Historical Trends and Long-term Outlook for Energy Supply and Demand in the United Arab Emirates and the Effects of Energy Conservation Technologies

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Summary

In this study, the author compiled energy consumption data in the little-known industry sector of the United Arab Emirates and used an econometric model to develop an energy supply/demand outlook for the country through 2030. If nuclear power generation and other energy conservation or carbon emission reduction measures fail to make progress, the UAE's fossil fuel consumption will continue increasing in line with the past trend, expanding by 1.5-fold from 67 million tons of oil equivalent in 2011 to 97 Mtoe in 2030. If nuclear power plants now under construction start operation with energy conservation and low-carbon technologies promoted substantially in the industrial, building, transport and power generation sectors, fossil fuel consumption in 2030 will be limited to 72 Mtoe, slightly more than in 2011. Particularly, energy conservation effects of improvements in the efficiency of air-conditioning equipment will be great.

In the UAE, domestic consumption's share of oil production has been increasing over recent years. For natural gas, the country became a net importer in 2008, leading the nation to recognize the impacts of energy demand growth on trade balance as a key challenge. As energy supply and demand trends in oil/gas-producing countries in the Middle East exert great impacts on the international energy market, the challenge is a major problem for energy importing countries. Energy efficiency improvements are expected to make steady progress in the UAE through the introduction of latest technologies under proactive measures led by the government.

1. Introduction

Global energy demand has been continuing rapid growth, led by Asian non-OECD countries including China, India and ASEAN members. The Middle East, which is the largest energy producing region in the world, has also seen a rapid energy demand increase in line with high economic growth. According to the IEA statistics[1)], primary energy consumption in the Middle East expanded by 1.7-fold in the 10 years between 1990 and 2000 and by 1.8-fold in the 11 years between 2000 and 2011. Unlike other regions, the Middle East features the point that oil and natural gas account for more than 99% of primary energy supply. Therefore, expanding energy consumption in the Middle East is feared to reduce the region's oil and natural gas export capacity. Looking into energy conservation potential in the region, which discriminates itself from other regions with a unique energy demand structure that consumes massive electricity for air-conditioning under the very hot climate, is significant for considering global future energy supply and demand.

In this paper, the author projected energy supply and demand through 2030 in the United Arab Emirates among Middle East countries and analyzed energy conservation and carbon emission reduction potential in the UAE. Based on historical data of the International Energy Agency (IEA)'s energy balance tables, the author projected future energy supply and demand with the same econometric method as used for the IEEJ's "Asia/World Energy Outlook"[2)] and assessed the effects of various energy conservation and carbon emissions reduction measures. As noted later, however, the IEA statistics fail to fully break down energy consumption in the industry sector of the UAE, providing insufficient data for estimating energy conservation potential. Therefore, the author used sustainability reports and other information of major domestic companies to estimate energy consumption, and utilized the data to develop the energy demand outlook.

In the following, Chapter 2 compiles the UAE's present energy supply and demand before Chapter 3 gives forecasted UAE energy supply and demand through 2030.

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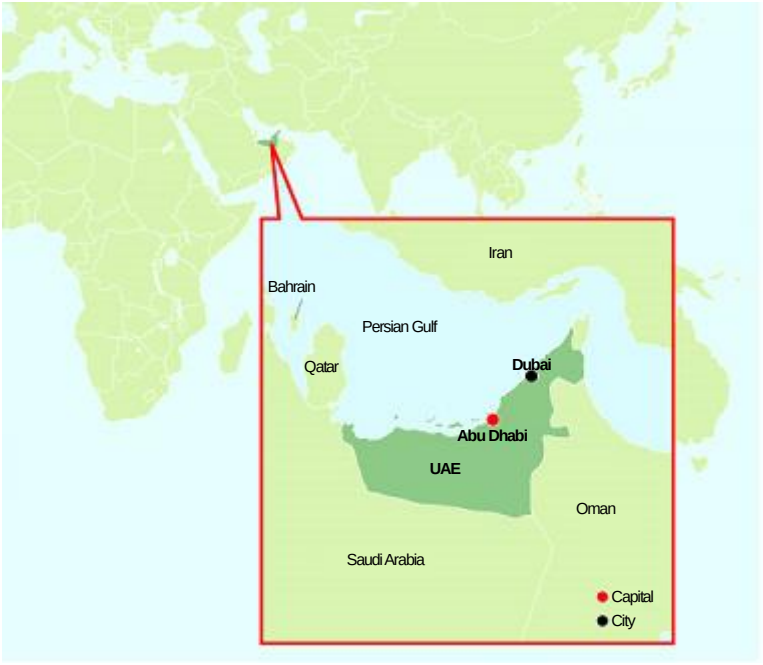
2. Overview of UAE Energy Supply/Demand

2-1 Overview of UAE

The UAE is a young country founded in 1971. Britain declared its withdrawal from East of Suez in 1968 following the end of World War II, after keeping the present UAE site under control since the late 19th century. In 1971, six emirates -- Abu Dhabi, Dubai, Sharjah, Fujairah, Ajman and Umm al-Quwain -- formed a federation. In the next year, Ras al-Khaimah joined the six to found the UAE covering the seven emirates. Initially, the federation had been planned to cover nine emirates including Qatar and Bahrain in addition to the seven. The two emirates eventually became independent countries and have remained so.

The largest among the seven emirates is Abu Dhabi, accounting for 80% of the federation's territory. The Abu Dhabi emir has served as president of the federation. Positioned after Abu Dhabi is Dubai, the emir of which doubles as vice president of the federation. Particularly, oil and natural gas production mainly in Abu Dhabi has supported the UAE economy. According to the BP Statistical Review[3)] , the UAE's crude oil output in 2012 totaled 3.38 million barrels per day accounting for 3.7% of global output. Its natural gas output came to 51.7 billion cubic meters capturing 1.5% of global output. The UAE, particularly Dubai, has sought to reduce the economy's dependence on oil, which has made some successful efforts so far. But the reduction is mostly left for future efforts.

The UAE's largest oil export destination is Japan, accounting for 36% of crude oil exports from Abu Dhabi in 2010. Of Japan's crude oil imports in 2012, the UAE provided 22%, ranking second after Saudi Arabia as the largest oil exporter to Japan. In this way, the UAE has had close relations with Japan. The two countries have promoted bilateral exchanges in various areas other than crude oil trade.



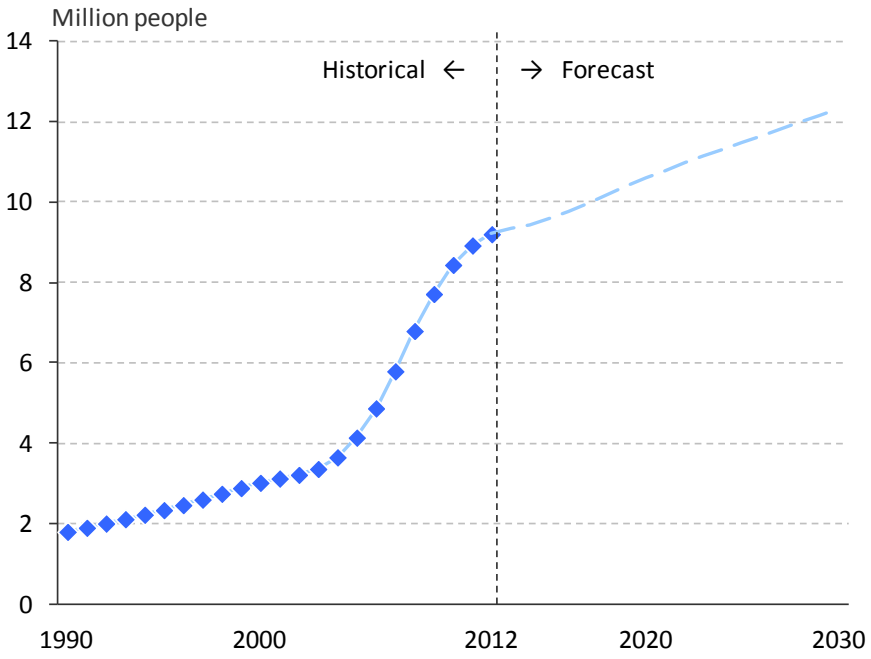
Source: Ministry of Foreign Affairs of Japan Website

Figure 2-1 UAE Location

2-2 Population and economic growth

UAE population increased from 1.8 million in 1990 to 3 million in 2000, scoring a steady annual average growth rate of 5-6% before accelerating to an average growth of 15% between 2005 and 2010. The population reached 8.4 million in 2010 and 9.2 million in 2012[4]. The fast population expansion has resulted from increasing immigration and foreign workers amid economic growth. According to the National Bureau of Statistics[5], the number of UAE citizens increased by 1.1-fold from late 2005 to mid-2010, while that of non-UAE citizens grew 1.8-fold. UAE citizens' share of total population fell from 20% to 11%.

The rapid economic expansion and population growth coinciding with crude oil price spikes are unlikely to continue permanently. Population growth will fall back to a moderate level. The United Nations' World Population Prospects (median estimate)[6], adopted as one of the basic assumptions for this analysis, indicates an annual average population growth rate of 1.6% through 2030. UAE population in 2030 will increase by 1.3-fold from the present level to 12.3 million.

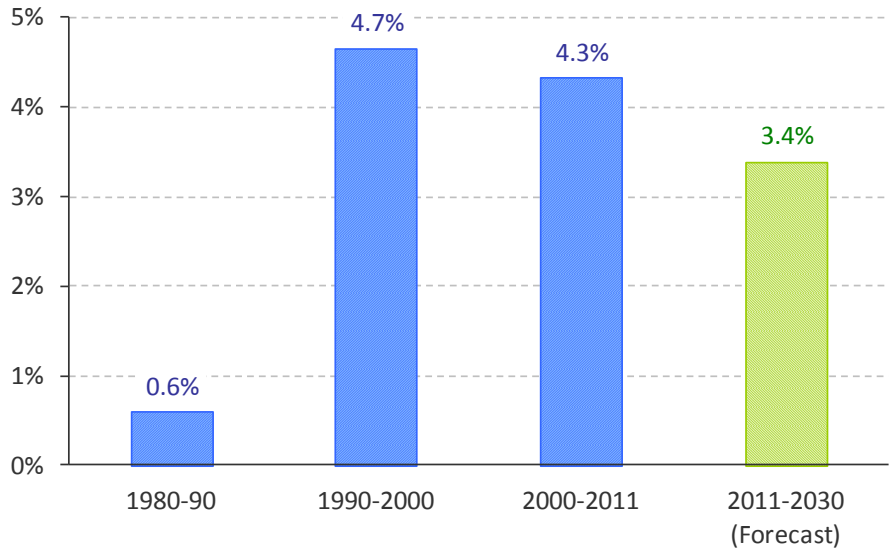


Sources: World Bank[4] and author's estimate based on the United Nations[6]

Figure 2-2 Population in UAE

The UAE's real GDP has continued steady growth since the 1990s. When crude oil prices rose sharply between 2004 and 2007, particularly, its annual real GDP growth was as high as 8-9%. But the UAE economy later showed signs of decline including a contraction in 2009 caused by the Lehman Shock in 2008.

The UAE has been seeking to diversify its economy, achieving some successful results. But the economy is still strongly dependent on fossil fuel exports. As Asian developing countries expand oil and natural gas demand in the future, Middle Eastern oil producing countries are expected to continue increasing fossil fuel exports to Asia. However, high growth like that caused by sharp hikes in fossil fuel prices in the mid-2000s cannot be expected to continue long. Given these conditions, this study assumes annual average GDP growth at 3.4% for 2011-2030, slightly lower than 4.7% for 1990-2000 and 4.3% for 2000-2011.

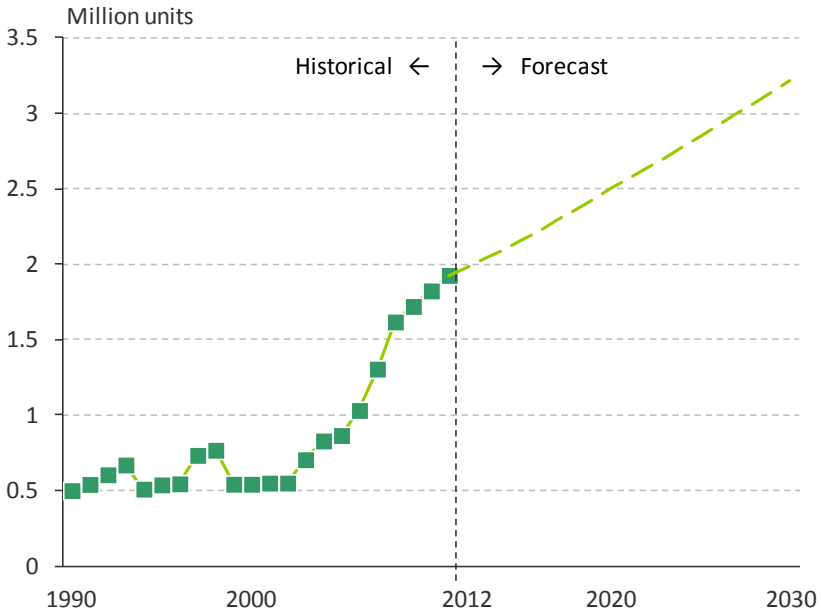


Sources: World Bank[4] and author's estimate

Figure 2-3 Real GDP Growth Rates

2-3 Vehicle ownership

Figure 2-4 indicates the UAE's vehicle ownership[7]. The number of vehicles in 2011 totaled 1.9 million, with per capita ownership standing at 0.22 units. Although per capita ownership usually rises along with per capita income, in the UAE it has fallen slightly from a peak of 0.3 in the 1990s, indicating the impact of increasing non-national residents. For the period up to 2030, it is expected to increase in a usual manner. The total number of vehicles is projected to expand to 3.2 million in 2030.

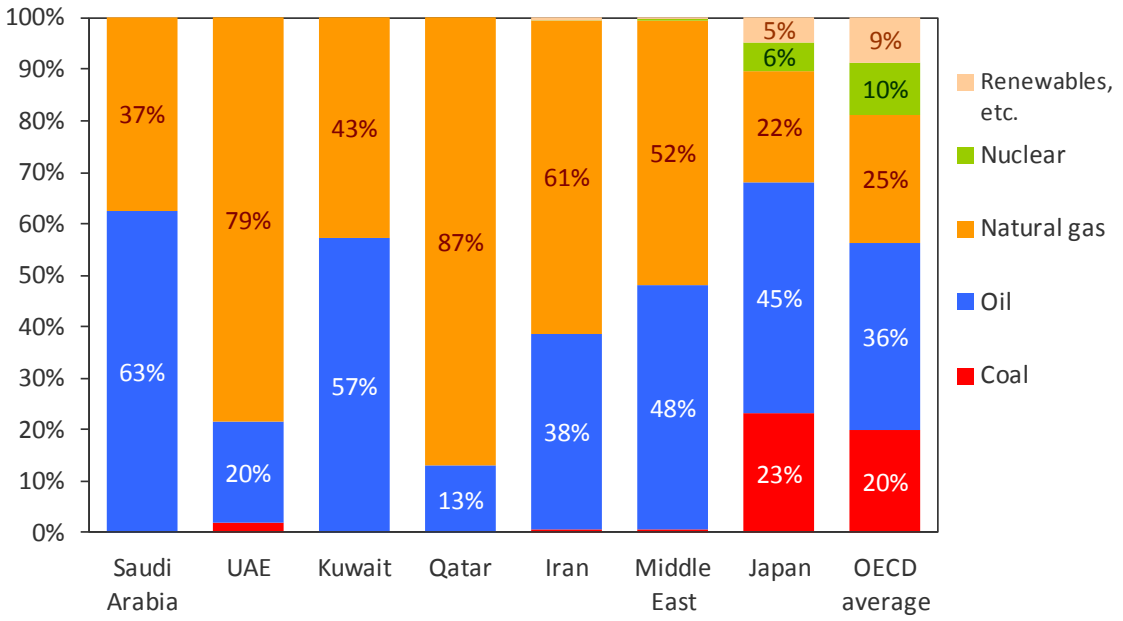


Sources: Japan Automobile Manufacturers Association (JAMA)[7] and author's estimate

Figure 2-4 Vehicle Ownership

2-4 International comparison of energy consumption

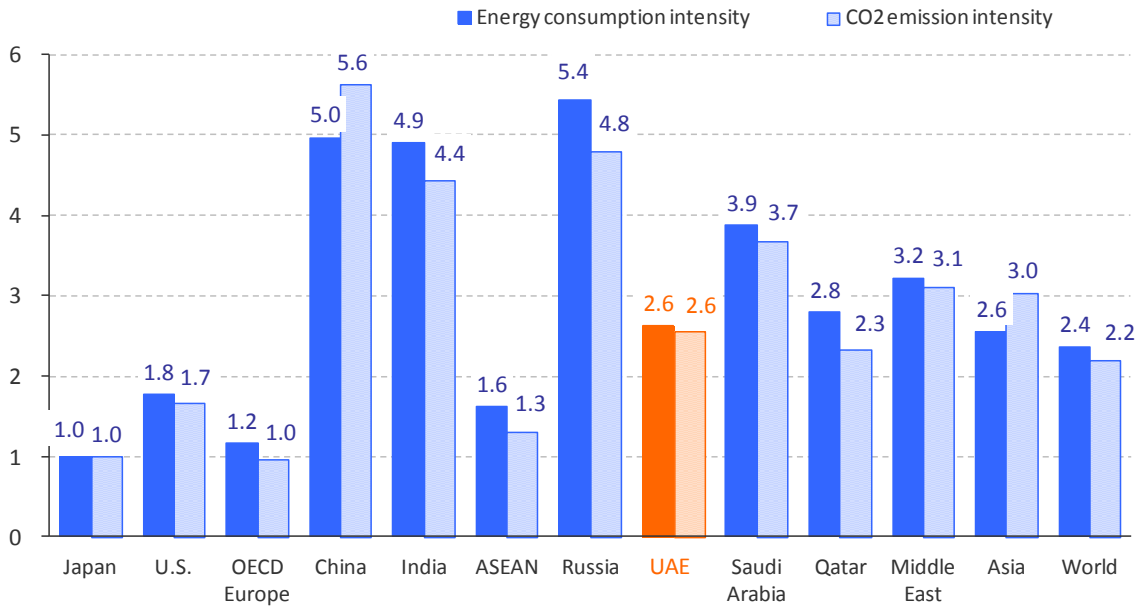
Figure 2-5 indicates the primary energy consumption mix for selected countries. OECD countries consume coal, oil, natural gas, nuclear and renewable energy in a well-balanced manner, while oil and natural gas account for most of the energy consumption in Middle Eastern countries. Some Middle Eastern countries depend on oil more heavily than on natural gas, while others depend on natural gas more heavily than on oil. The latter include the UAE and Qatar. Natural gas accounted for 80% of energy supply in 2011 in the UAE. A factor behind the heavy dependence on natural gas is natural gas-fired power generation's domination of electricity sources. (In contrast, oil-fired power generation accounts for 50% or more of electricity sources in Saudi Arabia and Kuwait.) The UAE energy mix indicates a strategy to export oil as much as possible while covering domestic energy demand with natural gas. As noted later, however, natural gas demand in the UAE has surpassed its domestic output, indicating that the UAE will have to change its energy strategy.



Sources: IEA[1),8)]

Figure 2-5 Primary Energy Consumption Mix for Selected Countries (2011)

As indicated in Figure 2-6, the UAE's energy consumption and carbon dioxide emission intensities are lower than in other Middle Eastern countries and in most Asian countries. But they are still higher than in Japan and European countries, indicating that there is great room for energy conservation.



Note: The intensities were computed by dividing primary energy consumption and energy-related CO_2 emissions by real GDP in 2011 and normalized as 1 for Japan.

Sources: IEA[1),8)], World Bank[4)]

Figure 2-6 Energy Consumption and CO_2 Emission Intensities in Major Countries/Regions (2011)

2-5 Overview of energy supply/demand mix

According to the IEA's energy balance tables, the UAE's primary energy consumption in 2011 totaled 66,108 kilotons of oil equivalent (ktoe). Final energy consumption, excluding consumption in the energy transformation sector, aggregated 48,675 ktoe. Of final energy consumption, the industry sector captured the largest share at 62% or 30,063 ktoe. Given that most of the consumption for non-energy use accounting for 4% is for petrochemical feedstock, the industry sector effectively accounted for nearly 70% of final energy consumption. The transport sector captured 21% or 10,391 ktoe of final energy consumption, while the buildings sector (residential, commercial and others) accounted for 13% or 6,388 ktoe. The following indicates sector-by-sector energy demand.

2-5-1 Industry sector

Of the industry sector's energy consumption at 30,063 ktoe in 2011, natural gas accounted for 89%, bituminous coal for 4.2%, heavy fuel oil for 3.8%, electricity for 2.6% and LPG for 0.08%. The IEA's energy balance tables provide an industry-by-industry breakdown of the industry sector's energy consumption for each country. As for the UAE, however, the table allots bituminous coal consumption to "non-metallic minerals" (such as the cement industry) and some natural gas and LPG consumption to "chemical and petrochemical" while leaving the rest (95% of the total) to the "non-specified industry" category without providing any more detailed industry-by-industry breakdown. In fact, however, the UAE not only has a petrochemical industry but also energy-intensive industries including steel and aluminum producers that have been expanding production rapidly. Figuring out energy consumption in these industries is important for considering future supply and demand in the UAE. The following describes present conditions of energy-intensive industries such as aluminum, steel, cement and paper manufacturers in the UAE in addition to its mainstay oil and natural gas industry:

(a) Oil and natural gas industry

i) Oil and natural gas companies

Abu Dhabi National Oil Co., known as ADNOC, plays a leading role in the UAE's oil and natural gas industry. Controlled by the Supreme Petroleum Council led by the Abu Dhabi emir, ADNOC has 15 subsidiaries as described below,

including joint ventures with foreign firms, covering oil and natural gas production, oil refining, petrochemical production and other relevant operations comprehensively[9].

According to IEA statistics, the UAE energy transformation sector in 2011 put 9,610 ktoe in crude oil and 12,738 ktoe in natural gas liquid into oil refineries to turn out 22,715 ktoe in petroleum products, including 245 ktoe in refinery gas consumed at the refineries. The chemical and petrochemical industry consumes 177 ktoe in energy including 125 ktoe in natural gas and 25 ktoe in LPG. It also uses 1,569 ktoe in petroleum products and 232 ktoe in natural gas, or a total of 1,801 ktoe, as feedstock for petrochemical production. No further details about the oil and natural gas industry are available from the energy balance tables.

ADCO (Abu Dhabi Company for Onshore Oil Operations)

The company operates onshore oilfields, producing crude oil at nine oilfields. BP, Shell, Total, ExxonMobil and Partex, as well as ADNOC, had had stakes in ADCO. Although these foreign companies' stakes expired in 2014, none has renewed the stakes. Tentatively, ADNOC now wholly owns ADCO.

ADMA-OPCO (Abu Dhabi Marine Operating Company)

The company operates offshore oilfields, producing crude oil at the Umm Shaif and Zakum oilfields. It is 60% owned by ADNOC and 40% by BP, Total and Japan Oil Development Co. (JODCO), which is a subsidiary of INPEX Corp.

ZADCO (Zakum Development Company)

The company operates the Upper Zakum, Umm Al-Dalkh and Satah oilfields. Its shareholders include ExxonMobil and JODCO as well as ADNOC.

NDC (National Drilling Company)

The company provides onshore and offshore drilling services.

GASCO (Abu Dhabi Gas Industries Limited)

The company processes natural and associated gas from onshore gas fields. It provides gas as fuel to such UAE companies as the Abu Dhabi Water & Electricity Authority (ADWEA) and produces ethane, propane, butane and pentane as petrochemical materials and sulfur as by-product. Its shareholders include Shell and Total in addition to ADNOC.

ADGAS (Abu Dhabi Gas Liquefaction Company Ltd.)

The company processes associated gas from offshore oilfields operated by ADMA-OPCO into LNG for exports mainly to Tokyo Electric Power Co. Its shareholders include Mitsui & Co., BP and Total as well as ADNOC.

Al Hosn Gas (Abu Dhabi Gas Development Company Ltd.)

The company was founded in 2010 for developing the Shah gas field. Its shareholders include Occidental Petroleum Corp. (OXY) of the United States as well as ADNOC.

ELIXIER (ADNOC Linde Industrial Gases Company Ltd.)

The company was founded in 2007 to provide gas to UAE industries. It provides nitrogen and rare gases as well. It is owned by ADNOC and Linde of Germany.

TAKREER (Abu Dhabi Oil Refining Company)

The company refines crude oil at the Abu Dhabi (Umm Al Nar) and Ruwais refineries.

ADNOC Distribution

The company undertakes distribution and sales of petroleum products.

BOROUGE (Abu Dhabi Polymers Company Ltd.)

The company operates a petrochemical plant under a joint venture with Australia's Borealis. It tripled production capacity to 2 million tons in 2010. The company and Borealis have a combined polyethylene and polypropylene production capacity of more than 5.4 million tons. It is expected to expand production capacity by 2.5 million tons in the near future.

FERTIL (Ruwais Fertilizer Industries)

The company has been founded by ADNOC and Total to operate a plant producing ammonia and urea, exporting 92% of its output to foreign countries.

ESNAAD (Petroleum Services Company)

The company provides services related to oil and gas field development and operation.

IRSHAD (Abu Dhabi Petroleum Ports Operating Company)

The company conducts mainly maintenance services for ports (export terminals).

ADNATCO (Abu Dhabi National Tanker Company) and NGSCO (National Gas Shipping Company Ltd.)

The company transports crude oil, petroleum products, LNG, etc.

In this way, ADNOC has a central position in the UAE's oil and natural gas industry. But there are some other companies in the industry. While the three major oil producers of ADCO, ADMA-OPCO and ZADCO as listed above account for some 90% of the UAE's crude oil production[10], Abu Dhabi Oil Co. (Japan), United Petroleum Development Co. (Japan), Total ABK (a joint venture of France's Total and Japan's INPEX) produce oil at smaller oilfields. In addition, Mubadala Petroleum under the umbrella of Mubadala Development Co. owned by the Abu Dhabi government, Abu Dhabi National Energy Co. PJSC (TAQA), produces oil in other emirates than Abu Dhabi.

As for petrochemical operations, Dubai National Gas Co. (Dugas) operates an MTBE (methyl tertiary-butyl ether) plant (with a production capacity at 500,000 tons per year) while undertaking gas operations. Green Dome Petrochemicals[11] produces ammonia (production capacity at 410,000 tons per year) and urea (production capacity at 350,000 tons per year) in Sharjah's Hamriyah Free Zone. A large petrochemical complex is under construction by ChemaWEyaat owned by International Petroleum Investment Co. (IPIC), the Abu Dhabi Investment Council (ADIC) and ADNOC.

Among the abovementioned oil refineries, the Umm Al-Nar refinery has the capacity to process 150,000 bpd in crude oil and the Ruwais refinery plans to launch the second train with a capacity of 400,000 bpd by late 2014, in addition to the existing capacity of 350,000 bpd. Other refineries in the UAE include a 120,000-bpd capacity refinery of Emirates National Oil Co. in Dubai, an 82,000-bpd capacity refinery of Fujairah Refinery Co. Ltd. in Fujairah and a 71,000-bpd capacity refinery of Sharjah Oil Refining Co. Ltd. in Sharjah[12].

ii) Energy consumption

Energy consumption, carbon dioxide emissions and other data are available in ADNOC's Sustainability Report[13]. This report covers the abovementioned three independent oil companies (Abu Dhabi Oil, United Petroleum Development's Bunduq Oil Producing Co., and TotalABK) in addition to the ADNOC group companies.

In 2011, their energy consumption included 450 petajoules in direct consumption (including 37 terajoules in renewable energy) and 18 PJ in indirect consumption. (In 2012, direct consumption totaled 527 PJ including 28 TJ in renewable energy). Of the 450 PJ in 2011 direct consumption, energy consumption accompanying crude oil and natural gas development, production, gasification and other relevant operations came to 257 PJ for the ADNOC group and 72 PJ for the

three independent companies. Their combined consumption of 329 PJ for such operations accounted for about 70% of the total.

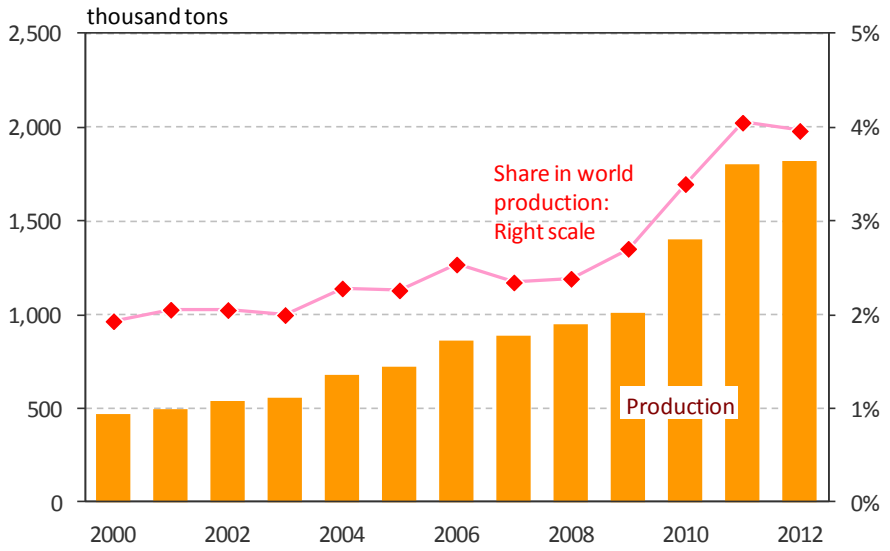
The energy consumption of 329 PJ in 2011 included 18 PJ for ADCO, 36 PJ for ZADCO and 22 PJ for ADMA-OPCO. The three resource development and production companies in the ADNOC group thus consumed a combined total of 76 PJ (1,640 ktoe). This total is combined with the three independent firms' consumption into 147 PJ (3,180 ktoe). The remainder is suspected as energy demand concerning gas operations (including gasification) of such companies as ADGAS, GASCO and Al Hosn Gas. Meanwhile, efforts have continued to reduce natural gas flare that accompanies resource production and is included into the energy consumption under review in this paragraph. As a result, flare gas consumption in the UAE, Saudi Arabia and other Persian Gulf countries is far less than in African and South American countries. Flare gas consumption by the ADNOC group and the three independent firms totaled 400-500 ktoe in 2011.

In addition to the energy consumption concerning crude oil and natural gas production and relevant operations in 2011, petrochemical firms (BOROUGE and FERTIL) consumed 62 PJ and others (including oil refineries) 60 PJ.

(b) Aluminum industry

The aluminum industry is one of the industries that the UAE has proactively nurtured. Thanks to cheap electricity, the industry has achieved great successful results in recent years. Dubai Aluminum (DUBAL), which has traditionally undertaken the UAE's aluminum production, was founded under the leadership of the Dubai emir family in 1979 to help diversify the UAE's industrial structure depending heavily on oil. DUBAL has continued expanding production since its founding. Its production in 2012 totaled about 1 million tons. In 2009, Emirates Aluminum (EMAL), a joint venture between DUBAL and Mubadala Development Co. owned by the Abu Dhabi government, launched aluminum production in Abu Dhabi. Its production capacity totaled 750,000 tons per year in 2011. It later implemented the second-phase investment under a plan to boost its annual production capacity to 1.3 million tons by the end of 2014.

As indicated in Figure 2-7, the UAE accounted for 4% of world aluminum production in 2012.



Source: U.S. Geological Survey[14)]

Figure 2-7 Primary Aluminum Production

DUBAL has a proprietary natural gas-fired power generation facility to power aluminum production almost in a self-sufficient manner[15)], though receiving a little electricity supply from the outside -- Dubai Electricity and Water Authority (DEWA). The plant's generating efficiency was 44.4% (on a sending end, lower calorific value basis) in 2012. In the year, the facility generated 16,300 gigawatt-hours (GWh) in electricity for aluminum production totaling 1.05 million tons. The

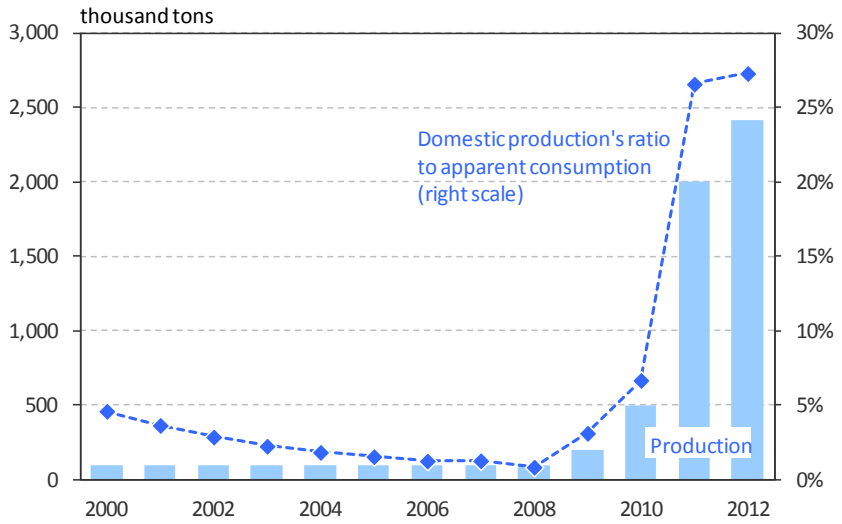
company thus consumed 144 GJ per ton of aluminum output (on a higher calorific value basis) in power generation fuel. The power consumption was combined with other energy consumption into 164 GJ/t (on a higher calorific value basis). Electricity for electrolyzation accounted for 14.7 megawatt-hours per ton (MWh/t) of the electricity consumption intensity at 15.5 MWh/t.

If EMAL's production efficiency were the same as DUBAL's, the UAE aluminum industry's electricity consumption would have totaled 28,800 GWh in 2011, with other energy consumption in the industry coming to 1,300 ktoe. On an oil equivalent basis, the industry's combined energy consumption comes to about 3,800 ktoe, amounting to 13% of the UAE industry sector's energy consumption in the IEA statistics.

The above electricity consumption far exceeds 9,200 GWh given as the UAE industry sector's consumption in the IEA statistics. Although the energy balance tables should include energy consumption for private power generation into consumption in the energy transformation sector, the IEA statistics have failed to do so. Although power generation in the IEA statistics should combine generation by electric utilities with private generation, UAE power generation is given by the IEA statistics as 97,728 GWh for 2010 and 99,137 GWh for 2011, close to 97,339 GWh for 2010 and 104,142 GWh for 2011 as announced by the UAE Ministry of Energy as total generation of ADWEA, DEWA, SEWA and FEWA (as described later). Therefore, the IEA-given UAE power generation can be interpreted as excluding private power generation in aluminum and other industries. Apparently, fuel consumption for private power generation in the aluminum industry might have been included into natural gas consumption in the non-specified industry category. If this is the case, the aluminum industry's energy consumption might have totaled 6,500 ktoe accounting for some 21% of the industry sector's total consumption, as losses through power generation might have been included into the industry sector's energy consumption.

(c) Steel industry

Figure 2-8 indicates the UAE's crude steel production trends. The UAE had depended on imports for most of its steel supply. From 2006, however, Emirates Steel under the umbrella of state-run General Holdings Corporation (SENAAT) implemented a facility expansion program to construct an annual capacity of 2.2 million tons for direct reduction iron production in the first phase and that of 2 million tons in the second phase. They were completed in 2009 and 2011, respectively, expanding the company's overall capacity substantially. It is proceeding with the third-phase capacity expansion plan[16].



Source: World Steel Association[17]

Figure 2-8 Crude Steel Production

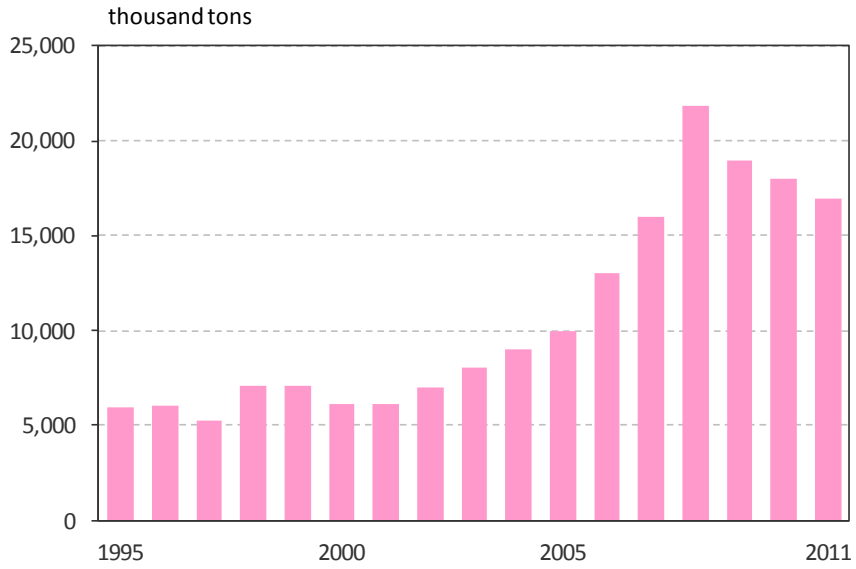
The IEA energy balance table does not specify energy consumption in the UAE's steel industry. Given the direct reduction steelmaking process's standard energy consumption including 15.9 GJ per ton of crude steel in non-electricity

(natural gas) input and 2.5 GJ per ton in electricity input[18], the steel industry's energy consumption in 2011 is estimated at 880 ktoe comprising 760 ktoe in natural gas and 120 ktoe in electricity. The consumption amounts to about 3% of the industry sector's total energy consumption.

(d) Cement industry

The long-existing cement industry in the UAE includes some 10 UAE cement makers[19] and some foreign companies such as Lafarge of France and Cemex of Mexico. Under a joint venture with Dubai investment firm Dubai Group and the Fujairah government, Lafarge has a cement plant with an annual production capacity of 3.2 million tons in Fujairah. Cemex owns a grinding mill with an annual capacity of 1.6 million tons.

Figure 2-9 indicates the UAE's cement production trends. Cement output rapidly expanded in line with fast economic growth until 2008 before stagnating from 2009. Nonetheless, production levels in recent years were still higher than in the early 2000s.



Source: U.S. Geological Survey[14]

Figure 2-9 Cement Production

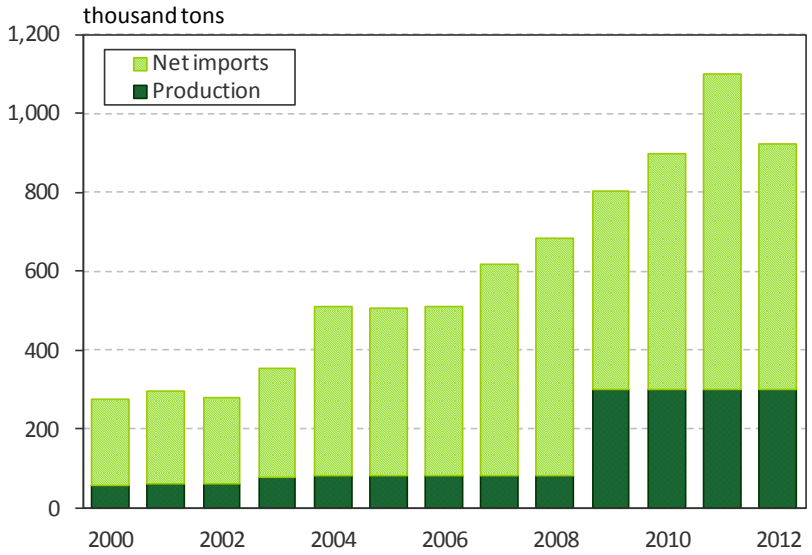
The IEA energy balance table specifies only bituminous coal consumption for the non-metallic minerals category including the cement industry. The consumption remained at around 100 ktoe (accounting for some 1% of the UAE industry sector's total energy consumption) between 2002 and 2007 and expanded rapidly to 716 ktoe (accounting for 3% of the total) in 2010 and to 1,250 ktoe (4%) in 2011. Energy consumption per ton of cement output came to 0.6 GJ between 2002 and 2007, 1.7 GJ in 2010 and 3.1 GJ in 2011.

Fujairah Cement puts energy consumption for cement production at about 6 GJ/t[20]. According to the IEA, the cement industry's energy consumption intensity was 3.5 GJ/t on a world average basis for 2009, close to levels for Lafarge and Cemex[21][22]. The abovementioned energy consumption in the non-metallic minerals category is divided by cement output to get 3.8 GJ/t for 2011. Given these points, the IEA statistics before 2011 are interpreted as including only a small part of the cement industry's energy consumption into the non-metallic minerals category, falling short of giving any accurate data. For 2011 as well, the IEA statistics might have covered only bituminous coal consumption in the cement industry and included the industry's other energy consumption into consumption in the non-specified industry category.

Based on the abovementioned energy consumption intensity, the average intensity for cement production is assumed at some 5 GJ/t here. In this case, the cement industry's energy consumption in 2011 comes to 2,000 ktoe accounting for about 7% of the UAE industry sector's total energy consumption.

(e) Paper industry

Figure 2-10 indicates paper and paperboard output and their net imports in the UAE. Paper demand in the UAE has increased along with population and economic sizes. The UAE had traditionally depended on imports for most of its paper supply before boosting domestic output in recent years. Its paper and paperboard output in 2012 totaled 300,000 tons. Like other Middle Eastern countries, however, the UAE still depends on imports for most of its pulp supply.



Source: FAOSTAT[23)]

Figure 2-10 Paper and Paperboard Output and Net Imports

Despite the fact that paper and paperboard production is implemented in Saudi Arabia, Iran and other countries as well as the UAE, the IEA statistics has failed to specify energy consumption in the paper, pulp and print industry for any of non-OECD Middle Eastern countries.

If paper industry energy consumption in the world in 2011 is divided by paper and paperboard output to get the average energy consumption intensity, the intensity can be multiplied by the UAE's output to estimate the UAE paper industry's energy consumption at 118 ktoe accounting for some 0.4% of the UAE industry sector's total energy consumption. Given that the UAE produces no pulp domestically as mentioned above, the UAE paper industry's energy consumption may be assumed as smaller than the estimate.

(f) Conclusion

The UAE industry sector consumed 30,063 ktoe in energy in 2011. In addition, the energy transformation sector consumed 245 ktoe in refinery gas at oil refineries and 634 ktoe in natural gas at LNG plants. The former may cover Dubai, Fujairah and Sharjah refineries as well as ADNOC (TAKREER) refineries. The latter may be included into energy consumption at the ADNOC group's ADGAS and some others.

An attempt to estimate a breakdown of the UAE industry sector's final energy consumption is as follows: ADNOC's energy consumption is outlined in ADNOC's report titled "Strengthening Our Energy Presence – Sustainability Report 2012[13)]". Its energy consumption at 468 PJ in 2011 includes 60 PJ for "marketing and refining." This may cover not only in-house consumption for oil refining as mentioned above, but also consumption for distribution by ADNOC Distribution and international transport by ADNATCO and NGSCO. Most energy consumption for distribution and transport might have been included into consumption for the transport sector and the international bunker. This energy consumption is deducted from ADNOC's final energy consumption estimate. Energy consumption totaling 634 ktoe for natural gas liquefaction is also deducted. Although energy consumption for crude oil and natural gas production should be included into consumption for "oil

and gas extraction" in the energy transformation sector instead of the industry sector in the IEA energy balance tables, the IEA gives this consumption as zero. Therefore, in this study, energy consumption for crude oil and natural gas production is assumed to be included along with other consumption at ADNOC into the industry sector in the IEA statistics. Assuming that energy consumption in the ADNOC Sustainability Report is on a higher calorific value basis, energy consumption data in the ADNOC report are multiplied by 0.9.

The aluminum industry's energy consumption including fuel (natural gas) input to private power generation is assumed as being included into the industry sector as mentioned in Section 2-5-1 (b). The steel, cement and paper/paperboard industries are also assumed as having consumed energy as estimated above. As a result, the UAE industry sector's energy consumption breakdown in 2011 is estimated as shown in Figure 2-11. The oil and natural gas, and aluminum industries account for a large part of the sector's total consumption. Industries other than those specified below capture some 41% of the total.

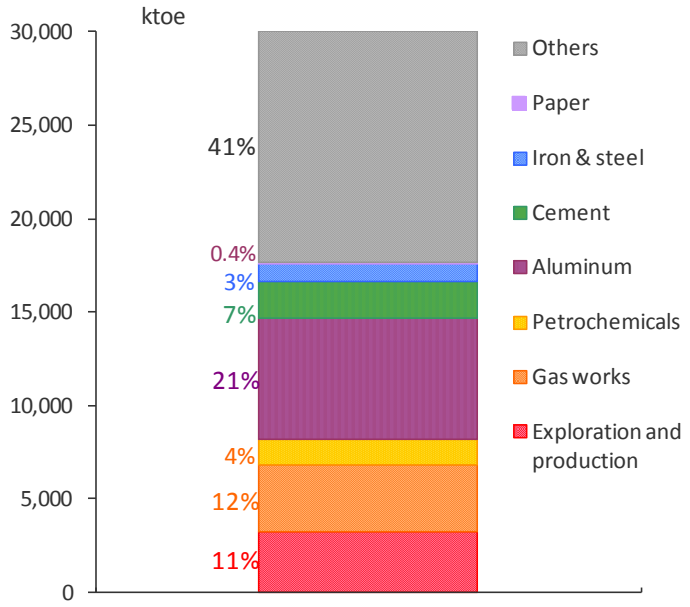


Figure 2-11 Breakdown of UAE Industrial Sector Energy Consumption (2011)

2-5-2 Transport sector

The IEA energy balance tables give the transport sector's energy consumption in 2011 as 10,391 ktoe, of which domestic aviation accounts for 5.6% or 584 ktoe and road transport (automobiles and motorcycles) for the remaining 9,807 ktoe. As for railway transport, the Dubai Metro network built by Japanese firms launched services in 2009. But its energy consumption is not included into the transport sector, at least not into the railways sector, in the IEA energy balance tables.

The UAE has a domestic air transport company named Rotana Jet, with transport demand increasing. But air transport's share of overall transport is limited as people can use automobiles to move from one city to another. Although international flights to and from the UAE are abundant and expected to increase, energy consumption for international air services is classified as the international bunker left out of national energy consumption. Accounting for most of the transport sector's energy consumption is road transport with automobiles and motorcycles. Gasoline captures 47% of energy consumption for road transport and diesel oil 53%. According to Abu Dhabi government's data[24], motorcycles account for 0.9% of the total auto fleet, passenger cars for 87.6%, buses for 2.2%, trucks for 5.6% and heavy mechanical equipment for 3.7%.

2-5-3 Buildings sector

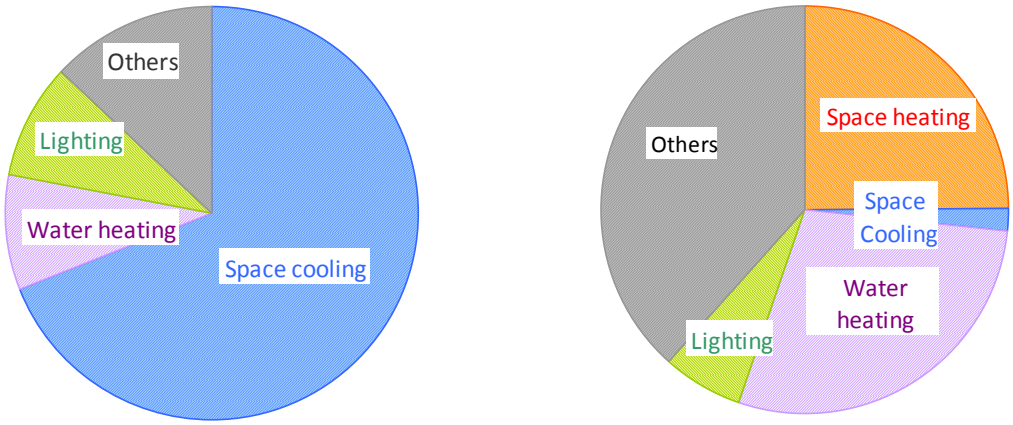
The UAE buildings sector ("Other" sector in IEA energy balance tables, including residential, commercial and other sectors) in 2011 consumed 6,388 ktoe in energy, including 2,411 ktoe for the residential subsector, 2,405 ktoe for the commercial subsector and 1,571 ktoe for the non-specified subsector. Electricity accounted for 89% of residential energy consumption (with LPG accounting for the remaining 11%), for 100% of commercial consumption and 96% of non-specified consumption (with imported charcoal accounting for the remaining 4%). Persian Gulf countries feature electricity' higher shares of the buildings sector's energy consumption. The share stands at 90% for Saudi Arabia and 94% for Qatar and Kuwait, compared with Japan's 47%, the OECD average of 42% and the world average of 29%. (The low world average is attributable to massive non-commercial biomass energy used in developing countries.)

The IEA statistics give the UAE's final electricity consumption in 2011 as 79,895 GWh, nearly 20% less than 95,508 GWh as reported by the UAE Ministry of Energy. One reason for the gap may be that the latter includes power plants' in-house consumption that the former does not cover. The former covers the industry, the residential, the commercial and public services and the non-specified, while the latter consists of the industry, the residential, the commercial and others that correspond roughly to the four components of the former. The "others" in the Ministry of Energy statistics are described as including power plants' in-house consumption, mosques, police stations, government-related hospitals and education facilities[25]. They should be included into the "commercial" subsector in the IEA energy balance tables. Given these points, this study interprets that the energy consumption in the "non-specified" subsector of the IEA statistics should properly be included in the commercial subsector. Since the residential subsector's electricity consumption is 25,070 GWh in the IEA statistics against 33,502 GWh in the Ministry of Energy statistics, however, we should remember that the subsector's actual energy consumption could be larger than the consumption given as for the residential subsector in the IEA statistics.

The UAE's electricity consumption features a very high share for air-conditioning (space cooling) demand. Air-conditioning demand accounts for 70% of the residential subsector's electricity consumption and lighting demand for 10%[26][27]. Therefore, improving the efficiency of air-conditioning equipment and buildings' insulation performance can bring about the largest effect among energy conservation measures.

Air-conditioning demand's high share of residential and commercial energy consumption may be common to Persian Gulf countries. For example, a local interview-based survey[28] in Qatar found that air-conditioning demand captured 54% of residential electricity consumption and 55% of commercial and administrative consumption. But the percentage for the residential subsector is lower than 70% for the UAE. The reason for the gap is that lighting demand's share of electricity consumption is higher at 34% for the residential subsector or 25% for the commercial and administrative subsector.

Lighting electricity demand in the residential subsector as estimated in the "Country Lighting Assessments[29]" by the United Nations Environment Programme is divided by total residential electricity demand in 2011 in the IEA energy balance table to get a share of 11% for the UAE and 10% for Qatar, which are close to each other. For Qatar, residential lighting electricity demand is estimated as 3.0 TWh in the abovementioned survey[28] against 0.48 TWh as estimated in the UNEP assessments[29]. This gap resulted in the difference in the air-conditioning electricity demand share. In this way, electricity demand estimates by use for Gulf countries are still insufficient. Relevant data should be developed further.



Assessments in UAE (covering electricity alone) Japan (FY2009: covering all energy sources)

Sources: Baeza[30], IEEJ[31]

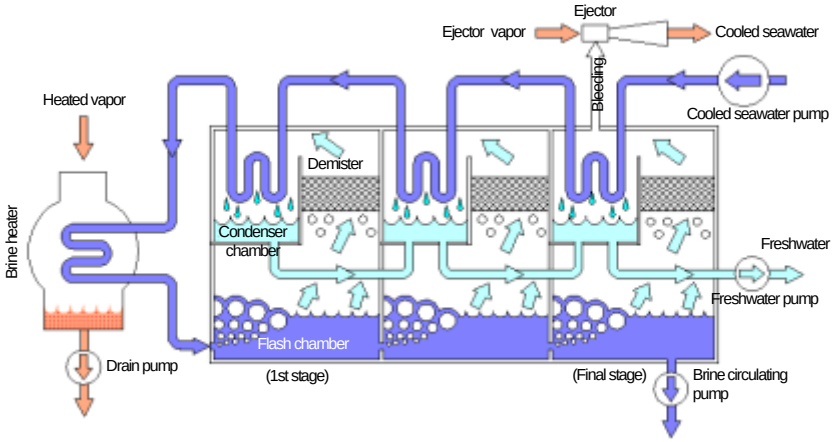
Figure 2-12 Residential Energy Consumption by Use

2-5-4 Power generation sector

(a) Seawater desalination and thermal power generation

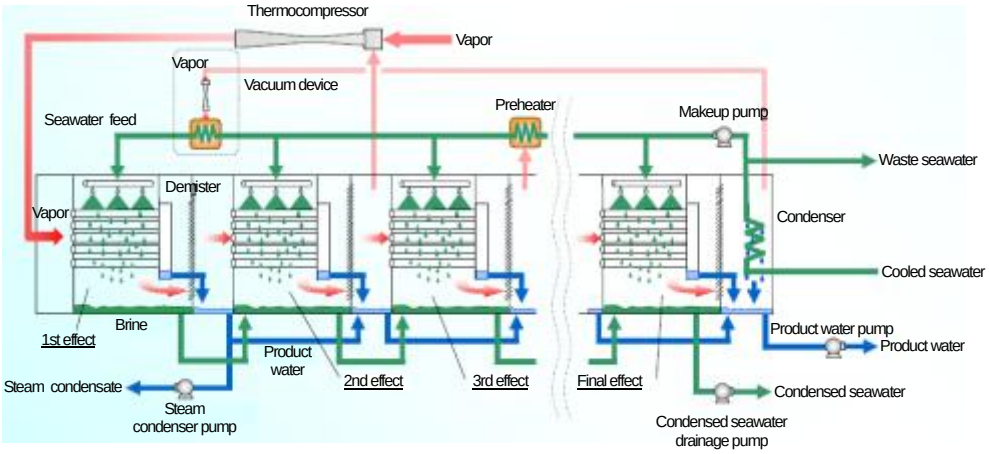
In Middle Eastern countries including the UAE, power generation is closely related to seawater desalination. There are three major seawater desalination methods used in the world -- the multi-stage flash (MSF) method, the multi-effect distillation (MED) method and the reverse osmosis (RO) method. The first two methods heat and evaporate seawater and cool the water vapor into freshwater. The MSF method is the oldest among them and is suitable for mass production of freshwater. In this method, evaporation chambers with different pressures are designed to distill water. The evaporation chambers are heated individually using the MSF method. In the MED method, however, steam generated in the previous stage ("effect") is used for heating the later effects. The MED plant is thus more complicated than the MSF plant, but achieves greater desalination efficiency.

The RO method, for which innovation has made the fastest progress recently, exerts pressure on seawater and leads seawater to pass through osmosis membranes so that mineral salt and other materials are separated. This method has taken advantage of lower initial investment and less energy consumption to expand its share of seawater desalination plants in recent years. Already, the RO method accounts for a half of existing seawater desalination plants and is expected to dominate new ones. As noted later, however, the RO method's adoption has still been limited in the UAE and other Middle Eastern countries where fossil fuel resources are abundant and cheap. The MSF and MED methods still account for most of seawater desalination plants in the Middle East.



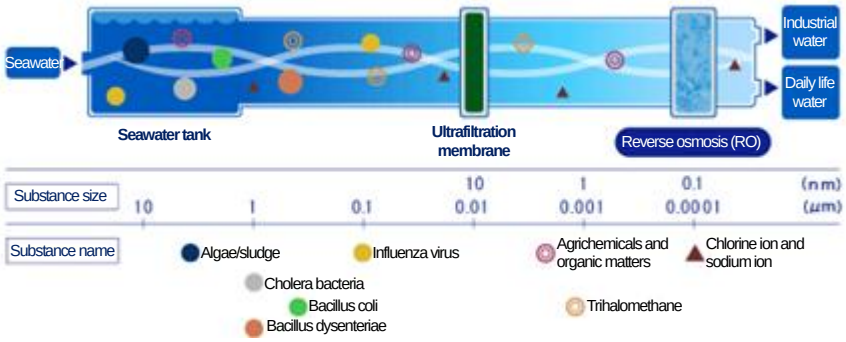
Source: Research Organization for Information Science and Technology

Figure 2-13 MSF (Multi-Stage Flash) Method



Source: Hitachi Zosen Corp.

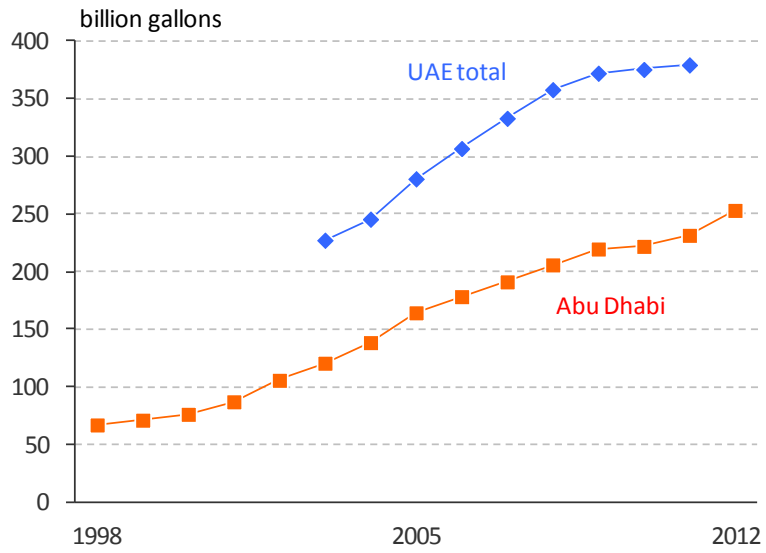
Figure 2-14 MED (Multi-Effect Distillation) Method



Source: Toray Industries Inc.

Figure 2-15 RO (Reverse Osmosis) Method

According to the Abu Dhabi Environment Agency, underground water covered about 65% of the emirate's water demand totaling 3.4 billion cubic meters in 2012, being used mainly for agriculture and vegetation. Most of the urban water supply is dependent on freshwater from seawater desalination. Figure 2-16 indicates rapid growth in water production in Abu Dhabi and the UAE.

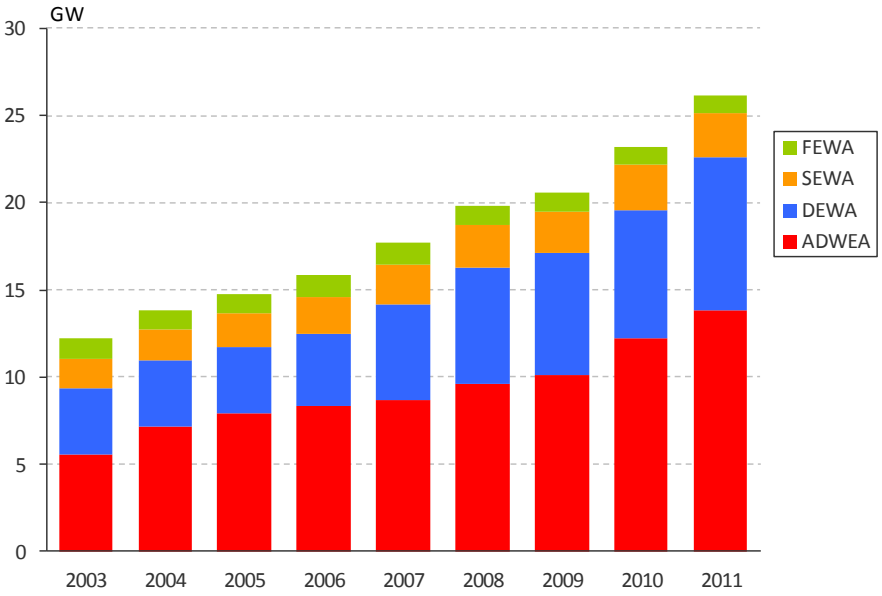


Sources: UAE Ministry of Energy[32], ADWEC[33]

Figure 2-16 Freshwater Production in UAE and Abu Dhabi

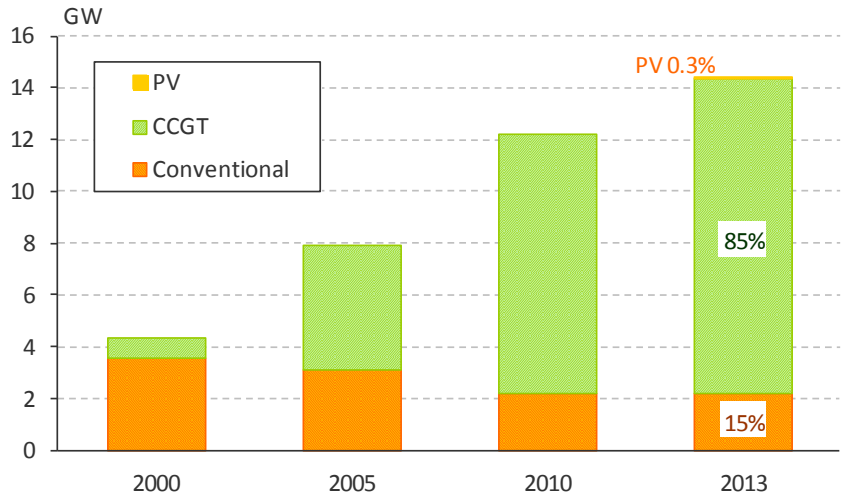
The UAE has traditionally used natural gas for power generation and waste heat from power generation for seawater desalination. Power generation has been controlled by the Abu Dhabi Water and Electricity Authority (ADWEA), the Dubai Electricity and Water Authority (DEWA), the Sharjah Electricity and Water Authority (SEWA) and the Federal Electricity and Water Authority (FEWA). Under the ADWEA is Abu Dhabi Water and Electricity Co. (ADWEC).

As shown in Figure 2-17, the UAE's power generation capacity has expanded along with electricity demand. As of 2011, Abu Dhabi (ADWEA) and Dubai (DEWA) accounted for nearly 90% of the UAE's total power generation capacity. Natural gas-fired power plants account for most of the capacity. Since 2000, these power generation utilities have replaced old plants with CCGT (Combined Cycle Gas Turbine) plants. In 2013, CCGT plants captured 85% of ADWEA's capacity and more than 70% of DEWA's. Solar photovoltaic power generation facilities in Masdar City, which are under construction as an advanced environmentally friendly city in Abu Dhabi, account for 0.3% of the Abu Dhabi power generation capacity.



Source: UAE Ministry of Energy[32]

Figure 2-17 UAE Power Generation Capacity



Source: ADWEC[33)]

Figure 2-18 Abu Dhabi's Power Generation Capacity

UAE power plants are characteristically accompanied by seawater desalination facilities. Most of these desalination facilities had been MSF plants as of 2000. Later, MED plants began to be introduced. Anyway, most seawater desalination plants in the UAE use these evaporation methods now. Meanwhile, recent integrated water and power plants (IWPPs) adopt hybrid desalination facilities and CCGT power generators. For example, the Fujairah F1 IWPP (that started operation in 2004) uses an MSF-RO desalination facility. An MED-RO desalination facility is adopted for the Fujairah F2 IWPP (that started operation in 2011). The F2 consists of 2,000 MW CCGT power generators, 100 MGD (million gallons per day) MED facilities and 30 MGD RO facilities. A reported reason for adopting such hybrid seawater desalination facility is that demand for electricity in the UAE increases in summer due to air-conditioning needs and declines in winter, while demand for water remains unchanged throughout a year. Under such climate, the UAE can satisfy electricity and water demand at the lowest cost by combining an MSF or MED facility producing fresh water in proportion to power generation with an RO facility using generated electricity for desalination[34)].

Given the above, the next chapter compares the Reference Scenario in which highly efficient CCGT-MED IWPPs will satisfy electricity and water demand with the Energy Conservation Scenario in which RO facilities will gradually replace existing desalination facilities.

(b) Power source diversification trends

Another key point regarding the UAE power generation sector is that the UAE is poised to proactively promote nuclear and renewable energy to diversify energy sources. While natural gas-fueled power plants are dominant in the UAE at present, Abu Dhabi plans to increase the power generation share to 25% for nuclear energy and 7% for renewable energy by 2020. Dubai aims to raise the power generation share to 12% for nuclear energy, 5% for renewable energy and 12% for coal by 2030.

As for nuclear power generation, Abu Dhabi is going ahead with the construction of four reactors with a total power generation capacity of 5.6 GW. It launched the construction in 2012 in cooperation with South Korea. Given that the UAE is the first country to introduce nuclear energy in the Middle East excluding Iran, however, it may take more time than expected to create institutions for operating nuclear power plants, for example. Some delay in the nuclear plant construction project is thus possible. Nuclear power generation in Dubai is not assumed in this study, because the plan has made no specific progress yet.

The UAE is proactively promoting research and development on solar PV (photovoltaics) and CSP (concentrated

solar power) among renewable energy sources. Unlike the abovementioned nuclear power generation plan, however, solar power development plans are still in the research and development stage. In the UAE where electricity rates are limited to low levels, constraints on the diffusion of high-cost photovoltaic power generation are greater than in other countries. Therefore, the UAE is assumed to introduce more nuclear energy than renewable energy for the period up to 2030.

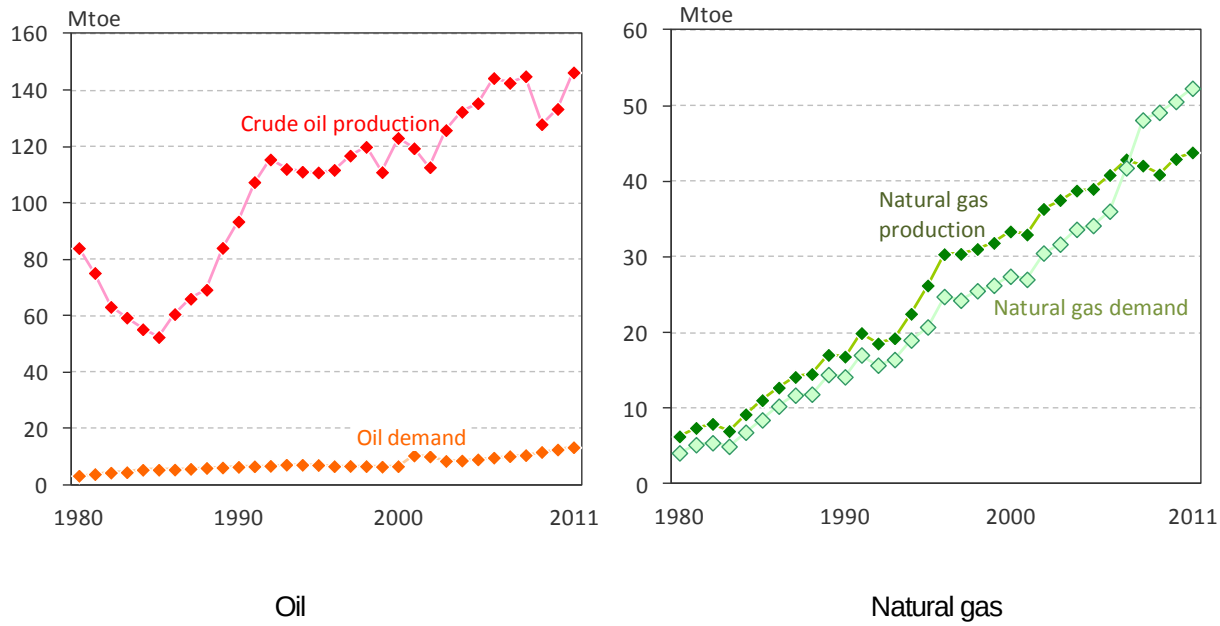
Regarding the diversification of energy sources, attention should also be paid to the fact that the UAE is planning to introduce coal-fired power generation for the first time ever. Specifically, Dubai intends to construct a 1.2 GW clean coal power plant. In addition, Ras al-Khaimah reportedly plans to build a 270,000 kW coal power plant. In this study, the UAE is assumed to gradually introduce coal-fired power generation in line with these plans.

2-6 Historical trends of energy demand and production

The UAE's energy demand has expanded rapidly in line with high economic growth. Particularly, the UAE features massive natural gas consumption, which accounted for 80% of primary energy consumption in 2011.

Figure 2-19 indicates oil and natural gas production and demand in the UAE. Crude oil output has continued increasing since the mid-1980s, which have supported the UAE economy. But domestic oil demand has also been increasing, with its ratio to crude oil output rising from 4% in 1980 to 9% in 2011.

Natural gas output had continued increasing together with demand, while exceeding demand. In 2008, however, natural gas demand surpassed domestic output, with the UAE becoming a net natural gas importer. The UAE still continues exporting liquefied natural gas to Japan and some other countries under long-term contracts. But attention is being paid to whether ADGAS's LNG supply contract with Tokyo Electric Power Co., set to expire in 2019, could be renewed or not. A great matter of concern regarding future natural gas supply and demand is how energy conservation measures could reduce natural gas consumption.



Source: IEA[1)]

Figure 2-19 UAE Oil and Natural Gas Supply and Demand

3. Energy Supply and Demand Outlook through 2030

Given the abovementioned situations, this study estimates the UAE's energy supply and demand over a long term through 2030. Section 3-1 analyzes the Reference Scenario, where the current energy supply and demand trends will continue. Next, Section 3-2 assesses effects of energy conservation measures and carbon reduction technologies in each sector (Energy Conservation Scenario).

Economic growth, population and car ownership assumptions are set as described in Chapter 2. Based on the IEEJ Asia/World Energy Outlook 2013[2)], the fossil fuel prices are assumed to rise from $115/barrel in 2012 to $122/barrel (in 2012 dollars) in 2030 for crude oil, fall from $16.7/MBtu to $14.0/MBtu for natural gas and increase from $134/ton to $141/ton for steam coal. The natural gas price is for exports to Asia. In other words, in this study, the UAE is assumed to export more LNG to Japan and other Asian countries and get more revenues if its domestic gas consumption declines.

3-1 Reference Scenario

3-1-1 Final energy consumption

Figure 3-1 indicates an outlook for final energy consumption. Consumption in 2011 totaled 48.7 Mtoe (million tons of oil equivalent), of which the industry sector (including non-energy use) accounted for 66%, the transport sector for 21% and the buildings sector for 13%. The industry sector's energy consumption increased drastically from 2005 to 2011 and is projected to continue expanding in line with economic growth and new petrochemical plants' operation. As population and income grow, the buildings and transport sectors will also increase energy consumption.

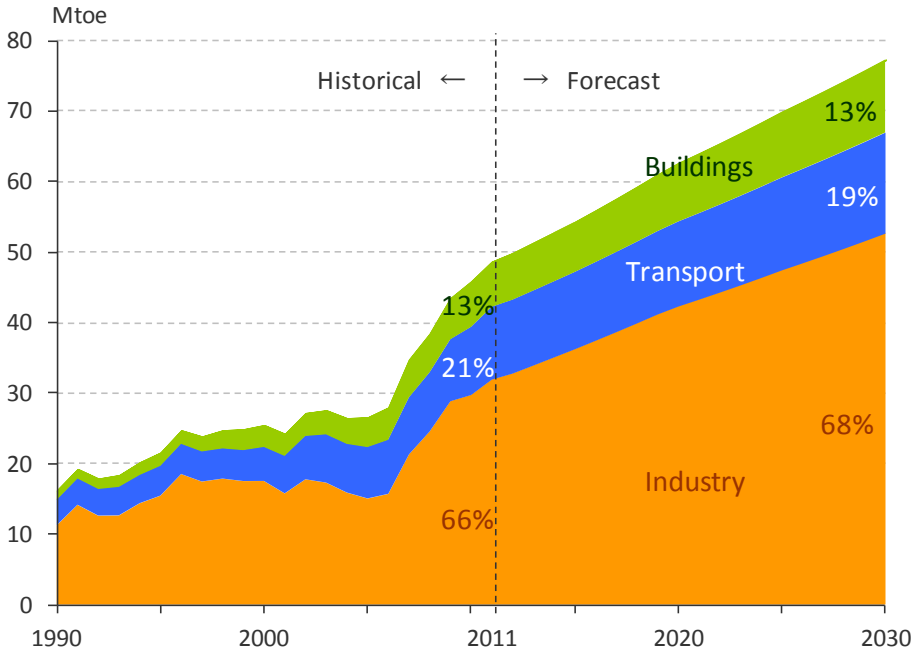


Figure 3-1 Outlook for Final Energy Consumption

Figure 3-2 shows the buildings sector's energy consumption by energy source. As of 2011, electricity accounted for 96% of the sector's energy consumption and oil for 4%. Electricity thus covers almost all energy supply at households and buildings (such energy mix is seen in many Middle Eastern countries). In the future, the buildings sector's energy consumption will continue to concentrate in electricity. At the same time, the buildings sector accounted for nearly 90% of electricity demand in 2011, as indicated in Figure 3-3.

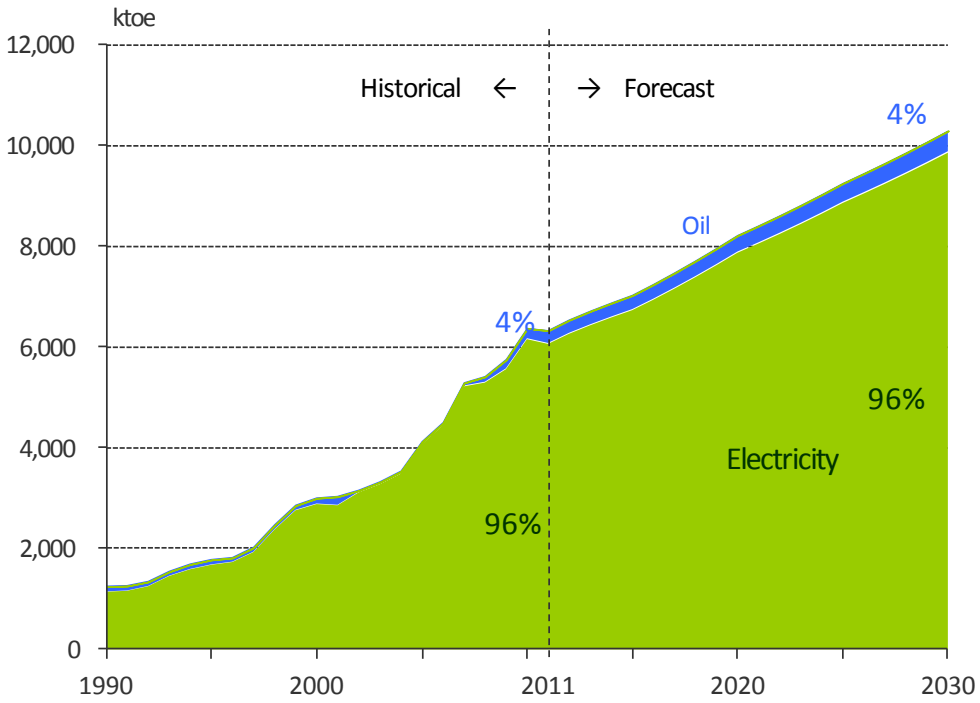


Figure 3-2 Outlook for Buildings Sector Energy Consumption

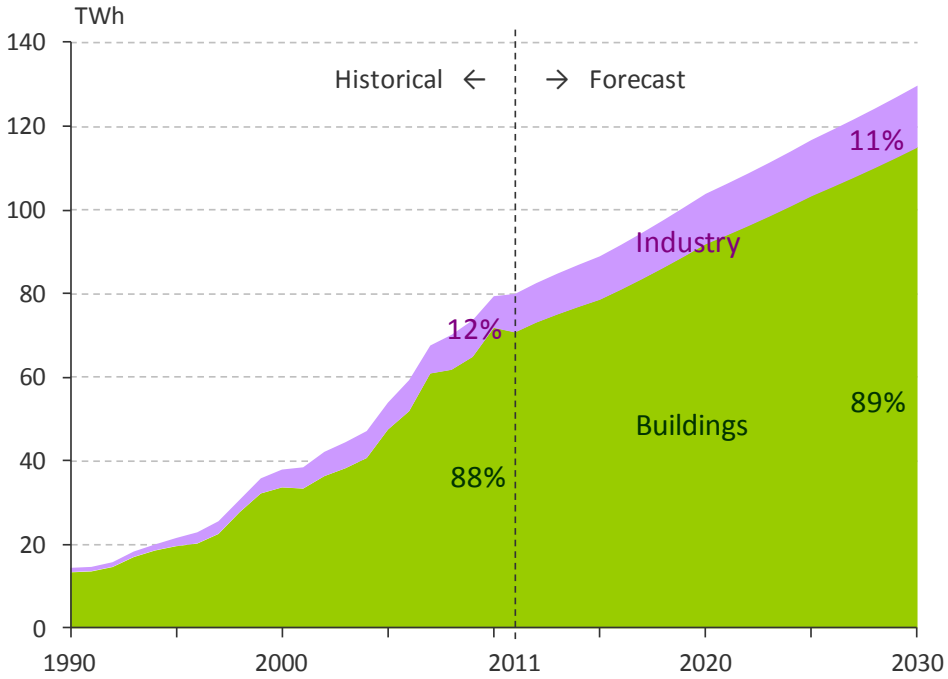


Figure 3-3 Outlook for Electricity Demand by Sector

3-1-2 Electricity mix

Figure 3-4 indicates an electricity mix outlook for the UAE. Power generation will increase 1.5-fold from 103 TWh in 2011 to 156 TWh in 2030 in the Reference Scenario. In 2030, natural gas will still be dominant as fuel for power generation. But nuclear energy will capture 25% of power generation with four reactors. Coal-fired thermal power generation will account

for some 6%. The renewable energy-based power generation is assumed to reach 0.9 TWh by 2030, centering on solar photovoltaics.

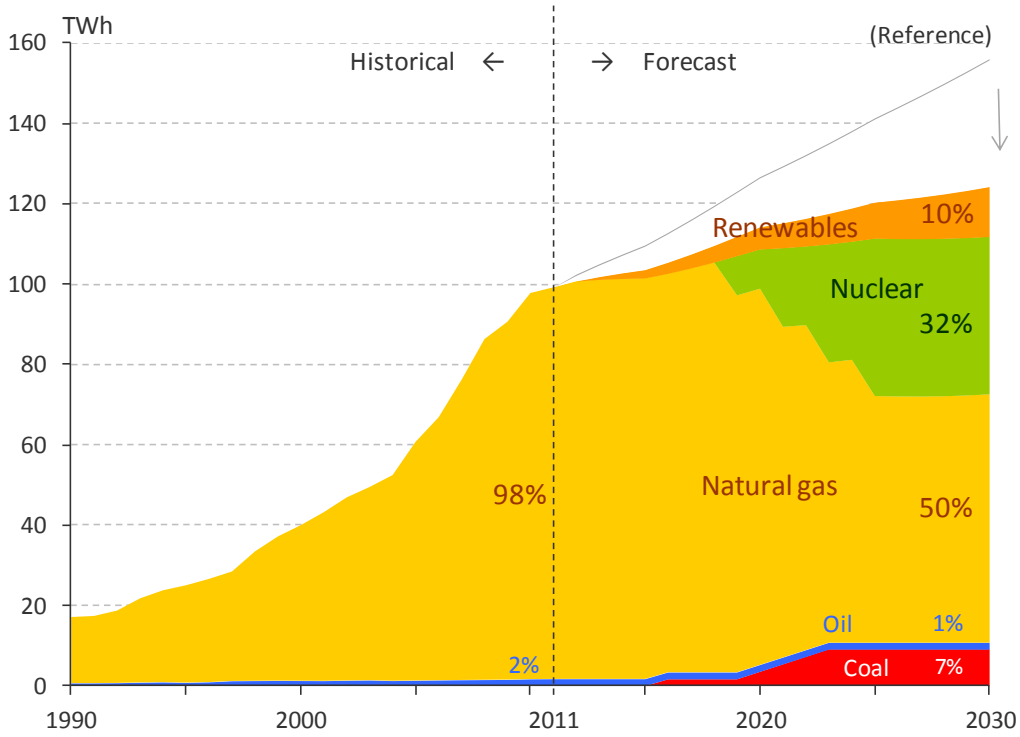


Figure 3-4 Projected Electricity Generation Mix

3-1-3 Primary energy consumption

Figure 3-5 indicates an outlook for primary energy consumption (or supply). Energy demand will expand in line with economic and population growth. As population growth slows down, however, the energy demand increase will not be as rapid as seen in the second half of the 2000s. In the Reference Scenario, primary energy consumption will expand from 66 Mtoe in 2011 to 99 Mtoe in 2030.

In 2011, natural gas accounted for 79% of primary energy consumption in the UAE and oil for 20%. The UAE's heavy dependence on natural gas will continue in the future. Nuclear power generation is assumed to start around 2020. If only the planned four reactors are assumed to become operational, nuclear energy's share of primary energy consumption will be around 10% in 2030.

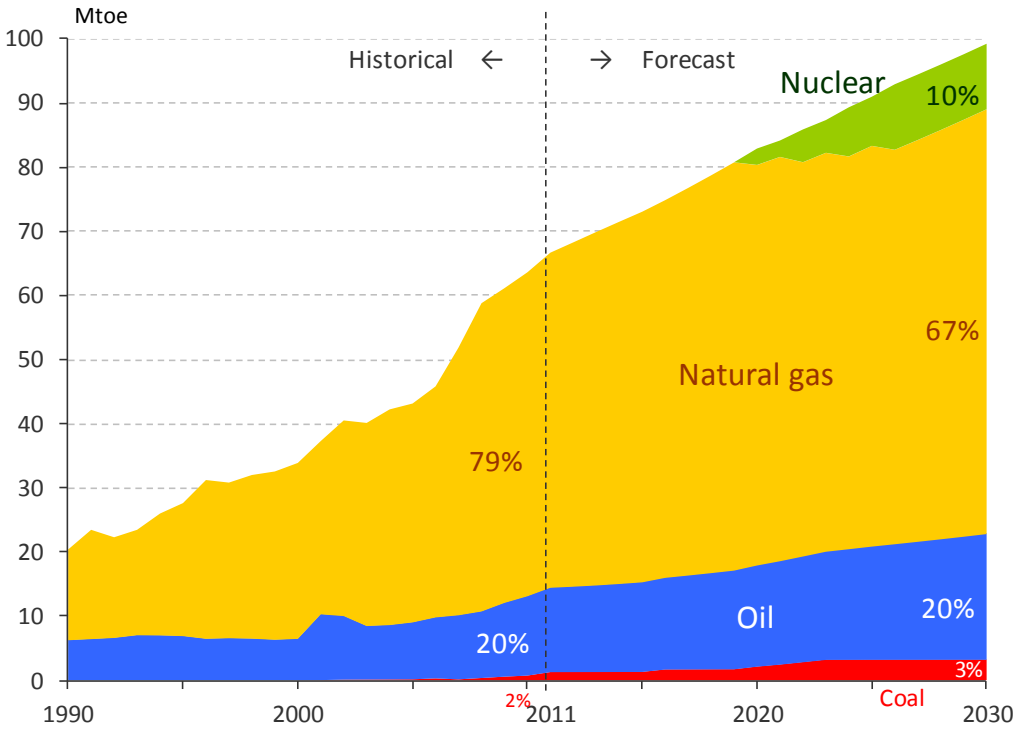


Figure 3-5 Outlook for Primary Energy Supply

As the vehicle ownership expands, oil consumption will also increase (Figure 3-6). In 2011, oil final consumption totaled 13 Mtoe, of which the transport sector accounted for 77%. On a primary consumption basis, the overall picture will remain almost the same as in Figure 3-6, though with a little consumption in the power generation sector and some statistical errors.

As the transport sector expands energy consumption in line with increasing vehicle ownership, oil demand in 2030 will reach 20 Mtoe, of which the transport sector will account for 72%. In the Reference Scenario, no large-scale diffusion of electric vehicles is assumed.

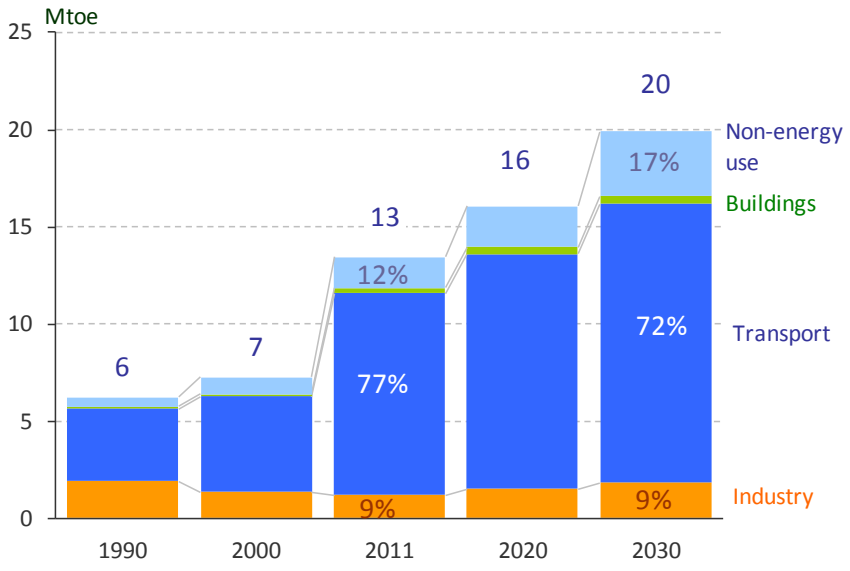


Figure 3-6 Outlook for Oil Final Consumption by Sector

Figure 3-7 indicates an outlook for natural gas consumption. Natural gas consumption in 2011 totaled 52 Mtoe, of which the power generation sector accounted for 48% and the industry sector for 51%. While the industry sector will expand energy consumption in the future, natural gas consumption in the power generation sector will post no sharp growth due to the introduction of nuclear power generation and the improvement of efficiency in natural gas-fired thermal power generation. Therefore, natural gas consumption growth will not be as large as oil consumption growth. Nevertheless, it will be 3.3 times as much as oil consumption. The UAE will thus remain heavily dependent on natural gas.

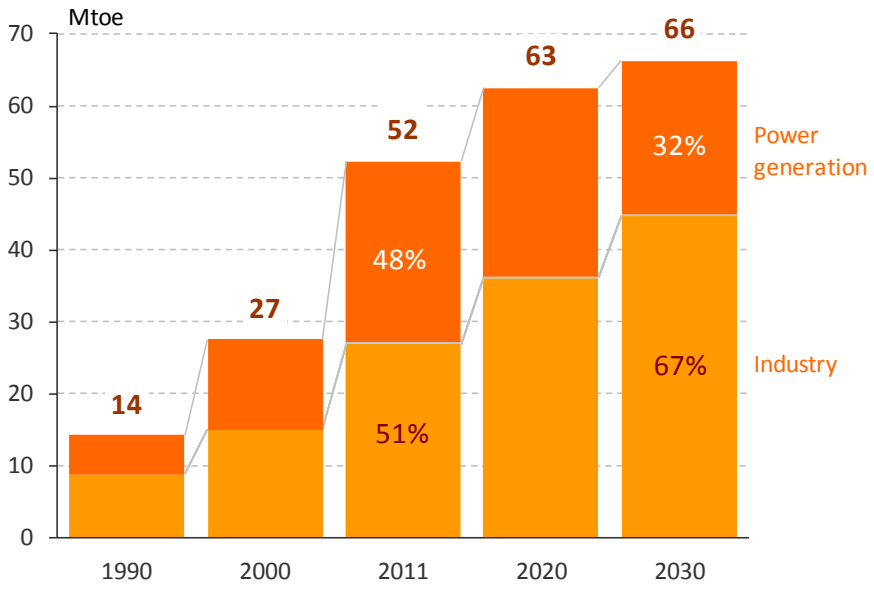


Figure 3-7 Outlook for Natural Gas Primary Consumption by Sector

3-2 Energy Conservation Scenario

In contrast to the Reference Scenario as described in Section 3-1, this section describes a scenario for the diffusion of various energy conservation and low-carbon technologies and assesses the effects of the diffusion (the Energy Conservation Scenario). Assumptions for the scenario are as follows:

3-2-1 Technology introduction assumptions

(a) Industry sector

The introduction of energy conservation technologies through 2030 is assumed as follows:

(i) Oil and natural gas industry

ADNOC, which is dominant in the UAE's industry sector, has given priority to environmental protection and energy conservation initiatives, spending 387.5 million dirhams (1 dirham is equal to about $US0.27) on widely-defined environmental conservation measures in FY2012. Of the spending, 19% was for "energy and emissions." Its 2011 sustainability report noted that the ADNOC group would raise its overall energy efficiency 25% by 2035. In the Energy Conservation Scenario, the ADNOC group is assumed to achieve the energy efficiency improvement target by continuing investment at the present pace.

(ii) Steel industry

Based on the literature[18)], the steel industry is assumed to introduce more efficient direct reduction steelmaking equipment (fuel input at 12.1 GJ per ton of crude steel and electricity input at 2.5 GJ per ton).

(iii) Other industries

As for the aluminum industry's electricity consumption and the cement and paper industries' energy consumption, IEA[35] is referred to regarding future energy intensity improvements and their costs. The aluminum industry's private power generation efficiency is assumed to increase at the pace of DUBAL's past efficiency improvement[15]. Other industries are assumed to raise their energy consumption efficiency by an average 7% through 2030, based on the literature[36].

(b) Transport sector

In 2007, Abu Dhabi started domestic automobile production. But the UAE's automobile industry is still in the development stage, while the fast increase in the auto fleet is covered by imported vehicles. However, the UAE could promote energy conservation in the transport sector by increasing the diffusion rate of next-generation vehicles including hybrid vehicles, electric vehicles and fuel cell vehicles. In Masdar City under construction in Abu Dhabi, electric vehicles have already been introduced.

In this study, the effects of massive introduction of electric vehicles are estimated. Specifically, costs and fuel efficiency are assumed based on the literature[37], and electric vehicles' share of the overall UAE auto fleet is assumed to reach 20% by 2030. Attention should be paid to the point that vehicle producing countries' technological development and considerable policy support for these vehicles' diffusion in the UAE will be required to achieve the target share.

(c) Buildings sector

As for the buildings sector, the improvements in the efficiency of air-conditioning and lighting equipment, which are expected to make the greatest contribution to energy conservation, are assumed.

Regarding the air-conditioning equipment efficiency improvements, the estimated annual sales shown in Reference 38) and the population outlook described in Section 2-2 are used to calculate the flow/stock of such equipment through 2030. Then, the costs and effects of replacing old air conditioners with efficient ones are estimated. Since accurate efficiency data for existing air conditioners in the UAE are unavailable, they are assumed as the same as those for Qatar given in Reference 28).

Reference 29) is referred to in regard to costs and effects of lighting equipment efficiency improvements.

(d) Energy transformation sector

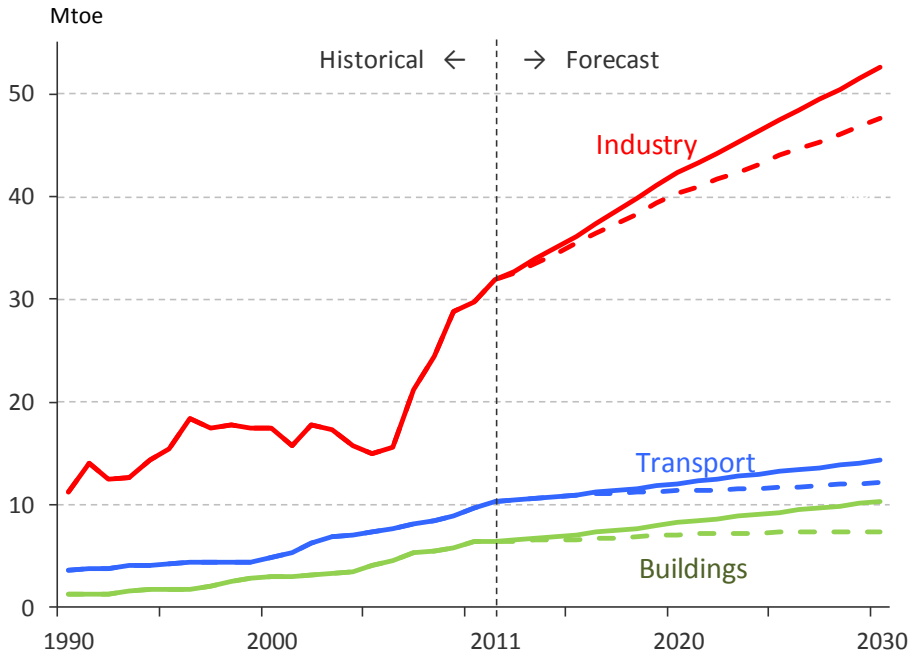
Power generation has the greatest influence within the energy transformation sector. The Middle Eastern countries feature a close relationship between power generation and seawater desalination. In the Energy Conservation Scenario, all seawater desalination facilities for future construction are assumed to adopt the RO method, and their electricity consumption is estimated based on historical data for existing RO facilities at the Fujairah F1 and F2 plants. The additional costs for replacing non-RO desalination facilities with RO facilities are assumed to be zero, and the costs and efficiency for thermal power plants to be built in line with electricity demand growth are assumed based on References 39) and 40).

As for nuclear power generation, the operation of four nuclear reactors under construction or planning is assumed as in the Reference Scenario. Renewable energy is planned to account for 1.5 GW or 7% of the total power generation capacity in Abu Dhabi by 2020 and for 1 GW or 5% of the total capacity in Dubai by 2030. In the Energy Conservation Scenario, the construction of renewable energy (solar PV) power generating facilities is assumed to make rapid progress, boosting renewable energy's share of the UAE's total power generation capacity to 10% (amounting to 8.3 GW in power generation capacity) in 2030. Initial investments for nuclear and renewable power generating facilities are assumed based on References 39) and 40). As for nuclear, particularly, operation/maintenance costs and fuel cycle costs are also taken into account.

3-2-2 Final energy consumption

Given the above assumptions, energy savings and total final energy consumption up to 2030 are estimated as shown in Figure 3-8. In the Energy Conservation Scenario, final consumption in 2030 will be 10% less than in the Reference Scenario in the industry sector, 15% less in the transport sector and 29% less in the buildings sector. Energy consumption will continue expanding mainly in the industry sector even in this scenario.

Total final energy consumption in 2030 in the Energy Conservation Scenario will decline 13% from 77 Mtoe in the Reference Scenario to 67 Mtoe. Even in the Energy Conservation Scenario, final energy consumption will expand 1.4-fold from 2011 by 2030.



Solid line: Reference Scenario
Broken line: Energy Conservation Scenario

Figure 3-8 Outlook for Final Energy Consumption

Figure 3-9 indicates an electricity demand outlook. Electricity consumption will decline by 35 TWh in the buildings sector from the Reference Scenario and by 2 TWh in the industry sector in line with energy conservation promotion while increasing by 9 TWh in the transport sector due to the projected greater diffusion of electric vehicles. Overall electricity demand in 2030 will fall by 28 TWh or 21% from the Reference Scenario. It is not possible to perfectly prevent an electricity demand increase even in the Energy Conservation Scenario.

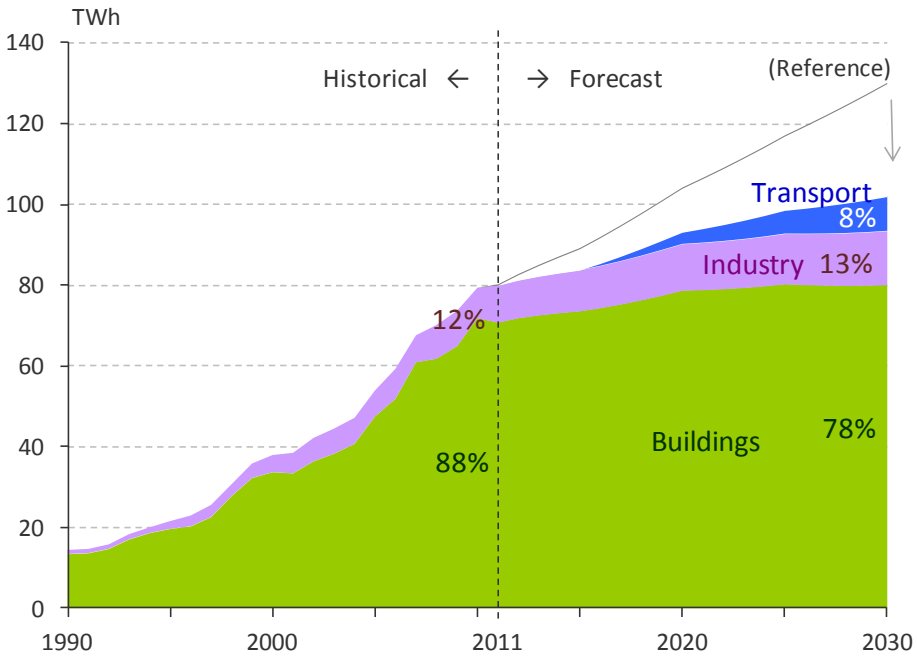


Figure 3-9 Outlook for Electricity Consumption (Energy Conservation Scenario)

3-2-3 Electricity Generation Mix

Figure 3-10 indicates a projected electricity generation mix. In the Energy Conservation Scenario, solar PV is assumed to account for 10% of power generation in 2030. Solar PV, nuclear and promoted energy conservation will be combined to produce a great complex effect in which fossil fuel-fired power generation's share of total generation will decline from almost 100% at present to 58% in 2030, with natural gas-fired generation's share falling to 50%.

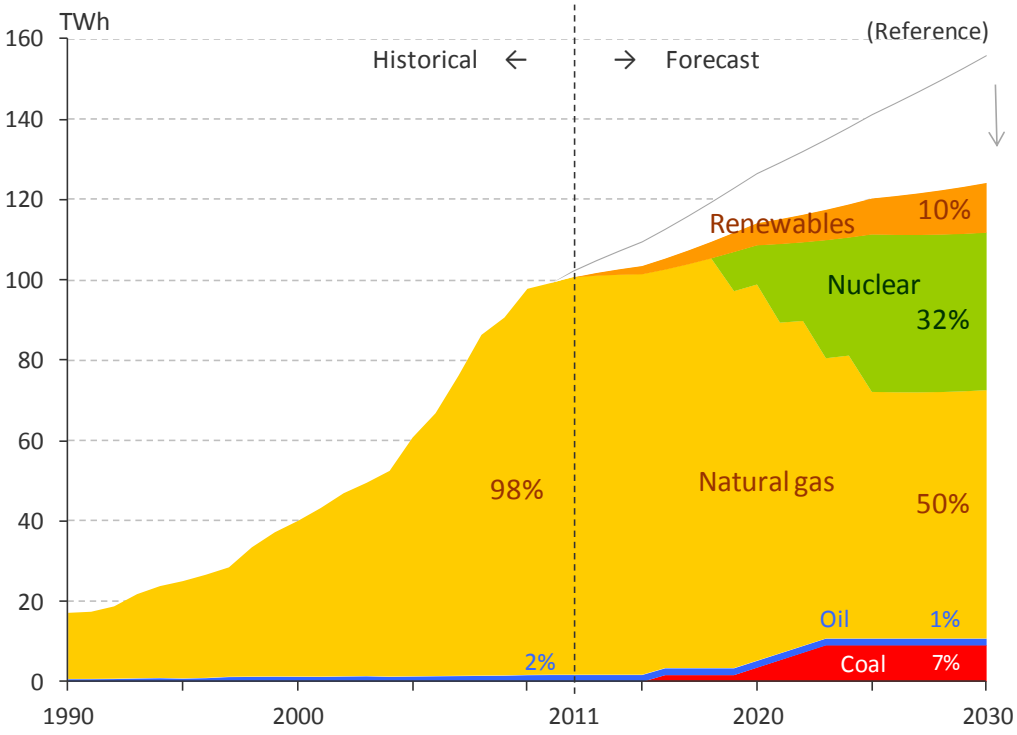


Figure 3-10 Projected Electricity Generation Mix (Energy Conservation Scenario)

3-2-4 Primary energy consumption

As indicated in Figure 3-11, primary energy supply in 2030 in the Energy Conservation Scenario will decline by 16% from 99 Mtoe in the Reference Scenario to 83 Mtoe. As this estimation is based on the IEA energy balance tables that defines the efficiency of solar power as 100%, renewable energy's share of primary energy supply in 2030 will be nominally limited to 1%. But the introduction of renewable energy, combined with nuclear power and energy conservation, will work to substantially reduce consumption of fossil fuels, particularly natural gas. The introduction of electric vehicles in the transport sector will work to moderate oil consumption growth.

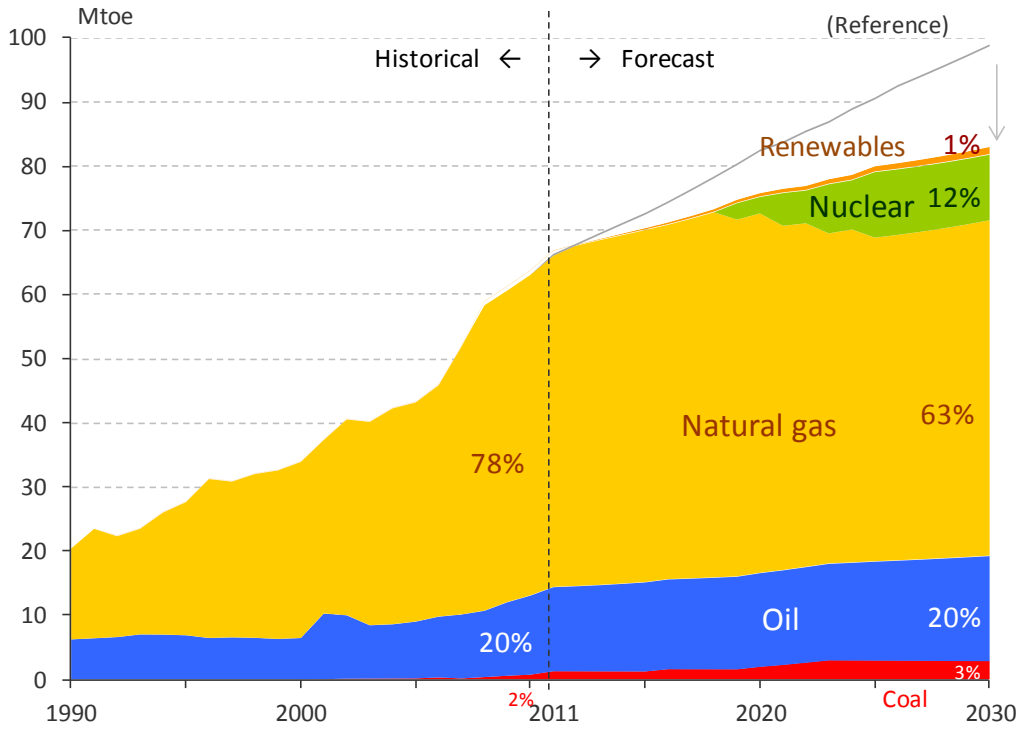
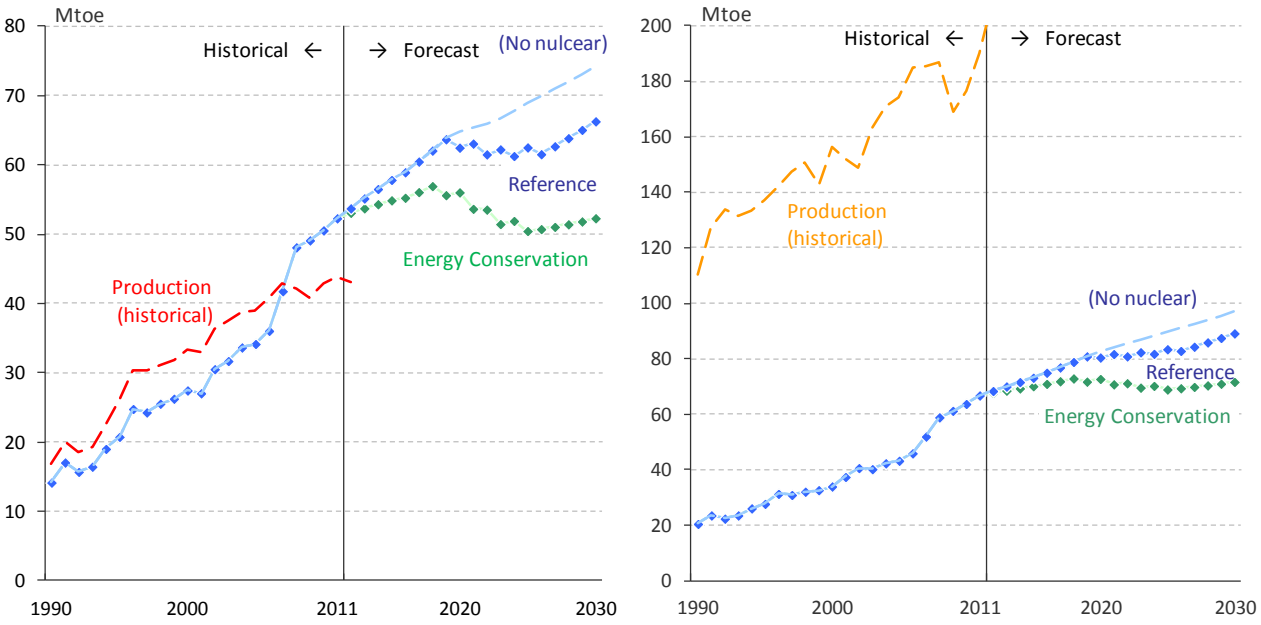


Figure 3-11 Outlook for Primary Energy Supply (Energy Conservation Scenario)

3-2-5 Fossil fuel consumption

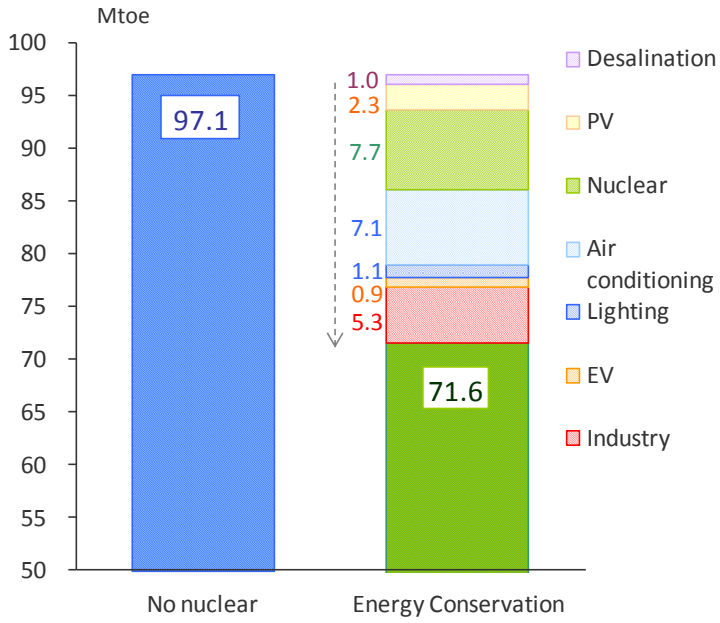
Figure 3-12 indicates a fossil fuel consumption outlook. The UAE economy heavily depends on exports of fossil fuels, particularly crude oil, with fossil fuel output far exceeding domestic consumption. But domestic consumption's share of fossil fuel output rose from 19% in 1990 to 35% in 2011. If domestic demand continues to increase, the UAE will have to continuously expand fossil fuel production in order to maintain its export capacity. As for natural gas alone, exports have accounted for less than 20% of total output. In 2008, the UAE turned a net natural gas importer due to a rapid increase in domestic demand. Whether the UAE will continue to increase net natural gas imports in line with domestic demand growth or expand domestic output to become a net exporter again is a key problem not only for the UAE but also for natural gas importing countries.



Natural gas Total fossil fuels

Figure 3-12 Outlook for Fossil Fuel Consumption

In the absence of progress in energy conservation measures and nuclear power generation ("No-nuclear" in Figure 3-12), the UAE's natural gas consumption will expand 1.4-fold from 52 Mtoe (about 58 Bcm) in 2011 to 74 Mtoe (83 Bcm) in 2030. In the Energy Conservation Scenario in which nuclear and renewable energy will be introduced with energy conservation promoted, natural gas consumption in 2030 will be reduced by 22 Mtoe (24 Bcm) or 30% from the No-nuclear Scenario to the level for 2011. Energy conservation and decarbonization progress will apparently be of great significance for the UAE's future energy supply and demand, and economy.



3-13 Breakdown of Fossil Fuel Consumption Reduction (2030)

The reduction of fossil fuel consumption in the Energy Conservation Scenario is broken down in Figure 3-13. Fossil fuel consumption will be reduced by 25 Mtoe from 97 Mtoe in the No-nuclear Scenario to 72 Mtoe. The largest factor behind the reduction will be nuclear power generation assumed to account for up to 32% of total electricity output in 2030, followed by the improvement of air-conditioning equipment efficiency. The two factors will account for more than half the reduction.

As for nuclear power, the four reactors under construction or planning will be required to smoothly launch operation and continue operating safely. At the same time, in Middle Eastern countries where energy consumption on air-conditioning is massive, the reduction of such consumption has a great effect. In this sense, government-led measures to reduce such consumption are expected to deepen. Figure 3-13 indicates the energy consumption reduction through the diffusion of electric vehicles as relatively small. This is because the introduction of low-carbon electricity sources is counted as nuclear or PV, with the effect of EV diffusion being calculated as a case in which fossil fuel-fired power generation covers an increase in electricity demand. If low-carbon electricity sources including nuclear and renewables cover the increase in electricity demand through the diffusion of electric vehicles, a fossil fuel consumption cut attributable to the electric vehicle diffusion may be much greater.

3-2-6 Energy-related CO_2 emissions

Figure 3-14 indicates an outlook for energy-related CO_2 emissions. In the past, CO_2 emissions rapidly expanded in line with energy demand growth. The emissions soared 3.2-fold from 51 million tons in 1990 to 163 million tons in 2011. If energy conservation makes no progress without the introduction of nuclear energy, the emissions will further increase to 237 million tons in 2030. If carbon reduction and energy conservation make progress, however, the year's CO_2 emissions will be cut by 63 million tons or 26% to 174 million tons, slightly more than in 2011.

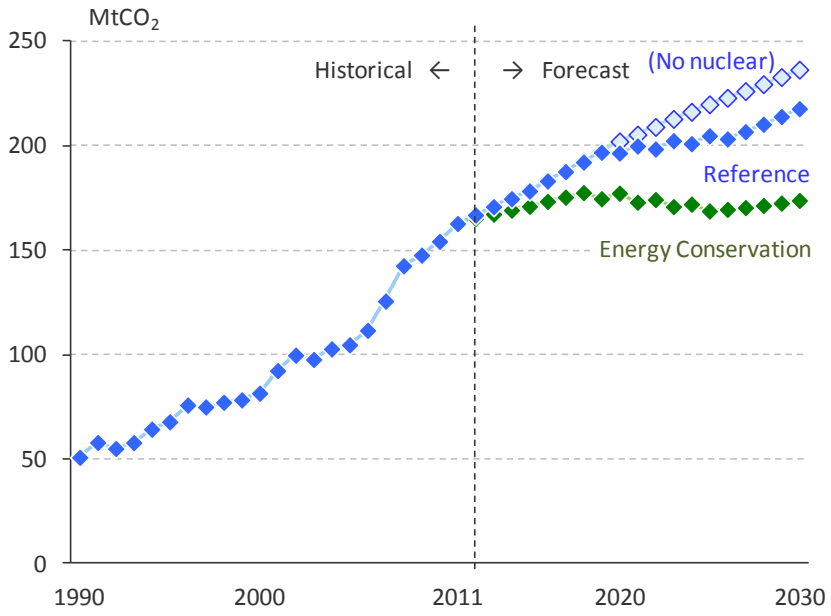


Figure 3-14 Outlook for Energy-related CO_2 Emissions

3-2-7 Costs and benefits of energy conservation measures

Figures 3-15 and 3-16 indicate costs and benefits of measures assumed in the Energy Conservation Scenario. Here, the "costs" mainly consist of additional investments related to the introduction of energy conservation or low-carbon technologies. Costs for nuclear power generation, however, include not only initial investment but also operation/maintenance and fuel supply costs.

As indicated in Figure 3-15, while massive costs are required to implement energy conservation and low-carbon measures every year, fossil fuel consumption savings can produce additional benefits. Since energy conservation and carbon

reduction facilities, once introduced, will be continuously used until their dismantlement, annual benefits will increase gradually in line with their diffusion. Figure 3-16 shows that accumulated costs through 2030 will total $72 billion against $142 billion in benefits, resulting in $70 billion in net benefits with no discount rate taken into account. If a discount rate of 5% or 10% is assumed to convert benefits into present value, the net benefits may become smaller. If a discount rate of 10% is used, the net benefits will turn out to be about $14 billion. Attention should be paid to the point that all measures do not necessarily produce great benefits as the energy conservation or carbon reduction efficiency differs from measure to measure.

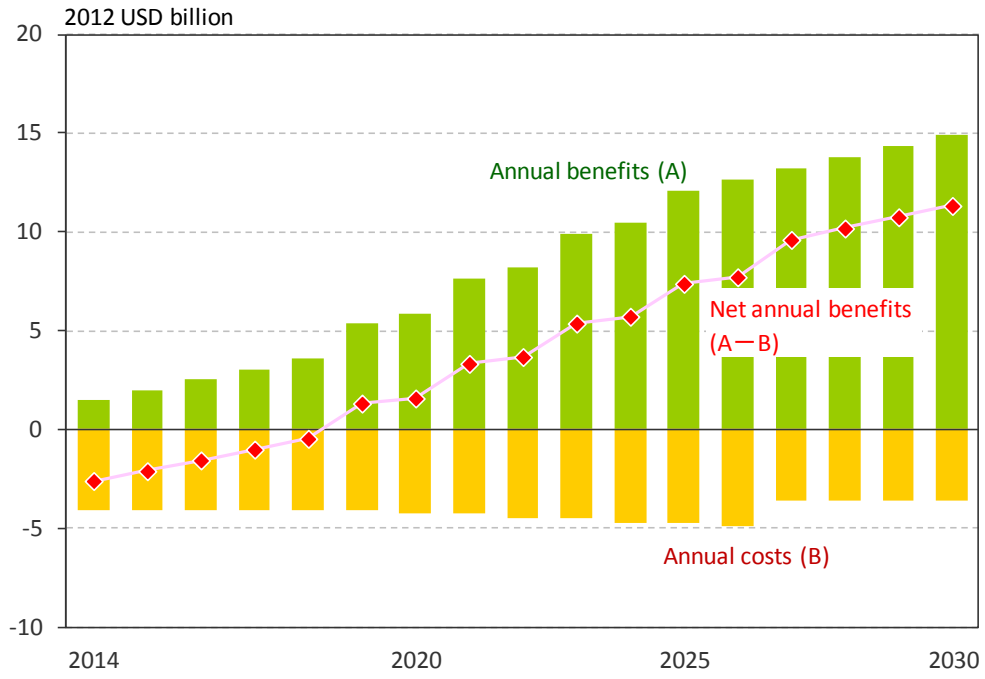


Figure 3-15 Benefits and Costs of Energy Conservation Measures

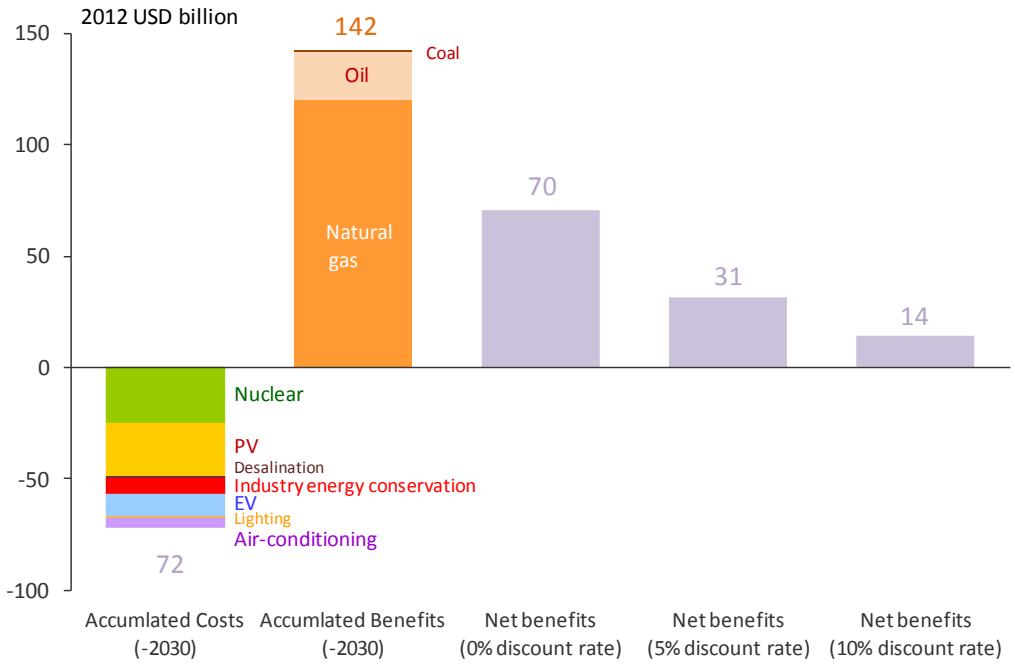


Figure 3-16 Benefits and Costs of Energy (Fossil Fuel) Conservation Measures (accumulated through 2030)

Each measure's costs and benefits are given in Table 3-1. For example, nuclear and solar photovoltaics produce far different energy savings (defined here as fossil fuel consumption cuts) or benefits even if their costs are almost the same. This is because there is greater power generated from a nuclear plant with a certain capacity than from a photovoltaic plant with the same capacity due to the nuclear plant's higher capacity factor, in spite of the higher initial investments and operation/maintenance costs, although it must be kept in mind that nuclear power generation has its own safety challenges. A comparison between costs and benefits indicates that an improvement in air-conditioning equipment efficiency can realize greater energy savings at lower costs. This kind of comparison provides some implications about desirable future policies. But actual energy policy decisions are not based on costs alone. All the measures should be implemented to make great progress in energy conservation and carbon reduction, including PV which features high initial investment for the moment.

Table 3-1 Each Measure's Costs and Benefits (accumulated through 2030)

	Accumulated energy savings ktoe	Accumulated benefits USD million	Accumulated costs USD million
Nuclear	74,011	40,925	25,611
PV	25,233	14,129	23,627
Desalination	12,175	6,877	422
Industry energy savings	47,963	26,259	7,271
Electric vehicles	6,177	9,842	10,492
Lighting	10,575	5,927	514
Air-conditioning	68,346	38,294	4,169
Total	244,480	142,253	72,105

4. Conclusion

In this paper, the author compiled energy supply and demand data in the UAE, estimated particularly unknown energy consumption in the UAE industry sector, created an energy supply/demand outlook through 2030 and projected fossil fuel consumption cuts through energy conservation and low-carbon measures in each of the industry, buildings, transport and energy transformation sectors. Progress in these measures is expected to substantially moderate future growth in fossil fuel consumption. If consumption savings are used to enhance exports to Asian countries, the UAE may be able to produce profit to recover costs for these measures through 2030. But cost recovery efficiency will differ from measure to measure. Any measure for which costs may not be recovered immediately may have to be introduced from a longer-term viewpoint. Given that each emirate has the rights to use underground resources in the UAE, however, only Abu Dhabi can effectively benefit from expanding energy exports. This point must also be taken into account.

Middle Eastern oil producing countries including the UAE have traditionally formed energy inefficient societies and lifestyles with energy conservation making little progress as they have used their abundant energy resources at lower costs. In fact, however, they are now seriously attempting to promote energy conservation and carbon reduction with a view to securing energy exports vital to their economic prosperity, amid their energy consumption expansion accompanying their economic growth in recent years. If the attempt proves successful, the benefits may be enormous. Progress in energy conservation in Middle Eastern oil and gas producing countries will contribute to stabilizing the international energy market and be important for energy importers. Under government leadership, these measures should achieve steady progress in the future.

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