes are intended to reduce energy consumption and peak energy demand for a building or factory. To encourage participation, the audit is either provided free of charge or is cost shared with the customer. The auditor will assess and develop a suggested list of improvements that can be made to the property. These measures may range from the addition of attic or pipe insulation to the total replacement of existing fully functioning systems like a chiller, compressor, or motor. Major improvements may affect production schedules and may need to be planned and implemented during a plant shutdown.

Before proceeding with an upgrade suggested by an energy audit, building owners will likely do a cost-benefit analysis. One technique used is the simple payback method. By taking the cost of the energy efficient product and dividing it by the annual energy savings resulting from use of the energy efficient product, the consumer can determine how long it takes to recoup the investment. The fundamental problem with using the simple payback method is that it does not take into account future energy savings. A better method of assessment is to consider the life cycle cost or net present value of the product. In this approach, the initial purchase price of the product is added to the stream of energy costs that will be incurred from operating the unit. Since a dollar today is worth more than a dollar tomorrow, these energy bills are discounted using a discount rate.[2] The use of more sophisticated economic tools should lead to longer-term investments that will produce greater energy and economic savings.

Measures recommended in the audit may be implemented by the company which performed the audit, the firm's maintenance staff or independent contractors hired by the firm. To encourage the firm to implement the measures recommended in the audit, the government or the utility service company which funded the audit, may offer attractive financing terms for the project. Often, a follow-up evaluation is conducted to document and verify the savings realised. However, most of the data from the audit and the follow-up evaluation are considered confidential and are usually not available to the public.

## CASE STUDIES

Each case study examines major energy audit programmes in selected APEC economies. Detailed data are often unavailable due to proprietary issues or because data has not been consolidated into one database. The purpose of these case studies is to show examples of audit programmes in APEC economies and to provide information to economies considering the use of an audit policy. Case studies are presented for Australia, Korea, Thailand, and the USA.

### AUSTRALIA

In Australia, the Enterprise Energy Audit Program (EEAP) operated from 1991 to 1997 and was applicable to service (commercial) buildings and industrial facilities. The Department of Primary Industries funded the programme which paid 50 percent of the audit cost up to a maximum of AUS$5,000 (US$3,712 WB 1997).[3] Approximately 1,200 firms participated in the programme. The average firm spent about AUS$400K (US$297K WB 1997) per year on energy which represented about four percent of its operating costs.

On average, 5.8 recommendations were made per firm and 4.7 (81 percent) of these measures were actually installed. Improvements to lighting systems were recommended in almost three out of every four audits and were the most common measure. The next most popular measures were air conditioning (45 percent), water heating (35 percent), and industrial equipment (34 percent). Implementation rates were fairly consistent across the different suggested measures, although the more expensive measures were implemented less often.

The audits were thoroughly evaluated using detailed surveys and follow-up visits. Results showed 58 percent of firms were conservative when considering investment in energy efficiency measures. The average required rate of return was around 20 percent, though data was limited and the numbers collected varied widely. At the same time, 93 percent of the firms believed that the EEAP audit had been worthwhile. To assess the measures suggested, 80 percent of firms used the simple payback method, only 30 percent used net present value.

Though the overall programme was considered to be very successful, evaluators did not think that EEAP should be reinstated. Evaluators felt that the programme had achieved its stated purpose and had demonstrated that the auditing process was viable. Moreover, since audits were shown to be cost effective, government subsidies were not necessary. The evaluators thought that if such a policy was to be pursued, it should focus on a firm's entire operations rather than a single facility. Another major recommendation was to promote the use of more sophisticated economic tools, such as net present value tools that account for risk and the cost of collecting additional data. In addition, the use of more sophisticated tools might encourage firms to implement more expensive measures. Table 23 shows an estimated summary of the EEAP results [Harris *et al*., 1998].

**Table 23 Estimated Summary of Australia's Audit Programme (1991 - 1997)**

| Cost Effective Energy Efficient Measures | Number of Measures per Firm | Investment (Million US$) | Annual Savings (Million US$/yr) | Simple Payback (years) |
|---|---|---|---|---|
| Recommended | 5.8 | 108 | 73 | 1.5 |
| Implemented | 4.7 | 78 | 60 | 1.3 |

Source Harris *et al*., 1998

## KOREA

The Korea Energy Management Corporation (KEMCO) funds and conducts audits for service buildings (commercial) and industrial facilities. The majority of the audits are conducted free of charge, however about 18 percent are funded by the customer. From 1995 through 1999, KEMCO performed almost 2,000 audits, approximately 80 percent were in the industrial sector.

KEMCO conducts mainly three types of audits, a Thermal Energy Audit, Electric Energy Audit, and Thermal Video System Audit. The Thermal Energy Audit deals mostly with fuel supplies, combustion processes, waste heat recovery, distribution, and several other areas such as process improvement. The Electric Energy Audit involves the inspection of the electrical supply system, electric service "quality" (power factor), load rates, heat source substitution, waste heat recovery, and overall process improvement. The Thermal Video System Audit uses heat-imaging equipment that measures the surface temperature within an accuracy of 0.1 degree Celsius. This type of audit covers the same areas as the other audits, but is more thorough and accurate.

Table 24, shows a sample of the results from several industrial and building audits. The overall average payback for the sample is 1.3 years with an annual energy savings of 199,313 toe per year. As can be seen from the table, though some building sector audits have been conducted, most investment has been in the industrial sector [KEMCO, 2000].

**Table 24 Sample of Korea's Implemented Energy Measures from Audits (1995 - 1999)**

| Programme Area | Number of Audits | Investment (Million US$) | Annual Savings (Million US$/yr) | Annual Energy Savings (toe/yr) | Simple Payback (years) |
|---|---|---|---|---|---|
| Buildings | 4 | 0.66 | 0.24 | 709 | 2.8 |
| Industrial | 8 | 48.65 | 37.33 | 198,604 | 1.3 |
| TOTAL | 12 | 49.31 | 37.57 | 199,313 | 1.31 |

Note Derived from KEMCO, 2000

## THAILAND

In Thailand, legislation passed in 1992 created the Energy Conservation Promotion Fund. This programme contained provisions for obligatory energy audits in government offices, in service buildings (commercial) and in factories. In addition to requiring audits, it also specified the appointment of energy managers, the reporting of energy consumption, and the submission of requests for grants and financial support.

The programme has made significant progress since its inception. Planned investment for the programme is summarised in Table 25. Thailand expects to spend US$ 1 billion to the end of 2003 with a simple payback of only 2.1 years. The benefits from the project include lower energy bills in the upgraded buildings as well as over 1 GW in avoided electric capacity.

**Table 25 Summary of Thailand's Energy Audit Plan**

| Programme Area | Years Covered by Plan | Investment (Million US$) | Annual Savings (Million US$/yr) | Annual Energy Savings (Million kWh) | Demand Savings (MW) | Simple Payback (years) |
|---|---|---|---|---|---|---|
| Government Buildings | 1995 – 2002 | 110 | 15 | 297 | 112 | 7.3 |
| Designated Buildings | 1997 – 2000 | 155 | 56 | 1,165 | 403 | 2.7 |
| Factories | 1998 – 2003 | 264 | 185 | 3,832 | 547 | 1.4 |
| TOTAL | | 528 | 257 | 5,294 | 1,062 | 2.1 |

Note Derived from ECPF, 1992; Exchange rate per EDMC 1998, 1US$ = 41.36 Baht

## UNITED STATES OF AMERICA

In the USA, there is energy audit activity in all segments of the economy. With Federal government support, industrial audits are conducted through university programmes at 30 locations across the USA. Low-income homes are inspected and weatherised using state and Federal funds. Utility service companies conduct energy audits for their commercial, industrial, and residential customers in a variety of ways. The utility service companies may charge a fee for a home audit and/or they may provide it as a free service, especially to larger customers. Data from the utilities are not usually available to the public.

### INDUSTRIAL

The US Department of Energy's Office of Industrial Technology funds over 30 Industrial Assessment Centers (IAC) which perform, at no cost, comprehensive industrial assessments for small and medium-sized manufacturers. Assessments are performed by local teams of engineering faculty and students from participating universities across the US. Recommendations from industrial assessments have averaged about US$55,000 in potential annual savings for each manufacturer. To be eligible, each facility must have annual sales below US$75 million, have less than 500 employees, and have annual energy bills between US$75,000 and US$1.75 million.

The Federal Government has been funding industrial assessments since 1976. The manufacturers are not the only benefactors of the IAC programme. Students involved in the programme have a unique opportunity to see a range of manufacturing operations first hand. Students, encouraged by their experiences and contributions, often choose energy management as a career field. An additional benefit of the programme is that data generated by the assessments are recorded in a database. With good data on energy use, waste and productivity in small and medium sized industry, researchers may be able to devise ways to further improve efficiency in these firms.

The database currently contains information from 36 research centres on 9,600 industrial site visits. Since 1981, 68,000 efficiency measure recommendations with a savings potential of US$740 million have been identified. Only about 50 percent of these recommendations have been implemented. The database and training materials are publicly available on the internet (see URL http://oipea-www.rutgers.edu/database/db_f.html).

### RESIDENTIAL

The primary source of data for residential homes is from the low-income weatherisation programme. Residential audits conducted by utilities and private for-hire companies are not reported. The US Department of Energy and other Federal agencies work to improve the efficiency of eligible low-income households and pay energy bills for people in need. The programme is geared to helping the elderly, the disabled, and families with children.

To date, five million households have been weatherised at a rate of approximately 170,000 homes per year. Weatherisation activity includes the installation of insulation, caulking, storm windows or new windows, new heating systems if there are safety issues, distribution system duct sealing and other energy saving measures. In addition, the programme may soon be expanded. Weatherisation Plus would allow auditors to consider measures that go beyond basic comfort, such as the installation of new high efficiency refrigerators or dedicated (pin based) compact fluorescent lighting fixtures.

The current programme allows for expenditures up to US$2,032 per household with about 40 percent budgeted for materials. The programme has resulted in an average savings of 22 percent and a benefit-cost ratio of approximately 2.4 including societal benefits [DOE, 2000b].

### SERVICE BUILDINGS (COMMERCIAL)

Numerous audits are conducted for service buildings usually through utility service companies and private for-hire companies. No data is currently available, but activities include the commissioning/recommissioning of building systems, the installation of high efficiency fluorescent lighting with electronic ballasts, improved chillers, heat pumps, blowers and the like.

## CONCLUSIONS

Energy audits can lead to reductions in energy consumption, improvement of firm profitability by reducing costs, protection of the environment and can defer construction of electric generation capacity. Once the initial investment for the upgrades has been recouped, lower energy bills improve cash flow and net profits for firms. It is common for building owners to implement only the measures with the shortest payback period. Implementing more expensive upgrades requires a longer payback period and more flexible financing, but the decision will result in additional long-term cost savings for the firm. Moreover, if only the most cost effective measures are adopted, it becomes less likely that more expensive longer-term measures will be implemented at a later date.

Several developing economies do not have audit programmes. There is an enormous amount of free information on the internet to assist in the establishment of an audit programme. In building an audit infrastructure, a good place for a government to start is with itself. In government buildings, the government can finance the project, build the audit infrastructure, and demonstrate the economic viability of the process. Government subsidised audit programmes for the private sector can also promote and help to establish an audits infrastructure. Energy service companies (ESCOs) can function as catalysts for establishing these types of programmes. Since ESCOs are private companies, there are concerns that ESCOs will only promote the most cost-effective measures and charge fees that reduce the energy savings earned by building owners. Since there is large potential for cost effective efficiency and conservation measures in service buildings and industrial facilities, there are opportunities for a wide range of energy audit programmes.

## Endnotes

1 See *Chapter 8: Energy Efficiency Policies* for additional information on energy efficiency and conservation policies.

2 Please see *Chapter 8: Energy Efficiency Policies* for additional information on discount rates.

3 Exchange rate based on International Monetary Fund, World Bank, 1997.

# APPENDIX D

## FINANCIAL INCENTIVES FOR ENERGY EFFICIENCY

### OVERVIEW

Economic and fiscal incentives encourage investment in energy efficient equipment and processes by reducing the cost of the initial purchase. Examples of fiscal incentives include tax credits or reductions, accelerated depreciation allowances, rebates and low-interest loans (soft loans) for energy efficient investments. The purpose of these initiatives is to increase energy efficiency and reduce energy consumption in end use sectors, particularly industry. To be effective, fiscal incentives should be part of a broader energy efficiency strategy.

Low energy prices in the late 1990s have been a major disincentive to energy efficiency improvements. Moreover, expenditures on energy are low relative to total costs. In the industrial sector, for example, energy accounts for only 3-8 percent of total cost. In energy intensive sub-sectors such as chemicals and pulp and paper, the figure is higher at 10-14 percent.

In the section below, economic and fiscal measures to promote energy efficiency improvements in China, Indonesia, Japan, the Philippines and Thailand are presented.

### CHINA

In the 1990s, particularly after 1994, China implemented policies to promote energy conservation. One aspect of this strategy has been to force energy users to pay the full costs of energy resources by removing energy subsidies. Another method of encouraging resource conservation is through fiscal incentives such as tax rebates for energy efficient investments.

Price reform in China has increased economic incentives for conservation. In 1994, except for coal used for power generation, all price subsidies for coal were annulled. In 1998, for the first time, domestic crude oil prices were allowed to float with international oil prices. Controls on the prices of oil products were removed in 2000. Prices rose substantially once these subsidies were lifted and, as economists would expect, energy-intensive industries reduced consumption of these resources. In the iron and steel industry, for example, energy prices increased by a factor of three between 1986 and 1995. By forcing users to pay the full cost of their energy inputs, firms responded by finding ways to conserve energy and reduce energy expenditures. Over this ten-year period, the iron and steel industry realised energy savings of 15 Mtoe and avoided an estimated 3.87 billion yuan in energy expenditures [Zhou, 2001].

Tax incentives in China favour low carbon energy and energy efficient equipment. Investment in co-generation facilities, energy efficient buildings and the like are exempt from fixed asset taxes. Since 1998, energy conservation and pollution reduction equipment which is imported from abroad, has been exempt from value-added import taxes. Projects which use advanced technology to provide low carbon alternatives such as coal-bed methane development, are exempt from income taxes for the first five years of the project.

## INDONESIA

In Indonesia, subsidies keep energy prices artificially low and are a disincentive to some energy efficiency projects. Instead of removing these price subsidies, Konservasi Energi Abadi (KONEBA), Indonesia's federal energy efficiency agency plans to introduce other incentives to promote conservation. These fiscal measures include reduced domestic and import taxes on energy efficient equipment used by the industrial, services and transportation sectors as well as soft loans for energy conservation projects. These below-market interest rates are meant to encourage the upgrading of obsolete facilities with new, efficient modern ones. In the sixth 5-year plan (1994-99), Indonesia estimates that these fiscal initiatives will achieve cumulative energy savings of 160 Mtoe of energy or about US$ 3 billion.

## JAPAN

In 1993 the "Energy Conservation and Recycling Assistance Law" was enacted. It included a variety of fiscal incentives such as tax exemptions, special depreciation allowances and soft loans, to promote energy conservation by industry in Japan. A reduction of - 1 percent per year in energy consumption levels by all factories was one of the goals of the new law.

The 1993 law introduced several special tax measures for energy efficient equipment. On corporate tax payable, the government offered a tax rebate equal to 7 percent of the purchase price of energy efficient equipment. In 1999, this tax measure was restricted to small and medium-sized firms. Special depreciation provisions of up to 30 percent of equipment costs, were also offered. To qualify for this allowance, the new equipment had to guarantee a 5 percent reduction in energy use. In 1996, 26,606 pieces of equipment qualified for special depreciation. In 1997, the number was 21,271 and in 1998 it was 24,609 pieces of equipment. These special taxation measures boosted investment in energy efficient products by 500 billion yen (US$ 4 billion). Investment rose from 300 billion yen in 1990 to 800 million yen in 1993. Purchases fell back to the 300 billion yen level by 1999 [Sato, 1999].

The New Energy and Industrial Technology Development Organization (NEDO) grants subsidies for financing energy conservation technologies. Under the "High Performance Industrial Furnace Field Test Project," NEDO paid for up to one-third of the cost of each high-performance furnace. In 1998-99, 109 furnaces were purchased through the programme. NEDO estimates that the project will result in energy savings equal to 5 percent of Japan's final energy consumption by 2010. NEDO also provides funds for demonstration projects. A third of the equity cost for installation of advanced energy efficient equipment is provided by NEDO. In 1997-98, 47 projects were subsidised at a cost of US$ 50 million. NEDO also provides funding for co-generation systems and energy service companies.

Japan also provides loan support for energy efficient investments by industry. The government offers a rate of 2.2 percent to industry on up to half of the cost of the project for a period of 1-30 years. This policy has been less than effective given the deflationary economic conditions in the 1990s.

## THE PHILIPPINES

The government of the Philippines provides assistance for energy efficiency and conservation projects. These programmes strengthen institutional capabilities in energy conservation, technology and research and development. The National Energy Program (1996-2025) provides US$ 1,035 million for energy efficiency and US$ 139 million for DSM programmes or about US$ 40 million per year. Over the life of the programme, 1996-2025, a total investment of US$ 1.2 billion is expected to generate cumulative energy savings of 90 Mtoe resulting in a net saving of US$ 5.5 billion. The amount budgeted for 1996-2010 for both energy efficiency and DSM programmes is less than 1 percent of the total energy budget.

The Department of Energy (DOE) in the Philippines provides financial support through soft loans to some energy efficiency projects. The DOE paid for 50 percent. A programme called "Technology Transfer for Energy Management" provided loans to demonstrate new technologies. This programme funded 40 projects at a cost of US$ 7 million and these investments are expected to yield 30 ktoe in energy savings over 10 years. The Strategic Business Unit (SBU) provided funds for 280 energy efficiency projects at a cost of US$ 100 million.

## THAILAND

The Energy Conservation and Promotion Act of 1992 created the Energy Conservation Promotion (ENCON) Program, administered by the Department of Energy Development and Promotion (DEDP) and the National Energy Policy Office (NEPO). Funds for ENCON and the Energy Conservation Promotion Fund (ECF) (created in 1995) come from a 0.002 US$/litre tax on petrol. The ECF, administered by NEPO, provides financial assistance for energy conservation efforts by both the public and private sectors. The Electricity Generating Authority of Thailand (EGAT), administers energy efficiency programmes through its Demand-Side Management Office (DSMO). Funds for these initiatives come from donations and a fuel adjustment levy.

Over the period 1994-1999, programmes from NEPO, DEDP and EGAT cost US$ 770 million. These programmes funded soft loans for energy conservation investments and reduced import duties on energy efficient equipment. In 1998, EGAT estimated that DSM programmes, at a cost of US$ 20 million (1993-1998) or US$ 0.01 per kWh, saved 710 GWh and lowered peak demand by 182 MW.

## FINANCING FRAMEWORKS

Financial and economic incentives are funded in a variety of ways. Utilities, governments, NGOs, banks and international organisations are all participating in the design and administration of these programmes.

Utility run programmes are financed by rate-payers and implemented by the utility or by sub-contractors like energy service companies or NGOs. A new method of financing is "wire charges." That is, all electricity consumers pay a surcharge and the money is funnelled into a fund to finance energy efficiency programmes. The fund is then administered by electric utilities, government agencies or NGOs.

Government energy-efficiency programmes are financed by taxpayers. They are created, organised, funded and administered by government. They are implemented by government agencies, contractors, NGOs and ESCOs.

Banks are becoming an important source of lending to ESCOs. Some accept the promised energy savings from the projects as collateral for the loans. Charitable foundations also provide funding, for example, the US-based China Sustainable Energy Foundation, funds projects in China. Government-to-government grants or multilateral funding agencies (World Bank, ADB, GEF) finance these projects as well. For example, the US Agency for International Development funds programmes in the Philippines. The GEF finances programmes administered by the Electricity Generating Authority of Thailand.

Programme evaluation is necessary to ensure that financial incentives are having the desired effect at minimal cost. Conventional cost/benefit analysis is a useful tool for this purpose.