8 RESIDENTIAL, COMMERCIAL, AND AGRICULTURAL SECTOR ENERGY DEMAND

This chapter examines the energy challenges and opportunities in the 'other' sector, which encompasses residential, commercial, agriculture, forestry, fishing and all other services.

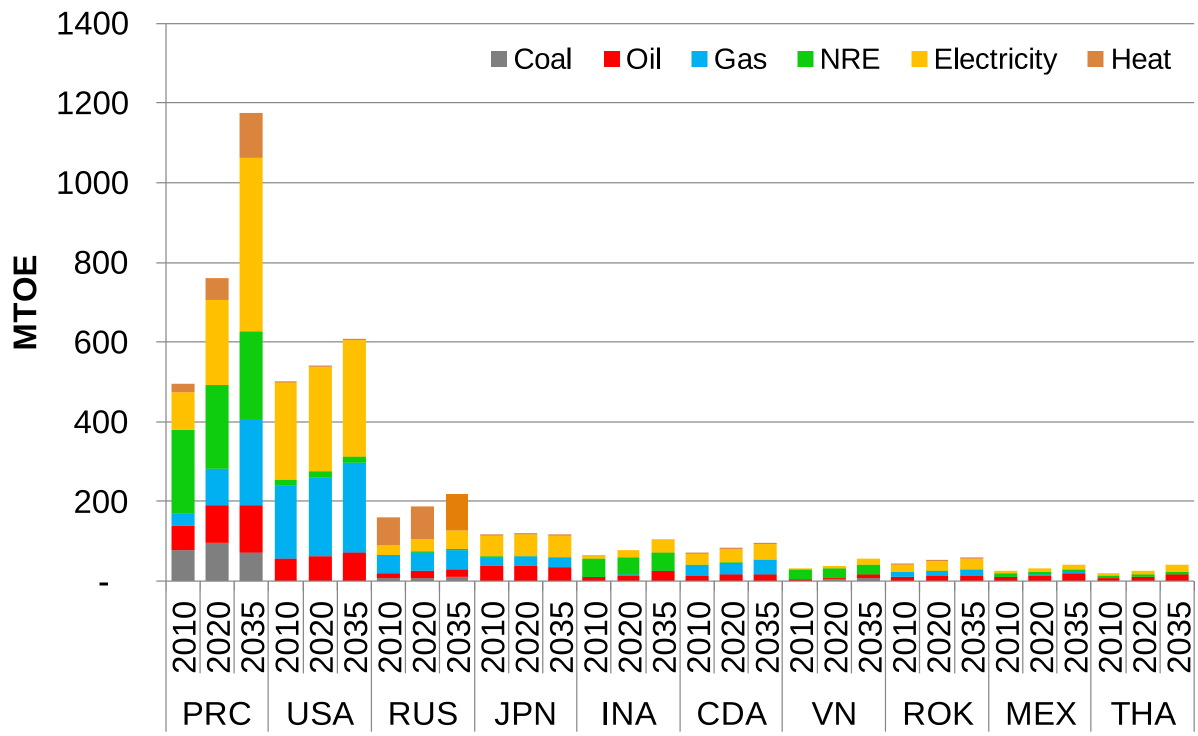
BUSINESS-AS-USUAL 'OTHER' SECTOR ENERGY DEMAND

In 2010, energy use in the 'other' sector accounted for about 33% of the total APEC final energy consumption. The energy sources and the amount of energy used in the 'other' sector vary greatly from economy to economy. Not surprisingly, developed economies had a much higher per capita energy use than did developing economies. Also, electricity and gas were the dominant energy sources in the 'other' sector in developed economies, while some developing economies still relied heavily on biomass and coal. For example, in the United States, where GDP per capita was about USD 42 000, energy consumption per capita in the 'other' sector was 1.61 tonnes of oil equivalent (toe)/capita, with electricity and gas as the main energy sources. In China, on the other hand, where GDP per capita was about USD 6800, energy consumption per capita in the 'other' sector was 0.37 tonnes of oil equivalent/capita, and new renewable energy (NRE), primarily biomass, was by far the largest 'other' sector energy source, with coal ranking number three after electricity.

'Other' Sector Total Energy Demand by Economy and Energy Source

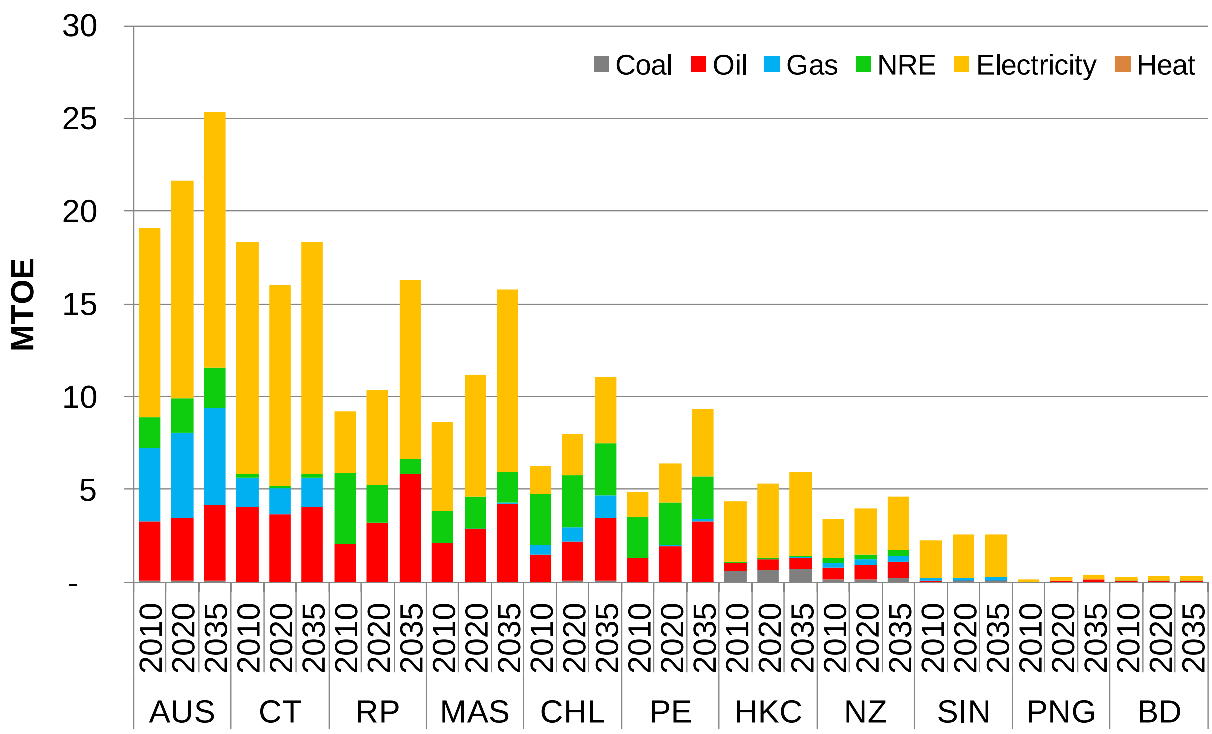
Figures 8.1 and 8.2 show the projected 'other' sector demand in each APEC economy, under business-as-usual. Note, the vertical axes of the two graphs have different scales. Over the period 2010–2035, the total 'other' sector demand is projected to increase from 1593 million tonnes of oil equivalent (Mtoe) in 2010 to 2617 Mtoe in 2035, an average annual increase of 2.0%. By 2035, the 'other' sector will account for about 38% of the total APEC final energy demand. By 2035, China will become the economy consuming the largest amount of energy in the 'other' sector (1177 Mtoe). This will account for about 45% of the total APEC 'other' sector energy demand. The US will be second, with 607 Mtoe (about 23%).

Figure 8.1: Other Sector Energy Demand by Energy Source, Higher Other Sector Demand Economies



Source: APERC Analysis (2012)

Figure 8.2: Other Sector Energy Demand by Energy Source, Lower Other Sector Demand Economies

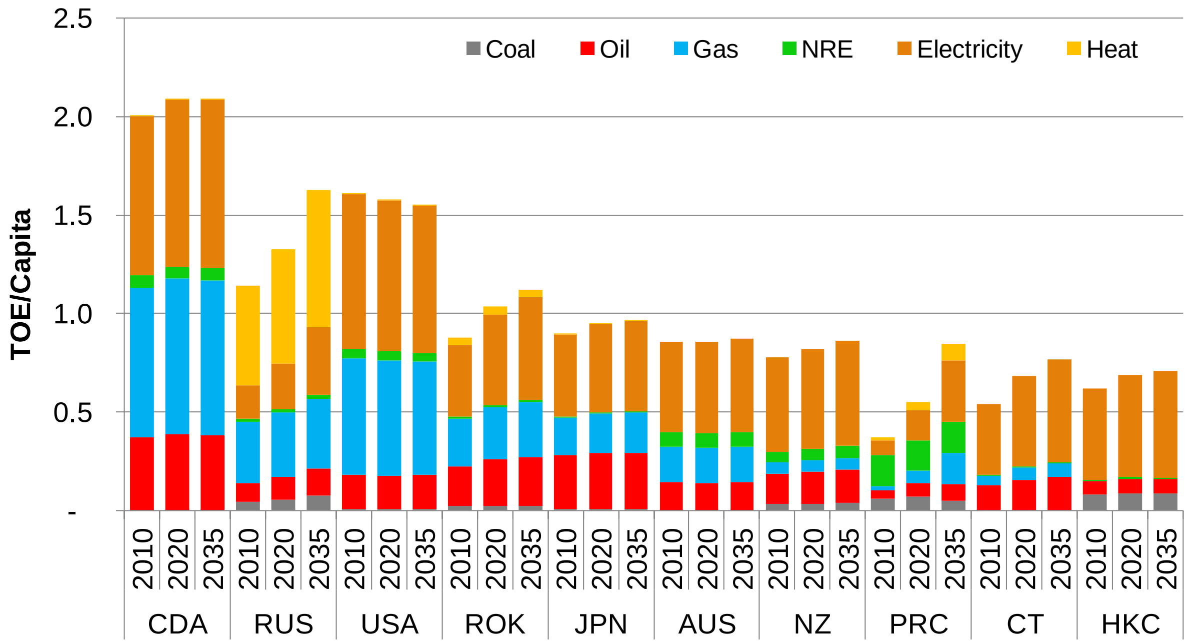


Source: APERC Analysis (2012)

'Other' Sector Per Capita Energy Demand by Economy and Energy Source

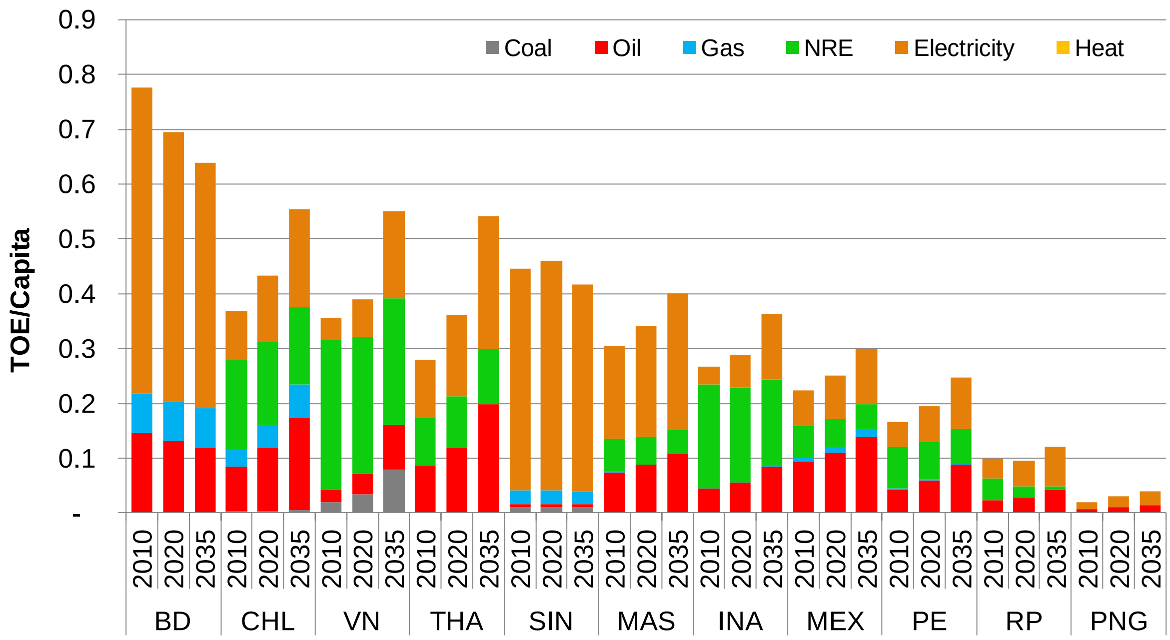
Figures 8.3 and 8.4 show 'other' sector energy demand on a per capita basis. It can be seen that, in 2035, the US will still be using far more energy per capita in the 'other' sector (at 1.55 toe/capita) than China (0.85 toe/capita).

Figure 8.3: Per Capita Other Sector Energy Demand by Energy Source, Higher Other Sector Demand per Capita Economies



Source: APERC Analysis (2012)

Figure 8.4: Per Capita Other Sector Energy Demand by Energy Source, Lower Other Sector Demand per Capita Economies

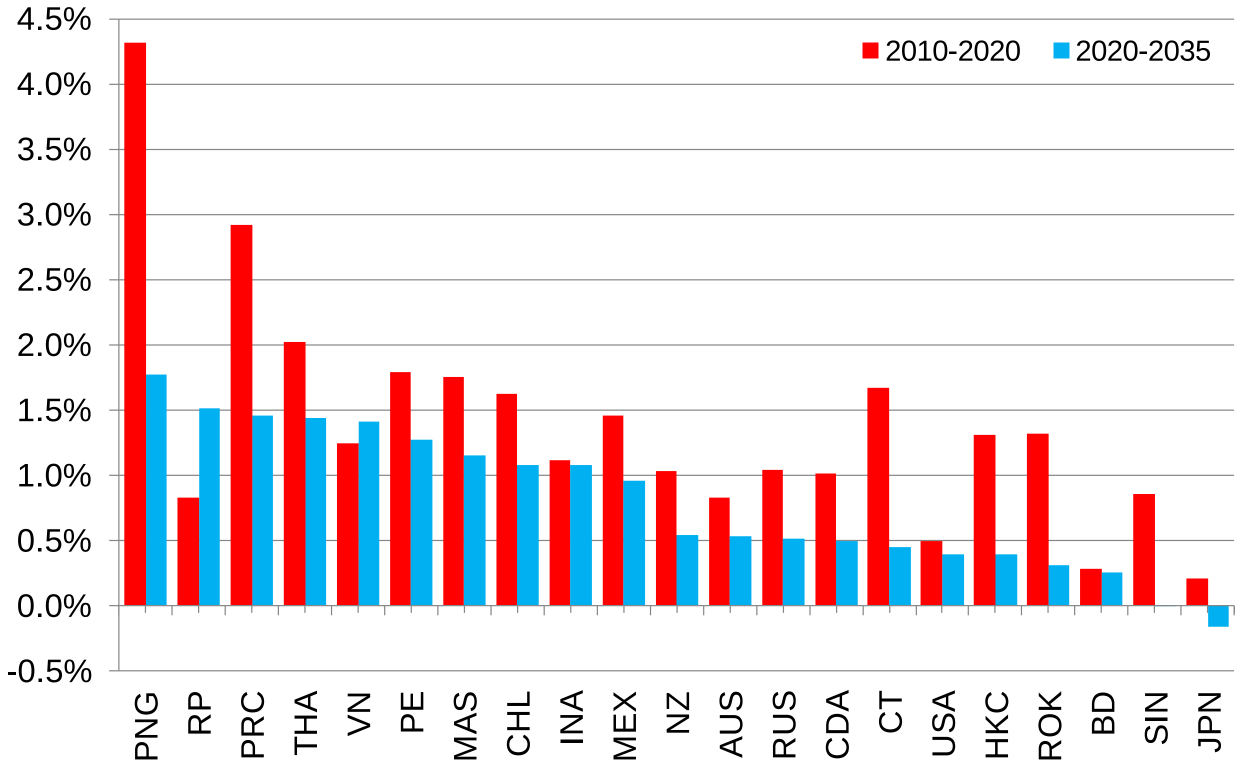


Source: APERC Analysis (2012)

'Other' Sector Percentage Growth in Energy Demand by Economy

Figure 8.5 shows the projected growth rates in the 'other' sector energy demand. The higher growth rates tend to be in the developing economies.

Figure 8.5: Annual Percentage Growth Rates in Other Sector Energy Demand by Economy



Source: APERC Analysis (2012)

APEC 'Other' Sector Total Energy Demand by Energy Source

Figure 8.6 shows the total APEC 'other' sector energy demand by energy source. Among these sources, electricity is projected to be consistently the largest between 2010 and 2035. Electricity demand will grow at an average annual rate of 2.8% over the outlook period, driven by increasing income levels and growing activity in the commercial sector. These factors will result in an increasing requirement for air conditioning, space and water heating, lighting, and home appliances. The expansion of rural electrification and the wider use of air conditioning and refrigerators in China and South-East Asia is a significant factor contributing to an increased demand for electricity in the residential sector. By 2035, China will account for 42% of the total APEC 'other' sector electricity demand, while the US will account for 28%.

Natural gas is projected to be the second-largest 'other' sector energy source between 2010 and 2035. Gas demand will grow at an average annual rate of 2.3%. Rapid growth in natural gas demand is expected as income levels expand and the extensive development of gas infrastructure continues. This will allow gas to replace non-commercial biomass for heating and cooking. 'Other' sector natural gas demand in China, in particular, is expected to grow at about 8.5% a year.

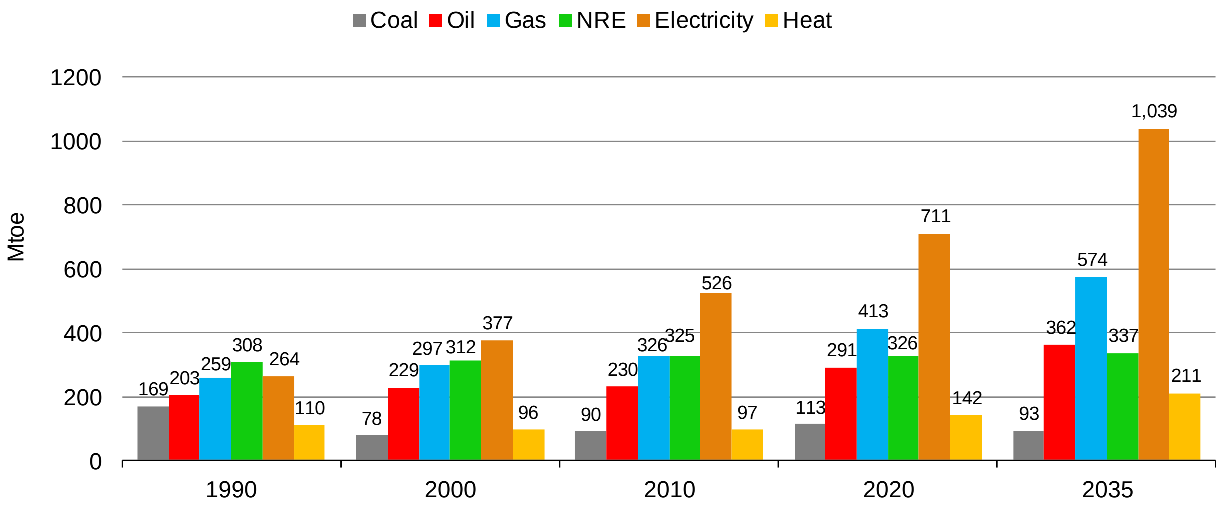
The demand for oil products, which is dominated in the 'other' sector by LPG (liquefied petroleum gas), will be at a more modest rate of 1.8% a year. The growth in demand for oil products will be held back by their relatively high prices and by the loss of some markets to natural gas, due to the expanded coverage of gas distribution networks.

The demand for heat (mainly district heating systems) is projected to be the fastest growing of any form of 'other' sector energy, at 3.2% a year. District heating is potentially a very efficient energy source, since relatively low-temperature heat from power plants and industrial facilities that would otherwise be wasted can be used for space and water heating in nearby buildings. China and Russia, which already have extensive district heating systems, are projected to represent about 98% of the total APEC 'other' sector heat demand in 2035.

Coal demand is expected to have the lowest growth among the commercial fuels in the 'other' sector, at 0.1% annually. Coal will be increasingly replaced by electricity, natural gas and LPG. In 2035, China will remain the largest 'other' sector coal consumer in the APEC region, consuming about 75% of the total 'other' sector coal demand.

Commercial fuels will increasingly replace biomass in the 'other' sector. However, while the biomass share of 'other' sector energy demand will decline overall, its use is expected to persist in rural areas, especially in China and South-East Asia, as a fuel for cooking and water heating. In regard to other NRE sources, there will also be some growth in the demand for solar water heating in the 'other' sector; however, it is not expected to be large compared to biomass. The net result will be a more or less stable demand for NRE in the 'other' sector over the outlook period.

Figure 8.6: APEC Total Other Sector Energy Demand by Energy Source



Source: APERC Analysis (2009)

'OTHER' SECTOR CHALLENGES AND SOLUTIONS

Growth of about 64% in the 'other' sector energy demand between 2010 and 2035 will have a number of favourable consequences. In many economies it will bring healthier living conditions, bring greatly improved standards of living, give children more time to pursue education, and give women more time to pursue both education and income earning opportunities.

It does, however, pose some challenges. These challenges include those related to greenhouse gas emissions, security of energy supply, and price risks for fossil fuels. There are also significant issues in the residential sector related to poverty and affordability. Although people will increasingly have access to electricity and commercial fuels, even in rural areas, many people may still not be able to afford to use very much of them.

All APEC economies recognize these issues, and are working to address them. Approaches to consider include:

- greater use of low-carbon energy sources, such as solar water heaters and the cleaner, more efficient use of biomass
- improved energy efficiency, such as higher energy-efficiency standards for buildings and appliances (see below), and a phase-out of incandescent light bulbs
- targeted assistance for those who would otherwise be facing energy poverty.

Most energy in the 'other' sector is either consumed by building systems (heating, cooling, hot water, lighting) or by appliances and other equipment in the buildings. APERC has been working with APEC developing economies to improve 'other' sector energy efficiency in both these areas through two phases of the APEC-sponsored Cooperative Energy Efficiency Design for Sustainability (CEEDS) project.

Phase 1 of CEEDS (2009–2010) addressed Appliance Energy Efficiency Standards and Labeling (APERC, 2010). Phase 2 of CEEDS (2010–2011) addressed Building Energy Codes and Labeling (APERC, 2011). In each phase, economy delegates worked with internationally recognized experts and APERC researchers to quantify potential energy savings, and to identify characteristics of an effective program. The next two sections discuss the potential energy savings identified in each phase.

Appliance Energy Efficiency Standards and Labeling

As discussed in Chapter 4, consumers often lack the information needed to make an informed trade-off between the initial purchase price of an appliance and the long-term operating costs, which are often primarily energy costs. This may be because comparative information on actual energy usage by different appliances is difficult to obtain, because the consumer lacks the skills to analyze this information, or because the consumer lacks the time to do the analysis of what is, for individual consumers, a relatively small cost difference. As a result, consumers tend to focus on the initial purchase price, and appliance manufacturers tend to focus on lowering the initial purchase price of their products.

For both consumers and society, these 'cheap' appliances may actually be quite expensive in the long run (ECS, 2009). Consumers themselves are burdened over the long term with excessively high energy costs, while society as a whole is burdened by excessively high investments in energy supply infrastructure, threats to energy security, and environmental damage.

Energy efficiency standards and labels break this cycle. Energy efficiency standards prescribe a minimum energy performance for specific types of appliances. Energy efficiency labels summarize key information consumers should know about the energy performance of an appliance. Standards keep the most inefficient and obsolete appliances off the market; labels encourage consumers to go beyond the standard and purchase even more efficient products.

Six developing economies participated in CEEDS Phase 1 on appliance energy efficiency standards and labeling: Chile, China, Malaysia, the Philippines, Thailand, and Viet Nam.

To understand the energy saving potential of appliance energy efficiency standards within these six economies, APERC undertook an analysis of energy saving potential in collaboration with the Collaborative Labeling and Appliance Standards Program (CLASP) and Lawrence Berkeley National Laboratory (LBNL). The model assumed cost-effective standards, achievable with existing technology, were adopted immediately in each economy for six types of appliances, as well as for fluorescent lamps, incandescent lamps, and standby power (power use while switched off) for electronic equipment.

The deployment of the new equipment was then modelled in each economy each year. The savings grow larger each year as the old inefficient appliances are replaced with models that meet the standards. By 2030, most appliances in service meet the standards. Table 8.1 shows the percentage energy savings by economy by type of equipment compared to business-as-usual.

These are obviously significant savings. The full analysis (APERC, 2010) also included a discussion of the total energy savings by economy by type of equipment, which is not reproduced here. Advances in technology over this period, which would allow a further tightening of the standards, as well as the additional benefits from labeling programs could add to these savings.

Table 8.1: Estimated Potential Percentage Energy Savings from Appliance Energy Efficiency Standards by Economy

	Fan	Fluorescent Lamps	Incandescent Lamps	Laundry	Refrigeration	Air Conditioner	Standby	Television	Rice Cooker
Chile	32.2%	NA	39.4%	33.7%	41.7%	26.2%	78.6%	35.4%	NA
China	36.4%	21.7%	41.6%	46.9%	43.3%	37.7%	79.9%	26.9%	29.7%
Malaysia	32.4%	17.1%	39.4%	42.5%	49.5%	20.1%	78.7%	35.4%	29.7%
Philippines	40.3%	9.6%	39.4%	3.7%	49.8%	17.1%	78.4%	35.4%	29.7%
Thailand	31.9%	9.6%	39.4%	41.9%	49.3%	19.0%	78.8%	35.4%	29.7%
Vietnam	40.0%	17.0%	39.4%	17.3%	50.8%	25.0%	78.4%	35.4%	29.7%

Source: APERC Analysis (2012)

Building Energy Codes And Labeling

Consumers and businesses seeking to buy or rent building space face the same informational challenges as appliance consumers discussed above. Building developers, therefore, face the same pressures as appliance manufacturers to keep the initial cost of buildings down, even when the result is higher total costs over the life of the building. The result is a similar under-investment in energy efficiency.

Although it is possible to improve the energy efficiency of buildings through retrofits after they are built, there are at least three additional factors that work strongly against such retrofits:

- First, and perhaps most importantly, it is usually far easier and cheaper to make buildings energy efficient at the time they are designed and built, rather than through later retrofits.
- Second, in the case of rental buildings, the landlord generally must make the investments to improve energy efficiency, but the tenant generally pays for the energy and will reap the benefits of the landlord's investment.
- Third, even in the case of owner-occupied buildings, the owner may not be confident of owning the building long enough to recover the investment through energy savings and, because of the informational challenges mentioned above, may not be confident of recovering the investment when the building is sold.

These three factors make energy efficiency building retrofits hard to justify.

So buildings need to be initially designed and built in an energy-efficient manner. If they are underinvested in energy efficiency at the time they are built, they are likely to stay that way. Because the life of a building is quite long—typically several decades or more—an energy inefficient building will lock-in wasteful energy use for decades to come (Laustsen, 2008).

Building energy codes and labeling can break this cycle. It is especially critical to do so in developing economies, where urbanization and building construction is proceeding at a rapid pace. In addition to energy and environmental benefits, energy efficient residential buildings can help to alleviate energy poverty without the need for on-going subsidies.

Six developing economies participated in CEEDS Phase 2 on building energy codes and labeling: China, Indonesia, Malaysia, Mexico, Thailand, and Viet Nam.

To understand the energy saving potential of building energy codes within these six economies, APERC undertook an analysis of energy saving potential using eQUEST building simulation software developed under the auspices of the California Public Utilities Commission (EDR, 2012).

Using the eQUEST software, APERC analyzed the energy saving potential of implementing the International Energy Conservation Code 2009 as tailored to the climate in each economy, to four building types common in each economy. Typical efficiency provisions included wall insulation, air-tightness, window insulation, window solar properties, lighting power density, ventilation system efficiency, pump and fan controls (VSD), high-efficiency chillers and boilers, and efficient motors for fans and pumps.

The International Energy Conservation Code 2009 is a model building code developed by the International Code Council (ICC). The ICC is a membership association which develops codes for the construction of residential and commercial buildings. It is dedicated to building safety, fire prevention and energy efficiency. Most US cities, counties and states choose to adopt the International Codes developed by the ICC. The International Codes also serve as the basis for the construction of US federal properties around the world, and as a reference for many economies outside the US (ICC, 2012).

The US Department of Energy Building Technologies Program has analyzed the International Energy Conservation Code 2009 for single family and multi-family homes and determined it would "yield positive benefits for US homeowners and significant energy savings for the nation" (USDOE, 2012).

Table 8.2 shows the resulting energy savings compared to business-as-usual for each building type in each of the six economies. Again, the energy savings are significant. The full analysis (APERC, 2011) also included a discussion of the total energy savings by economy by type of equipment, which is not reproduced here.

Because the turnover of buildings is relatively slow, even in developing economies, it would take a number of years for building energy codes to have a big impact. Therefore, it is important to implement building energy codes as soon as possible. As with appliance energy efficiency standards, future advances in technology, which would allow a further tightening of the standards, as well as the additional benefits from labeling programs could add to the savings.

Table 8.2: Estimated Potential Percentage Energy Savings from Building Energy Codes by Economy

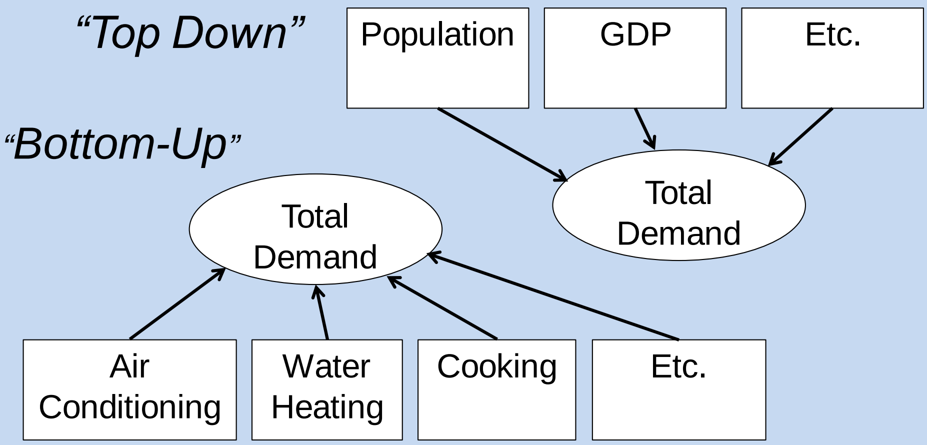
Economy	Building Type	Energy Savings
China	Apartment	16%
China	Office	35%
China	Retail	36%
China	Small Apartment	16%
Indonesia	Apartment	13%
Indonesia	Office	44%
Indonesia	Retail	19%
Indonesia	Single Family House	13%
Malaysia	Apartment	17%
Malaysia	Office	43%
Malaysia	Retail	45%
Malaysia	Terrace Housing	10%
Mexico	Apartment	6%
Mexico	Office	38%
Mexico	Retail	14%
Mexico	Single Family House	15%
Thailand	Apartment	12%
Thailand	Office	29%
Thailand	Retail	28%
Thailand	Single Family House	15%
Viet Nam	Apartment	13%
Viet Nam	Office	38%
Viet Nam	Retail	34%
Viet Nam	Single Family House	19%

Source: APERC (2011, p. 13)

APERC'S 'OTHER' SECTOR ENERGY DEMAND MODEL AND HOW IT WORKS

Two general approaches are possible for modelling residential, commercial, or agricultural energy demand, as shown in Figure 8.7. In the 'bottom-up' approach, separate sub-models are developed for each energy application and these are aggregated into the total residential demand. In the 'top-down' approach, energy demand is modelled based on aggregated statistics for the economy. The bottom-up approach is preferable, as it tells a more detailed story of what is happening to energy demand, and more easily allows the modelling of alternative policies that may affect specific energy applications, such as improving the efficiency of certain appliances. However, it requires detailed data on each energy application, which may not be available in many economies.

Figure 8.7: General Approaches to Modelling 'Other' Sector Energy Demand



APERC developed both kinds of models. However, because of data limitations, the bottom-up approach was used only for the residential sector and only for those economies with adequate data: Australia, Canada, Chinese Taipei, Japan, Korea, New Zealand, Russia, and Singapore. This section, therefore, focuses on the 'top-down' approach that was used elsewhere, and specifically focuses on residential demand modelling.

To model demand in the residential sector, APERC sought an approach that could:

- be consistent across economies
- work with the limited data available for many APEC economies
- use knowledge of what is happening in all APEC economies to project the demand in specific APEC economies.

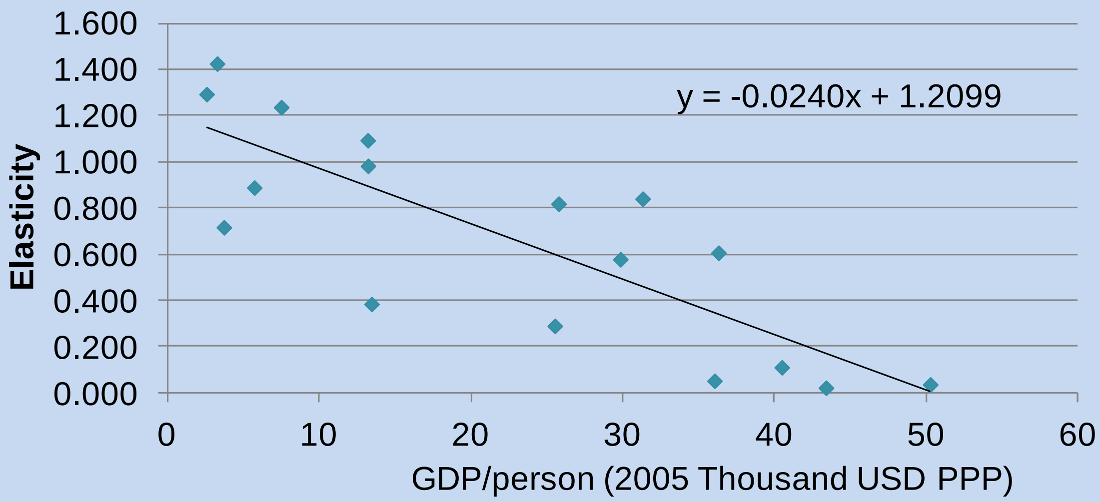
Economic literature (Judson et al., 1999) suggests that:

1. Per capita GDP is the major driver of residential energy demand.
2. The rate at which residential energy demand per capita increases as GDP per capita increases (the income elasticity) declines as GDP per capita increases.

The second conclusion is intuitively quite reasonable, especially for the residential sector. When a poor economy first starts to grow wealthier, among the first things its residents seek to buy are basic home appliances, such as commercial fuel cooking equipment, hot water heaters, refrigerators, washing machines, air conditioners, and televisions. As a result, the residential energy demand of an economy in the early stages of industrialization rises rapidly. A common flaw in residential demand modelling for developing economies is to assume this rapid rate of demand growth will continue indefinitely into the future. It does not. Once people get wealthy enough that they already have basic home appliances, further increases in income tend to be spent in other, less energy-intensive ways.

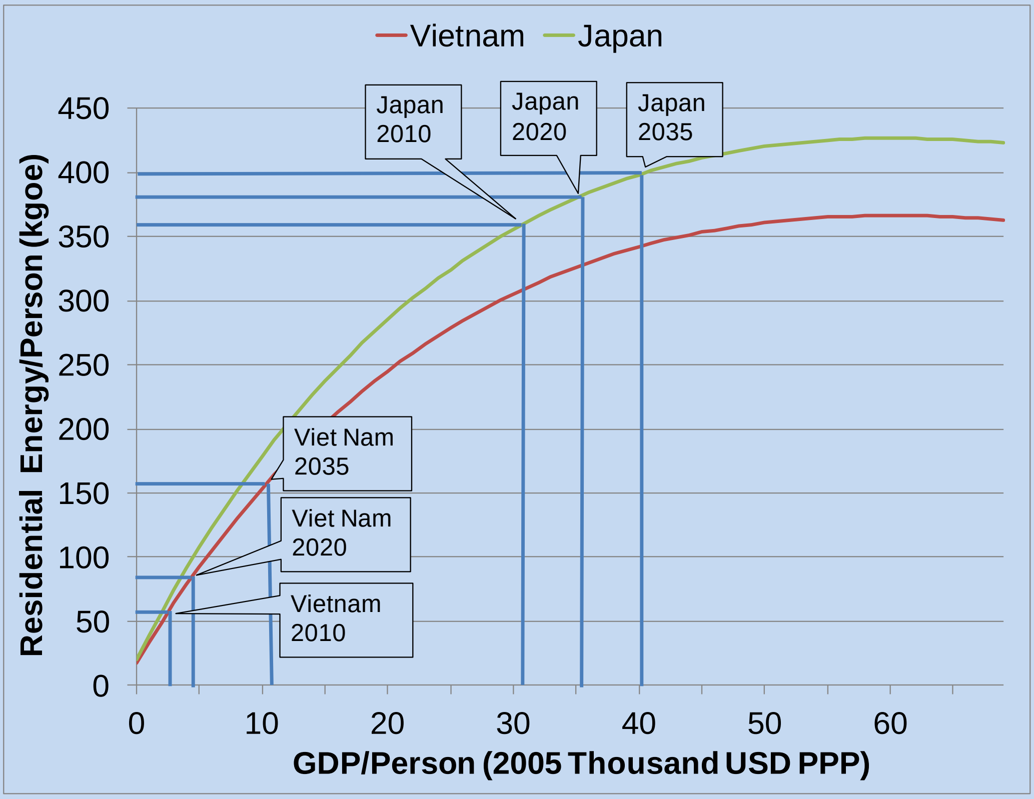
APERC modelled this relationship between the income elasticity of residential energy demand/person and GDP/person based on historical data, as shown in Figure 8.8. The results indicated the income elasticity of residential energy demand is greater than one for poorer economies (that is, a 1% increase in income results in a more than 1% increase in residential energy demand), but drops off rapidly as income rises.

Figure 8.8: Relationship Between Income Elasticity of Residential Energy Demand and GDP/Person by Economy



Using a bit of calculus, the elasticity relationship shown in Figure 8.9 can be used to construct a general relationship between per capita income and residential energy demand/person. Such a curve can be fitted to an individual economy by forcing it to pass through the economy's 2010 residential energy demand per capita and GDP per capita. If one has an estimate of future GDP per capita for the economy, the future residential energy demand per capita can then be simply read off the curve. Figure 8.9 shows an example for Japan and Viet Nam (which does not reflect the actual numbers used in APERC's final residential demand projection for these economies). Note, Viet Nam's residential energy demand/person, although much lower than Japan's, is increasing much more rapidly with GDP/person.

Figure 8.9: Residential Energy Demand Projection Example: Japan and Viet Nam



Note: kgoe = kilograms of oil equivalent

This section is a short summary of Chen and Samuelson (2012), which should be consulted for more detailed information on APERC's 'other' sector demand modelling.

IMPROVING ENERGY EFFICIENCY WITH RESIDENTIAL FUEL CELLS

Fuel cells use an electrochemical process—not moving parts—to generate electricity and heat from gaseous or liquid fuels. Fuel cells can be built in almost any size, and therefore have many potential applications in the energy sector. Perhaps the best known of these is as a source of electricity to power hydrogen vehicles, as discussed in Chapter 5. Another application is as a small scale source of electricity and domestic hot water that could be installed in individual residences. The fuel source for residential fuel cells would most likely be natural gas, but could also be hydrogen, biogas, propane, or liquid fuels.

The main advantage of fuel cells in a residential application would be their high level of efficiency. A modern residential fuel cell could produce electricity from gas with an efficiency of about 40%—comparable to many of today's utility generation plants—but, in addition, could produce hot water from the waste heat with an efficiency of up to 50% (Tokyo Gas and Panasonic, 2011). This would allow an overall efficiency far higher than even today's most efficient utility combined cycle gas turbine generating units, which are in the 55–60% range before transmission losses (Sano, 2010, Figure 3).

Additional advantages of residential fuel cells stem from the fact they are a form of distributed electricity generation, which could eliminate electricity transmission losses and enhance the security and robustness of the energy grid. Small power plants like these can be easily turned on or off remotely, making them amenable to integration into a future smart grid. They are almost noiseless and, when running on natural gas, produce emissions of CO_2 only.

In the future, residential fuels cells could also potentially integrate well with residential solar and wind installations. These renewable electricity sources could be used to electrolyze hydrogen from water during the hours when electricity demand is low; the hydrogen could then be used to generate electricity in a fuel cell during peak electricity demand hours. Such an arrangement could overcome the intermittency limitations of solar and wind power, while providing true zero-emission electricity and hot water.

The greatest barrier to the widespread commercialization of residential fuel cells is their high initial cost. For example, in Japan a 750 W Panasonic Ene-Farm fuel cell is currently sold for about USD 35 000 (JPY 2 761 500) (Tokyo Gas and Panasonic, 2011). This stationary fuel cell will provide about 50% of the electricity needed by a typical Japanese household, and save the household about USD 600 to USD 750 a year on electricity and gas costs compared to buying the electricity from the grid and buying gas for hot water only. The estimated life of the fuel cell unit is only about 10 years, so the initial purchase price cannot be recovered. However, there is substantial room for cost reductions. Various Japanese research and demonstration programs are aiming to reduce the initial cost to around JPY 500 000 by later in this decade (JX Nippon Oil & Energy Corporation, 2011; Daily Yomiuri, 2012), which could offer a payback period of as little as eight years.

While this target cost may still seem high, there may be additional benefits. The hot water could be circulated in the floor of the building to also provide comfortable and economical space heating, allowing the system to be more fully utilized. As these systems are upgraded to allow off-grid operations in the event of blackouts, they could provide even more value and peace of mind to homeowners.

One potential early application for residential fuel cells might be on small islands and in other off-grid communities, which exist in nearly every APEC economy. Here the fuel cells might run on propane or liquid fuels, but could offer substantial efficiency gains over the expensive and inefficient diesel generators commonly used in such locations today.

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