ISBN 92-64-02398-4
Infrastructure to 2030
Telecom, Land Transport, Water and Electricity


# Chapter 3

# Outlook for Global Investment in Electricity Infrastructure

*by*

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## Summary

The adequacy, quality and reliability of grid-based electricity supply are of crucial importance to economic development and growth. Large amounts of investment will be needed in the coming decades to meet the increase in demand for both the quantity and quality of electricity services, as well as to maintain and replace existing infrastructure that will be retired. Just how much investment will be needed and how much will actually be forthcoming will depend on a range of factors, including macroeconomic and population trends, prices, government policies, technology, and availability of capital.

In a Reference Scenario, in which no new government policies are assumed, global electricity demand is projected to grow at an average annual rate of 2.5% through to 2030. The world consumes twice as much electricity in 2030 as it does today. Developing countries account for much of the increase in global demand, their electricity use more than tripling by 2030. OECD electricity consumption grows less rapidly. Even so, in 2030 the 1.3 billion people in the OECD area still consume more electricity than the 6.5 billion people in the developing world. Moreover, some 1.4 billion in the developing regions still lack any access to electricity – a mere 200 million less than today.

Total cumulative electricity investment needs worldwide in the Reference Scenario amount to close to USD 10 trillion in year-2000 dollars over 2003-2030, equal to about USD 350 billion per year. More than half of this investment goes to transmission and distribution, with distribution taking the lion's share of overall network investment. Developing countries account for more than half of world electricity investment needs. China's needs will be the largest, exceeding USD 2 trillion. New investment is also substantial in North America and Europe. Attracting all this investment in a timely manner – especially in developing countries – may not be easy.

In an Alternative Policy Scenario, which considers the impact of new government policies to curb demand growth and promote switching to cleaner fuels, world electricity demand and investment needs grow less rapidly in almost every region. World demand grows by 0.5 percentage points more slowly than in the Reference Scenario as a result of end-use energy-efficiency improvements. Total cumulative investment needs over 2003-30, at USD 8.3 trillion, are USD 1.5 trillion – or 16% – lower. Lower supply capacity requirements more than outweigh the higher capital costs in power generation that result from switching to nuclear power, renewables and distributed generation.

Investment needs will be driven by demand growth. But it is not certain that all of the investment needed will be forthcoming whatever the rate of demand growth, such that some part of demand might go unmet. The main uncertainties surrounding the adequacy of electricity investment worldwide relate to the impact of market reforms, environmental constraints and access to capital. In general, the effects of the first two on investment are most uncertain in OECD countries. Policy makers are seeking to address concerns about the adequacy and timeliness of investment in both capacity and systems to ensure system reliability and an adequate quality of service in those countries by establishing a market framework that sends efficient market signals to investors.

Access to capital – a minor issue in the OECD – is perhaps the biggest uncertainty facing non-OECD countries, especially those in developing regions. They are increasingly looking to the private sector to fund at least part of the investment needed to finance electricity projects, mainly because of constraints on public funding. Yet, obtaining sufficient private sector capital in many cases will be difficult, due to poorly developed local financial markets and an unfavourable regulatory and investment climate. Overcoming these obstacles will require major improvements in governance and continued restructuring and reform in the electricity sector. A particularly pressing challenge is to reform tariff structures both to ensure that prices fully cover costs and to improve revenue collection.

## 1. Introduction

This chapter assesses the impact of socioeconomic, policy and technological developments on the outlook for global investment in electricity supply infrastructure – power plants and transmission and distribution networks. Modern economies are becoming increasingly dependent on grid-based electricity services. The adequacy, quality and reliability of electricity supply are, therefore, of crucial importance to economic development and growth.

Up to now, the bulk of electricity sector investment has taken place in OECD countries, which continue to dominate the global electricity supply industry. But the picture is changing rapidly, as demand in developing countries surges in response to strong rates of economic and population growth, especially in Asia. Most of the electricity investment over the coming decades is expected to take place in developing countries. But there are indications that financing problems are holding back investment in some countries, undermining prospects for economic development and poverty alleviation. Financing is unlikely to be an issue in OECD countries, but there are concerns about whether utilities are investing enough in capacity, in improving the quality of service to meet increasingly onerous customer needs, and in ensuring the reliability and security of supply.

This chapter first considers past trends in demand for electricity services and in investment in electricity supply infrastructure. It then goes on to review the main drivers of electricity demand and investment needs. This is followed by a summary of the International Energy Agency's latest electricity market Reference Scenario projections, broken down by major world region, and their implications for the amount of investment needed in power generation, transmission and distribution. Results are then presented of an Alternative Policy Scenario, which analyses the impact of a set of new government policies to curb demand growth and reduce energy-related airborne emissions. The following section describes the main uncertainties about whether all the investment needed will actually be forthcoming with respect to both capacity and the quality and reliability of electricity supply. The last section considers the implications of trends in electricity markets, investment needs for the structure of the electricity supply industry, and how new investments could be financed.

## 2. Past trends in global electricity supply and investment

### *Market Trends*

World electricity supply – gross output from generating plants – totalled 16 742 TWh in 2003. The OECD accounts for most of the electricity produced and consumed worldwide. The United States alone accounts for a quarter of world electricity output and other OECD countries for just over one-third (Table 3.1). However, the share of the OECD area in world consumption has fallen significantly in the last three decades, from almost three-quarters in 1971 to 59% in 2003.

Demand for electricity services has grown rapidly in recent decades. Worldwide, demand expanded at an average rate of 3.6% between 1971 and 2003. OECD countries saw average demand growth of 3.2%, while non-OECD countries experienced growth of 4.8%. Electricity use has grown fastest in developing Asian countries – notably China, where growth averaged 8.4%. The share of electricity in world final energy use almost doubled, from 9% in 1971 to 16% in 2003.

### *Investment patterns and trends*

Comprehensive data on total electricity industry investment are not available, but a number of indicators suggest that global electricity investment has picked up strongly in the last decade or so following a period of stagnation in the late 1970s and 80s. Investment has tended to follow a cyclical pattern around a steadily rising trend, in response to growing end-user demand for electricity. Orders for generating plant, for example, peaked between the late 1960s and early 70s at about 150 GW a year, and then plummeted in the mid-1980s (Figure 3.1). They recently increased again, reaching a new high at the start of the current decade, mainly because of a substantial increase in the

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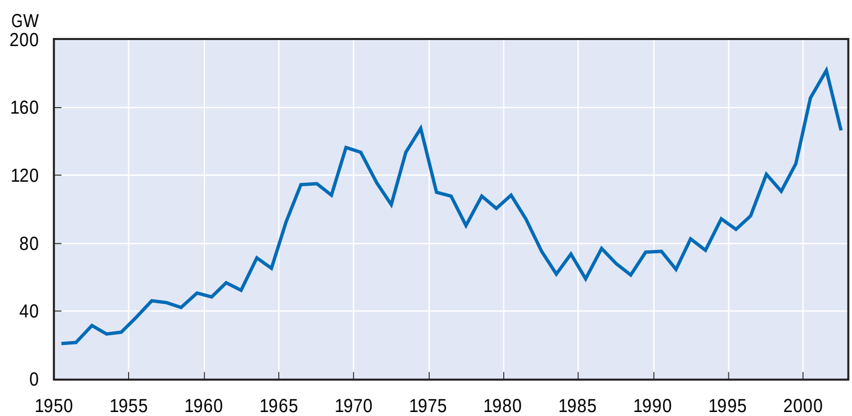
Table 3.1. **World electricity generation**

| | 1971 | | 2003 | |
|---|---|---|---|---|
| | TWh | Share in world (%) | TWh | Share in world (%) |
| **OECD** | **3 831** | **73** | **9 938** | **59** |
| United States | 1 703 | 32 | 4 081 | 24 |
| Japan | 386 | 7 | 1 047 | 6 |
| Germany | 329 | 6 | 599 | 4 |
| Canada | 222 | 4 | 587 | 4 |
| France | 156 | 3 | 567 | 3 |
| United Kingdom | 257 | 5 | 399 | 2 |
| Other | 778 | 15 | 2 658 | 16 |
| **Non–OECD** | **1 419** | **27** | **6 804** | **41** |
| China | 138 | 3 | 1 907 | 11 |
| Russia | n.a. | n.a. | 889 | 5 |
| India | 61 | 1 | 633 | 4 |
| Brazil | 52 | 1 | 365 | 2 |
| Indonesia | 2 | 0 | 113 | 1 |
| Other | n.a. | n.a | 2 897 | 17 |
| **World** | **5 250** | **100** | **16 742** | **100** |

*Source:* IEA databases.

Figure 3.1. **Worldwide orders for new power-generation capacity**

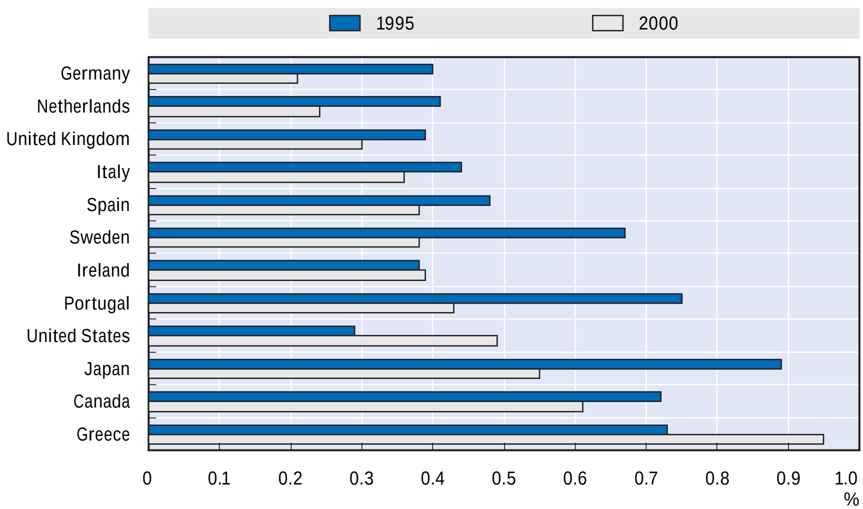



*Source:* IEA databases.

US market. Investment in transmission and distribution has lagged behind investment in generation in some countries, notably in the United States and some European countries. Nonetheless, global electricity network investment is thought to have risen in recent years.

In OECD countries, power sector investment typically accounts for less than 0.5% of GDP (Figure 3.2). With the notable exception of the United States, investment in the majority of them has declined since the mid-1990s for various reasons, including high reserve margins in some countries, the lower capital costs of new power plants, low demand growth and uncertainty caused by environmental policies and market liberalisation. Competition between utilities has reduced profit margins, especially in markets with excess capacity and low demand growth.

Figure 3.2. **OECD electricity sector investment relative to GDP**




*Sources:* National and regional electricity associations; IEA databases.

In contrast to Europe and Japan, investment in the United States has increased dramatically over the past few years, peaking at close to USD 57 billion (in nominal terms) in 2001 (Figure 3.3). Most of the increase in investment reflects increased power plant construction.

Investment in the EU electricity industry is currently running at about USD 30 billion per year. It was on average lower in the 1990s than in the 1980s, because the amount of capacity built was lower and because investment was directed towards low capital cost plant, notably combined-cycle gas turbines (CCGTs) (IEA, 2003). Investment in Japan has been declining since the mid-1990s. The level of investment in 2001, at just under USD 20 billion, was about half the 1994 level, as a result of a slowdown in electricity demand.

In most developing regions, power sector investment picked up in the 1990s in response to strong demand growth (Figure 3.4). The biggest increase occurred in China, following reforms initiated in the 1980s. Between 1991 and 2000, China


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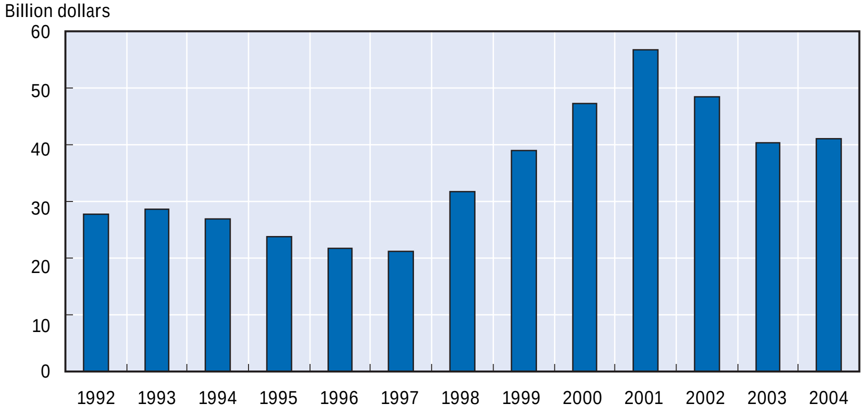
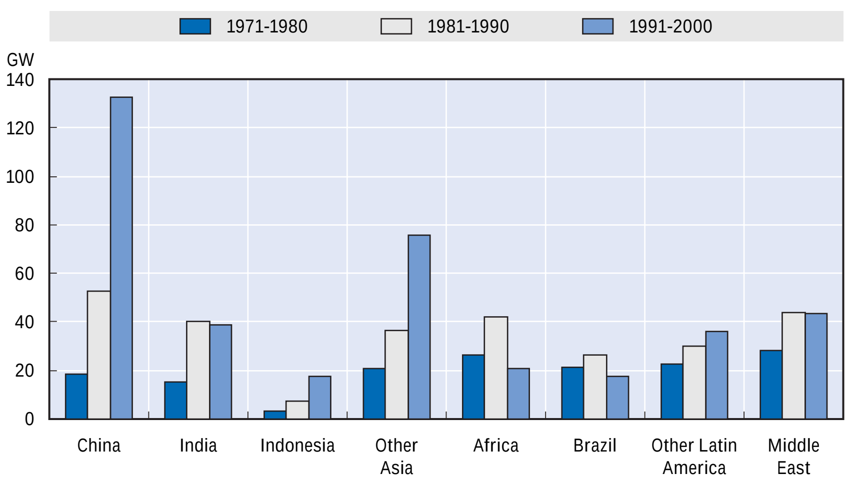
Figure 3.3. **Electricity sector investment in the United States**




*Source:* Edison Electric Institute (2005).

Figure 3.4. **Annual average capacity additions in developing regions**




*Source:* IEA databases.

increased installed capacity by as much as all other developing Asian countries put together. Nonetheless, Indonesia and other Asian countries saw continuous expansion throughout the 30-year period, despite the setback in the late 1990s attributable to the economic crisis. The rate of capacity expansion in India, the Middle East and Latin America in the 1980s did not continue into the 1990s. In the Middle East, this can be explained to some extent by the high levels of per capita electricity generation achieved in some countries in the region. In India and Latin America, particularly in Brazil, market reforms aiming at encouraging private investment did not bring the anticipated results. In Africa, the rate of investment in power infrastructure declined in the 1990s, reflecting slow economic growth. Only 5 GW of new capacity were added in the 1990s in sub-Saharan Africa.

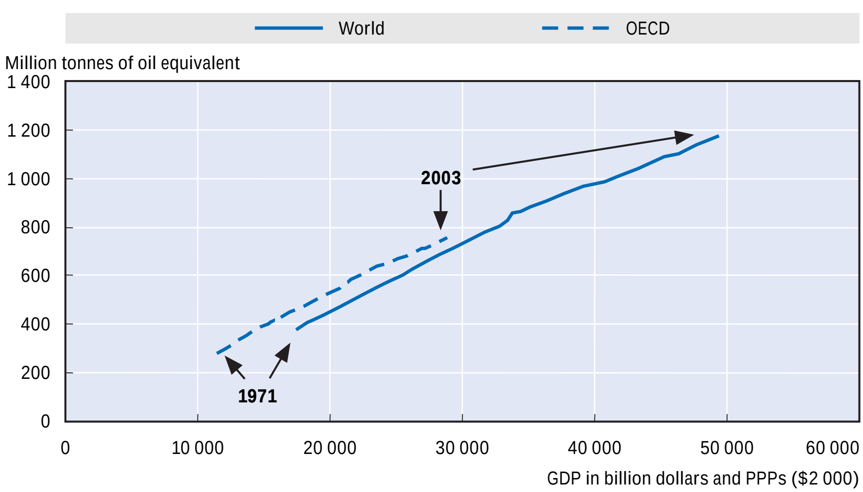
## 3. Key factors driving electricity infrastructure investment

Electricity supply is highly capital-intensive, with large lead times for building and bringing on stream new capacity. Because electricity is generally supplied in bulk over networks, investment tends to be driven by expectations of demand subject to adequate access to capital. Electricity companies project average and peak load in the near to medium term and attempt to build enough capacity in advance to meet that load. Errors in forecasting capacity needs can lead to sharp fluctuations in investment. The "lumpy" nature of power sector investment also contributes to this phenomenon.

Economic activity is the primary driver of electricity demand, although the relationship is to some extent two-way. Economic growth stimulates demand for electricity services, while the expanded supply of electricity contributes to economic growth and development. Empirical analysis confirms that demand for electricity is closely linked to changes in gross domestic product. Over the past thirty years, the global economy grew by 3.3% per year on average, and electricity demand grew at 3.6%. The relationship is remarkably stable and broadly linear (Figure 3.5).

However, this aggregate picture hides the fact that electricity intensity – the amount of electricity for each unit of GDP produced – has tended to fall in OECD countries, while it has risen in the rest of the world. This largely reflects

Figure 3.5. **World final electricity consumption and gross domestic product**




*Source:* IEA databases.

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saturation effects in the OECD and catching up by the poorer developing countries. It also reflects changes in the structure of economic activities. Most of the economic growth that has occurred since the 1970s has come from services and light manufacturing industry, which generally require small amounts of electricity per unit of output. In contrast, heavy electricity-intensive industry has contributed more of the increase in GDP in non-OECD countries. The energy efficiency of electric equipment and appliances in those countries is also typically lower than in the OECD, boosting electricity intensity.

Changes in the level and age composition of the population affect the level and composition of electricity demand, directly and through its impact on economic growth and development. A growing workforce will both boost the productive potential of the economy and lead to higher demand for electricity. The ageing of the population tends to increase the number of households and therefore per capita electricity consumption. Migratory movements in population also influence the need for new capacity and investment in production, transmission and local distribution. Migration to regions where capacity is already fully utilised will increase the overall need for investment, unless it relieves the need for new investment in those regions from which the population is migrating.

The price of electricity, in absolute terms and relative to other forms of energy, also has a significant impact on demand and investment needs. The cost of supplying electricity is determined largely by the cost of building and operating power plants and transmission and distribution lines. Maintenance costs are low for most generating technologies and networks. The share of generation in the total cost of supply varies across countries, but is typically more than half. Fuel often accounts for a large part of the cost of generation, and therefore the final cost of electricity to end users. Depending on the choice of technology, increases in oil, gas and coal prices can drive up the cost of electricity and curb demand. Where nuclear power or renewable energy technologies are used to generate power, higher fossil fuel prices can actually boost electricity demand, as electricity becomes cheaper relative to other end-use fuels and consumers switch to electricity.

A host of other factors influence rates of growth in electricity demand and thus the amount and type of investment in infrastructure needed to meet that demand. The most important among these are:

- *Energy and environmental policies.* Government policies affect electricity demand and investment in several different ways. Tax and other economic instruments can deliberately or inadvertently curb demand by increasing the real cost of electricity to end users. Energy efficiency and conservation measures, such as standards, labelling and building codes, can also reduce electricity intensity. Environmental policies may favour some fuels and technologies in power generation, and may hinder the construction of high-tension transmission lines. Regulations requiring power plants to reduce emissions of pollutants such as sulphur dioxide are becoming tighter in many countries, pushing up investment costs. The impact of a range of new policies and measures that might be introduced in the future on electricity demand and investment are analysed in Section 4.

- *Technology.* Advances in power generation, transmission and distribution technology affect both the efficiency and the cost of electricity supply. The deployment of technology that reduces distribution losses, for example, reduces the need for generating and transmission capacity. The choice of generating technology also has a major impact on the amount of capital needed for new capacity: natural gas-fired CCGT plants, for example, often have the lowest investment cost per kW of capacity, although the competitive advantage over other technologies may be reduced by the higher cost of gas compared with coal or other fuel inputs. The choice of generating technology also affects the size and location of power plants and, consequently, the need for transmission capacity. Distributed generation plants located at an end user's site or at a local distribution utility, supplying power directly to the local distribution network, reduce the need to invest in long-distance high-tension transmission lines. Distributed generation technologies include engines, small turbines, fuel cells and photovoltaic systems. They represent a small share of the electricity market today, but the wide range of potential applications and favourable government policies for combined heat and power and for renewable energy technologies are expected to boost their market share over the coming decades (IEA, 2002). Improvements in the efficiency of end-use technology – to the extent that they are actually deployed – also affect electricity demand (see Section 4).
- *Climatic conditions.* Changes in climate, resulting from global warming and leading to marked changes in average ambient temperatures, could have a significant impact on electricity demand for cooling and heating purposes. The impact is likely to be greater for cooling, as the bulk of heating needs in most countries are met by other, more direct forms of energy, such as natural gas and oil products. Air conditioning is one of the leading drivers of electricity demand in many OECD countries and the richest developing economies.

The rate of growth of demand will determine how much investment is needed in supply infrastructure. But there is no certainty that all of the investment needed is forthcoming. If actual investment falls short of that required or is delayed, some part of demand might go unmet, leading to temporary or persistent power shortages. The main uncertainties surrounding the adequacy of electricity investment worldwide relate to the impact of market reforms, environmental constraints and access to capital.

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In general, the effects of market reforms and environmental constraints on investment are most uncertain in OECD countries. Policy makers in those countries are seeking to address concerns about the adequacy and timeliness of investment – both in capacity and in systems, to ensure system reliability and an adequate quality of service – by establishing a market framework that sends efficient market signals to investors. Financing has rarely been a major problem in OECD countries up to now, but doubts about whether investment needs can be fully financed in the future have arisen with the greater investment risks brought by liberalisation of electricity markets. The ability to finance new electricity projects varies among countries, mainly according to the regulatory environment, the extent to which investment has to be funded by publicly owned companies or out of state funds, and where the private sector is responsible for investment – the perceived balance of risk and return. In non-OECD countries, access to capital is the main concern. The private sector is being called upon to finance a growing share of electricity investment as governments find it increasingly difficult to meet rising power-sector investment needs out of their own budgets. Whether all the capital needed can be mobilised quickly enough is a major question.

Uncertainties surrounding the impact of market reforms and environmental policies, as well as the prospects for obtaining sufficient financing from private investors in developing countries, are assessed in Section 5.

## 4. Outlook for the electricity supply industry

The IEA's *World Energy Outlook* adopts a scenario approach to analyse the possible evolution of energy markets to 2030. The central projections are derived from a Reference Scenario, based on a set of assumptions about government policies, macroeconomic conditions, population growth, energy prices and technology. The Reference Scenario takes into account only those government polices and measures that have already been enacted, though not necessarily implemented. These projections should not be interpreted as a forecast of how energy markets are likely to develop, but rather as a baseline vision of how the global energy system will evolve if governments take no further action to affect its evolution beyond that to which they have already committed themselves.

Other key assumptions in the Reference Scenario include the following:

- Global GDP growth – the primary driver of energy demand – is assumed to average 3.2% per year over the period 2003-30, slightly less than in the previous three decades. The rate is assumed to drop from 3.8% in 2003-10 to 2.7% in the last decade of the projection period, as developing countries' economies mature and population growth slows. The economies of China, India and other Asian countries are expected to continue to grow most rapidly (Table 3.2).

Table 3.2. **GDP growth assumptions in the Reference Scenario**

| | 1971-2003 | 2003-10 | 2010-20 | 2020-30 | 2003-30 |
|---|---|---|---|---|---|
| **OECD** | **2.9** | **2.7** | **2.2** | **1.8** | **2.2** |
| OECD Europe | 3.1 | 3.2 | 2.4 | 1.9 | 2.4 |
| OECD North America | 2.4 | 2.4 | 2.2 | 1.7 | 2.1 |
| OECD Pacific | 3.5 | 2.5 | 1.9 | 1.7 | 2.0 |
| **Transition economies** | 0.8[1] | **4.6** | **3.7** | **2.9** | **3.7** |
| Russia | –1.1[1] | 4.4 | 3.4 | 2.8 | 3.5 |
| **Developing countries** | **4.7** | **5.1** | **4.3** | **3.6** | **4.3** |
| China | 8.4 | 6.4 | 4.9 | 4.0 | 5.0 |
| East Asia | 5.0 | 4.5 | 3.9 | 3.1 | 3.8 |
| *Indonesia* | *5.9* | *4.5* | *4.1* | *3.3* | *3.9* |
| South Asia | 4.8 | 5.5 | 4.8 | 4.0 | 4.7 |
| *India* | *4.9* | *5.6* | *4.8* | *4.0* | *4.7* |
| Latin America | 2.9 | 3.4 | 3.2 | 2.9 | 3.2 |
| *Brazil* | *3.8* | *3.0* | *3.1* | *2.8* | *3.0* |
| Middle East | 3.2 | 4.3 | 3.4 | 3.0 | 3.5 |
| Africa | 2.7 | 4.1 | 3.8 | 3.4 | 3.8 |
| **World** | **3.3** | **3.7** | **3.2** | **2.7** | **3.2** |

1. 1992-2003.

- The world's population is assumed to expand from 6.5 billion today to over 8 billion in 2030 – an increase of 1% per year on average. Population growth will slow progressively over the projection period, mainly due to falling fertility rates in developing countries. The share of the world population living in developing regions will nonetheless increase from 76% today to 80% in 2030.
- In the Reference Scenario, the average price for IEA crude oil imports is assumed to fall back from recent highs of over USD 60 a barrel to around USD 35 in 2010 in year-2004 dollars, and then climb to USD 39 in 2030 (USD 65 in nominal terms). Gas and coal prices are assumed to move broadly in line with oil prices. Electricity prices in each region are assumed to move in line with marginal power generation costs, which are in turn determined to a large degree by fossil fuel prices.

### *Electricity demand*

In the Reference Scenario, electricity demand is expected to grow at an average annual rate of 2.5% over the projection period (2003-30), as the global economy increases at 3.2% per year (Figure 3.6). The world will consume twice as much electricity in 2030 as it does today. Developing countries will account for much of the increase in global demand for electricity. Their demand will rise at about the same rate as their GDP. Electricity use in those countries is projected to

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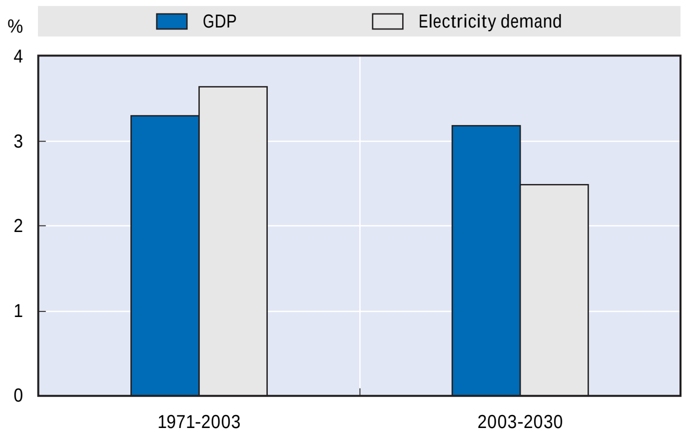
Figure 3.6. **World GDP and final electricity demand growth in the Reference Scenario**




more than triple by 2030. In the OECD, the pace of growth will be slower, at 1.4% per year. Even so, at the end of the projection period, the 1.3 billion people in the OECD area will still be consuming more electricity than the 6.5 billion people in the developing world. Moreover, some 1.4 billion in the developing regions will still lack any access to electricity – only 200 million fewer than today.

Outside the OECD area, the Asian economies will experience the highest growth in electricity demand. Demand is projected to grow in India by 4.9% per year and in China by 4.5% per year. In 2030, China will generate as much electricity as the United States (Table 3.3). In the transition economies, demand will grow at 2% per year, as these countries are already large consumers of electricity. Moreover, they have the opportunity to use electricity much more efficiently, particularly in industry.

Global electricity use will grow most rapidly in the residential sector, more than doubling between 2003 and 2030. Demand in the services sector will grow by 97%, while industry demand will increase by 86%. Industry will remain the largest final consumer of electricity at the end of the projection period (Figure 3.7).

### *Power generation and supply*

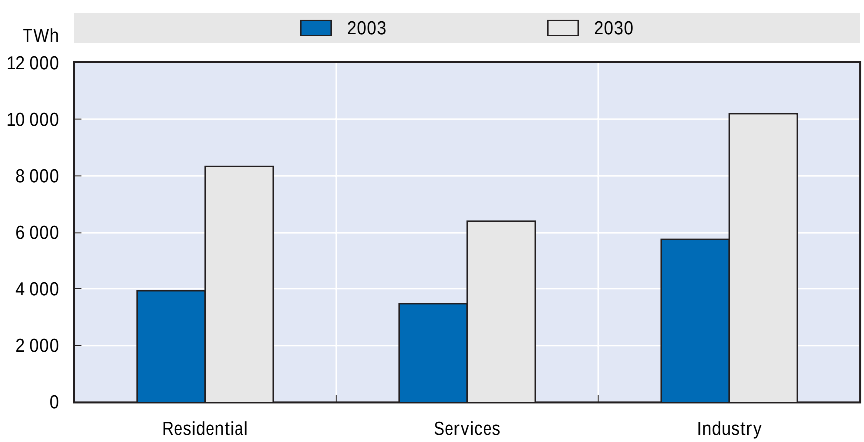
World electricity generation is projected to rise from 16 742 TWh in 2003 to 31 840 TWh in 2030, growing at an average rate of 2.5% per year. The largest increase will be in China, where output will jump by 3 898 TWh in that period, a quarter of the world's projected increase. Coal- and gas-fired generation will provide over three-quarters of the world's incremental demand for electricity between now and 2030 (Figure 3.8). Natural gas and non-hydro renewables – biomass, wind, geothermal, solar, tidal and wave energy – will continue to

Table 3.3. **Final electricity consumption by region in the Reference Scenario (TWh)**

| | 1971 | 2003 | 2010 | 2030 | 2003-30[1] (%) |
|---|---|---|---|---|---|
| **OECD** | **3 222** | **8 478** | **9 839** | **12 537** | **1.4** |
| OECD Europe | 1 663 | 4 152 | 4 861 | 6 303 | 1.5 |
| OECD North America | 1 163 | 2 849 | 3 187 | 4 047 | 1.4 |
| OECD Pacific | 407 | 1 477 | 1 779 | 2 198 | 1.4 |
| **Transition economies** | **709** | **1 070** | **1 256** | **1 791** | **2.0** |
| Russia | n.a. | 632 | 721 | 989 | 1.7 |
| **Developing countries** | **442** | **4 117** | **5 699** | **12 142** | **4.2** |
| China | 116 | 1 477 | 2 082 | 4 443 | 4.5 |
| East Asia | 47 | 605 | 826 | 1 733 | 4.2 |
| *Indonesia* | 2 | 90 | 140 | 361 | 5.2 |
| South Asia | 58 | 535 | 709 | 1 745 | 4.9 |
| *India* | 52 | 418 | 593 | 1 442 | 4.9 |
| Latin America | 116 | 663 | 896 | 1 768 | 3.6 |
| *Brazil* | 42 | 330 | 384 | 698 | 2.9 |
| Middle East | 23 | 442 | 640 | 1 151 | 3.6 |
| Africa | 81 | 395 | 547 | 1 303 | 4.4 |
| **World** | **4 385** | **13 665** | **16 794** | **26 470** | **2.5** |

1. Average annual rate of growth.

Figure 3.7. **World final electricity consumption by sector in the Reference Scenario**




increase their market shares (Table 3.4). The share of non-hydro renewables is projected to rise from 2% in 2003 to 6% in 2030. If countries adopt stronger policies to promote them, a much higher contribution from renewables can be expected by 2030. Coal will lose some of its market share, especially in the OECD, although it will remain the predominant fuel. The decline in coal's

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Figure 3.8. **World electricity generation in the Reference Scenario**

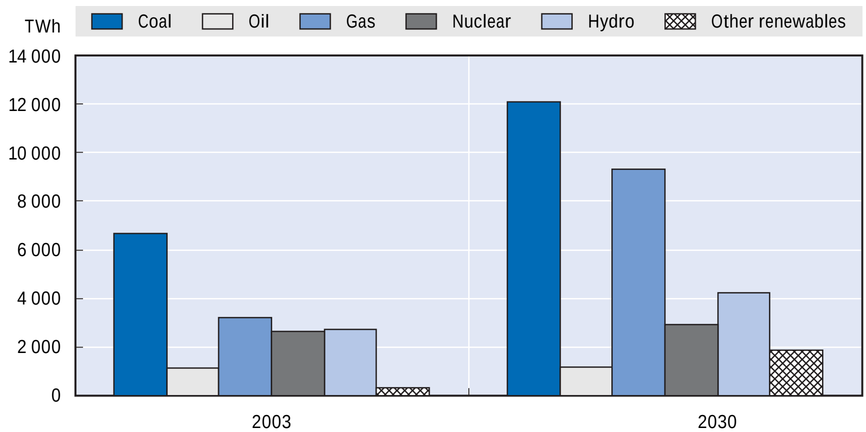


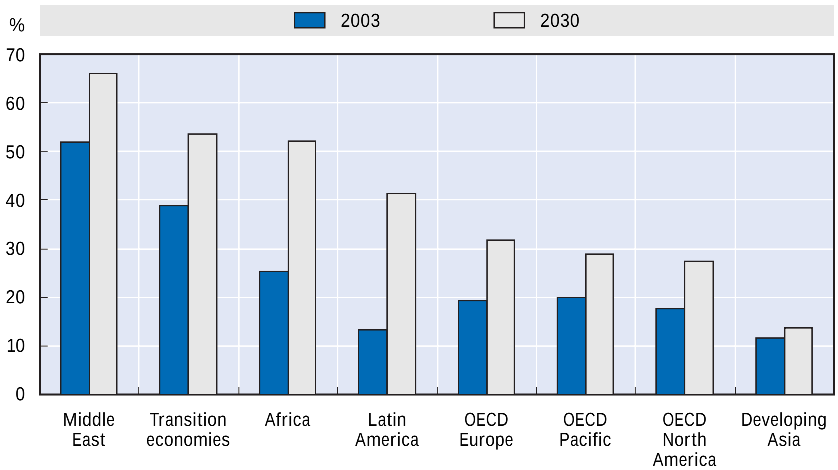

Table 3.4. **Market shares in electricity generation in the Reference Scenario (%)**

| | OECD | | Transition economies | | Developing countries | | World | |
|---|---|---|---|---|---|---|---|---|
| | 2003 | 2030 | 2003 | 2030 | 2003 | 2030 | 2003 | 2030 |
| Coal | 39 | 33 | 22 | 16 | 47 | 47 | 40 | 38 |
| Oil | 6 | 2 | 4 | 2 | 10 | 5 | 7 | 4 |
| Gas | 17 | 29 | 39 | 54 | 17 | 26 | 19 | 29 |
| Nuclear | 22 | 15 | 17 | 11 | 3 | 3 | 16 | 9 |
| Hydro | 13 | 11 | 18 | 15 | 22 | 16 | 16 | 13 |
| Other renwables | 3 | 10 | 0 | 2 | 1 | 3 | 2 | 6 |

market share, by two percentage points to 38% by 2030, could be even sharper if efforts to reduce $CO_2$ emissions are strengthened.[1] The share of oil, already small, will decline still further, falling to 4% in 2030 compared with 7% today. Future oil-fired generation will be concentrated in distributed-generation applications in industry and in remote areas. The share of hydropower will fall from 16% now to 13% in 2030. Nuclear power will lose a large part of its market share, which could drop from 16% now to 9% in 2030 on current policies. Few countries are planning to build nuclear plants.

Gas-based electricity production is expected to triple between now and 2030, continuing a trend that began in the late 1980s and early 1990s. The contribution of gas to generation worldwide will rise from 19% in 2003 to 29% in 2030. Gas-fired electricity generation will increase everywhere in the OECD (Figure 3.9). In developing countries, the share of gas is expected to rise from 17% in 2003 to 26% by 2030. Most of the increase will occur in Latin America, the Middle East and Africa. The transition economies will also see a substantial increase in gas-fired electricity generation.

Figure 3.9. **Share of natural gas in electricity generation by region in the Reference Scenario**




CCGT plants will account for most of the increased use of gas for power. CCGTs are expected to remain the preferred option for new power generation because of their economic and environmental advantages. They have lower capital costs than any other type of base-load plant – half as much as a coal plant, and a quarter as much as a nuclear plant. Construction time for a CCGT plant is two to three years; it takes at least twice as long to build a coal-fired or nuclear plant. CCGT plants have the lowest carbon dioxide emissions of all fossil fuel-based technologies, because of the low carbon content of natural gas and the high efficiency of the plants themselves. This advantage reduces investment risk for gas-fired power plants in countries that plan to limit $CO_2$ emissions. Natural gas is free of sulphur dioxide, while CCGT technology reduces emissions of nitrogen oxides and particulates. Fuel cells using hydrogen from reformed natural gas are expected to emerge as a new source of power generation after 2020, though their share in total generation will still be very small by 2030.

### *Electricity supply capacity and investment needs*

New power plants with combined capacity of 4 800 GW are expected to be built worldwide over the period 2003-30; half of them will be in developing countries (Table 3.5). OECD countries will need nearly 2 000 GW. China will need more new capacity than any other country or region. More than a third of this new capacity will be built to replace ageing power plants in China: most existing coal-fired capacity will have to be replaced by 2030. Over a third of existing nuclear plants in the OECD are expected to be shut down before 2030, either because they become too old or because of government policies to phase out

Table 3.5. **Electricity generating capacity additions and total electricity investment by region in the Reference Scenario, 2003-30**

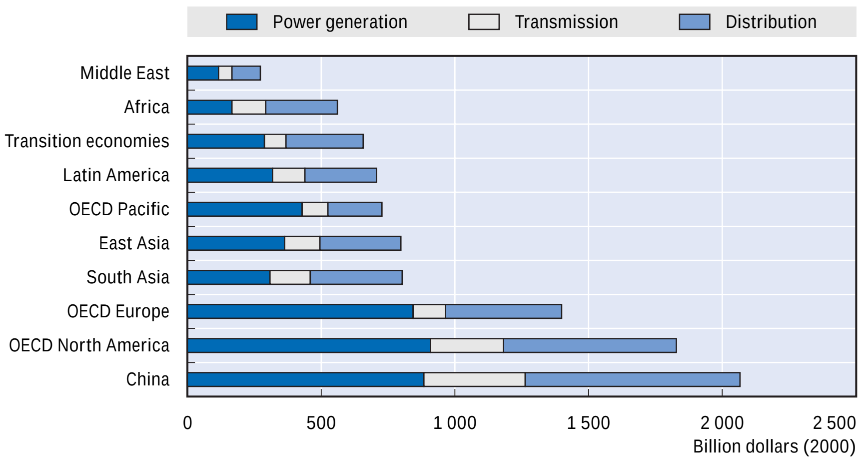
| | Capacity additions (GW) | Investment (2 000 USD billion) | | | |
|---|---|---|---|---|---|
| | | Generation | Transmission | Distribution | Total |
| **OECD** | **1 975** | **2 167** | **498** | **1 276** | **3 940** |
| OECD Europe | 801 | 842 | 125 | 433 | 1 399 |
| OECD North America | 842 | 910 | 273 | 643 | 1 827 |
| OECD Pacific | 332 | 416 | 100 | 199 | 714 |
| **Transition economies** | **372** | **287** | **79** | **287** | **653** |
| Russia | 154 | 138 | 26 | 92 | 256 |
| **Developing countries** | **2 437** | **2 153** | **962** | **2 090** | **5 205** |
| China | 860 | 883 | 378 | 802 | 2 063 |
| East Asia | 391 | 364 | 133 | 302 | 798 |
| *Indonesia* | *77* | *69* | *29* | *67* | *166* |
| South Asia | 349 | 306 | 155 | 340 | 801 |
| *India* | *272* | *256* | *132* | *289* | *678* |
| Latin America | 373 | 317 | 122 | 269 | 708 |
| *Brazil* | *114* | *125* | *46* | *102* | *273* |
| Middle East | 195 | 118 | 48 | 107 | 272 |
| Africa | 269 | 165 | 127 | 271 | 563 |
| **World** | **4 784** | **4 607** | **1 539** | **3 652** | **9 798** |

nuclear power. The transition economies will have to build some 370 GW, with half of this capacity replacing ageing nuclear and fossil-based plants.

About 8% of the new capacity that will need to be built worldwide between now and 2030 is already under construction, and another 21% is planned. The largest as-yet-unplanned capacity additions will be in OECD North America and OECD Europe. Africa, Latin America (excluding Brazil) and Indonesia have very little capacity being built. These three regions could fall short of meeting local demand if they fail to attract sufficient investment to speed up construction. China will need to accelerate the pace of construction of new power plants if it is to avoid a repetition of recent electricity shortages. India will also need to accelerate capacity additions to meet increasing demand and to improve electrification rates.

Total cumulative electricity investment needs worldwide will amount to USD 9.8 trillion in year-2 000 dollars over 2003-30, equal to about USD 350 billion per year. Developing countries will account for more than half of world electricity investment (Figure 3.10). China will need the largest increase, exceeding USD 2 trillion. New investment will also be substantial in North America and Europe. Attracting all this investment in a timely manner may not be easy.

Figure 3.10. **Cumulative world electricity investment in the Reference Scenario, 2003-30**




More than half of global electricity investment will go to transmission and distribution, with distribution taking the lion's share of overall network investment. The share of transmission and distribution will generally be highest in non-OECD countries, where there is the greatest need to extend and expand existing networks. In those countries, investment in distribution alone will be almost as large as in generating capacity; in the OECD area, network investment will be little more than half that of power generation investment needs.

Network investment needs are projected to grow steadily through to 2030 (Table 3.6). They grow most rapidly in OECD countries, as demand progressively approaches installed capacity and major new investments are needed. Nonetheless, in the decade 2021-30, network investments in non-OECD countries will be much larger than in the OECD area. Spending in the Big 5 non-OECD countries (Brazil, China, India, Indonesia and Russia) alone will be almost as large as that in the whole of the OECD area.

The bulk of electricity investment will be needed to build new infrastructure. Around 10% of global investment in power generation will go to refurbishment of existing plants. This includes major upgrades, which are assumed to take place once in the lifetime of each plant. Around two-thirds of this investment will occur in OECD countries. The share of refurbishment in total investment will amount to about 13% (16% in North America, 15% in the Pacific region and 9% in Europe). Refurbishment of transmission and distribution infrastructure, including the replacement of cables, substations and control centres, will account for well over half of total network investment worldwide. The share will be highest in OECD countries.

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Table 3.6. **Electricity network investment by region and decade in the Reference Scenario, 2003-30**

| | 2003-10 | | | 2011-20 | | | 2021-30 | | | 2003-30 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trans | Dist | Total | Trans | Dist | Total | Trans | Dist | Total | Trans | Dist | Total |
| **OECD** | **81** | **205** | **286** | **173** | **446** | **620** | **244** | **624** | **868** | **498** | **1 276** | **1 773** |
| OECD Europe | 20 | 70 | 90 | 45 | 158 | 203 | 59 | 205 | 264 | 125 | 433 | 557 |
| OECD North America | 43 | 100 | 143 | 94 | 220 | 314 | 137 | 323 | 460 | 273 | 643 | 917 |
| OECD Pacific | 18 | 35 | 53 | 34 | 68 | 102 | 48 | 96 | 143 | 100 | 199 | 299 |
| **Transition economies** | **10** | **38** | **48** | **30** | **110** | **140** | **39** | **139** | **177** | **79** | **287** | **366** |
| Russia | 3 | 12 | 15 | 9 | 32 | 41 | 13 | 48 | 61 | 25 | 92 | 117 |
| **Developing countries** | **203** | **440** | **643** | **329** | **715** | **1 044** | **430** | **935** | **1 365** | **962** | **2 090** | **3 052** |
| China | 92 | 196 | 288 | 131 | 277 | 407 | 156 | 329 | 485 | 378 | 802 | 1 180 |
| East Asia | 29 | 65 | 93 | 47 | 107 | 154 | 57 | 130 | 188 | 133 | 302 | 434 |
| *Indonesia* | *5* | *12* | *16* | *10* | *23* | *32* | *14* | *33* | *47* | *29* | *67* | *96* |
| South Asia | 28 | 62 | 90 | 55 | 122 | 177 | 71 | 157 | 228 | 155 | 340 | 495 |
| *India* | *23* | *50* | *73* | *47* | *103* | *151* | *62* | *135* | *197* | *132* | *289* | *421* |
| Latin America | 26 | 57 | 83 | 41 | 90 | 131 | 55 | 122 | 177 | 122 | 269 | 391 |
| *Brazil* | *9* | *21* | *30* | *16* | *36* | *52* | *20* | *45* | *66* | *46* | *102* | *147* |
| Middle East | 7 | 17 | 24 | 17 | 37 | 54 | 24 | 53 | 76 | 48 | 107 | 154 |
| Africa | 21 | 44 | 65 | 39 | 83 | 122 | 67 | 144 | 211 | 127 | 271 | 398 |
| **World** | **294** | **683** | **977** | **533** | **1 272** | **1 804** | **713** | **1 697** | **2 410** | **1 539** | **3 652** | **5 191** |

## *Alternative Policy Scenario*

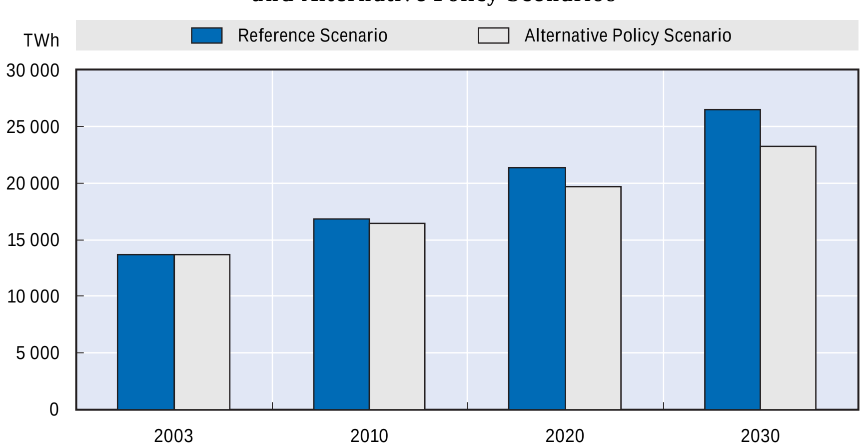
The Alternative Policy Scenario analyses how global energy markets could evolve were countries around the world to adopt a set of policies and measures that they are currently considering or that they might reasonably be expected to implement over the projection period. For each major region, the scenario considers policies to reduce air pollution and greenhouse gas emissions, and to enhance energy security. The choice of measures used to meet policy goals takes into account technical and cost factors, the political context and market barriers. Measures to improve energy efficiency and increase the use of renewables are the main instruments considered. Depending on the region, those measures result from a strengthening or a wider coverage of existing policies, or from the introduction of new policies. The basic assumptions about macroeconomic conditions and the population are the same as for the Reference Scenario. Energy prices change, because of the new equilibrium between supply and demand.

As with OECD countries, the developing country policies assessed in the Alternative Policy Scenario include those currently under discussion at the national level. In general however, there are fewer such policies than in OECD countries because environmental issues and energy security concerns are lower on the agenda than in the OECD area. But it is likely that many of these countries will devise new policies in the future to tackle such problems. In most cases the environmental policies would tackle local or regional pollution, though some countries could take climate change effects into consideration in devising their policies. More efficient and less polluting technologies are assumed to become more widely and rapidly available to these countries, thanks to their faster development and deployment in OECD countries. As a result, global energy intensity falls more rapidly in this scenario than in the Reference Scenario.

Many of the policies considered push for faster deployment of more efficient and less polluting technologies. The rates of efficiency gains vary with local conditions, including past efforts to encourage more efficient energy use and to reduce environmental damage. On average, the improvement in energy efficiency is assumed to be higher in the developing world than in OECD countries. This reflects a far larger potential for efficiency improvements, as well as a faster rate of technology transfer from the OECD area. As more efficient technologies are deployed in OECD countries their unit costs fall, and they eventually become affordable for all countries.

The rate of growth of electricity demand is significantly slower in the Alternative Policy Scenario. In 2030, electricity demand is 3 100 TWh – or 12% – lower than in the Reference Scenario (Figure 3.11). It then reaches 23 202 TWh, an increase of 70% over 2003 compared with 94% in the Reference Scenario. The annual average rate of growth over 2003-30, at 2%, is 0.5 percentage points lower than in the Reference Sceanrio. Energy efficiency measures for industrial processes, appliances and lighting are the main causes of these savings in all regions. The residential sector accounts for 67% of the drop in electricity

Figure 3.11. **World electricity consumption in the Reference and Alternative Policy Scenarios**

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demand, with the rest coming from industry (Table 3.7). The overall decline in demand is greatest in the developing countries, where it falls by 13% in 2030 compared with the Reference Scenario. The demand gap between the two scenarios widens progressively over the projection period, as the capital stock in the electricity sector is gradually replaced and new measures are introduced. The difference in electricity consumption is only 2% in 2010.

Table 3.7. **Change in electricity consumption by sector in the Alternative Policy Scenario compared with the Reference Scenario, 2030**

(%)

| | OECD | Transition economies | Developing countries | World |
|---|---|---|---|---|
| Residential | –12.4 | –16.7 | –15.9 | –14.1 |
| Industrial | –9.2 | –8.9 | –11.5 | –10.3 |
| **Total** | **–10.8** | **–11.0** | **13.0** | **–11.8** |

In the Alternative Policy Scenario, world electricity generation in 2030 is 13% lower than in the Reference Scenario. The reduction results mainly from end-use efficiency improvements, which reduce demand, as well as from reduced losses in transmission and distribution and from greater use of distributed generation. The difference between the two scenarios is roughly equal to the current electricity output of the United States. The fuel mix in power generation is also markedly different. In the Reference Scenario, fossil fuels account for 70% of electricity generation in 2030. In the Alternative Policy Scenario, the share of fossil fuels falls to 61%, while the shares of carbon-free fuels rise substantially (Figure 3.12).

In the Reference Scenario, coal's share in electricity generation remains almost unchanged up to 2030, at a little less than 40%. In the Alternative Policy Scenario, coal gradually loses market share, dropping to less than a third of total generation by 2030. At 8 700 TWh, coal-fired generation is 28% lower than in the Reference Scenario (Table 3.8). The decline is sharpest in the OECD, where the share of coal drops to 25% in 2030 compared with 33% in the Reference Scenario. Coal-based electricity generation is 15% less than in 2002, because many coal-fired plants are retired and replaced with plants using other fuels. China and India also see their coal-fired generation reduced by more than a quarter in 2030 compared to the Reference Scenario. Nevertheless, these two countries still account for 45% of the world's coal-fired generation in 2030.

Gas-fired electricity generation, excluding hydrogen, is 1 666 TWh, or 19%, lower in 2030 than in the Reference Scenario, although the share of gas in total generation drops only slightly. Within the OECD area, the largest reductions in gas-fired generation occur in Europe and Japan, where renewables and nuclear energy play a large role. In Russia, gas-fired power plants produce a quarter less

Figure 3.12. **Fuel shares in electricity generation in the Reference and Alternative Policy Scenarios**

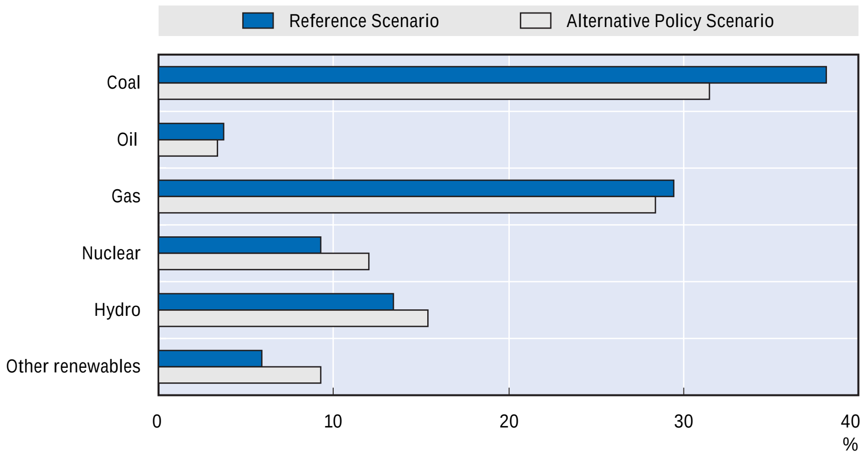



Table 3.8. **Change in electricity generation by fuel in the Alternative Policy Scenario compared with the Reference Scenario**

(TWh)

| | 2010 | 2020 | 2030 |
|---|---|---|---|
| Coal | –352 | –1 787 | –3 392 |
| Oil | –71 | –163 | –243 |
| Gas | –239 | –638 | –1 481 |
| Nuclear | 15 | 154 | 400 |
| Hydro | 0 | 10 | 19 |
| Other renewables | 109 | 301 | 692 |
| **Total** | **–538** | **–2 122** | **–4 004** |

electricity in 2030 than in the Reference Scenario. In the Reference Scenario, Russian gas-fired generation nearly doubles between 2002 and 2030 and its share increases from 43% to 53%. In the Alternative Policy Scenario, it increases at a much slower pace and its share increases only slightly, because electricity demand is much lower and because nuclear power substitutes for gas. Global electricity generation from fuel cells using hydrogen from reformed natural gas is 530 TWh, twice as high as in the Reference Scenario in 2030.

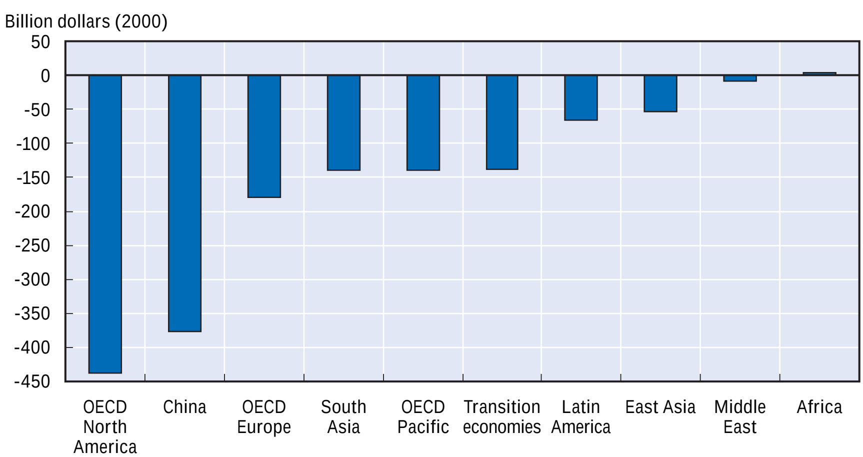
Nuclear power capacity expands to 428 GW in 2030, about 50 GW more than in the Reference Scenario. Nuclear power production is 14% higher. The largest increases in output occur outside the OECD, notably in Russia where nuclear production is 40% higher in 2030 compared with the Reference Scenario. Nuclear production rises by 16% in China and by 21% in India. All three countries have ambitious nuclear programmes and plans for nuclear plant construction.

In the Alternative Policy Scenario, hydroelectric generation in 2030 is slightly higher than in the Reference Scenario. Hydropower's share in world generation drops from 16% in 2002 to 13% in 2030 in the Reference Scenario, while its share falls only by one percentage point, to 15%, in the Alternative Policy Scenario. The share of non-hydro renewables increases much more, from 6% in 2030 in the Reference Scenario to 9% in the Alternative Scenario. The strongest increase is in OECD Europe, driven by the European Union's strong support for renewables. Electricity generation using non-hydro renewables is almost ten times higher in 2030 in the Alternative Policy Scenario than in 2002, and more than a third higher than in the Reference Scenario.

In the Alternative Policy Scenario, worldwide cumulative investment requirements for electricity supply infrastructure over 2002-30 are just over USD 1.5 trillion (in year-2000 dollars) – or almost 16% – less than in the Reference Scenario. Although the average unit capital cost of power generation is 14% higher in the Alternative Policy Scenario than in the Reference Scenario (because of the greater use of more capital-intensive nuclear power, renewables and distributed generation), this effect is more than offset by slower demand growth, which reduces the need for new power plants and new network capacity. The increased use of distributed generation also reduces the need for transmission capacity – and, therefore, investment. The fall in cumulative investment amounts to around USD 300 billion for power generation, USD 375 billion for transmission and USD 860 billion for distribution.

The biggest dollar reductions in investment needs compared with the Reference Scenario occur in North America and China (Figure 3.13). The only

Figure 3.13. **Change in investment requirements in electricity supply by region in the Alternative Scenario compared with the Reference Scenario, 2003-30**



region that sees an increase in investment is Africa, where the higher cost of renewables – which grow much more rapidly than in the Reference Scenario – more than offset the reduction in capacity needs. In percentage terms, the reductions are biggest in North America and South Asia, where electricity demand falls heavily and where the shares of renewables and nuclear power increase less than in most other regions (Table 3.9).

Table 3.9. **Electricity sector investment by region in the Alternative Policy Scenario, 2003-30**

| | Cumulative Investment (USD billion in year-2000 dollars) | | | | Difference *vis–à-vis* Reference Scenario (%) |
|---|---|---|---|---|---|
| | Generation | Transmission | Distribution | Total | |
| **OECD** | **2 088** | **300** | **797** | **3 184** | **–19.2** |
| OECD Europe | 851 | 81 | 288 | 1 220 | –12.8 |
| OECD North America | 798 | 175 | 417 | 1 390 | –23.9 |
| OECD Pacific | 438 | 44 | 92 | 574 | –19.6 |
| **Transition economies** | **273** | **52** | **190** | **515** | **–21.2** |
| Russia | 138 | 17 | 62 | 218 | –15.0 |
| **Developing countries** | **1 945** | **813** | **1 807** | **4 564** | **–12.3** |
| China | 775 | 286 | 625 | 1 686 | –18.3 |
| East Asia | 329 | 127 | 290 | 745 | –6.6 |
| *Indonesia* | 61 | 24 | 55 | 140 | –15.6 |
| South Asia | 261 | 124 | 277 | 661 | –17.5 |
| *India* | 219 | 102 | 226 | 547 | –19.3 |
| Latin America | 298 | 106 | 238 | 642 | –9.3 |
| *Brazil* | 121 | 31 | 71 | 223 | –18.2 |
| Middle East | 110 | 47 | 107 | 264 | –3.1 |
| Africa | 173 | 123 | 271 | 567 | 0.6 |
| **World** | **4 306** | **1 164** | **2 793** | **8 263** | **–15.7** |

## 5. Critical uncertainties surrounding the adequacy of investment

The main uncertainties surrounding the adequacy of electricity investment worldwide in the medium term relate to the impact of market reforms, environmental constraints and access to capital. The relative importance of these uncertainties varies among developed and developing countries. In general, the effects of market reforms and environmental constraints on investment are most uncertain in OECD countries, while access to capital – a minor issue in the OECD – is perhaps the biggest uncertainty facing developing countries.

### *Impact of market reform*

Market liberalisation or reform is creating new challenges and uncertainties in the electricity sector in OECD countries and in many other parts of the world.[2] There is no reason to believe that competitive electricity markets cannot provide incentives for timely and efficient investments (IEA, 2005b). The key requirements are effective competition through properly regulated third-party access to unbundled networks; cost-reflective pricing of network services; and market rules that ensure transparency and low transaction costs. In addition, there is the challenge of creating a smooth regulatory framework for transparent and clear approval processes of new generation plants and network infrastructure. At present, market players are investing in liberalised electricity markets, even without additional capacity measures. Market reforms are expected to bring major economic benefits through more efficient investment and industry operation.

There are nonetheless growing concerns about the adequacy of investment as markets adapt to the new competitive environment. Prior to the liberalisation of electricity markets, electricity companies were usually operated as integrated monopolies, able to pass on their full costs to energy consumers. In such an environment, there was only limited risk in investment decisions. With the introduction of competition in power generation and supply, investors are now more exposed to risk. As competition develops, power companies are being forced to improve their risk management skills and strategies. Physical transmission and distribution activities remain regulated natural monopolies in most cases, though regulated rates of return on capital invested in those areas still need to be high enough to give investors sufficient incentive to expand capacity as demand grows and to maintain existing infrastructure. Investment in power generation, transmission and distribution has fallen in some countries where market reforms have been introduced in recent years, raising fears of a shortfall in peak capacity in the future.

The level of future electricity prices in competitive electricity markets can be a major source of risk to electricity generators and marketers. Price volatility can greatly affect investors' revenues and profits. Uncertain electricity prices expose projects that have a long lead and construction time to additional risks. Economies of scale favour large power projects over small ones, as capital costs per kW for a given technology generally decrease with increasing scale. However, the combination of a long lead time for constructors, uncertain growth in demand for electricity, and the cost of financing add to the risks for these types of investments. Estimates of profitability for such projects rely principally on a long-term market assessment, independent of the spot power market conditions. Very large projects that must effectively be built as a single large plant, such as a large-scale hydroelectric facility, are more vulnerable to this type of risk than projects that can be developed as several smaller power plants, in response to market conditions.

There are a number of ways to manage electricity price risk, for example through the use of long-term bilateral contracts, futures and forwards contracts, either through established or over-the-counter exchanges. The more liquid these markets become, the easier it will be to use these tools. Although fuel prices have always been uncertain, fuel price risks are increased by the liberalisation of the natural gas market. Very long-term contracts are not generally available, with the exception of "take-or-pay" arrangements in LNG markets.

Reserve margins – the difference between maximum available capacity and peak demand – have declined in most countries that reformed their electricity markets in the 1990s. This partly reflects more efficient management and the elimination of excessive spare capacity that had been built previously – a key objective of liberalisation. But this trend has provoked a debate about the appropriate level of reserve margin to ensure that electricity demand will be met during peak demand periods. Supplying electricity at these times requires maintaining adequate generating capacity or buying power from another generator in a market which has a different peak, as well as maintaining adequate transmission capacity. Peak demand is most economically met with power plants of low capital cost, since fixed expenses can be recovered only over relatively short annual periods of operation. The risks to investors building this type of peaking capacity may be high, especially when compared to base-load plant. Such risks include:

- *Market risk*. Peak demand is greatly influenced by weather conditions. Unusual weather patterns such as very warm winters or cool summers could result in certain types of peaking plant not being required at all, and so yielding no annual revenues.
- *Fuel-supply risk*. In systems where the demand for natural gas for space heating and for peak electricity generation coincide, gas supply for space heating will generally be given a higher priority. Thus there is a risk that fuel supply to gas-fired peaking plants could be interrupted or curtailed during cold periods.
- *Regulatory risk*. Because peaking plants are called into service when prices are highest, they are disproportionately exposed to the risk of government-imposed caps on electricity prices.

Market reform is creating uncertainty about future investment in transmission and distribution networks as well. Transmission owners and operators have far less certainty about the demands that will be placed on their networks and, with the unbundling of vertically integrated utilities, less capacity to undertake integrated planning and development of transmission networks as

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a whole. Transmission system operators' capacity to manage system balancing is thus greatly reduced, particularly within regional markets incorporating several owners and operators. At the same time, regulatory and policy uncertainty can heighten the business risks faced by transmission system owners, which can discourage investment. The situation can be further complicated by vested interests seeking to weaken incentives for efficient network performance, and by jurisdictional boundaries cutting across networks and interconnections.

Large-scale blackouts occurred in 2003 and 2004 in a number of OECD countries, notably in North America, Italy, southern Sweden and eastern Denmark. These incidents raised concerns that the transmission infrastructure was inadequate and that major new investment in transmission capacity was needed to improve transmission system reliability. In each of these cases, official investigations concluded that the blackouts were not caused by market reforms. They did, however, raise some issues that will need to be addressed in the future concerning investment in ensuring system security in competitive markets.

Although investment in transmission capacity may help to improve transmission system security to a degree over a period of time, it is not expected to be a critical factor in managing the "operational" reliability of an existing transmission system (IEA, 2005c). This is because system security or reliability is not simply a function of available transmission line capacity. More importantly, there is a need for investment in upgrading and improving system operating tools that would enhance system operators' capacity to effectively monitor, understand and more flexibly control transmission systems in real time. Investment to strengthen the competence and expertise of system operators and other professionals directly involved in the task of maintaining system security helps to improve real-time responses, particularly during emergency situations. Investments that enhance the likelihood of system components operating as designed, especially during emergency situations, may also help to improve transmission system security. The costs of such investments are modest compared with the cost of building transmission capacity.

Investment will increasingly need to be directed at improving the *quality* of supply, rather than simply meeting increased demand for reliable electricity service. This essentially involves ensuring a stable voltage. When the voltage dips below a stable threshold the system can become unstable; this leads to a collapse in voltage, with the potential to cause serious damage to motors and electronic equipment and appliances at the point of use. The growing prevalence of electronics as we move into the digital age is increasing the importance of high-precision electricity supply (EPRI, 2003).

There is enormous potential for developing and deploying technologies to improve operating tools to enhance transmission and distribution system security, and quality of service. This covers the whole range of activities from operational contingency planning through to security monitoring and network control. Better technology can improve the accuracy, quality and timeliness of information. It can also support the development of more accurate and dynamic system modelling, which in turn can allow for more flexible and adaptable contingency preparation and promote greater real-time situational awareness. Technology also has the potential to improve effective operator control over power flows, which would permit more flexible operation of transmission systems and more effective real-time responses to alleviate congestion, manage emergency situations, and enable timely service restoration. Electricity companies and governments are spending considerable amounts of money on developing new transmission technologies in part aimed at improving reliability.

Policy makers are seeking to address concerns about the adequacy of investment by establishing a market framework that sends the right market signals to investors, so that investment is forthcoming when required. The challenge is to exploit the price signals for efficiency that effective markets produce. At the same time, regulators have to take into account cost-effectiveness, reliability concerns and the role of transmission interconnectors in enhancing competitiveness. Some countries have concluded that direct market intervention to stimulate investment in peaking and transmission capacity is unnecessary at this time. In others, measures are being taken to ensure that enough investment in peak capacity occurs so as to guarantee adequate reserve margins. Others are seeking ways to enhance the short-term responsiveness of electricity demand to changes in price, as a means of reducing peak demand and the volatility of prices. Such measures include campaigns to increase consumer awareness of the threat of power cuts when demand peaks, demand-side bidding to induce industrial customers to reduce their load during peak periods, and the use of advanced technology, such as advanced meters, to reduce or reschedule peak load.

### *Impact of environmental regulations*

Environmental regulations, requiring power plants and other industrial facilities to limit or reduce their emissions, are becoming tighter. Uncertainty about future environmental legislation increases investor risk, creating uncertainty about future investment. Existing coal plants in most countries are already subject to controls over emissions of three local or regional pollutants: sulphur dioxide, nitrogen oxides and particulates. However, today's investor faces a high risk of those controls being made tighter and new constraints being imposed on emissions, particularly $CO_2$. Nuclear power plants may also be subject to additional safety regulations.

More environmental protection will without doubt increase investment requirements for both existing and new power plants. Environmental costs may account for 10% to 40% of total plant costs in fossil-fuelled plants and

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more in nuclear plants. Emissions of sulphur dioxide, nitrogen oxides and particulate matter depend on the fuel mix used in power generation. They are highest in countries where electricity generation is based heavily on coal. Emission standards for these pollutants are tight and becoming tighter in many OECD countries. Developing countries will also be increasingly seeking to reduce these pollutants. This will increase further their already large needs for power sector investment.

Environmental regulation may increasingly address carbon dioxide emissions in all countries. However, in the medium term the impact will be greater in the countries that act to reduce their greenhouse gas emissions under the Kyoto Protocol. Power generation currently accounts for 38% of total energy-related $CO_2$ emissions in the OECD countries and 40% worldwide. Measures to reduce these emissions will require increased investment in power generation – in more efficient fossil-fuel plants, in nuclear plants, or in renewables-based technologies. Carbon capture and storage may also become a cost-effective option in the medium to long term, though this technology has not yet been proved on a large scale. More investment in upgrading transmission and distribution networks, to reduce losses and therefore the need to generate power, might be a more cost-effective response in some cases. In general, a clear and stable regulatory framework, which gives investors adequate warning of a tightening of environmental regulations, is needed to give investors confidence that current capital outlays will be able to yield a satisfactory return.

Environmental regulations may also make it more difficult to obtain approval to build new generating plant and high-tension transmission lines. The absence of transparent and smooth approval procedures – whether to use a particular technology or to site a new generation plant or network at a particular location – continues to be a serious barrier to investment in many OECD countries. The so-called "not in my back yard" (NIMBY) syndrome was a primary cause of the California power crisis in 2001. The syndrome is expected to become an increasingly serious obstacle to new investment in most parts of the world.

### *Access to capital*

Financing all the investment that will be needed to meet rising demand is a major challenge for the electricity supply industry, and a key source of uncertainty about the prospects for installing electricity infrastructure, especially in developing countries. Their investment needs will increase rapidly in the coming decades. Some developing regions, Africa and India will struggle to mobilise the amounts of capital required.

Investment in electricity infrastructure in developing countries has traditionally been the responsibility of governments. Public utilities in several large developing countries are unprofitable. As a result they are not able to finance new projects themselves. Moreover, investing in new plant is only part of the challenge. Utilities must also purchase fuel to run their power plants. Expenditure on fuel in power stations in developing countries over the next thirty years is expected to be of the same order of magnitude as the investment in infrastructure. The poor financial health of public utilities results from a number of factors:

- *Under-pricing of electricity.* Average electricity tariffs in many developing countries are not high enough for the public utility to cover its full costs. In some cases they do not even cover short-run marginal costs. India is a glaring example of this problem. In 2001/2, the latest year for which data are available, the average price of electricity sold was equal to only about 65% of the full cost of supply (TERI, 2004). As a result, the state electricity boards have been unable to invest fast enough to keep pace with demand, despite additional funding from the central government and private investors for some projects. Shortfalls in peak capacity, which averaged about 13% in 2001/02, result in widespread and frequent power outages and voltage fluctuations.
- *Under-collection of revenues*, caused by non-payment or theft, is also a serious problem in many countries. Non-collection is akin to a 100% subsidy, and can be more distorting and costly than under-pricing of electricity. In some cases, small amounts owed by poor households are not collected for social reasons. But the loss of revenues, by lowering the capacity of the utility to invest, holds back the extension of the network and electrification, especially in rural areas where costs are generally highest.
- *High production costs*, which make it more difficult to eliminate subsidies. The cost of producing electricity in many developing countries is higher than in the OECD area, usually because of low plant efficiency (because of poorly maintained equipment), poor fuel quality, high network losses (because of poor technical performance or theft), high capital costs (because of non-competitive and non-transparent purchases of equipment), high unit transmission and distribution costs (because of low consumption density) and high operating costs (because of poor management and low productivity). Exchange rates also adversely affect a utility's costs when loan servicing and purchases of fuel and equipment have to be made in a foreign currency. Many utilities have accumulated large debts and incur heavy interest charges, which increase their overall costs.

The 1990s saw an increasing number of countries turning to the private sector for part of the investment needed to finance the electricity sector. That trend is set to continue, because of the limited availability of public funds – as the call on government budgets for other forms of spending such as education and welfare increases – and rising electricity investment needs. Governments are also increasingly looking to expand the role of the private sector as a way of improving

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economic efficiency. Yet, obtaining adequate private sector funding will be difficult (see next section). The private sector, while in principle welcoming business opportunities in rapidly growing developing economies, will invest only if it perceives a sufficiently stable and attractive legal framework, and if it can expect returns high enough to compensate for the risks.

While most investment in the developing world is carried out by public utilities or by independent power projects, another source has been direct investment by private electricity consumers in their own electricity-generating capacity, either as back-up to the public supply or as a replacement for it. This response to underinvestment in public supply is most notable in those countries where the quality of electricity supplied by public utilities is poor and deteriorating, such as India, Indonesia and Nigeria. In Indonesia, for example, autonomous electricity producers own 15 GW out of the country's 40 GW of total installed capacity. This trend could become more significant in the future, if shortfalls in investment in centralised production and transmission persist.

Overcoming these obstacles to investment will not be easy. It will require major improvements in governance and continued restructuring and reform in the electricity sector. That will test the institutional capacity of developing countries. Perhaps the most pressing challenge is to reform tariff structures to make prices reflective of costs and to improve revenue collection. It is a major challenge to do this in a way that does not unduly hurt poor households that are not able to afford even basic electric services.

Given the large amount of investment needed in distribution networks in these countries (about USD 2 trillion, or 40% of total power sector investment, over 2003-30), reform of the electricity distribution sector will be of particular importance. In many developing countries, the priority is to reduce non-technical losses from theft of electricity, utility goods and cash, and from non-payment of bills. Such reforms are difficult and take considerable time, at least five years and more likely ten or so. The gap between investment needs and actual investment is likely to continue for some time in the worst-affected countries, with blackouts and brownouts remaining a major problem.

## 6. Implications for industry structure and financing

Liberalisation and market reforms, largely driven by the goal of achieving more efficient investment in and operation of the electricity supply industry through more private sector participation and the introduction of competition, are having a profound impact on industry structure and the way in which investments are financed. The traditional structure of the electricity utility is a vertically integrated entity, which is often state-owned. Competition is introduced by breaking up or unbundling that structure into its constituent parts – generation, transmission, distribution and supply. In most cases, the physical transmission and distribution functions remain regulated by the authorities as natural monopolies. The way in which the electricity sector has been unbundled varies considerably across countries. The ownership of some components is the same in many cases, but the commercial and operational relationships between them have to be made transparent if competition in generation and supply is to be effective. The participation of a sufficient number of generators and marketers is also a critical condition for effective competition to develop.

Today, the electricity market is organised around power companies whose size varies substantially. The ten largest power companies in the world – led by Electricité de France (EdF) – account for about one-fifth of the world's installed capacity. Until the 1990s most utilities were national, focusing almost exclusively on their domestic markets. In the past decade or so, many utilities chose to invest in other countries and regions. Activity was particularly intense in Europe. A number of large power companies have invested in power projects in developing countries. However, many of these companies are now withdrawing or selling their assets, and interest in new projects in developing countries is very limited.

Several markets, particularly that in the United Kingdom, have recently experienced varying degrees of vertical re-integration. This has involved the horizontal mergers of power-generation and retail companies, and the acquisition by generating companies of retail operations. Economies of scale are clearly a major driver of this reintegration trend, particularly in retailing: a relatively large number of customers seem necessary to make a profitable business of supplying small commercial and residential consumers. In power generation, mergers and acquisitions can help improve the stability of cash flow as a source of finance for large capital-intensive investments in an environment where there is reduced access to debt capital. This has been a key driver in the emergence in Europe of "Seven Brothers" – EdF, E.On, RWE, Vattenfall, Endesa, Electrabel and Enel. These very large electricity firms, which also have significant investments in other businesses, are expected to finance a significant portion of new investment from internal resources. This consolidation has raised concerns about undue concentration and its impact on competition and pricing.

In OECD countries generally, electricity companies finance new projects by providing part of the project capital as equity (internally generated cash or equity issued as public shares). The remainder is financed as debt, with borrowing from banks or through issuing bonds. The current debt-equity structure of OECD power companies varies considerably, with some countries having seen an increase in the share of debt and others a fall (Figure 3.14). Japan relies more on debt, while reliance on equity is larger in the United States. Companies with high levels of debt, such as Japan and France,

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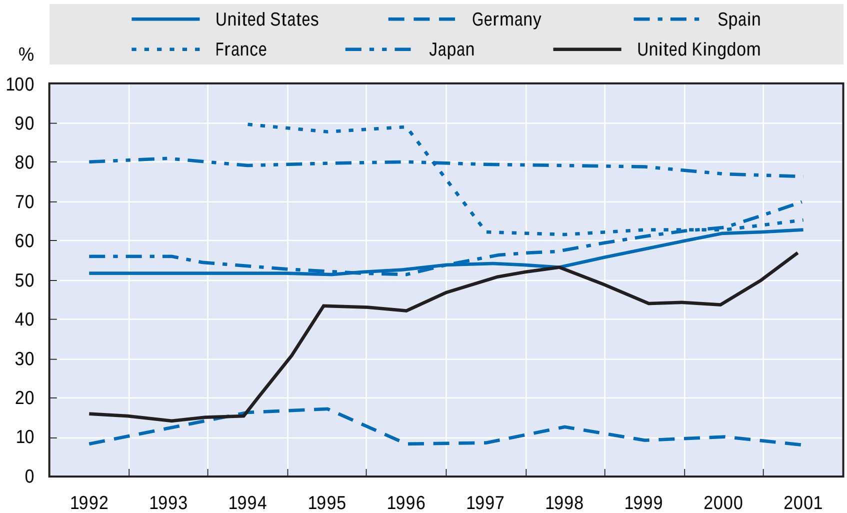
Figure 3.14. **Debt-equity ratio[1] of power in selected OECD countries**

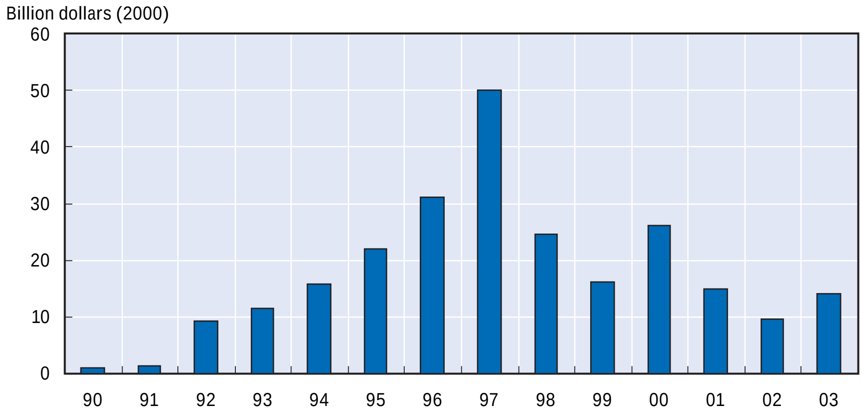



*Note:* For France, the sharp change in EdF's debt-equity structure in 1997 was due to the issuance of stocks.
1. Share of total debt in the sum of shareholders' equity and total debt.
*Source:* Standard and Poor's database.

have reduced their debt in anticipation of the emergence of competition. Countries which have seen increased investment in recent years, particularly the United States and the United Kingdom, have increased their debt, although US companies are now looking to reduce debt. It remains to be seen how market reforms and the development of competitive electricity markets will affect the debt-equity structure in the future, and in particular whether the share of equity will move toward the high levels typical in the oil industry.

In non-OECD countries, where utilities are often state-owned and profitability and revenue collection are poor, capital often comes from the government or from multilateral lending agencies, such as the World Bank or the Asian Development Bank. In most developing countries, market reforms have been largely focused on the opening of the electricity sector to private investment, rather than on establishing competitive wholesale and retail markets. Many countries initiated reforms in the 1990s, aimed at attracting private domestic and foreign investment. The initial response was encouraging, but private investment declined rapidly after 1997 (Figure 3.15). Total private sector investment in electricity between 1990 and 2003 in developing countries amounted to USD 249 billion in 2003 dollars. Brazil and other Latin American countries attracted about half of it. However, much of it was spent on existing assets that were privatised rather than on new projects (Izaguirre, 2004).

Figure 3.15. **Investment in electricity infrastructure projects with private participation in developing countries, 1990-2003**




*Source:* World Bank Private Participation in Infrastructure database.

Reasons for the recent sharp decline in private investment include badly designed investment and energy policies and regulations, economic collapse, and bad business judgements. The result was disappointing rates of return on investment. Many private companies have sold assets they had acquired in the early to mid-1990s. A loss of position in their home markets (notably in the case of US investors) and mergers and takeovers under corporate retrenchment policies (in the case of European investors) contributed to this trend. The result has been a drastic reduction in the number of active international investors in developing countries.

Private investment rebounded in 2003 to just over USD 14 billion, from less than USD 10 billion – its lowest level since 1993. The increase was focused on greenfield power plants in East Asia. There are signs that domestic and regional investors are becoming more prominent in the electricity sectors, especially in Asia. But maintaining the momentum of the growth in financing from this source will take time and appropriate policies. Today, private participation in the electricity sector remains relatively low across developing countries. It is generally highest in power generation and lowest in transmission and distribution, which are usually regarded as a public service (Table 3.10). Participation also tends to be highest in the better-off countries. The role of the private sector is significantly larger in Latin America than in any other part of the developing world. The Middle East and South Asia have been much less successful or interested in attracting private capital.

The ease of financing for electricity projects will continue to vary widely, according to the country in which the investment is made, the risk-return

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Table 3.10. **Share of countries with private participation in the electricity sector by developing region, 2004 (% of sample)**

| Country | Power generation | Transmission and distribution |
|---|---|---|
| Sub-Saharan Africa | 41 | 28 |
| East Asia and Pacific | 67 | 20 |
| Eastern Europe and Central Asia | 41 | 48 |
| Latin America and Caribbean | 68 | 61 |
| Middle East and North Africa | 31 | 13 |
| South Asia | 38 | 13 |
| Other countries | 70 | 43 |
| **Total developing regions** | **51** | **37** |

*Source:* Estache and Goicoechea (2004).

profile of individual projects, and whether the investment is in generation, transmission or distribution:

- In *OECD countries*, electricity companies will most likely remain relatively highly leveraged, *i.e.* they will keep their high debt-to-equity ratios. Returns on investment could fall as competition develops, which could drive up borrowing especially for the most leveraged firms and for power generation companies. Transmission and distribution will remain a relatively low-risk business, with returns remaining protected to a large degree by regulators. The cost of their capital will depend partly on how the regulatory framework evolves and, in the case of state-owned firms, the ability and readiness of governments to finance investment themselves.
- In many *non-OECD countries* financing will remain difficult, especially in Africa, the transition economies and South Asia, because of poorly developed domestic financial markets and the higher cost of capital caused by higher risk. Private investment is expected to play a growing role in the medium term, but the success of efforts to attract private capital will depend critically on the economic, political, regulatory and legal environment in each country.

## *Notes*

1. However, the widespread deployment of carbon sequestration and capture technology – not assumed here – could help coal maintain a high share in electricity generation.
2. Many developing and transition economies are seeking to restructure their electricity industries by introducing new market structures to encourage competition. Many of their efforts have not brought about the expected results. Some of these countries may want to delay the introduction of competition until their electricity sector is sufficiently mature and economically viable.

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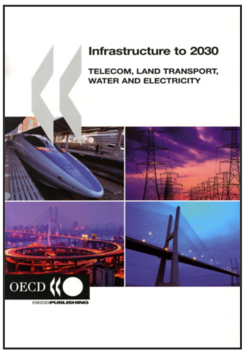


**From:**

# Infrastructure to 2030

## Telecom, Land Transport, Water and Electricity

**Access the complete publication at:**

https://doi.org/10.1787/9789264023994-en

**Please cite this chapter as:**

Morgan, Trevor (2006), "Outlook for Global Investment in Electricity Infrastructure", in OECD, *Infrastructure to 2030: Telecom, Land Transport, Water and Electricity*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9789264023994-4-en



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