9 ELECTRICITY DEMAND AND SUPPLY

HISTORICAL TREND

Electricity demand in the APEC region grew robustly between 1990 and 2009 at an average annual rate of 3.3% per year, from 5720 terawatt-hours (TWh) in 1990 to 10 528 TWh in 2009. Rapid growth was observed particularly in developing Asian economies. Viet Nam experienced the highest average annual growth rate from 1990 to 2009 (14.2%), followed by China (10.2%), Malaysia and Indonesia (both 8.6%), as shown in Table 9.1.

In 1990, developed OECD-member economies including Australia, Canada, Japan and the United States (US) accounted for 69% of the APEC region's total electricity consumption, with the US alone consuming 46%. However, by 2009, the total share consumed by these economies had decreased to 50%; this was due mainly to increasing electricity demand in China and other developing South-East Asia economies. China's share of the APEC region's total electricity demand has increased from 8% in 1990 to 29% in 2009, as calculated from Table 9.1.

BUSINESS-AS-USUAL ELECTRICITY OUTLOOK RESULTS

ELECTRICITY DEMAND

Electricity demand is expected to continue to grow between 2009 and 2035, at a rate of 2.5% per year. By region, North America, especially the US, is projected to contribute significantly to demand for electricity. Electricity demand in the US is projected to reach 4544 TWh in 2035 or about 22.9% of APEC's total electricity demand in 2035. However, China's expected high economic growth rate will mean its electricity demand will surpass all other APEC economies by the end of the outlook period—it is expected to reach 8765 TWh or 44% of APEC's total electricity demand in 2035, as shown in Table 9.1.

Table 9.2 shows electricity demand as a share of projected total final energy demand (TFED) for each APEC member economy. Electricity's share of TFED is expected to increase for all economies during the outlook period, with the exception of Brunei Darussalam and Singapore. For these two economies, a growing demand for other fuels (especially natural gas feedstock in Brunei Darussalam and oil feedstock in Singapore) will cause electricity's share to decline.

Table 9.1: APEC's Electricity Demand by Economy, in TWh

Economy	Final Electricity Demand (TWh)			Average Annual Percentage Change	
	1990	2009	2035	1990-2009	2009-2035
Australia	129	214	318	2.7%	1.5%
Brunei Darussalam	1	3	4	6.3%	0.5%
Canada	418	477	701	0.7%	1.5%
Chile	15	54	128	6.8%	3.4%
China	482	3065	8765	10.2%	4.1%
Hong Kong, China	24	42	56	3.0%	1.2%
Indonesia	28	135	546	8.6%	5.5%
Japan	750	934	957	1.2%	0.1%
Korea	94	406	573	8.0%	1.3%
Malaysia	20	96	206	8.6%	3.0%
Mexico	100	201	402	3.7%	2.7%
New Zealand	28	38	50	1.6%	1.1%
Papua New Guinea	2	3	11	3.5%	5.0%
Peru	12	30	82	5.0%	4.0%
Philippines	21	51	157	4.7%	4.4%
Russia	827	686	1278	-1.0%	2.4%
Singapore	13	36	51	5.5%	1.3%
Chinese Taipei	77	202	312	5.2%	1.7%
Thailand	38	135	339	6.9%	3.6%
United States	2634	3643	4544	1.7%	0.9%
Viet Nam	6	77	385	14.2%	6.4%
APEC Total	5720	10528	19864	3.3%	2.5%

Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Table 9.2: APEC's Electricity Demand as a Percentage of Total Final Energy Demand (TFED)

(Percentage)

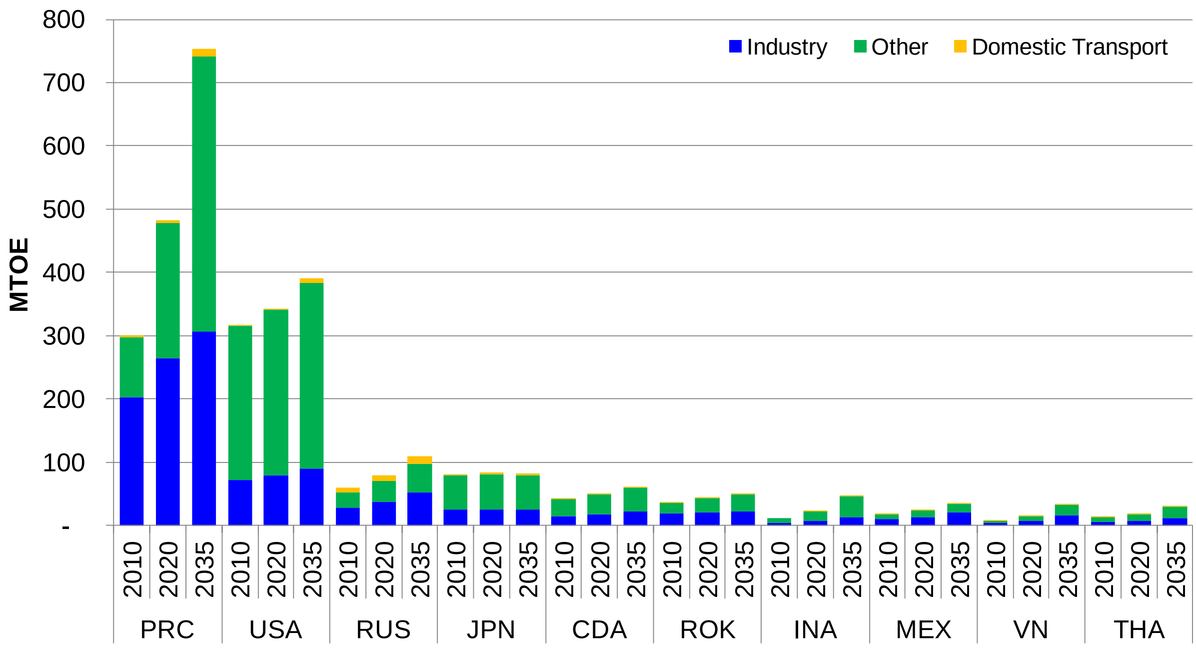
Economy	1990	2009	2035
Australia	20	24	27
Brunei Darussalam	25	31	19
Canada	23	21	32
Chile	12	21	26
China	6	18	28
Hong Kong, China	39	40	42
Indonesia	3	8	15
Japan	21	26	31
Korea	13	24	28
Malaysia	12	21	26
Mexico	10	16	18
New Zealand	24	26	31
Papua New Guinea	26	24	31
Peru	12	18	23
Philippines	9	19	28
Russia	11	14	17
Singapore	22	22	19
Chinese Taipei	22	28	34
Thailand	11	15	20
United States	18	21	24
Viet Nam	2	12	24
APEC	14	20	25

Source: APERC Analysis (2012)

Final Electricity Demand by Sector

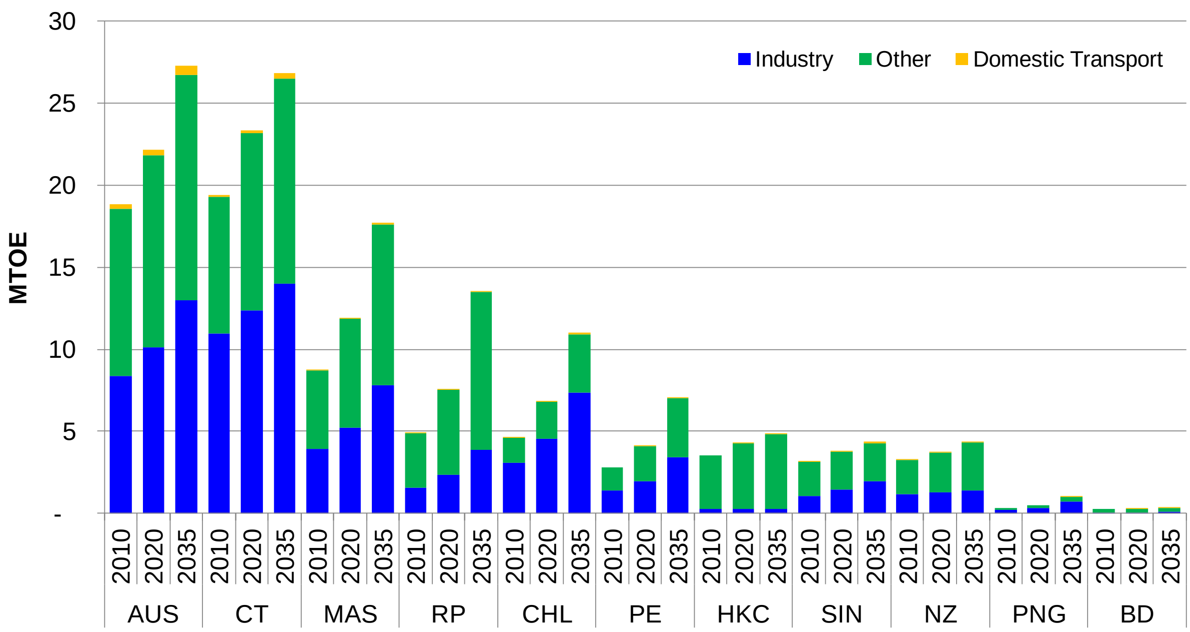
Projections for final electricity demand by sector for each APEC economy are shown in Figures 9.1 and 9.2. Note the difference in the scales of the vertical axes in the two figures. Total electricity demand is projected to increase in all APEC economies from 2010 to 2035.

Figure 9.1: Projected APEC Electricity Final Demand by Sector, Higher Final Demand Economies



Source: APERC Analysis (2012)

Figure 9.2: Projected APEC Electricity Final Demand by Sector, Lower Final Demand Economies



Source: APERC Analysis (2012)

For most APEC economies, by 2035, more than half of the electricity demand will be from the 'other' sector—this includes the residential, commercial and agricultural sub-sectors. The exceptions are Russia, Mexico, Chinese Taipei, Chile and Papua New Guinea. In these economies, more than half the electricity final demand will be from the industry sector.

The rise in electricity demand in the 'other' and industry sectors will be underpinned by increasing trends in both population and economic growth rates. Another important factor will be the continuing shift to electricity from primary energy sources. For instance, in the 'other' sector, primary fuels like traditional biomass, coal and kerosene are still used for cooking, lighting and space heating in some of the less developed areas of the APEC region. With better access to electricity, it is expected these primary fuels will be supplemented or displaced by electricity. At the same time, rising incomes and improving standards of living will drive the demand for electrical devices, which in turn will spur electricity demand in the 'other' sector, particularly in developing Asian economies like China and Indonesia.

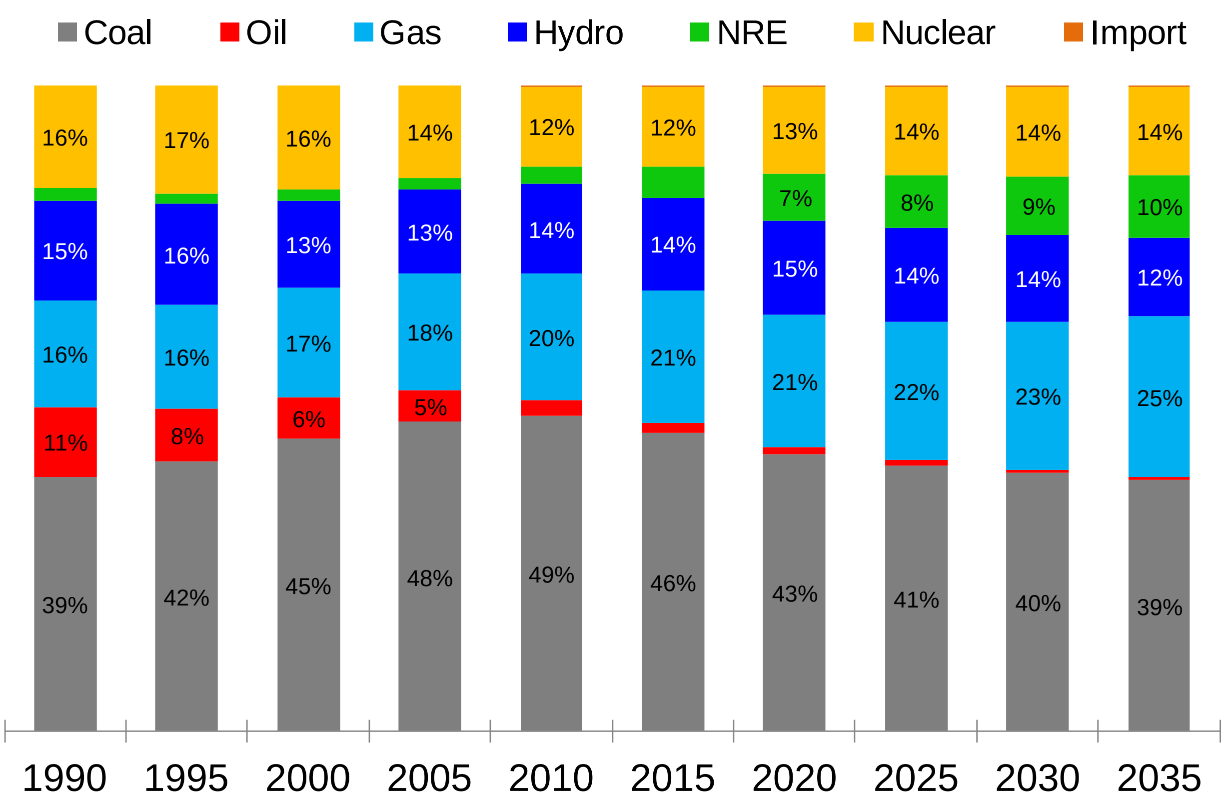
For the domestic transport sector, although the share for each economy is small (less than 5% for all economies with the exception of Russia) the total electricity demand will increase from 2010 to 2035 for all economies. This increase can reflect either one of two major developments, or a combination of both. The first is a transportation modal shift from private vehicles to electrically-powered public transport. The second is the penetration of more vehicles that use electricity instead of oil as their energy source.

ELECTRICITY SUPPLY

Electricity supply across the APEC region is expected to grow at an average annual rate of 2% between 2010 and 2035. Figure 9.3 shows APEC's historical and future electricity generation mix in percentage terms.

Nuclear shares will remain fairly consistent throughout the outlook period. New renewable energy (NRE)—that is renewable energy other than hydro—and gas will show increasing trends, while coal and oil will show significant decreases. Please refer to Chapter 2 for a detailed discussion of projected electricity supply by energy source in absolute quantities.

Figure 9.3: APEC's Electricity Generation Mix (1990–2035)



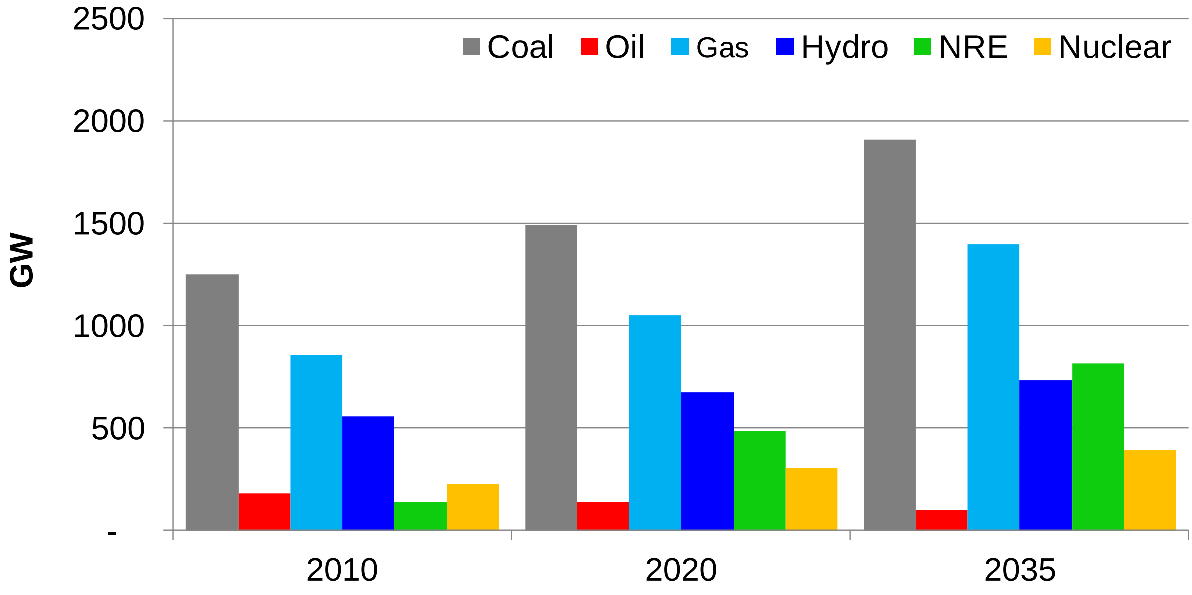
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Electricity Generating Capacity by Energy Source

Figure 9.4 shows the projected electricity generating capacity by energy source. To meet the projected increase in total electricity demand, total generating capacity in the APEC region is projected to almost double over the outlook period, from 3212 gigawatts (GW) in 2010 to 5340 GW in 2035. As new generating capacity is added, the supply mix is expected to change, driven by a number of factors. Some of the more vital drivers are as listed below:

- available energy resources — which includes both indigenous resources and available imports, and can be either fossil fuels, renewable energy resources or nuclear
- fuel costs and capital investment costs, and the ability to secure funds for both
- available technologies and infrastructure, and the feasibility of implementing new technologies
- government policies — especially policies related to energy security, environmental regulations and emissions targets
- public acceptance of certain resources that may be perceived as either "risky" (nuclear) or "dirty" (coal).

Figure 9.4: APEC's Projected Electricity Generation Capacity by Energy Source



Source: APERC Analysis (2012)

Over the outlook period, oil prices are expected to continue to increase while coal prices are expected to remain stable and relatively low, as coal is an energy resource with abundant deposits worldwide. On the other hand, with more unconventional gas resources like shale gas and coal bed methane being produced, gas prices will probably begin to decrease—especially in Asia. Gas prices in North America are already low although they are expected to trend upward in the coming years but it is unlikely they will reach the same level as oil prices. For these reasons, coal and gas capacities will continue to be the dominant electricity resources in the APEC region.

Coal, however, generates more greenhouse gases (GHG) than any other fossil fuel and causes more severe local air pollution. Even under business-as-usual (BAU) assumptions, concerns about climate change may limit the growth of coal-fired generating capacity.

Coal-fired generating capacity is expected to grow at an average annual rate of 1.7%, while the share of generating capacity that is coal fired will decrease, from 39% in 2010 to 36% in 2035. The decrease in share is mainly due to growing concerns about the detrimental effects of emissions from coal-fired generation, and a general shift from coal-fired generation capacity togas, NRE and nuclear generation capacities.

Oil-fired electricity generation is expected to continue its historical decline during the outlook period. It will be maintained only in areas where no other fuels are readily available, such as on small islands and other remote off-grid communities. This is due primarily to high fuel costs, security of supply risks and environmental considerations. Oil-fired generating capacity APEC-wide is projected to decrease at an average annual rate of 2.5%. The share of generating capacity that is oil fired will also decrease significantly from 6% in 2010 to 2% in 2035.

Natural-gas-fired combined-cycle gas turbines (CCGT) are very efficient at converting gas to electricity, have little impact on the local environment, can be built quickly, have a fairly low initial capital cost, and have fewer GHG emissions than coal. Additionally, older steam turbines (which may use coal, oil or natural gas as fuel) will be replaced by the more efficient CCGTs, thus increasing CCGT capacity in the APEC region. Nonetheless, the combined share for all natural-gas-fired generating capacity (which includes CCGTs, open-cycle gas turbines and steam turbines burning gas as fuel) will likely experience a slight decrease in share of capacity from 27% in 2010 to 26% in 2035.

Hydro is an attractive option as it has no fuel costs and low GHG emissions (see Chapter 15), but its further development will be hindered in many APEC economies by a lack of suitable sites. Hydro generating capacity is expected to grow at an average annual rate of 1.1%, but the hydro share of generating capacity will slowly decrease from 17% in 2010 to 14% in 2035.

A number of initiatives are being undertaken by APEC member economies to promote the rapid development of NRE under our BAU assumptions. Therefore, the installed capacity of NRE is expected to increase at the fastest rate of any generation energy source, 7.3% per year from 2010 to 2035. The NRE share of generating capacity will increase significantly from 4% in 2010 to 15% in 2035.

The Fukushima Nuclear Accident of March 2011 has somewhat changed the nuclear outlook in the APEC region. Higher safety standards, increasing costs and construction times, as well as eroding public acceptance of nuclear energy power plants mean the APEC economies will become more cautious in expanding their nuclear generation capacity. Our nuclear generating capacity projection has been revised to reflect this situation, especially in Japan and Chinese Taipei. In this new climate, nuclear energy is projected to grow at a slower rate of 2.2% annually, and the nuclear share of generating capacity will remain constant at about 7% throughout the outlook period.

To reduce GHG emissions and to control costs, APEC economies are expected to focus on energy efficiency and conservation measures that include reducing transmission and distribution losses, as well as increasing the efficiency of electricity generation from fossil fuels.

Our BAU projections indicate that average coal generation efficiency will increase from 36% in 2010 to 42% in 2035, and average gas generation efficiency will increase from 44% to 50%. Similarly, we expect that overall electricity losses will be reduced by about 29% from 2008 to 2035. For this outlook, electricity losses are defined as the difference between the amount of electrical energy entering the system (electricity generated and imported) and the demand. These losses may include power dissipated from transmission and distribution lines, transformers and measurement systems (also known as transmission and distribution losses) as well as internal losses and auxiliary consumption in the power generation stations. Further discussions on improvements in generation, transmission and distribution efficiencies are included in a later section of this chapter.

Electricity Generation Capacity by Economy

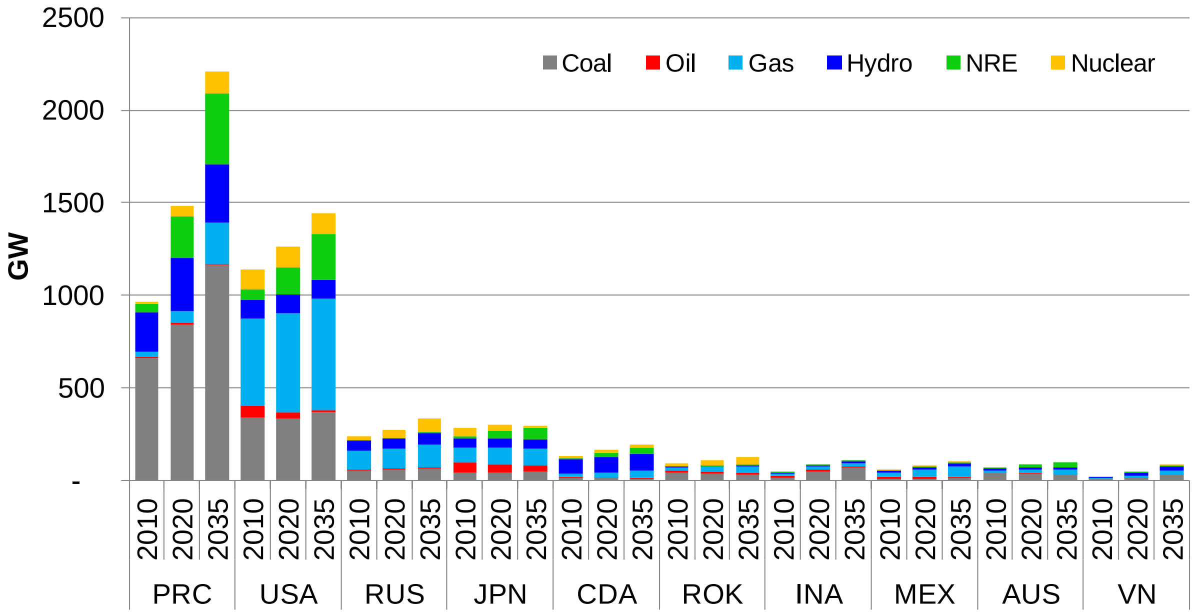
In 2010, the largest installed generation capacity was in the US. Its total capacity, of over 1130 GW, was dominated by gas (42%) and coal (30%). China's 2010 installed capacity was the second highest, at 966 GW, of which coal was 68% and hydro was 22%. However, by 2035, China's installed capacity is expected to exceed that of the US, reaching 2211 GW compared to the US's 1444 GW. After these two economies, Japan and Russia will have the next largest installed capacities, in both 2010 and 2035.

By 2035, thermal generating capacities are still dominant in most APEC economies. The exceptions are Canada, New Zealand and Papua New Guinea where hydro generating capacities are more prominent. Several of APEC's Asian economies are expected to introduce nuclear generating capacity by 2035; these include Thailand and Viet Nam, while Chinese Taipei and Japan are expected to reduce their nuclear generating capacity over the outlook period.

As technologies for harnessing NRE improve, economies with suitable resources are projected to further develop their NRE capacities to improve energy security and to mitigate environmental emissions problems. As a result, several economies will experience a substantial increase in NRE penetration. In Australia, for example, NRE's share of generating capacity will increase from 4.6% in 2010 to 31% in 2035—this will consist mostly of wind generation capacities. Please refer to Chapter 15 on Renewable Energy Supply for a more complete discussion of renewable energy power installations in the APEC region.

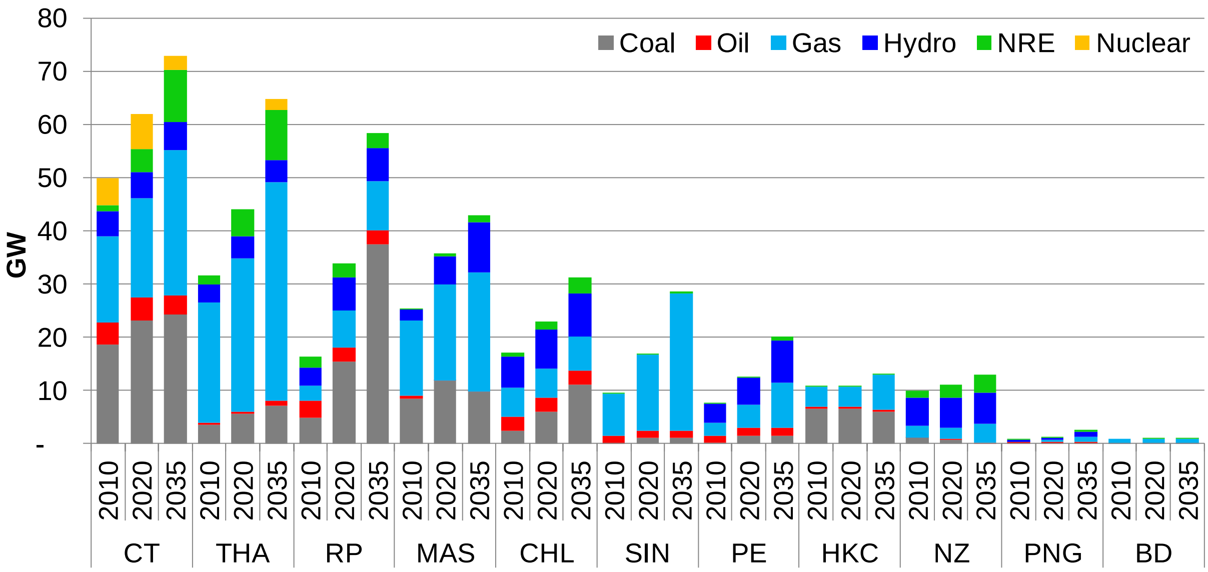
Figures 9.5 and 9.6 show the installed generation capacities by energy source and economy. Note the two graphs have different scales on the vertical axes.

Figure 9.5: Projected Generating Capacity by Economy and Energy Source, Economies with Larger Capacities



Source: APERC Analysis (2012)

Figure 9.6: Projected Generating Capacity by Economy and Energy Source, Economies with Smaller Capacities

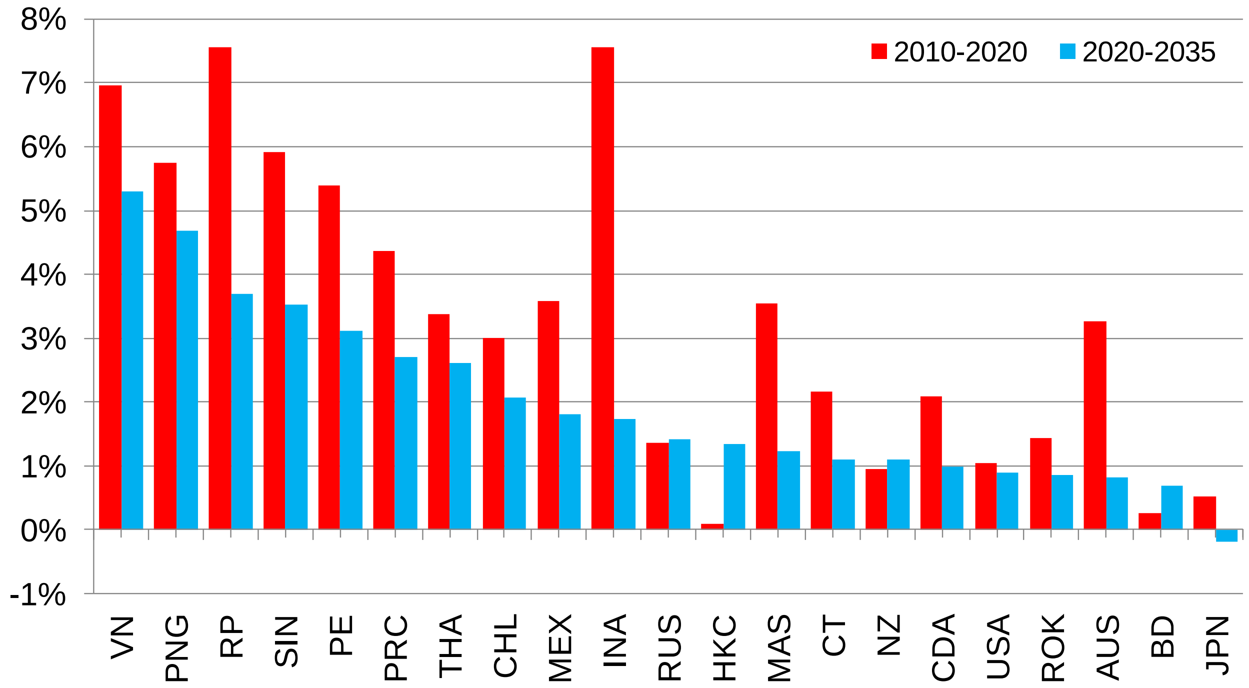


Source: APERC Analysis (2012)

Figure 9.7 shows the annual growth rates for generating capacity across all APEC economies during the first 10 years compared to the final 15 years of the outlook period.

With the exception of four economies (Hong Kong, China; Russia; New Zealand; and Brunei Darussalam), it is projected that capacity build-up will be more aggressive during the earlier years of the outlook period. Electricity growth rates are generally higher overall for developing Asian economies like Viet Nam, the Philippines and Indonesia, where there is much room for growth and massive generation capacity will be necessary to meet the rapidly growing demand. For developed, high-income economies like Japan and Brunei Darussalam where demand growth is slower, there will be more focus on maintaining and improving existing infrastructure.

Figure 9.7: Annual Growth Rates of APEC Economies' Generation Capacities between 2010–2020 and 2020–2035



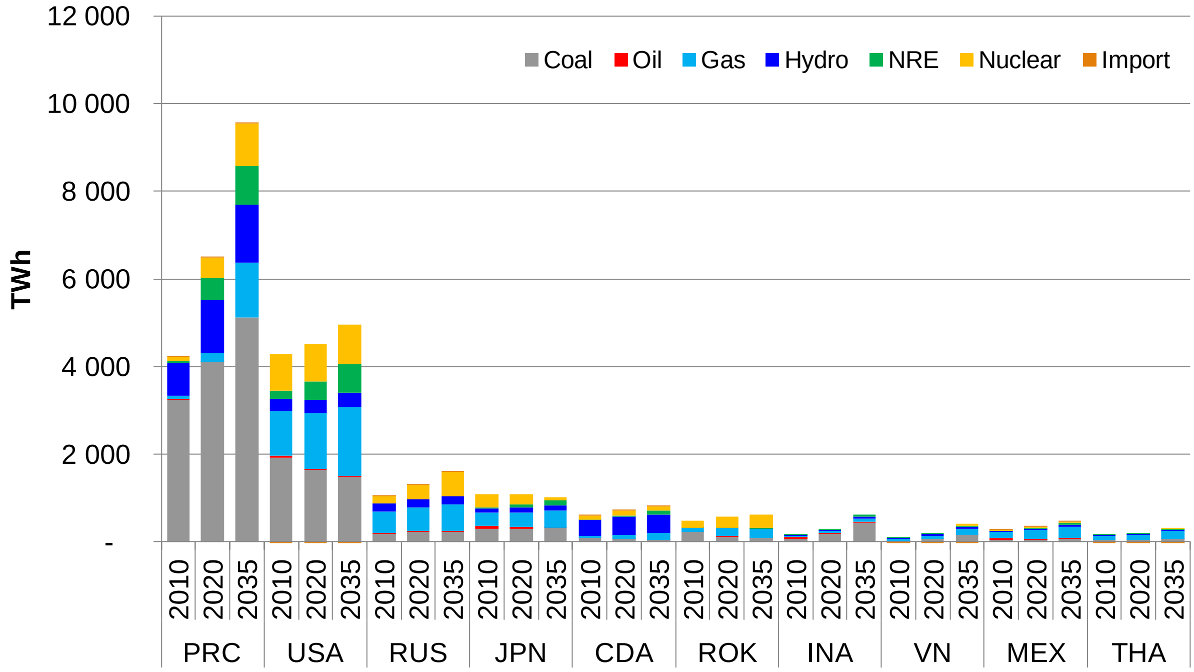
Source: APERC Analysis (2012)

Electricity Generation Supply by Economy

Figures 9.8 and 9.9 show the electricity supply for each APEC economy by energy source for the years 2010, 2020 and 2035. Again, note the vertical axes of the two graphs have different scales. The results are very much in line with the graphs of generating capacity by economy presented in Figures 9.5 and 9.6 above.

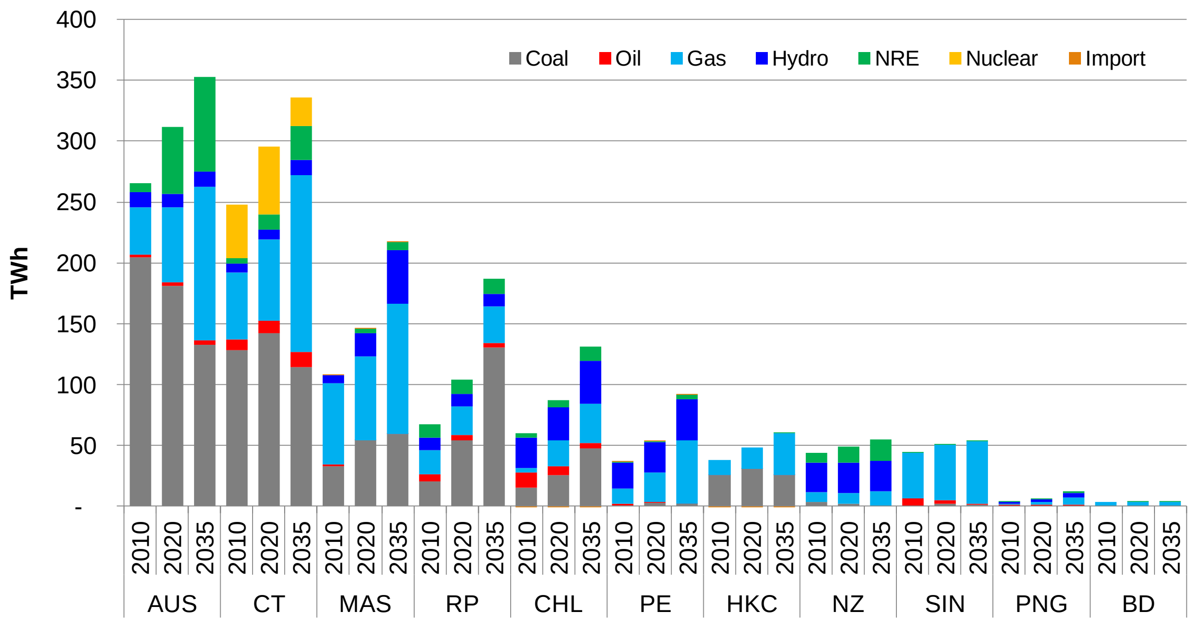
China and the US once again dominate the APEC region: the two economies will account for over 60% of total electricity generation supply over the outlook period. At the other end of the spectrum are the smaller-sized economies: Singapore, Papua New Guinea and Brunei Darussalam.

Figure 9.8: Electricity Generation Supply by Economy and Energy Source, Larger Generating Economies



Source: APERC Analysis (2012)

Figure 9.9: Electricity Generation Supply by Economy and Energy Source, Smaller Generating Economies

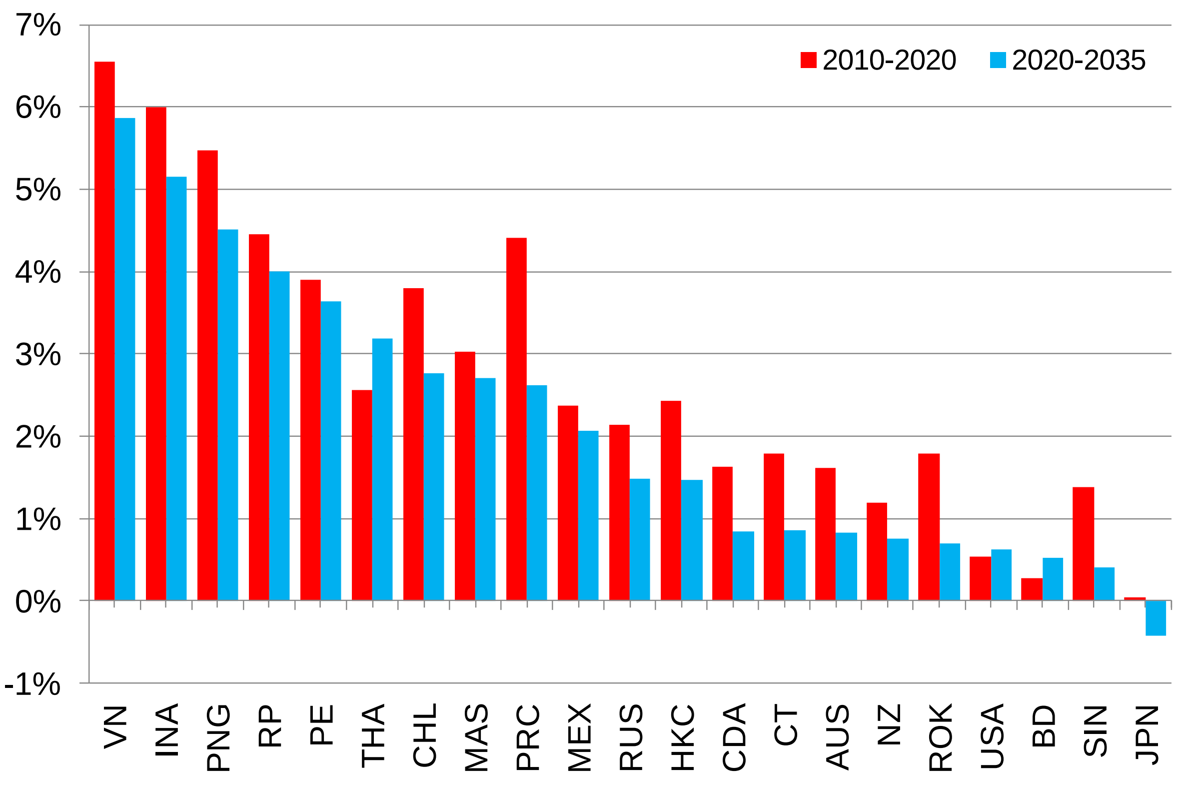


Source: APERC Analysis (2012)

Figure 9.10 shows the electricity supply growth rates for the APEC economies. There is a marked trend of higher generation growth in the earlier 10 years of the outlook period compared to the later 15 years. The exceptions to this trend are China, the US and Brunei Darussalam.

The slower electricity generation growth rate in the APEC region for the later years can probably be attributed to the increasing maturity of most APEC economies, as developing economies tend to have faster GDP growth rates and therefore faster electricity demand growth rates. This increasing maturity is also accompanied by a shift from energy-intensive industry to a less energy-intensive high-value added industry and services.

Figure 9.10: Annual Growth Rates of APEC Economies' Electricity Generation Supply between 2010–2020 and 2020–2035



Source: APERC Analysis (2012)

ACCESS TO ELECTRICITY

Rural electrification is quite properly a key development objective for those economies that have not yet achieved nearly universal access to electricity. Rural electrification not only significantly enhances the quality of life of people living in rural areas, but it can also bring significant economic benefits. Studies show that providing communities with access to electricity has significant positive impacts on household income, expenditure, and the educational achievement of children. It can also lead to significant reductions in poverty (Khandker et al., 2012; World Bank, 2009).

Table 9.3 shows that most APEC economies have already achieved this critical development milestone. The successes of China and Viet Nam in the last decade in providing 99% and 98%, respectively, of their populations with access to electricity in 2009, are especially impressive.

Table 9.3: APEC Economies' Access to Electricity

Economy	Percentage of Population	Percentage of Household
Australia[a]	100	100
Brunei Darussalam[b]	99.7	n/a
Canada[a]	100	100
Chile[c]	98.5	n/a
China[c]	99.4	n/a
Hong Kong, China[a]	100	100
Indonesia[d]	n/a	67.2
Japan[a]	100	100
Korea[a]	100	100
Malaysia[c]	99.4	n/a
Mexico[e]	97.3	n/a
New Zealand[a]	100	100
Papua New Guinea[f]	n/a	12.9
Peru[c]	85.7	n/a
Philippines[g]	n/a	73.7
Russia[h]	100	100
Singapore[c]	100	100
Chinese Taipei[a]	100	100
Thailand[i]	n/a	86.8
United States[a]	100	100
Viet Nam[j]	97.6	98.5

n/a= not available

Sources: [a] APERC Analysis (2012), [b] BDEPD (2010), [c] World Bank (2012), [d] IDGEEU (2011), [e] MSener (2010), [f] PNG (2010), [g] PNGCP (2011), [h] RME (2012), [i] TDEDE (2010) and [j] VGSO (2009)

Only five APEC economies still had access-to-electricity rates less than 95% in the most recent year for which data is available (generally 2009): Indonesia at 67.2% of households, Papua New Guinea at 12.9% of households (PNG, 2010, p. 77), Peru at 85.7% of the population, Philippines at 73.7% of households, and Thailand at 86.8% of households. These economies are moving aggressively to provide increased access, and we expect nearly universal access by 2035, although Papua New Guinea's goal is 70% access by 2030 (PNG, 2010, p. 77).

POTENTIAL FOR ENERGY EFFICIENCY IMPROVEMENTS IN THE ELECTRICITY SUPPLY SYSTEM

Energy efficiency improvements can greatly enhance energy security, reduce costs, and help protect the environment. In an electricity supply system, improving energy efficiency refers to minimizing the primary energy used in producing each unit of electricity consumed. This utilisation can be broadly divided into two categories. The first is the power generation category which encompasses converting primary energy into electricity. The second is the transmission and distribution of electricity category which consists of energy that is used in transporting electricity between sources of supply and the ultimate end-users.

Energy Efficiency in Electricity Generation

About one-third of the APEC total primary energy supply is used to generate electricity, and from this amount, more than 70% are from fossil fuels (In 2009, about 2006 million tonnes of oil equivalent (Mtoe) of fossil fuels were used for electricity generation, out of 2662 Mtoe of total energy supplied for electricity generation and 7005 Mtoe of total primary energy supply). Of the primary fossil fuels used for electricity generation, less than 40% of their energy content is actually converted to electricity (767 Mtoe of electricity produced from 2006 Mtoe of fossil fuels in 2009). The remainder is lost in the transformation process. Therefore, there is a great potential for energy savings in the APEC region by improving the thermal efficiency of fossil-fuel electricity generation. For APEC economies, this can be achieved through either retro-fitting or refurbishing existing capacity to improve efficiency, or by installing new generation capacity with higher efficiencies (APERC, 2008, p. 32).

Thermal generation plant efficiency deteriorates with time but it is possible to offset this aging process with timely investment in refurbishment and retrofitting measures (IEA, 2010, p. 22). There is a broad range of technical possibilities since entire parts of a plant are subjected to replacement or reconditioning. Measures that can lead to energy savings include improvements in a plant's heat recovery system (economisers) and heat transfer (including condensers); better energy management supported by the variable control of energy consuming devices (such as pumps and fans), better combustion control, and the use of more efficient turbine blades (when blade replacement is necessary).

It is also possible to completely refurbish a plant. One example of a complete refurbishment measure is generation plant repowering, in which a coal-fired generation plant is converted into a gas-fired generation plant. Another example is converting a simple open-cycle gas turbine into a combined-cycle gas turbine. Both examples will improve the overall efficiency of the plant, since the latest combined-cycle gas turbine technology, the H-Class, is capable of achieving efficiency of over 60% compared to the 39–47% efficiency of a typical coal steam turbine or the 35–40% efficiency of a typical open-cycle gas turbine (Siemens, 2012; Eurelectric, 2003).

The refurbishment and retrofitting measures described, in conjunction with the implementation of best practices in generation plant operation and maintenance, would likely improve a generation plant's performance and efficiency, as well as extend its lifetime.

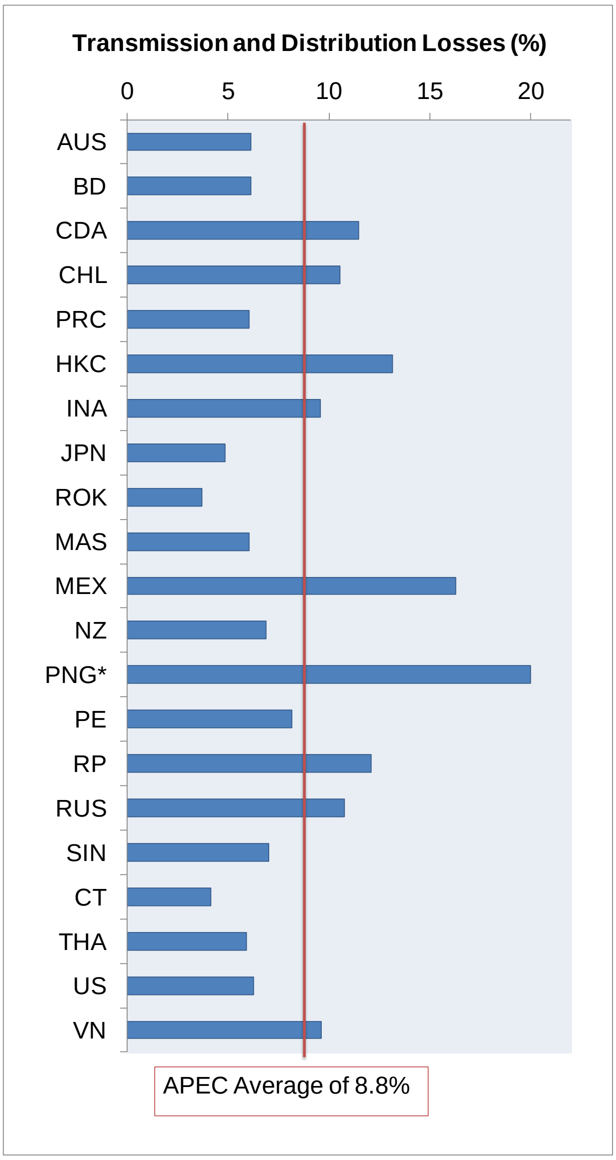
Of course, new generation capacity will also be needed either to replace obsolete existing capacity or to meet the needs for additional electricity in those economies where electricity demand is growing despite efforts to improve end-user energy efficiency. Choosing the generation technology to be used is a major investment decision. It requires a complex decision-making process, taking into account various technical, economic and environmental factors that will best suit the economy's needs.

The variety of options available for new capacity additions is especially broad for coal-fired generation. There are currently several new technological options that are being developed or are commercially available that offer high-efficiency and low-emissions relative to conventional coal-fired technology. These are discussed in the sidebar 'Improving the Efficiency of Coal-Fired Electricity Generation' in Chapter 13. Given the climate change challenges facing the APEC region, as discussed in Chapter 16, all new generation capacity should ideally be low-carbon: renewable, nuclear, or fossil-fuel with carbon capture and storage (CCS). However, if an economy must build non-CCS coal-fired capacity, these advanced technologies for coal-fired generation can significantly reduce emissions, as well as fuel costs, and deserve careful consideration.

Energy Efficiency in Transmission and Distribution

Transmission and distribution (T&D) losses are defined as the share of electricity losses between sources of supply (generating stations), and the ultimate end-users. In 2009, the T&D losses among APEC economies ranged from 3.7% (Korea) to about 20% (Papua New Guinea), with an average of about 8.4% for all APEC economies.

Figure 9.11: APEC Economies T&D Losses in 2009



Sources: *World Energy Statistics 2011* © OECD/IEA 2011 and *PNG (2011)

T&D losses can be attributed to both technical and non-technical losses, where technical losses are related to the dissipation of energy in conductors and equipment while non-technical losses are caused by pilferage and meter-related issues (Bhalla, 2000). Technical losses can be reduced by installing more energy efficient equipment in the T&D network.

Several technological improvements that would improve efficiency in T&D networks are tabulated in Table 9.4. The better management of grid electricity flow will also boost efficiency. This can be achieved through load forecasting, optimal load flow planning, loss minimization and reactive power management (Pezzini et al., 2011).

Table 9.4: Energy Efficient Technologies for T&D Networks

Equipment	Energy Efficiency Technology
Cables	Superconductors, HVDC lines, Underground Distribution Lines
Power flow control	Flexible AC Transmission System (FACTS) devices, Phase Shifting Transformers (PTS)
Transformers	High energy efficiency classes, Amorphous Metal Distribution Transformer (AMDT)
Substations	Gas-Insulated Substations (GIS)

Sources: Pezzini et al. (2011) and ABB (2007)

Smart Grids

The APEC region's grids are constantly evolving. Energy resources are becoming increasingly heterogeneous with the introduction of distributed technologies like intermittent renewable energy generation, plug-in electrical vehicles, combined heat and power (CHP) and energy storage facilities. Modern electrical and electronic devices are much more complex, being more sensitive to voltage or frequency fluctuations in electricity supply.

To meet these new challenges, several APEC economies are planning to update their grids with sophisticated 'smart grid' technologies. The smart grid concept is set to restructure the traditional T&D network from one that is centralized and producer-controlled to one where control is more distributed, automated, and consumer-interactive. Digital technologies and communications are used to coordinate the actions of intelligent devices and systems throughout the electricity power network.

Smart grid monitoring applications, automation and control functions will provide more flexibility to integrate distributed energy resources with their varied characteristics into the T&D system. The same smart grid applications can also enhance overall T&D system efficiency with real-time system performance optimization and increased asset utilization.

The importance of smart grid technology in the APEC region is emphasized in The Fukui Declaration from the Ninth Energy Ministers Meeting in June 2010 (APEC, 2010) which states that "smart grid technologies, including advanced battery technologies for highly-efficient and cost-effective energy storage, can help to integrate intermittent renewable power sources and building control systems that let businesses and consumers use energy more efficiently, and they can also help to enhance the reliability of electricity supply, extend the useful life of power system components, and reduce system operating costs".

This declaration was reinforced with instructions to the Energy Working Group (EWG) "to start an APEC Smart Grid Initiative (ASGI) to evaluate the potential of smart grids to support the integration of intermittent renewable energies and energy management approaches in buildings and industry" (APEC, 2011). ASGI comprises four main elements:

1. Survey of Smart Grid Status and Potential.
2. Smart Grid Road Maps.
3. Smart Grid Test Beds.
4. Smart Grid Interoperability Standards.

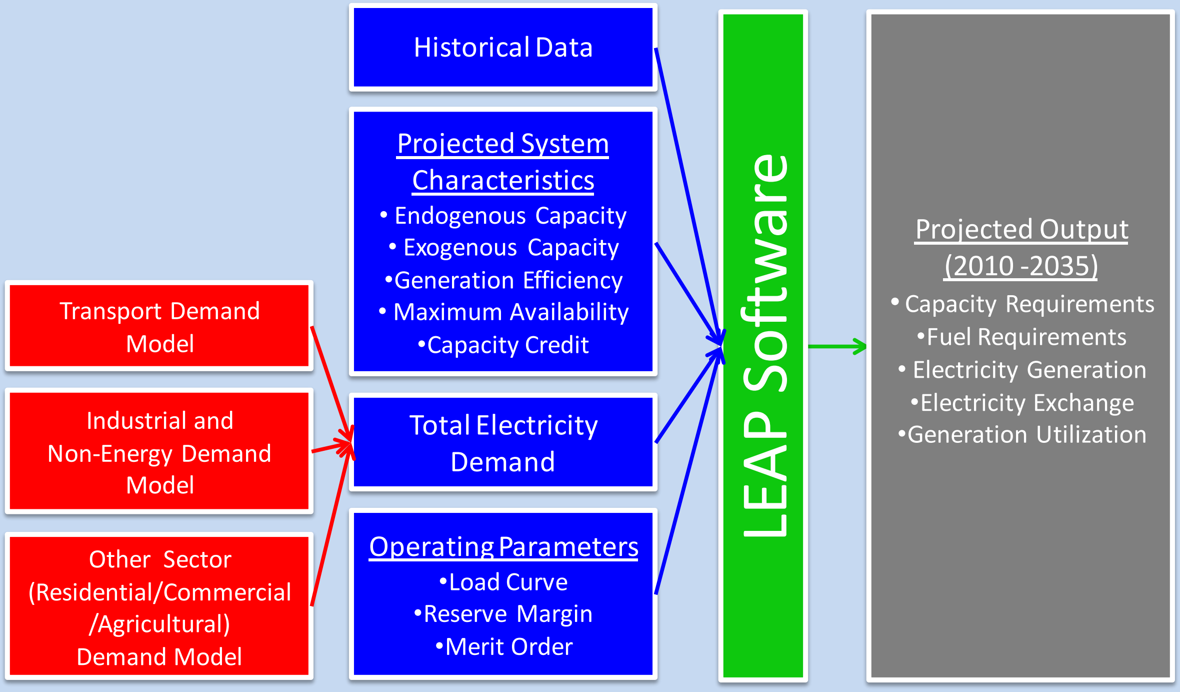
As of 2011, APEC member economies are in various states of smart grid development, including conducting demonstrations and engaging in joint projects with other economies (APEC, 2011). The Knowledge Sharing Platform (KSP), established in the EWG-41 Meeting in May 2011, is a tool for collecting and sharing best practices for creating energy smart communities. The KSP website is the best resource for the latest information on smart grid initiatives and projects in APEC economies (APEC, 2012).

APERC'S ELECTRICITY SUPPLY MODEL AND HOW IT WORKS

Because of the complexities involved in modelling electricity supply, APERC uses an off-the-shelf model known as the LEAP (Long-Range Energy Alternatives Planning) system developed by the Stockholm Environment Institute (SEI, 2012). LEAP is a flexible planning tool used in many organizations worldwide. Although LEAP is a complete energy supply and demand modelling system, APERC has elected to use LEAP only for modelling electricity supply. Other parts of the APEC Energy Demand and Supply model were developed by APERC and are described in other chapters of this volume.

LEAP simulates decision-making in the electricity supply sector based on the inputs shown in Figure 9.12 below. The outputs extracted from LEAP simulations are listed in the same figure.

Figure 9.12: APERC's Electricity Supply Model



Two types of generation capacities are defined in LEAP. 'Exogenous capacity' is generation capacity that either already exists or which the modeller believes is sure to be built. 'Endogenous capacity' is additional generation capacity that LEAP can choose to build if required by the system. Both types of generation capacities are defined in terms of key variables, including fuel type and generation efficiency, maximum availability, and percentage capacity credit. For exogenous generation, the year in which the capacity will be retired is also defined.

Total demand for electricity in each year is a model input that comes from summing the electricity demand results from each demand sector model. For this outlook, the demand sector models are the Industrial and Non-Energy Demand Model, the Transport Demand Model and the Other Sector Demand Model. These demand models are described elsewhere in this volume.

LEAP requires the modeller to specify a load curve for the economy, which defines how this demand fluctuates throughout the day and throughout the year. LEAP is thus able to effectively estimate a demand for electricity during each hour of the year. The modeller also supplies a merit order, which defines the order in which various types of generation capacities are to be used. In general, renewable generation is used first since it has no fuel cost, next the efficient base-load generation (usually coal or combined-cycle gas turbine) is used, and, when these types are not sufficient, a less efficient peaking unit such as an open-cycle gas turbine is used. Based on this information, LEAP decides how to dispatch the generation in each hour of the year.

Over the longer term, LEAP must also decide what new generation should be added. The user supplies a required level of reserve capacity for the economy. In years when this reserve requirement cannot be met during the hour of peak demand, LEAP adds capacity from the modeller-specified endogenous capacity. The modeller specifies an addition order for each increment of endogenous capacity, allowing LEAP to add endogenous capacity according to this pre-specified order until it can meet the reserve requirement in that year.

In this way, LEAP simulates electricity supply for an economy in each year of the outlook period. It then sums up and reports the results in each year, including fuel requirements for each fuel, the amount of electricity generated by each fuel type, the required capacity additions, and the use of each type of generation.

In setting up the model inputs for each economy, APERC researchers considered the energy resources available in the economy and the economy's policies and plans for generation capacity additions.

REFERENCES

ABB (2007), *Energy Efficiency in the Power Grid*, http://www04.abb.com/global/seitp/seitp202.nsf/c71c66c1f02e6575c125711f004660e6/64cee3203250d1b7c12572c8003b2b48/$FILE/Energy+efficiency+in+the+power+grid.pdf

APEC (Asia-Pacific Economic Cooperation) (2010), *Fukui Declaration – Low Carbon Paths to Energy Security: Cooperative Energy Solutions for a Sustainable APEC*, www.apec.org/Meeting-Papers/Ministerial-Statements/Energy/2010_energy.aspx

— (2011), *Using Smart Grids to Enhance Use of Energy-Efficiency and Renewable-Energy Technologies*, APEC Energy Working Group, http://publications.apec.org/publication-detail.php?pub_id=1152

— (2012), *Smart Grids, APEC Energy Smart Communities Initiatives – Knowledge Sharing Platform*, http://esci-ksp.org/?task=smart-grids

APERC (Asia Pacific Energy Research Centre) (2008), *Energy Efficiency in the APEC Region*, www.ieej.or.jp/aperc/2008pdf/2008_Reports/Energy%20Efficiency%20in%20the%20APEC%20Region%20l%20APERC%202008.pdf

BDEPD (Brunei Darussalam Department of Economic Planning and Development) (2010), *Brunei Darussalam Statistical Yearbook 2010*, www.depd.gov.bn/SI/BDSYB2010/BDSYB%202010.pdf

Bhalla, M. S. (2000), "Transmission and Distribution Losses (Power)", National Conference on Regulation in Infrastructure Services: Progress and Way Forward, 14–15 November 2000, www.teriin.org/index.php?option=com_publication&task=details&sid=355

Eurelectric (Union of the Electricity Industry) (2003), *Efficiency in Electricity Generation*, www.eurelectric.org/Download/Download.aspx?DocumentID=13549

IDGEEU (Indonesia Directorate General of Electricity and Energy Utilization) (2011), *Statistics Book of Electricity and Energy Number 24-2011*, www.djlpe.esdm.go.id/modules/_website/files/1049/File/Statistik%202010%20DITJEN%20LISTRIK.pdf

IEA (International Energy Agency) (2010), *Power Generation from Coal: Measuring and Reporting Efficiency Performance and CO_2 Emissions*, www.iea.org/ciab/papers/power_generation_from_coal.pdf

— (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

Khandker, Shahidur R., Douglas F. Barnes and Hussain A. Samad (2012), "The Welfare Impact of Rural Electrification in Bangladesh", *The Energy Journal*, Vol 33 No 3, 2012, pp. 187–206.

MSener (Mexico Secretaría de Energía) (2010), *Cuarto Informe de Labores 2010*, www.sener.gob.mx/res/0/CuartoInformeLaboresSENER2010.pdf

Pezzini, Paola, Oriol Gomis-Bellmunt and Antoni Sudrià-Andreu (2011), "Optimization techniques to improve energy efficiency in power systems", *Renewable and Sustainable Energy Reviews*, No 15, pp 2028–2041.

PNG (Papua New Guinea Department of National Planning and Monitoring) (2010), *Papua New Guinea Development Strategic Plan 2010–2030*, www.treasury.gov.pg/html/publications/files/pub_files/2011/png-development-strategic-plan.2010-2030.pdf

— (2011), *Papua New Guinea presents Power Energy and Sources,* http://nrec.mn/data/uploads/Nom%20setguul%20xicheel/Water/badrakh%20china/Papua%20new%20guinea%20presents.pdf

PNGCP (Philippines National Grid Corporation) (2011), *Transmission Development Plan 2011*, www.ngcp.ph/tdp.asp

RME (Russian Federation Ministry of Energy) (2012), *The Russian Federation Energy Data 2011*, in Russian, www.minenergo.gov.ru/activity/

SEI (Stockholm Environment Institute) (2012), 'Introduction to LEAP' website page, www.energycommunity.org/default.asp?action=47

Siemens (2012), "Siemens receives German Industry's Innovation Award – Award for world's most efficient gas turbine power plant", 12 February 2012, www.siemens.com/press/en/pressrelease/?press=/en/pressrelease/2012/energy/fossil-power-generation/efp201202028.htm

TDEDE (Thailand Department of Alternative Energy and Efficiency) (2010), "Electric Power in Thailand" in *Annual Report 2010*, www.dede.go.th/dede/images/stories/060554_circular/report_electric__2553_3.pdf

VGSO (Vietnam General Statistics Office) (2009), *Statistical Yearbook of Vietnam*, www.gso.gov.vn

World Bank (2009), *Welfare Impact of Rural Electrification, Evidence from Vietnam*, http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2009/09/17/000158349_20090917100619/Rendered/PDF/WPS5057.pdf

— (2012), 'Access to Electricity' website page, http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS/countries?display=default