CHAPTER 16

FOCUS ON BRAZIL

HIGHLIGHTS

- Brazil is Latin America's largest energy consumer, accounting for over 40% of the region's consumption. Its energy mix is dominated by renewable energy sources and oil. In the Reference Scenario, primary energy demand is projected to grow annually at 2.1%, from 200 Mtoe in 2004 to 352 Mtoe in 2030. Energy demand is 38 Mtoe lower in the Alternative Policy Scenario, growing at just 1.7% per year, thanks to energy-efficiency improvements. Electricity and oil make up most of the reduction.
- Crude oil production is expected to reach 3.1 mb/d in 2015 and 3.7 mb/d in 2030 in the Reference Scenario. Brazil became self-sufficient on a net basis for the first time in 2006 and remains so in both scenarios over the *Outlook* period, provided that the necessary investment in the upstream oil sector, especially for exploration, is forthcoming. The share of imports in natural gas use drops, despite rapidly rising demand – on the assumption that the country's gas reserves are developed quickly enough. This will call for more private investment and a more effective regulatory framework.
- Brazil is the world's second-largest producer and largest exporter of ethanol. It is also expanding its production and use of biodiesel. The share of biofuels in road-transport fuel demand rises from 14% in 2004 to 23% in 2030 in the Reference Scenario and to 30% in the Alternative Policy Scenario.
- Brazil is expected to continue to rely on hydropower to meet most of its power-generation needs, building about 66 GW of new capacity in 2004-2030 in the Reference Scenario. Dams are likely to be located far from centres of demand, requiring large investments in transmission lines to connect them to the national grid.
- The investment needed to meet the projected growth in energy supply in the Reference Scenario is considerable, some $470 billion (in year-2005 dollars) in 2005-2030. The power sector alone needs over $250 billion, half for generation and half for transmission and distribution. Cumulative upstream oil investment totals over $100 billion. In the Alternative Policy Scenario, investment needs on the supply side are reduced by $7 billion in the oil and gas sectors and

$46 billion in the power sector, but demand-side investments are higher. Winning investor confidence in order to secure financing in the power sector will hinge on careful implementation of the new power model.

- The major challenges for Brazil's energy sector will be mobilising investment in oil, gas and electricity infrastructure and resolving environmental issues over the construction of large dams, pipelines and transmission lines. A priority for the government will be to strengthen its policy and regulatory framework in order to secure the necessary investments.

Overview

Brazil has a very dynamic energy sector. Recent government policies have brought considerable improvements in energy efficiency in the residential and industry sectors and have succeeded in increasing the penetration of non-hydro renewable energy in the power-generation mix. Impressive technological advances have been made in production of crude oil in deep and ultra-deep water and of ethanol from sugar cane. These achievements will continue to serve as an inspiration to other developing countries with similar aspirations.

Brazil is the largest country in Latin America and the fifth-largest in the world by surface area. It also had the world's fifth-largest population in 2004, with 184 million inhabitants. Brazil is Latin America's largest energy consumer, accounting for over 40% of the region's primary consumption in 2004. Brazil's primary energy mix is dominated by oil, which accounts for 42% of total demand, hydropower (14%) and other renewable energy sources (27%). Energy intensity, measured by the ratio of energy demand to GDP, has declined over the past three decades. But the share of fossil fuels in the primary mix has increased and growth in CO_2 emissions has been on a par with growth in energy demand (Table 16.1).

Table 16.1: **Key Energy Indicators for Brazil**

	1980	2004	1980-2004*
Total primary energy demand (Mtoe)	111	200	2.5%
Total primary energy demand per capita (toe)	0.9	1.1	0.8%
Total primary energy demand /GDP (toe/dollar of GDP in PPPs)	0.1	0.1	0.4%
Share of oil in total primary energy demand (%)	50	42	–0.7%
Share of hydro in total power generation (%)	81	65	–0.9%
CO_2 emissions (Mt)**	178	323	2.5%

* Average annual growth rate. ** Excludes emissions from land use, land use change and forestry.

Brazil has vast energy and natural resources, including about 11.2 billion barrels of proven oil reserves and 306 billion cubic metres of gas. Among Latin American countries, Brazil ranks second to Venezuela in oil and natural gas reserves. In April 2006, Brazil achieved self-sufficiency in crude oil consumption, largely as a result of investments in exploration and production. Rising domestic ethanol production and consumption, combined with a slowdown in the growth rate in energy demand in the transport sector, has also helped to free up oil for export. Brazil has a large renewable energy supply potential, with 260 GW of technical hydropower potential and 143 GW of technical wind-power potential. Brazil is the world's second-largest ethanol producer, after the United States, and the world's largest ethanol exporter. The ethanol is derived from sugar cane. Development of these vast resources, however, has been hindered by cyclical economic disruptions and shortages of long-term and low-cost capital.

Brazil faces a number of energy and environmental challenges. Natural gas demand has increased considerably over the last few years, as the government kept gas prices low to encourage energy diversification. A rapid expansion of gas imports fuelled this growth. In 2004, imports from Bolivia accounted for 43% of gas consumption in Brazil.[1] Particularly in the light of the recent nationalisation of the energy sector in Bolivia, Brazil is seeking to reduce this concentrated gas import-dependence by accelerating development of the Espirito Santo and Santos basins and by importing LNG. Environmental concerns will, however, need to be addressed. Much more investment will be needed to exploit domestic gas resources and to expand the gas transportation and distribution infrastructure. Hydropower accounted for over three-quarters of Brazil's electricity-generating capacity in 2004 and the government plans to authorise the building of new large hydropower plants; but there are important environmental and financial obstacles. The government is actively promoting the use of sugar-cane residue (bagasse) for cogeneration of heat and power and other non-hydro renewables-based electricity generation.

The Political and Economic Outlook

The Political Scene

In 2002, Luiz Inacio Lula da Silva was elected president of Brazil. The new administration's macroeconomic management has generally exceeded expectations. To consolidate its support, particularly among the poor, the

1. The Brazilian government estimates that, in the first quarter of 2006, imports from Bolivia accounted for 48% of gas consumption.

Administration has increased public spending and raised the minimum wage. A presidential election is scheduled for October 2006, as this book goes to press.

The Brazilian government is very active on the international scene. At the fifth ministerial conference of the World Trade Organization (WTO) at Cancun, Mexico in September 2003, Brazil assumed the leadership of a new group of developing countries, the G20 group. Under its direction, this group has shown resistance to changing the rules of government procurement, investment and competition, unless industrialised countries agree to concessions on subsidies, particularly in agriculture. The government is working to remove tariffs on global ethanol trade. Brazil has ratified the Kyoto Protocol.

The National Economy

Brazil's economy is the largest in Latin America, with GDP of $1 577 billion (in PPP terms and year-2005 dollars) in 2005. Growth in gross domestic product slowed during 2001 and 2002, to some 2% per year from around 2.7% per year in the 1990s, reflecting the slowdown of the world economy. GDP declined by 0.4% in 2003 but rebounded in 2004, to 4.9%. The expansion was driven predominantly by higher investment and external demand for Brazil's manufactured goods. This sector's contribution to GDP fell in 2005, however, and, combined with weak growth in the agricultural sector due to drought, GDP expanded by only 3.3%. GDP growth is expected to recover slightly in 2006 to 3.5%. The services sector accounts for about half of Brazil's GDP. Industry represents about 40% and agriculture 10%.

GDP per capita, at $8 311 in 2004, was higher than the average for Latin America, but still far below the average per-capita income of $28 400 in the OECD countries. There are sharp disparities in per-capita income in Brazil. According to the United Nations Development Programme, Brazil had the highest Gini coefficient – a measure reflecting the degree of income inequality – in Latin America and the seventh-highest in the world in 2001 (UNDP, 2004). Government reforms, however, have been successful in lowering the degree of income inequality in recent years. Only 4% of Brazilian households lack access to electricity, but the share reaches 25% in rural areas and is even higher in the north and northeast regions. The "Electricity for All" programme aims to give access to all households by 2015.

The Brazilian government has been successful in meeting and, in some cases, surpassing stringent fiscal targets set in consultation with the International Monetary Fund. In December 2005, the government paid off $15.5 billion owed to the IMF (IMF, 2006a). The Central Bank raised interest rates sharply during the first half of 2003. The easing of monetary policy in the second half of 2003, however, combined with a strengthening world economy, allowed growth to rebound in 2004, but the recovery was dampened by further monetary tightening in 2005. Economic volatility has stymied the current administration's efforts to reduce poverty and unemployment.

The Brazilian economy has experienced several periods of volatility in the past. By 2004, Brazil had accumulated $200 billion of external debt. Public debt has declined, thanks to large primary surpluses (at about 5% of GDP), steady GDP growth, a marked appreciation of the exchange rate and rising international reserves. Public domestic debt as a percentage of GDP remains high, however, reaching 59% in 2003. Financing this debt and controlling inflation, has pushed up domestic interest rates, which peaked at just under 20% in 2005, among the highest in the world (World Bank, 2006). This has had the effect of reducing domestic public and private investment, including that in long-term energy projects. The net public debt to GDP ratio is expected to continue to fall slightly over the *Outlook* period (EIU, 2006).

Brazil is second only to China among emerging markets as a recipient of net foreign direct investment. Foreign direct investment was $15.1 billion in 2005 and is expected to reach $15.6 billion in 2006 (IMF, 2006b). Since structural reforms were first launched in the energy sector in the 1990s, the share of foreign capital in energy projects has increased rapidly. However, participation in energy infrastructure investment by private-sector capital, both domestic and international, has been lower than expected, because of regulatory risk and high interest rates.

Key Assumptions

The projections in this *Outlook* assume that the Brazilian economy will grow on average by 3.3% per year from 2004 to 2015 (Table 16.2).[2] Growth is assumed to slow thereafter, bringing down the average for the entire *Outlook* period to 3% per year. In the short and medium term, both private consumption and investment are expected to support somewhat faster growth, but growth is expected to be slower towards the end of the projection period.

Table 16.2: **GDP and Population Growth Rates in Brazil in the Reference Scenario** (average annual rate of change)

	1980-2004	1990-2004	2004-2015	2015-2030	2004-2030
GDP	2.1%	2.6%	3.3%	2.8%	3.0%
Population	1.7%	1.5%	1.2%	0.8%	0.9%
GDP per capita	0.4%	1.0%	2.1%	2.0%	2.1%

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2. See Chapter 1 for a discussion of GDP and population assumptions.

Brazil's rate of population growth is declining, from some 2% per year in the 1980s to 1.5% from 1990 to 2004. This *Outlook* assumes that the population will increase by 0.9% per year on average to 2030, reaching 235 million. Over 80% of the population is urban. This relatively large share by developing world standards is explained by historically high rates of population growth in towns and cities, rural to urban migration and the urbanisation of areas previously classified as rural.

Recent Trends and Developments in the Energy Sector

In the last decade, Brazil's energy sector has undergone profound regulatory and structural changes. Petrobras, the national oil and gas company, had exclusive rights to explore and produce oil and gas up to 1995, when the Ninth Amendment to the Brazilian Constitution was issued. This change allowed other companies to become involved in oil and gas exploration and production. In 1997, the Oil Law was adopted, establishing the legal and regulatory framework for the oil industry in Brazil. Since then, over fifty companies, including Petrobras, have acquired rights to explore and produce oil and gas in Brazil. The national regulator for oil and gas, Agência Nacional do Petróleo (ANP), began auctioning exploration blocks in 1999. The seventh bidding round for oil concessions in October 2005 was considered one of the most successful rounds so far since most of the blocks with potential for gas discoveries were awarded. There was also increased participation from domestic companies.

Since December 2000, the oil and gas upstream sector has been fully liberalised and opened to private investors. More than 50 companies are currently active in exploration, though Petrobras retains a dominant position in the sector, producing almost all of Brazil's oil and natural gas. This dominance will lessen as other companies reap the benefits of their investments in exploration. In August 2003, Shell became the first private company to operate an offshore producing field.

As part of the deregulation of the oil and gas sector, end-user prices were liberalised in May 2001 and major subsidies were eliminated. A voucher programme for liquefied petroleum gas (LPG) was set up to assist the poorest households. In Brazil, 98% of households have access to LPG (Box 15.1 in Chapter 15).

Reforms in the power sector were launched in the 1990s.[3] After a period of experimentation with mixed success and the power crisis of 2001, the Brazilian government introduced a new regulatory framework aimed at attracting

3. See de Oliveira (2003) for an overview of power sector reform in Brazil.

investment in 2004. Concessions for the construction of over 10 000 kilometres of transmission lines were awarded and the reliability of the integrated grid has improved. Electricity generation and distribution have also been opened up to private capital. Today 66% of the distribution capacity and 28% of the generating capacity in the Brazilian electricity sector is privately owned.

Box 16.1: **Regional Integration in South American Energy Markets**

Brazil plays an important role in the South American energy market. During the 1970s and 1980s, large multinational hydroelectric dams on the borders of Brazil, Paraguay, Argentina and Uruguay were constructed, providing the main drivers for regional energy integration. In 1991, Argentina, Brazil, Paraguay, and Uruguay formed the Mercado Comun do Sul (Mercosur) to promote intra-regional trade and to co-ordinate macroeconomic policies.

In the late 1990s and early 2000s, projects for transmission grids and gas pipelines boosted regional energy integration. Brazil signed agreements with Venezuela, Uruguay and Argentina in early 2000 to import/export electricity. Meanwhile, gas connections were built with Bolivia and Argentina. There are now three transnational gas pipelines and several electricity transmission lines linking Brazil with neighbouring countries. Another cross-border project under discussion is "Blue Corridors" – a pipeline network that would ultimately connect several cities across Latin America, including Rio de Janeiro and São Paulo in Brazil, Buenos Aires in Argentina, Montevideo in Uruguay and Santiago in Chile.

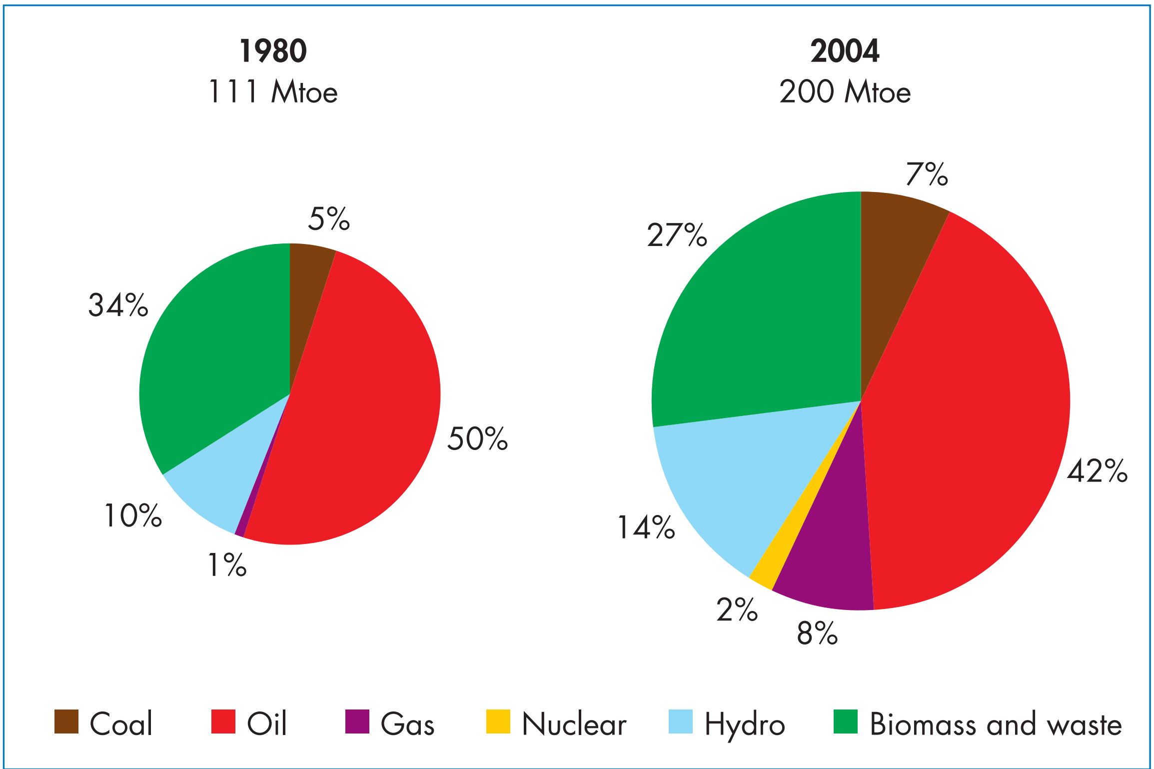
In February 2005, the Venezuelan state oil company, PDVSA, announced the signing of 14 energy accords with Petrobras. The accords anticipate cooperation in the oil, gas, refining, transport and petrochemical sectors, as well as the exchange of biofuels technology and the possible participation by Petrobras in an LNG export project in Venezuela. The two countries are also interested in cooperating on a project to build a refinery in Pernambuco State in the northeast of Brazil.

The nationalisation of Bolivia's gas sector in May 2006 put a strain on Bolivian-Brazilian relations. Bolivian imports covered 43% of Brazil's consumption in 2004. Future import levels are uncertain: prices are currently being renegotiated. The assets of Petrobras in Bolivia have been nationalised and the near-term prospects of expanding the Brazil-Bolivia pipeline have dimmed.

Outlook for Energy Demand

Brazil's energy mix has become more diversified over the past several decades. In 1980, biomass use accounted for 34% of total energy demand. Most of this was traditional use for cooking and heating in the residential sector. Total biomass use declined to 27% in 2004 (Figure 16.1). The use of biomass today is predominantly based on modern energy technologies, such as the production of ethanol from sugar cane, the cogeneration of electricity from sugar cane bagasse, the use of sawdust and black liquor (a by-product of the pulp and paper industries) and the production of charcoal from eucalyptus plantations by steelmakers. Fuelwood use for cooking and heating fell from 25 Mtoe in 1971 to 11 Mtoe in 2004, though there are indications that high oil prices have recently reversed this trend. Poor households in the north and northeast, the least developed part of the country, still rely predominately on fuelwood to meet their cooking and heating needs.

Figure 16.1: **Primary Fuel Mix, 1980 and 2004**



The share of oil in total primary energy demand has declined since the 1980s. The share of natural gas has grown considerably, particularly in recent years, reaching 8% in 2004. Between 1999 and 2004, gas demand grew by over 20% per year – the result of a deliberate government policy to diversify energy sources. Gas-fired generation is used as a backup source of electricity, to stabilise seasonal changes in hydropower supply due to rainfall variations. Today, about 44% of marketed gas consumption is in the industry sector, while about a quarter is used for power generation. Gas is also used in the transport sector. Brazil had over one million vehicles running on compressed natural gas (CNG) in 2005.[4] In some large metropolitan areas, like São Paulo and Rio de Janeiro, the government is promoting programmes to displace diesel with natural gas in city buses. The share of coal in the primary energy mix increased from 5% in 1980 to 7% in 2004.

Reference Scenario

In the Reference Scenario, Brazil's primary energy demand is projected to grow at an average annual growth rate of 2.1%, from 200 Mtoe in 2004 to 349 Mtoe in 2030 (Table 16.3). This is somewhat slower than the growth of 2.5% per year from 1980 to 2004. Demand grows more rapidly in the period up to 2015, at 2.6%. Brazil's energy intensity continues to decline, by 0.9% per year, as the structure of its economy progressively approaches that of OECD countries today.

Table 16.3: **Primary Energy Demand in the Reference Scenario in Brazil** (Mtoe)

	1990	2004	2015	2030	2004-2030*
Coal	9.7	14.2	15.1	18.0	0.9%
Oil	57.7	84.8	108.4	141.7	2.0%
Gas	3.2	15.8	25.9	41.2	3.8%
Nuclear	0.6	3.0	6.3	6.3	2.9%
Hydro	17.8	27.6	38.0	50.0	2.3%
Biomass ans waste	41.6	54.4	70.6	89.8	1.9%
Other renewables	0.0	0.0	0.5	1.9	25.4%
Total	**130.6**	**199.8**	**264.8**	**348.8**	**2.1%**

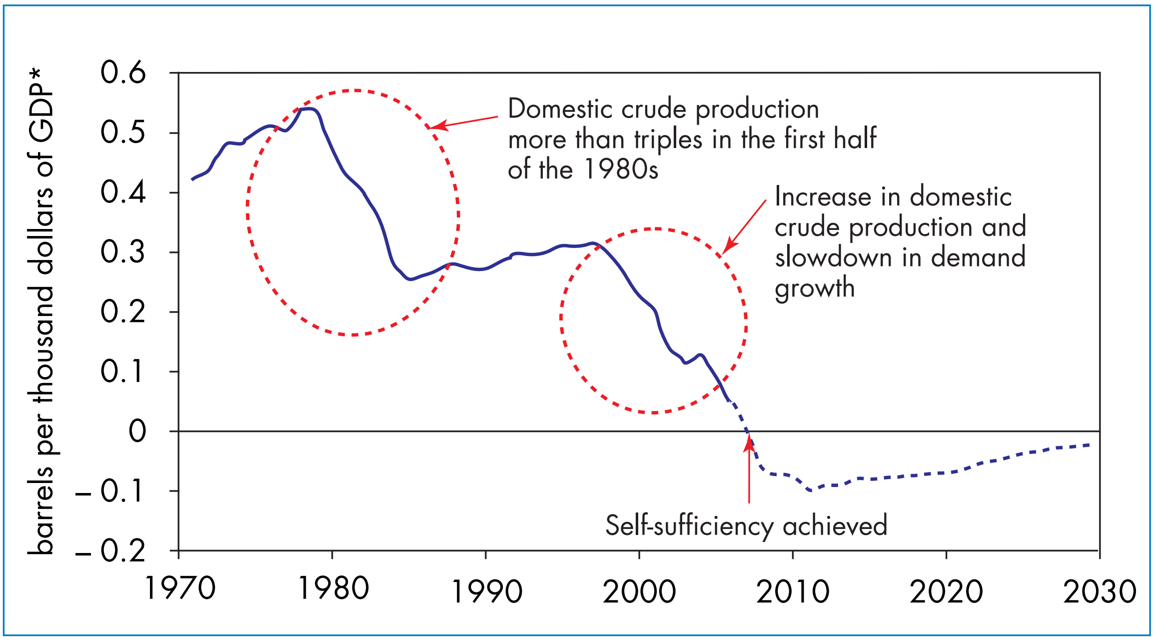
* Average annual rate of growth.

Oil remains the dominant fuel in Brazil's energy mix. Its share of total primary energy supply remains broadly unchanged at around 40% throughout the projection period. Oil consumption is expected to increase from 2.1 mb/d in 2004 to 3.5 mb/d in 2030. Some two-thirds of this increase is for transport. Oil-import intensity – oil imports relative to GDP – fell dramatically in Brazil in the early 1980s and in the second half of the 1990s, as a result of rapid growth in

4. www.greencarcongress.com, 17 November 2005.

domestic oil production and increased use of ethanol for transport. Although Brazil still imports oil products, these volumes are balanced by exports of crude oil. The country became self-sufficient for the first time in April 2006, when the latest deep-water project came on stream. Import intensity is expected to continue to decline over the first half of the projection period. Though it begins to rise by around 2012 (Figure 16.2), Brazil remains a net oil exporter through to 2030.

Figure 16.2: **Oil Import Intensity in Brazil**



* In year-2005 dollars, adjusted for PPP.

Natural gas use increases rapidly over the *Outlook* period in the Reference Scenario, at an annual rate of 3.8%, mainly in the industry and power-generation sectors. The share of gas in total primary energy demand rises from 8% in 2004 to 12% in 2030. Demand increases faster in the period to 2015, at 4.6% per year. Coal demand increases by only 0.9% per year, and its share in primary demand falls from 7% in 2004 to just over 5% by 2030. The contribution of nuclear power will increase when a third nuclear power plant comes on line some time before 2015. The capacity factor of nuclear power plants is assumed to improve from 69% in 2004 to 87% by 2010 and to stay at this level thereafter. The share of non-hydro renewable energy, mostly biomass, remains roughly constant at about 27%. The trend towards greater use of modern forms of biomass is expected to continue.

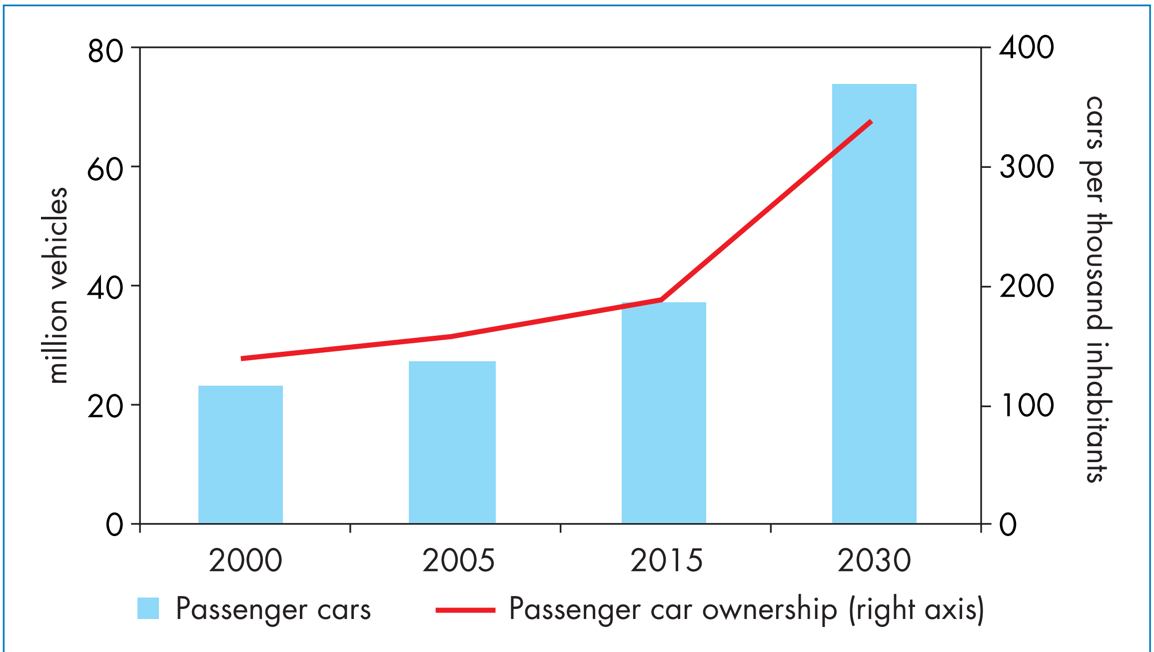
Total final energy consumption increases from 171 Mtoe in 2004 to 298 Mtoe in 2030, an average rate of growth of 2.2% per year. This is less than the rate from 1990 to 2004, reflecting expected efficiency improvements in all end-use sectors. Final oil demand rises by 2% per year and oil accounts for 77% of total energy demand for transport in 2030. Final natural gas consumption more than doubles, reaching 21.2 Mtoe in 2030, with industrial demand accounting for 80% of the increase. Demand for renewable energy, almost entirely biomass and waste, increases from 47 Mtoe in 2004 to nearly 80 Mtoe in 2030.

Among end-use sectors, **transport** demand grows most briskly, by 2.7% per year. Transport demand grew much slower in recent years, by some 1.6% per year from 1999 to 2004, thanks to efficiency gains. These improvements are expected to continue, but stronger GDP growth over the next decade causes demand growth to accelerate. The share of transport energy demand in total final consumption is projected to rise from 30% in 2004 to 35% in 2030.

Rising incomes will lead to increased car ownership and driving, as well as to more freight. Policies are expected to have a significant impact; in particular, the vehicle labelling policy, part of Petrobras' CONPET programme, is likely to encourage the uptake of more efficient vehicles. The share of ethanol-fuelled cars and flex-fuel vehicles (FFVs) in the car stock is also expected to continue to rise. Demand for biofuels for transport increases from 6.4 Mtoe in 2004 to 20.3 Mtoe in 2030, an average rate of increase of 4.6% per year.

Passenger car ownership in Brazil, at about 150 vehicles per 1 000 people, is more than three times higher than the average for the rest of Latin America. Car ownership in Brazil is projected to rise to over 335 per 1 000 people by 2030, roughly three-quarters the ownership in Europe today. The passenger car stock nearly triples over the *Outlook* period (Figure 16.3).

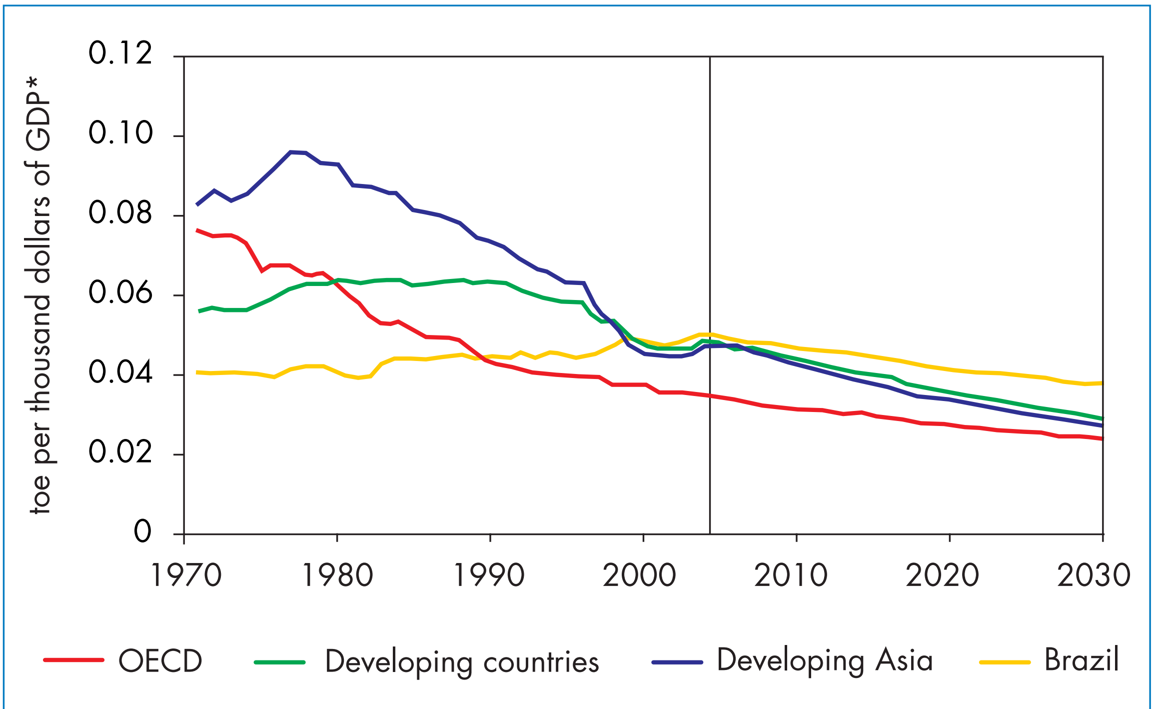
Figure 16.3: **Passenger Car Stock in Brazil in the Reference and Alternative Policy Scenarios**



Industrial energy demand grows by 1.9% per year on average over the *Outlook* period, compared with past growth of 3.5% per year from 1990 to 2004. Despite investments in energy efficiency over the past decade, there is still plenty of scope for reducing energy intensity, particularly in the cement, pulp and paper and aluminium industries (Machado *et al.*, 2005). Over the past three decades, industrial energy intensity declined on average in developing countries. Intensity rose, however, in Brazil. Efficiency is only expected to improve slowly over the *Outlook* period (Figure 16.4). The shares of gas and electricity in final consumption in industry rise. Electricity use in industry accounts for 21% of total demand by 2030, up from 19% in 2004. Gas demand rises the fastest, however, at 3.4% per year on average, and will account for 13.5% of industrial energy demand in 2030. Gas demand in the petrochemical industry accounts for most of this increase. The iron and steel industry will account for more than 90% of the increase in coal demand. Biomass use in the industrial sector grows from 30 Mtoe in 2004 to 43 Mtoe in 2030, but its share falls from 39% to 34%.

The Brazilian petrochemical sector is currently undergoing a phase of rapid expansion, with Petrobras taking an active role. Rio Polímeros, located near Petrobras' Duque de Caxias refinery in Rio de Janeiro and close to the Campos basin, was inaugurated in June 2005. The complex consists of a polyethylene unit of 540 000 tonnes per year and pioneers the use of ethane and propane as feedstock. Rio Polímeros is close to demand centres in the south and

Figure 16.4: **Industrial Energy Intensity in Selected Regions, 1970-2030**



* In year-2005 dollars, adjusted for PPP.

Table 16.4: **Primary Energy Demand in the Alternative Policy Scenario in Brazil**
(Mtoe)

	1990	2004	2015	2030	2004-2030*
Coal	9.7	14.2	13.3	14.8	0.2%
Oil	57.7	84.8	100.7	118.7	1.3%
Gas	3.2	15.8	25.9	35.0	3.1%
Nuclear	0.6	3.0	6.3	8.9	4.2%
Hydro	17.8	27.6	35.7	41.3	1.6%
Biomass and waste	41.6	54.4	69.2	88.7	1.9%
Other renewables	0.0	0.0	0.5	3.1	27.8%
Total	**130.6**	**199.8**	**251.6**	**310.5**	**1.7%**

* Average annual growth rate.

Figure 16.5: **Primary Energy Demand in the Reference and Alternative Policy Scenarios in Brazil** (Mtoe)

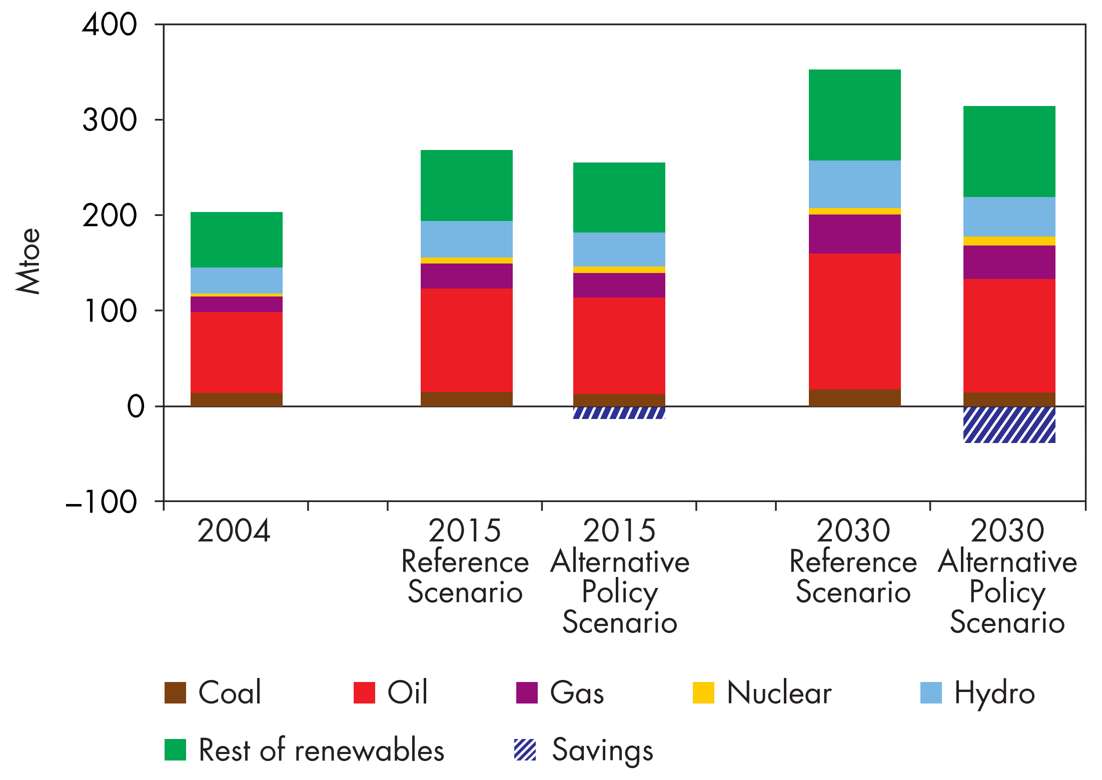


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Table 16.5: **Main Policies and Programmes Considered in the Alternative Policy Scenario**

Sector	Policy	Programme/measure	Impact/target
Power	CDE Conta de Desenvolvimento Energético (Energy Development Account)	Financing for renewable energy power projects	Encourages renewable energy use at the state level; in force until 2030 and is managed by Eletrobrás.
	SWERVA Solar and Wind Energy Resource Assessment	Assessment of wind and solar energy resources	Wind atlases have been developed for the entire country, to help increase penetration of wind energy.
	PROINFA, Phase 2	Target for renewable energy	10% target for renewable energy in power generation sector.
Transport	PROBIODIESEL Programme of Technological Development for Biodiesel	Mandated biodiesel ratio	2% will be mandated by 2008 and 5% by 2013.
Industry	Energy-efficiency standards	Tax incentives and low-interest loans for efficient technologies	Replace current installed motors by high-performance electric motors at the end of their useful life and more efficient industrial equipment.
	Local pollutant emissions offset law (São Paulo)	Air quality improvements	Provides for the establishment of Air Emissions Reduction Programmes in areas with restricted air quality.

Table 16.5: **Main Policies and Programmes Considered in the Alternative Policy Scenario** *(Continued)*

Sector	Policy	Programme/measure	Impact/target
Residential and services	Reluz National Programme for Efficient Public Lighting	Energy-efficiency standards	Improves energy efficiency of public lighting, saving 2.4 TWh/year and reducing consumption by 540 MW in peak time (state-run programme).
	CONPET Programa de Etiquetagem de Fogões e Aquecedores	Programme for labelling of household goods, such as refrigerators	Increased efficiency of appliances.
	Solar thermal law (São Paulo)	Renewable energy technology standards	Requires the installation of solar water heating systems in new buildings and in those being rehabilitated in São Paulo after 2010.

southeast regions of Brazil, which account for about 80% of the domestic consumption of polyethylene. In March 2006, Petrobras announced plans to build a 150 000-b/d refinery and petrochemical complex in the State of Rio de Janeiro – the COMPERJ complex. The plant is designed to use heavy oil coming from the Marlim field. Production is expected to start in 2012.

Residential and services[5] energy demand is projected to grow by 2% per year on average over the *Outlook* period, broadly in line with previous growth of 2.1% per year from 1990 to 2004. Because of rationing during the power supply crisis of 2001, electricity demand in the residential sector fell dramatically. The Brazilian Labelling Program, which encouraged the uptake of more efficient technologies, achieved considerable energy savings. Since the labelling of stoves, in particular, new models purchased consume on average 13% less LPG than older ones (Centro Clima *et al.,* 2006). Appliance ownership is much higher in urban areas. Whereas some 90% of urban households had a refrigerator or freezer in 2000, only about half of rural households owned one. Nationwide, ownership of air-conditioners (7%) and computers (11%) is low.

Energy demand in the residential and services sector is projected to grow fastest in the first half of the projection period. Electricity accounts for most of the growth in demand to 2030, as appliance ownership levels increase, and its share of total residential and services energy use rises from 39% in 2004 to 46% in 2030. Use of biomass and waste continues to grow in the short term because of high oil prices, but this effect weakens over the projection period.

Alternative Policy Scenario

Primary energy demand grows much less quickly in the Alternative Policy Scenario (Table 16.4). By 2030, primary demand is 38 Mtoe lower than in the Reference Scenario (Figure 16.5). Most of the energy savings come from lower demand in the transport and industry sectors, thanks to policies and programmes to improve energy efficiency. Policies are assumed to have an even greater impact on energy savings in the Alternative Policy Scenario (Table 16.5). Fuel switching in the power sector towards more nuclear energy and non-hydro renewables, mainly bagasse, accounts for 3.4 Mtoe of fossil-fuel savings. In 2030, oil demand is 23 Mtoe lower than in the Reference Scenario. The increased use of flex-fuel vehicles, higher efficiency of conventional vehicles and an increase in the use of biodiesel result in a 15.2 Mtoe reduction in oil demand for transport.

In the Alternative Policy Scenario, total final consumption in 2030 is 11% lower than in the Reference Scenario (Table 16.6). Most of the gains come

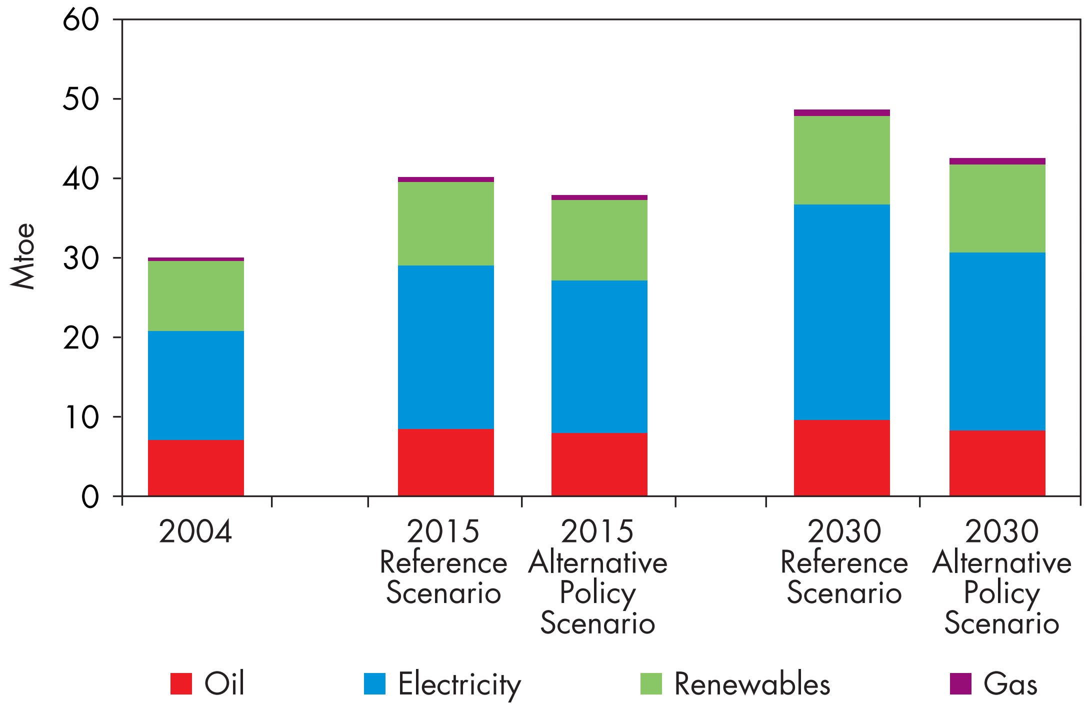
5. Residential and services demand also includes energy demand in the agricultural and public sectors.

Table 16.6: **Change in Total Final Consumption in the Alternative Policy Scenario* in 2030**

	Industry	Transport	Residential	Services	Total
Coal	–12%	0	0	0	–12%
Oil	–11%	–19%	–14%	–12%	–15%
Gas	–8%	–2%	0%	0%	–7%
Electricity	–14%	0%	–19%	–16%	–15%
Biomass and waste	–7%	13%	–7%	–6%	–2%
Other renewables	0	0	77%	0	76%
Total	**–10%**	**–12%**	**–12%**	**–15%**	**–11%**

* Compared with the Reference Scenario.

Figure 16.6: **Residential and Services Energy Demand in the Reference and Alternative Policy Scenarios**



from faster improvements in energy efficiency in the transport and industry sectors. Energy savings amount to around 12.5 Mtoe in each of these sectors. The 6-Mtoe reduction in residential and services energy demand is substantial, given the efficiency improvements which are already incorporated 16 into the Reference Scenario. End-use oil demand sees the greatest decline, from 131 Mtoe in 2030 in the Reference Scenario to 111 Mtoe in the Alternative Policy Scenario. Final demand for biomass and waste declines slightly, by 2 Mtoe, mostly because of energy efficiency improvements in the industry sector. Although demand for biofuels for transport is higher, energy savings in the use of biomass for industry and residential use offset this expansion.

Transport demand is 12.6 Mtoe lower than in the Reference Scenario. Oil demand in the transport sector grows by 1.5% per year, much slower than in the Reference Scenario, while demand for biofuels grows more rapidly, at 5.1% per year. By 2030, biofuels for transport account for 30% of road transport fuel demand. Policies aimed at increasing the efficiency of the vehicle fleet also lower transport demand growth in the Alternative Policy Scenario.

Demand in the industry sector in the Alternative Policy Scenario grows by 1.5% per year on average. By 2030, it is 10% lower than in the Reference Scenario. The biggest drop is in electricity demand, thanks to the increased efficiencies of motors. Gas demand is only slightly lower in the Alternative Policy Scenario. Use of biomass is 7% less, but its share stays at about 35%.

Energy demand in the residential and services sector in the Alternative Policy Scenario grows by 1.5% per year on average and is 10% less in 2030 compared with the Reference Scenario (Figure 16.6). Overall percentage savings in this sector are less than savings in both the residential and services sectors because there is very little change in energy demand in the agricultural sector. Electricity demand is lower, growing by only 1.9% per year, as a result of stronger policies to promote energy-efficient lighting and the enforcement of tougher standards for appliances.

Outlook for Supply

Oil

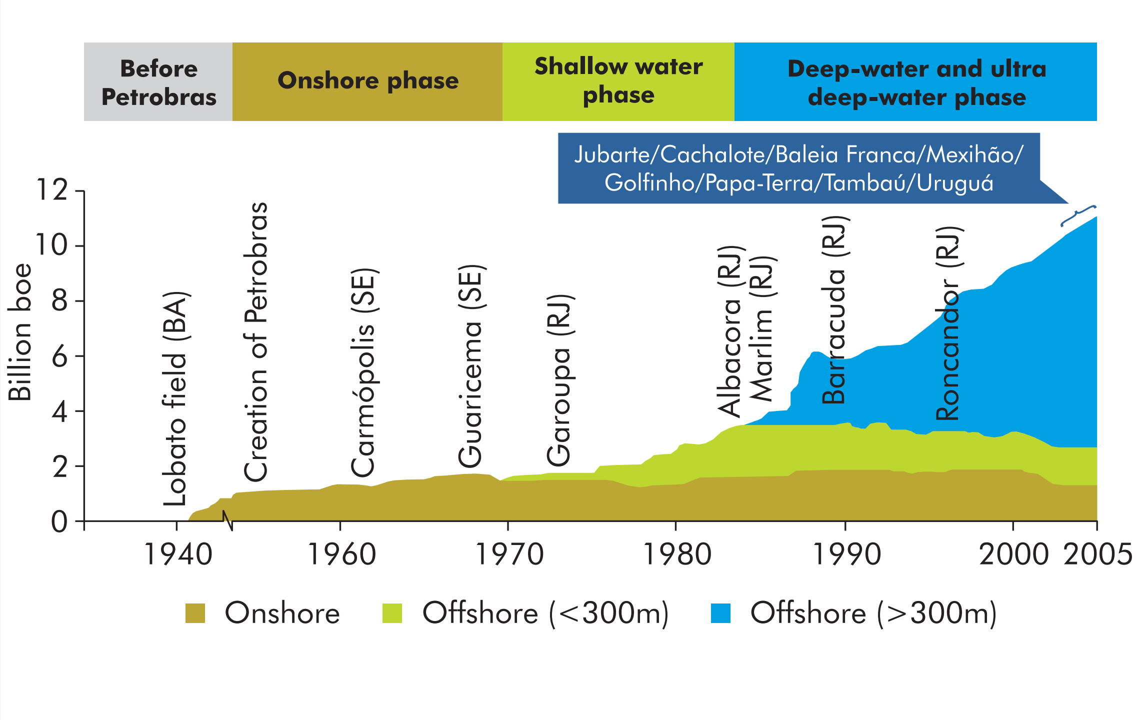
Resources and Reserves

Brazil is the world's 15th-largest oil producer, with proven reserves of 11.2 billion barrels (*Oil and Gas Journal,* 2005).[6] Oil reserves increased nearly eightfold from 1980 to 2005. Brazil has made impressive technological advances in deep-water exploration and production, with several recent discoveries of large fields containing over one billion barrels of oil equivalent. Deep-water and ultra-deep-water exploration have yielded significant discoveries (Figure 16.7).

There are still vast unexplored areas, which have high potential for new discoveries. So far, drilling concessions have been offered for less than 7% of the promising areas. The offshore basins of Espirito Santo, Campos and Santos, where large discoveries have been made, have been the main focus of interest.

6. Petrobras reported reserves of 12.3 billion barrels in December 2005.

Figure 16.7: **Brazil's Proven Reserves by Date of Discovery**



Note: State abbreviations are BA – Bahia; SE – Sergipe; RJ – Rio de Janeiro; AM - Amazonas.
Source: Petrobras.

In 2003, Petrobras discovered new light-oil reserves in Espirito Santo, in what is one of the largest light-oil offshore fields. Most known Brazilian reserves are heavy oil and Petrobras imports light oil for blending to improve oil quality.

Brazilian oil production reached 1.7 mb/d in 2005 and is expected to reach 1.9 mb/d in 2006. Output has nearly doubled since the late 1990s. The main oilfields are offshore Rio de Janeiro State, in the Campos basin (Figure 16.8). About 85% of oil comes from offshore fields, increasingly from deep waters.[7] Roncador is the largest discovery made in Brazil, with estimated proven reserves of around 2.9 billion barrels (Table 16.7). The field is located in the Campos basin at 1 360 metres. In the Reference Scenario, crude oil production is expected to reach 3.1 mb/d in 2015 and 3.7 mb/d in 2030. Production from currently producing fields is expected to increase by 44% to 2015 (Table 16.8), then begin to decline. Fields awaiting development and new fields will represent some 45% of crude oil production in 2030.

Oil demand in Brazil rises to 2.7 mb/d in 2015 and to 3.5 mb/d in 2030 in the Reference Scenario (Figure 16.9). It increases to 2.9 mb/d in 2030 in the

7. Deep and ultra-deep water definitions can vary by basin. Deep water is typically defined as water depths greater than 500 metres, and ultra-deep water beyond 1 000 metres

Figure 16.8: **Oil and Gas Fields and Related Infrastructure in Brazil**

The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Table 16.7: **Major Oilfields Currently in Production in Brazil**

Field	**Year of first production**	**Remaining proven and probable oil reserves at end-2005** (million barrels)	**Cumulative production to 2005** (million barrels)	**API gravity** (degrees)
Agua Grande	1951	319	306	37
Albacora	1987	879	558	28
Aracas	1965	172	141	37
Barracuda	1997	807	97	24
Bicudo	1982	169	109	22
Bijupira	1993	156	46	30
Bonito	1979	195	102	25
Buracica	1959	220	173	37
Canto do Amaro	1986	301	192	44
Carapeba	1988	228	198	25
Carmopolis	1963	442	202	20
Cherne	1983	270	220	25
Enchova	1977	174	149	21
Espadarte	2000	246	56	n/a
Fazenda Alegre	1996	211	24	17
Garoupa	1979	207	122	31
Guaricema	1968	86	0	41
Linguado	1981	166	124	30
Marimba	1985	432	278	29
Marlim	1991	2 680	1 446	20
Marlim Sul	1994	2 485	295	20
Miranga - Miranga Profundo	1965	271	212	41
Namorado	1979	397	353	28
Pampo	1980	336	262	21
Roncador	2000	2 900	117	25
Ubarana	1976	297	100	36

Note: NGLs and condensates are not included.
Source: IHS Energy databases.

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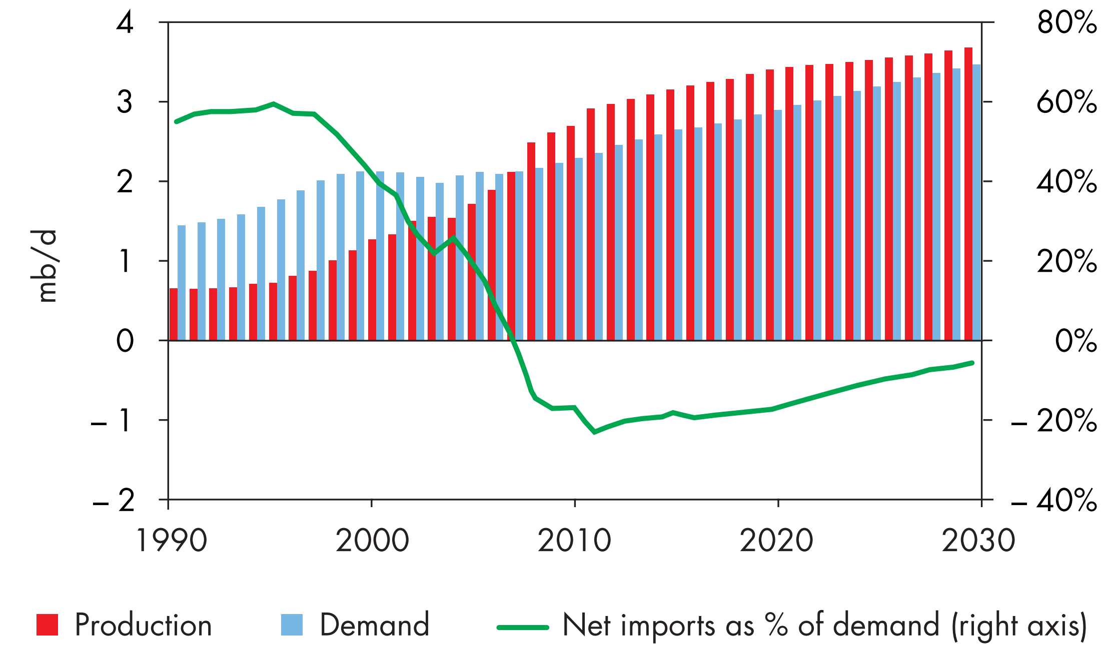
Alternative Policy Scenario. In both scenarios, Brazil remains self-sufficient throughout the *Outlook* period on the assumption that the large investments in exploration and infrastructure that this would entail occur in a timely fashion.

Table 16.8: **Brazil's Oil Production in the Reference Scenario** (mb/d)

	2004	2015	2030
Currently producing fields	1.5	2.7	2.0
Fields awaiting development	0.0	0.4	0.7
Reserve additions and new discoveries	0.0	0.0	1.0
Total	**1.5**	**3.1**	**3.7**

Source: IEA analysis.

Figure 16.9: **Brazil's Oil Balance in the Reference Scenario**



To maintain self-sufficiency, Brazil needs to continue to invest heavily in exploration, as today it is producing the oil that was discovered in the 1980s and 1990s. Petrobras has set itself a new target of domestic oil and gas production of 2.9 mb/d by 2011, with planned investments in exploration and production of $41 billion. Production is expected to focus increasingly on deep-water fields (Box 16.2). Maintaining self-sufficiency beyond 2012-2014 will require major new discoveries. The IEA has undertaken a field-by-field analysis of oil production in Brazil, which has been used to project production by source over the *Outlook* period (Figure 16.10).

Box 16.2: **Petrobras's Development of Deep-Water Crude Oil Production**

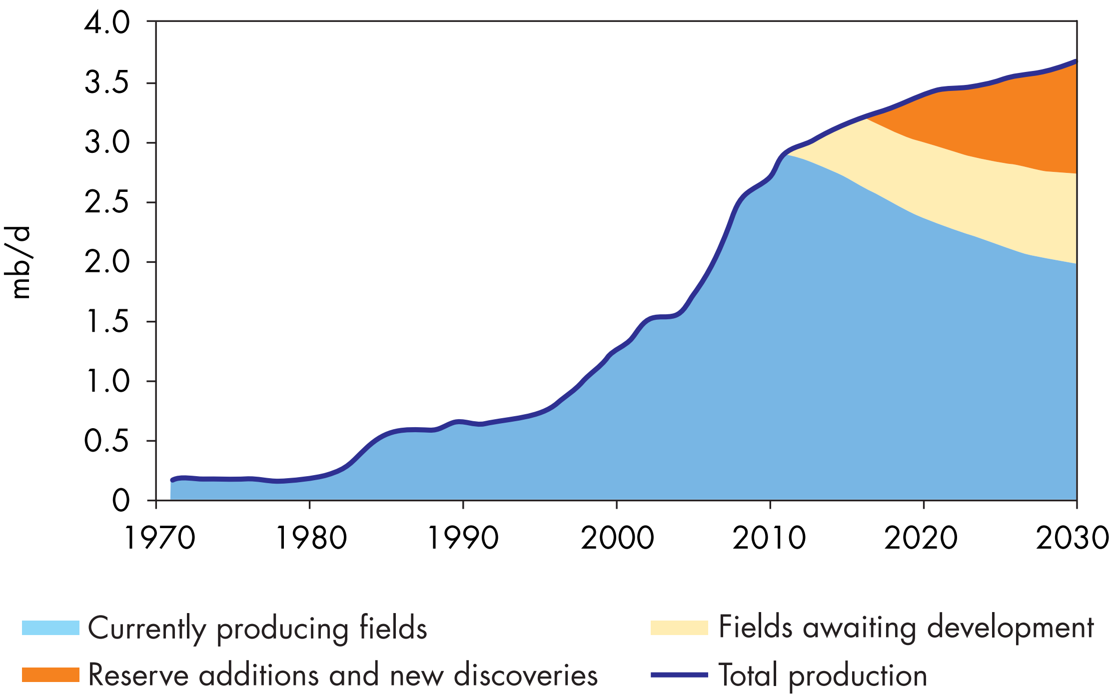
Following the oil price peaks in the 1970s, offshore oil exploration commenced in Brazil. Fields closest to shore were exploited first and technological improvements in drilling, rigs, mooring, robotics and pipes followed. Research into new technologies was spearheaded by CENPES, the research arm of Petrobras. In 1986, a Technological Development Programme on Deepwater Production Systems (PROCAP) was established. The six-year programme led to the development of semi-submersible floating production systems that permitted production in waters 1 000 metres deep in the Albacora and Marlim oilfields. In 1993, Petrobras embarked on PROCAP 2000, which aimed at designing systems capable of producing in 2 000 metres of water. This programme led to the design and execution of an extended-reach well in deep water, the development of a horizontal Christmas tree for use at 2 500 metres depth, installation and operation of an electric submersible pump in a subsea deep-water well, a subsea separation system called the vertical annular separation and pumping system, and a subsea multiphase pumping system for deep water. This programme supported exploration and production in the Campos basin, leading to the discovery of the major Roncador oilfield.

PROCAP 3000, launched in 2000, aims to increase production from existing deep-water fields and to extend exploration and production to depths of around 3 000 metres. PROCAP 3000 is expected to support the next phases of the Marlim Sul, Roncador, Marlim Leste and Albacora Leste oilfields. Unit capital costs and lifting costs in deep-water fields already in production are expected to be reduced.

Refining Capacity and Oil-Product Supply

Current installed refining capacity in Brazil is around 1.9 mb/d, which is insufficient to meet domestic consumption. Petrobras plans to increase refining capacity to 2.4 mb/d by the middle of the next decade. More than four-fifths of Brazil's oil refining capacity is located in the south and southeast regions. Only two refineries are not in these regions: a large refinery in Bahia State, with capacity of 284 000 b/d, and a small refinery for domestic supply in Manaus in Amazonas, with capacity of 43 000 b/d. There are currently 13 refineries operating in Brazil, of which 11 are operated by Petrobras. The remaining two are the Refinaria de Petroleos Manguinhos (in Rio de Janeiro State), which is owned by Repsol-YPF in partnership with Grupo Peixoto de Castro, and the Refinaria de Ipiranga. These two refineries, however, are currently not operating at full capacity because they are not designed to refine Brazilian crude, and high international oil prices make operation unprofitable.

Figure 16.10: **Brazil's Crude Oil Production by Source in the Reference Scenario**



Any expansion of refining capacity must conform to the government's refining plan, which aims to minimise oil-product imports. A key element of this plan is the use of vegetable oil to replace fossil diesel (Box 16.3). The major focus of

Box 16.3: **Refinery Conversion with H-BIO Technology**

Brazil has undertaken a major initiative to supplement fossil diesel with diesel produced from biomass. In the H-BIO process, vegetable oil is blended with mineral diesel fractions in hydrotreating units. Today, these units are mainly used to reduce the sulphur content of diesel and for quality improvement in petroleum refineries. The most important aspect of the H-BIO process is its very high conversion yield. The converted product improves the quality of diesel in the refinery, mainly by increasing the cetane number and by reducing the sulphur content and density.

Petrobras plans to have the H-BIO process operating in at least three refineries by the end of 2007. Vegetable oil consumption will be about 256 000 m^3 per year, which was about 10% of Brazilian soybean oil exports in 2005. Introduction of the H-BIO process in two more Petrobras refineries is planned for 2008, which will increase the total vegetable oil consumption to about 425 000 m^3 per year. These two programmes will require investments of around $60 million.

Petrobras's investments is to improve the quality of oil products. New legislation requires sulphur in diesel/gasoline to be below 50 parts per million (ppm). Most of Petrobras's refineries are not designed to process heavy crude oil, which accounts for most of Brazilian crude oil production. Petrobras plans to invest $14.2 billion from 2007 to 2011 to expand and modernise its refineries and to add value to its products. Some 31% of this investment will be to improve the quality of diesel and gasoline, 26% to improve conversion and the rest to expand and overhaul existing refinery units.[8] Petrobras is planning to build two new refineries, one in Rio de Janeiro State and another in Pernambuco, in the northeast, in association with PVDSA, the Venezuelan state-owned oil company. These are expected to come on line in 2012.

Natural Gas

Resources and Reserves

Proven natural gas reserves at the end of 2005 were 306 bcm (Cedigaz, 2006). The United States Geological Survey estimates that undiscovered gas reserves are 5 500 bcm, more than 15 times proven reserves (USGS, 2000). The Santos and Campos basins have the largest reserves with about 37%, followed by São Paulo with about 24% and Amazonas with about 15%. About two-thirds of the gas reserves are located offshore, usually as associated gas. In 2003, Petrobras announced the discovery of 419 bcm of new reserves in the offshore Santos basin in the southeast, but only 70 bcm has as yet been certified as proven.

Until recently, natural gas was produced solely as a by-product of oil and about 30% was reinjected or flared. Petrobras plans to increase investment to accelerate the development of Brazil's domestic natural gas resources, especially from the Santos basin, in order to supply the large and rapidly growing market of the southeast. In the seventh licensing round in 2005, about 90% of the blocks in new onshore exploratory areas which were thought to be gas-prone were awarded. To reduce the country's dependence on imported Bolivian gas, the government recently requested a 30% increase in the number of gas-prone exploration blocks to be offered at the eighth bidding round, scheduled for November 2006. This round includes the Espírito Santo and Santos basins as well as the unexplored offshore basins of Curumuxatiba, Pará-Maranhão and Ribeirinhas, in the country's northeastern region. The Campos basin was excluded from this round.

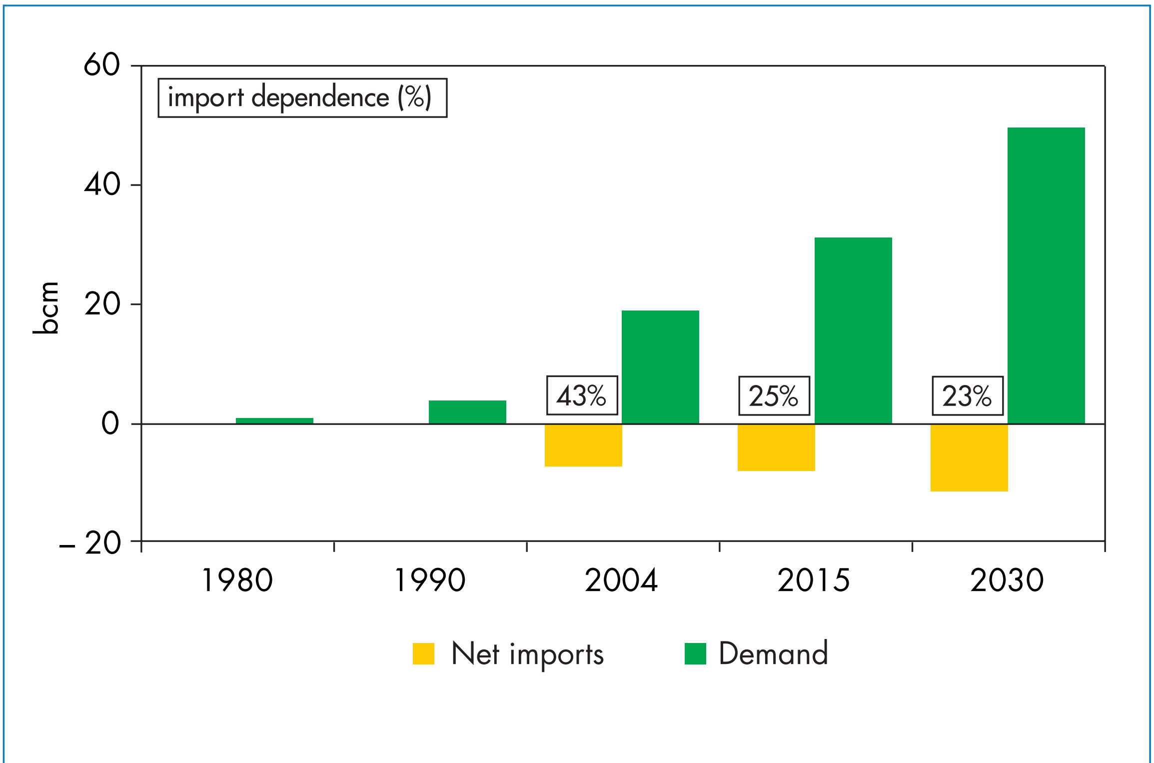
8. Speech by Jose Sergio Gabrielli de Azevedo, President and CEO of Petrobras, "Business Plan 2007-2011", 5 July 2006.

Production and Imports

Gas production reached 18.7 bcm in 2005, up from 7.2 bcm in 2000. Production is projected to increase to 23 bcm in 2015 and to 38 bcm in 2030 in the Reference Scenario, growing at an average rate of 4.6% per year over the *Outlook* period. Gas-import dependence declines over the *Outlook* period, but the rate of decline slows after 2015 (Figure 16.11).

In order to increase domestic gas production, Brazil needs to make major investments in resource development and in its gas distribution network. Compared with other Latin American countries, the Brazilian gas pipeline network is underdeveloped. The total network spans some 8 000 km, including the Brazilian portions of cross-border pipelines. However, it covers only a small part of the country, mainly serving São Paulo and Rio de Janeiro in the south and the coastal states in the northeast. Petrobras also recently announced an "Anticipated Production Plan" to accelerate natural gas production at the Espírito Santo and Campos basins. In the Campos basin, there are two main offshore gathering platforms, at Enchova and Garoupa, from which gas is piped to shore before being transported to the Duque de Caxias refinery. Petrobras is planning a large-scale project to construct an integrated pipeline system (GASENE) connecting the southeast of the country with the north and northeast. This would enable the development of markets in the northern regions, which could be supplied in the future by the new discoveries made in the Santos basin.

Figure 16.11: **Natural Gas Balance in Brazil in the Reference Scenario**



Development of the onshore natural gas reservoir in Urucu in Amazonas State is limited to producing and processing a small fraction of LPG for local consumers, because of inadequate transport infrastructure. The Urucu proven reserves total 48 bcm. Petrobras has been investing in two pipelines connecting the Urucu gas field to Porto Velho and to Manaus, but environmental concerns have slowed construction. The pipeline from Coari to Manaus, one of the main consumer centres of the region, is currently under construction. When this pipeline goes into service, Petrobras will produce and sell natural gas in Amazonas.

Our projections for natural gas supply are based on the assumption that Brazil is able to increase investment in domestic gas production and infrastructure. Gas demand growth, which has been phenomenal in recent years, is expected to slow with the liberalisation of gas prices. Demand is, nevertheless, expected to continue to rise. Given that expanded gas imports from Bolivia are no longer an acceptable option for the Brazilian government, domestic production will have to increase considerably to meet demand. Renegotiations with Bolivia on gas import prices are expected to result in higher gas prices in Brazil. Prices already increased in July 2006, since they are indexed to a basket of international fuel oil prices.

The key uncertainty is whether the investment needed to develop the reserves and build the new transportation infrastructure will be forthcoming. In addition to the investment planned by Petrobras, private and foreign investment will also be required. We project that $16 billion will be needed in the period to 2015 in the Reference Scenario. A further $32 billion is needed from 2015 to 2030. The success of the 8th bidding round will be an indicator of what level of foreign participation can be expected and so of future production trends. Expanding gas output will hinge on a stable investment environment.

Even if Brazil is able substantially to increase domestic gas production, it will still need to expand imports. The first pipeline to connect Brazil to foreign natural gas sources was the Bolivia-Brazil gas pipeline (Gasbol), inaugurated in 1999. The Transportadora de Gas del Mercosur (TGM) pipeline came on line in June 2000, marking the first exports of gas from Argentina to Brazil. In the Reference Scenario, imports account for a quarter of total gas demand in 2015 and 23% in 2030. In the short term, gas imports from Bolivia will not increase since all the planned investment in expanding capacity has been cancelled by Petrobras following the 1st May 2006 nationalisation of the company's assets in Bolivia. In the long term, gas could be imported from Venezuela.

LNG imports are expected to boost supplies over the *Outlook* period. Petrobras is planning to install LNG regasification terminals by 2008. One terminal will be close to Rio de Janeiro, with production capacity of 14 million m^3 per day. A second unit would be located off the coast of the northeastern State of Ceará, where there is large demand from power stations, with production capacity of 6 million m^3 per day.

Coal

Coal resources amount to about 30 billion tonnes (Federal Institute for Geosciences and Natural Resources Reserves, 2004). Proven reserves are just over 10 billion tonnes (BP, 2006). Coal reserves are not well surveyed in the vast northern regions of the country. Coal deposits of various qualities and quantities have been found in many areas in Brazil, but the largest and lowest-cost reserves are found in the south (Rio Grande do Sul and Santa Catarina). The largest reserves are located in the Candiota mine, in Rio Grande do Sul, accounting for almost one-quarter of total reserves.

Brazil produced 5.4 million tonnes of coal in 2004; however, it consumed 21.9 million tonnes. Brazil's coal reserves have high ash and sulphur contents, with low caloric values, which explains the low level of domestic production. Brazil imports coking coal for steel-making, mainly from the United States and Australia, and uses domestic resources for power generation. Brazil has only one mine-mouth generating complex, Candiota I and II, where local coal is able to compete in price with imported coal. A very limited amount of coal is exported to Argentina. Brazil's national development bank, Banco Nacional de Desenvolvimento Economico e Social (BNDES), is developing a plan to expand the country's coal industry. Two new coal-fired generation projects are under construction: Candiota III and Jacuí.

In the Reference Scenario, coal production is projected to increase to 7.6 million tonnes in 2015. Production increases further in the second half of the *Outlook* period, reaching 11.8 million tonnes in 2030. As demand for coal continues to rise, from 21.9 million tonnes in 2004 to 34 million tonnes in 2030, coal imports keep growing. They reach 22 million tonnes in 2030, up from 16 million tonnes now.

Biomass

Resources and Production

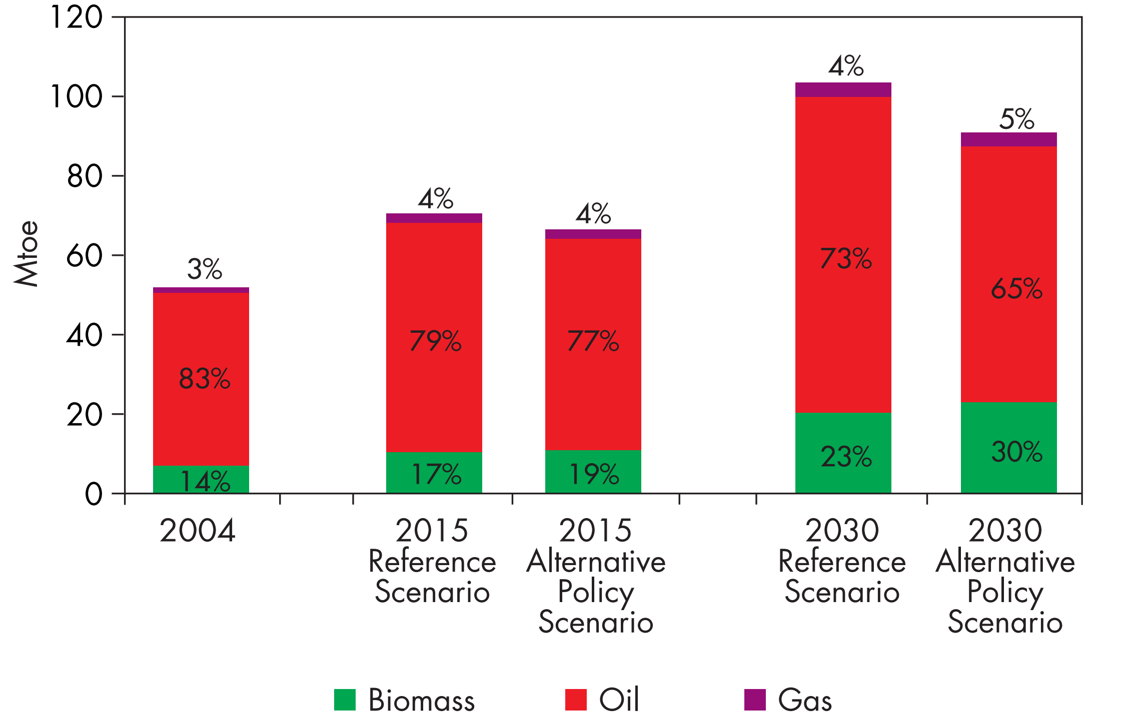
Brazil has extensive and diverse biomass resources, which are exploited for energy in many ways. The country is a highly efficient producer of large-scale industrial charcoal, with biomass-to-charcoal conversion efficiencies ranging from 30% to 35%, particularly from plantations. Charcoal production has increasingly become a professional activity, with most charcoal being produced from dedicated plantations.[9] In 2000, about 72% of charcoal was produced from eucalyptus plantations, compared with 34% in 1990.

9. Dedicated plantations are not being employed in Maranhão State in the northeast for environmental reasons.

Almost all sugar-cane distilleries in Brazil use bagasse-fired steam turbine systems to provide steam and electricity to meet on site factory needs. Most biomass cogeneration is in São Paulo State, where 40 sugar mills sell some 1.3 GW of surplus power to the grid. The Brazilian cane industry has the potential to produce up to 12 GW in the long term – 6 GW in São Paolo State (WADE, 2004). The public authorities are promoting bagasse-based cogeneration to reduce the country's reliance on hydropower. Apart from bagasse, only a small proportion of the large potentially recoverable residues from commercial crops and forestry are used for energy purposes. Landfill gas is also underdeveloped. With the exception of bagasse, there is a lack of consistent and reliable data on biomass resources and their potential as an energy source. This is particularly the case with regard to residues in the pulp and paper industry, which are produced in large quantities.

Brazil is a major producer and consumer of biomass-based ethanol for transport. Biodiesel demand and production are growing steadily. Demand for biofuels for transport increases rapidly in the Reference Scenario, from 6.4 Mtoe in 2004 to 20.3 Mtoe in 2030 – an average rate of growth of 4.6% per year. Their share of Brazil's road transport fuel increases from 14% in 2004 to 23% in 2030 (Figure 16.12).[10]

Figure 16.12: **Biofuels Penetration in the Road-Transport Sector in Brazil in the Reference and Alternative Policy Scenarios, 2004-2030**



10. See Chapter 14 for an analysis of the global biofuels market and Brazil in this context.

This trend is bolstered by strong growth in sales of flex-fuel vehicles, which can run on gasoline or ethanol or a mixture of both. Another factor contributing to the growth in biofuels is a programme started in late 2004 to add 5% of biodiesel to diesel fuel by 2013. The programme was set up to assist poor rural farmers. In the Alternative Policy Scenario, demand for biofuels grows more rapidly, by 5.1% per year over the projection period. By 2030, biofuels for transport account for 30% of road transport fuel demand.

Ethanol

Brazil is the world's largest producer of fuel ethanol from sugar cane. Brazil's national ethanol programme, ProAlcool, was launched in response to the oil crises in the 1970s. From 1983 to 1988, 90% of the 800 000 new cars sold each year on average in Brazil were running on ethanol. The strong increase in consumption caused a severe shortage of ethanol at the end of 1989. This shortage resulted in a loss of consumer confidence in the security of ethanol supply and discredited ProAlcool. By the end of the 1990s, the sales of ethanol-fuelled cars amounted to less than 1% of total car sales because of uncertainties about future ethanol availability and price. But the benefits of the ProAlcool programme were important: lead was phased out completely in 1991 and carbon monoxide, unburned hydrocarbons and sulphur emissions were reduced considerably. Moreover, major investments were made in improving the production of sugar cane (Box 16.4), and the country developed a competitive advantage in the production of ethanol.

In 2003, car manufacturers, beginning with Volkswagen, introduced "flex-fuel" vehicles, which are capable of running on any combination of hydrous ethanol and a gasoline-anhydrous ethanol blend. Such vehicles allow consumers to choose any combination of the cheapest fuel while protecting them from any fuel shortages. FFVs do not cost any more than conventional vehicles. Today, the government estimates that flex-fuel vehicles account for more than three-quarters of new car sales in Brazil. Pure gasoline is no longer sold.

Brazil's ethanol production was 15.9 billion litres in 2005, more than a third of global production, of which 2.6 billion litres were exported. Brazil has a 50% share of global ethanol trade. Importers include the United States (but not for transport), India, Venezuela, Nigeria, China, South Korea and Europe. The Brazilian government is negotiating exports with Japan. South Africa and Brazil are also in the process of signing a memorandum of understanding for technical assistance in ethanol production. Brazil is also offering support to India to produce ethanol and the two countries signed an agreement in September 2006 to increase cooperation. The Brazilian government believes that increasing the number of suppliers in developing countries will expand the global ethanol market. Several Central American Caribbean countries have duty-free access to the US market. By encouraging ethanol production and refining through joint

Box 16.4: **Technological Developments in Sugar-Cane and Ethanol Production**

Most of the reduction in the cost of producing ethanol in recent years has come from the agricultural phase of ethanol production. Around 60% to 70% of the final cost of ethanol is the cost of the sugar cane. Agricultural yield and the amount of sucrose in the plant have a strong impact on cost. Average productivity in Brazil is around 65 tonnes per hectare (t/ha), but it can be as high as 100 to 110 t/ha in São Paulo State. Since the beginning of ProAlcool, yields have improved by about 33% in São Paulo, with the development of new varieties and the improvement of agricultural practices (IAEA, 2006). Many operations have been mechanised over the past 25 years, but advances in harvesting are more recent. In the past five years in the midwest, southeast and southern regions, about 35% of the area planted with sugar cane has been harvested mechanically and, of this, about 20% has been harvested without previously burning the field. Up to 90% of the sugar cane is harvested mechanically in some regions. It is estimated that the widespread application of mechanised harvesting would achieve a significant further reduction in the per-tonne cost of sugar cane.

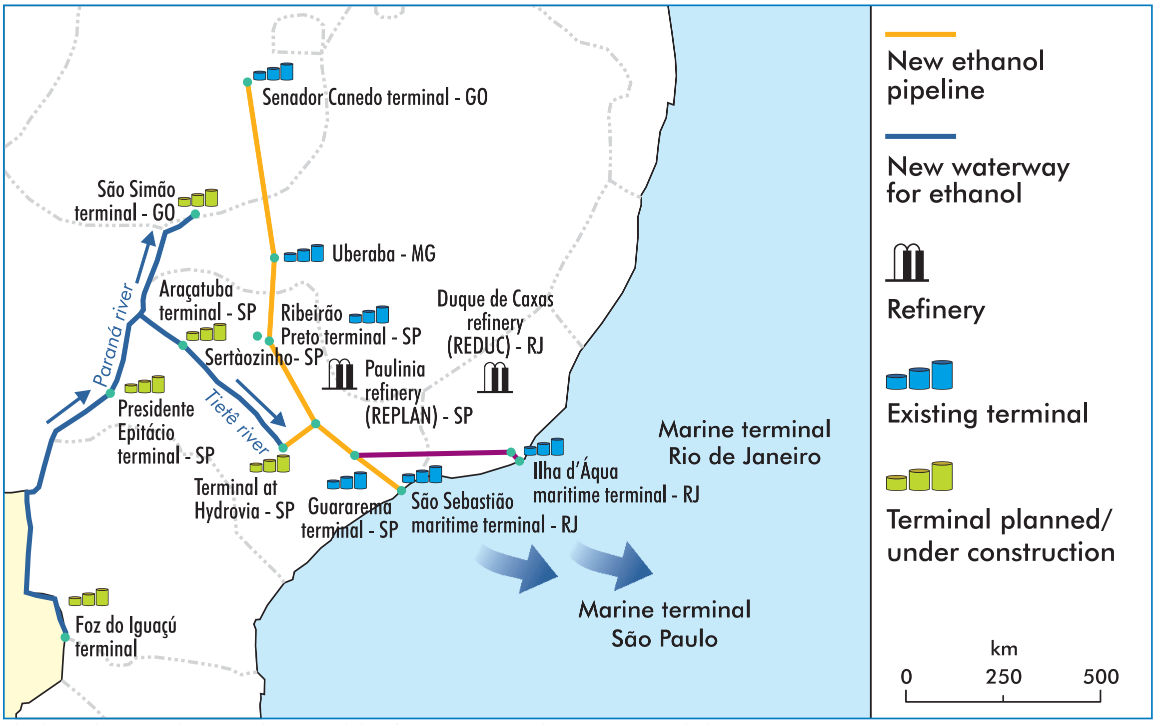
Throughout the evolution of ProAlcool, technological priorities have changed. Initially, the focus was on increasing equipment productivity. The size of Brazilian mills also increased. Some mills now have a crushing capacity of 6 million tonnes of sugar cane per year and capacity is expected to increase to 10 million tonnes by 2010. The focus was then shifted to improvements in conversion efficiencies. Over the past 15 years, the primary focus has been on better management of the processing units. In the future, attention is expected to be given to reducing water needs. On average, five cubic metres (cm) of water are used for each tonne of sugar cane processed, though values range from 0.7 cm/tonne to 20 cm/tonne.

Average ethanol production yields have grown from 3 900 litres per hectare per year (l/ha/year) in the early 1980s to 5 600 l/ha/year in the late 1990s. In the most efficient units, yields are now as high as 8 000 to 10 000 l/ha/year.

programmes in these countries, Brazilian sugar producers can export ethanol to the United States. Brazil is also working more generally to remove trade barriers that prevent the development of a global biofuels market.

To meet rising domestic and export demand for ethanol, the Brazilian government plans to increase productive capacity and to build ports with storage tanks and loading facilities. It also plans to improve railway and pipeline links between the ports and sugar-producing regions. Petrobras is building a new ethanol port in Santos, which will increase Brazil's export capacity to 5.6 billion litres by the end of 2007. New waterways are also planned (Figure 16.13).

Figure 16.13: **Planned Infrastructural Developments for Ethanol in Brazil**



The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Note: State abbreviations are: GO – Goais; SP – São Paulo; MG – Minas Gerais; RJ – Rio de Janeiro.
Source: Petrobras.

Brazil will also need to establish a clear regulatory framework in order to increase production and to address the potential environmental and social impacts of expanding ethanol production. To this end, the Brazilian government is carrying out a strategic environmental assessment to determine where to plant sugar cane in the future. Currently, the amount of land devoted to the growing of sugar cane is far less than land set aside for planting other crops. In 2005, less than 10% of the cultivated area was used for growing sugar cane, compared with 20% for corn and nearly 35% for soybeans. Yet the highly-intensive production systems for ethanol have caused environmental damage through the use of fertilizers and pesticides. Sugar cane is also a major source of air pollution, due to burning practices prior to manual harvesting. The phase-out of burning is being enforced in Brazil, with a deadline for complete phase-out by 2022. In the longer term, the possible emergence of ligno-cellulosic ethanol production could lower costs and increase demand for ethanol (see Chapter 14). Good environmental legislation and enforcement are essential to ensure the sustainability of ethanol production. In this regard, Brazil is in a position to be a role model for other countries with emerging biofuels markets.

Biodiesel

Brazil is actively pursuing a domestic biodiesel market. The government expects that by December 2006 about 3 500 stations will market biodiesel. Biodiesel distribution and marketing are carried out by Petrobras Distribuidora, The company has already invested nearly $9.3 million to adapt its facilities to biodiesel. The logistics of the biodiesel market differ from those of fossil diesel. Refineries that produce conventional oil are located closer to distribution centres, while biodiesel production centres are in the interior of the country.

Fuel distributors will be required to market biodiesel as of 2008. The government plans to give priority to the programme in less developed regions, such as the northeast and the Jequitinhonha Valley. Targets under Probiodiesel, the Brazilian Programme of Technological Development for Biodiesel, call for 2% of diesel from biodiesel by 2008 and 5% by 2013. The government estimates that the planted area that would be required to supply the 2% biodiesel/diesel fuel mix would be 1 500 million hectares. Biodiesel is supplied to distributors by rural producers through auctions promoted by the National Petroleum Agency (ANP).

Power and Heat

In 2004, electricity generation in Brazil was 387 TWh. Brazil's share of hydropower in the electricity mix, at 83%, is one of the highest in the world. In terms of the volume of electricity output from hydro, Brazil ranked third in the world in 2004 behind China and Canada. Natural gas, however, has made an increasing contribution over the past several years. Its share reached 5% in 2004, up from less than 1% in 1999. Oil, coal, nuclear and non-hydro renewables each contributed about 3% in 2004. Use of biomass, mostly in the form of bagasse, accounts for the majority of non-hydro renewable energy-based generation.

Brazil is expected to develop further its large hydropower resources. The Belo-Monte hydropower plant will be the first large dam built in Amazonas since the Tucuruí dam was completed in the early 1980s. The capacity of the Belo-Monte plant has not been confirmed, because of concerns about the environmental impacts associated with reservoir size. A decision is expected at the end of 2006. Other dams upstream from Belo-Monte are also being considered. Dams are also planned for the Madeira River in Rondonia State in the west. All of these plants are located far from centres of demand and will require significant investment in new transmission lines to connect them to the national integrated grid.

The construction of very large hydro facilities in the Amazon region has been controversial. There is a fear that the environmental and social impacts of the Tucuruí dam, which were more severe than was foreseen during construction and persist in operation, will be replicated if other dams are built (Rovere and Mendes, 2000). The problems include forest loss, leading to loss of natural ecosystems and to greenhouse gas emissions. The current administration has undertaken reforms to address environmental effects, building on the lessons learnt from Tucuruí, Alvina and Barra Grande. In September 2006, the government approved the environmental impact study for the planned Santo Antonio and Jirau hydroelectric projects along the Madeira River. Although the projects still have to be submitted for public consultation and have to obtain environmental licences, the government's approval is a positive development in light of delays that have held up numerous projects in the past. There is a growing consensus at the global level about the potential benefits of hydropower. The private sector's interest in financing hydropower projects is also growing (Box 6.1 in Chapter 6).

Brazil built gas-fired power plants at a rapid rate following the electricity crisis in 2001. But today, many of them are running well below capacity. Most of the plants were built in partnership with Petrobras. Development of more gas-fired power plants is very uncertain at the moment and will depend on the terms, including price and availability, of contracts for natural gas and the development of gas infrastructure. Investors are seeking long-term contracts to protect their investments. But in an electricity market dominated by hydropower, electricity prices will be highly dependent on rainfall levels.

The economic attractiveness of gas-fired power plants for foreign investors will depend critically on the type of contracts established. Few new gas-fired power plants are expected to be built in the next decade or so. Gas supply is expected to increase over time, however, so that output from plants already built will increase and some new gas-fired power stations will be built in the longer term. Gas-fired electricity generation is expected to represent 9% of total electricity generation in 2030, growing, on average, at a rate of about 5% a year over the *Outlook* period.

Brazil has two nuclear power plants, Angra I (626 MW) and Angra II (1 275 MW). Angra II was connected to the grid in July 2000. Construction of a third nuclear power plant, Angra III, was halted for political and economic reasons, but may be resumed in the next few years. Angra III will not go on line before 2010. The Reference Scenario projections assume that Angra III will add another 1.3 GW of capacity in southeastern Brazil after 2010. The construction of more nuclear power plants is once again under discussion, as in many other countries around the world, spurred by high fossil-fuel prices and concerns about security of supply. Brazil has the seventh-largest uranium reserves in the world, of which 57% are "reasonably assured" – a category akin to proven (NEA/IAEA, 2006).

In the Reference Scenario, electricity generation is projected to reach 731 TWh in 2030 (Table 16.9). Generation grows by 3.2% per year between 2004 and 2015, and then slows to 1.9% per year through to 2030. Hydropower is projected to grow at 2.9% per year in the period to 2015. From 2015 to 2030, however, as demand for electricity grows at a lower rate and the best hydro sites have been exploited, hydropower development decelerates. The share of hydropower in total electricity generation dips slightly to 79% in 2030. Electricity generation from biomass, mostly bagasse in the southeast region, is projected to rise to 29 TWh in 2030. Wind power increases to 11 TWh. The growth in non-hydro renewables results largely from government incentives, such as the PROINFA programme (Box 16.5).

Electricity generating capacity was 87 GW in 2004, 80% of which was accounted for by large hydropower plants. About 1%, or 900 MW, of total generating capacity in Brazil is in combined heat and power plants, mostly in industrial facilities. Some 46% of these plants run on sugar-cane bagasse and 31% use natural gas (Machado *et al.*, 2005). To meet demand growth over the *Outlook* period, Brazil needs to add 98 GW of new capacity by 2030 in the Reference Scenario. Hydropower makes up 67% of the additional capacity and new gas-fired capacity 15% (Figure 16.14). Some 9 GW of additional capacity from non-hydro renewable energy sources comes on line by 2030, mostly biomass and wind. Solar power emerges as a new source of generation towards the end of the projection period, on the assumption that it becomes competitive. To increase flexibility of supply, gas-fired plants are likely to be converted to running on a combination of gas and either biomass, diesel or light fuel oil. The investment required to build additional generating capacity over the next three decades in Brazil is enormous (see the Investment section below).

Table 16.9: **Electricity Generation Mix in Brazil in the Reference Scenario** (TWh)

	1990	**2004**	**2015**	**2030**
Coal	4.5	10.4	7.4	6.5
Oil	5.6	12.3	11.0	12.7
Gas	0.0	19.3	41.5	65.3
Nuclear	2.2	11.6	24.2	24.2
Hydro	206.7	320.8	441.5	581.1
Other renewables	3.8	12.5	23.1	41.3
Total	**222.8**	**386.9**	**548.8**	**731.2**

Box 16.5: **Prospects for Renewable Energy-Based Generation**

The Brazilian Alternative Energy Sources Incentive Programme (Programa de Incentivo às Fontes Alternativas de Energia Elétrica – "PROINFA"), launched in 2004, provides incentives to stimulate the use of alternative sources of energy. PROINFA's long-term goal is to increase the share of wind, biomass, and small and medium-sized hydroelectric facilities to 10% of electricity generation by 2020. The Brazilian government has designated Eletrobrás as the primary buyer of electricity generated by PROINFA projects, entering into long-term power purchase agreements at a guaranteed price. The guaranteed price for wind is 90% of the average supply tariff, for small hydro it is 70% and for biomass 50%. Several of the Eletrobrás Group's regional electricity companies are minority shareholders (up to 49%) in special purpose entities which own and operate PROINFA projects. Brazil's national development bank (BNDES) agreed to provide 70% of the financing for the projects and the Brazilian Energy Fund, launched in December 2004, should assist in funding the remaining 30%.

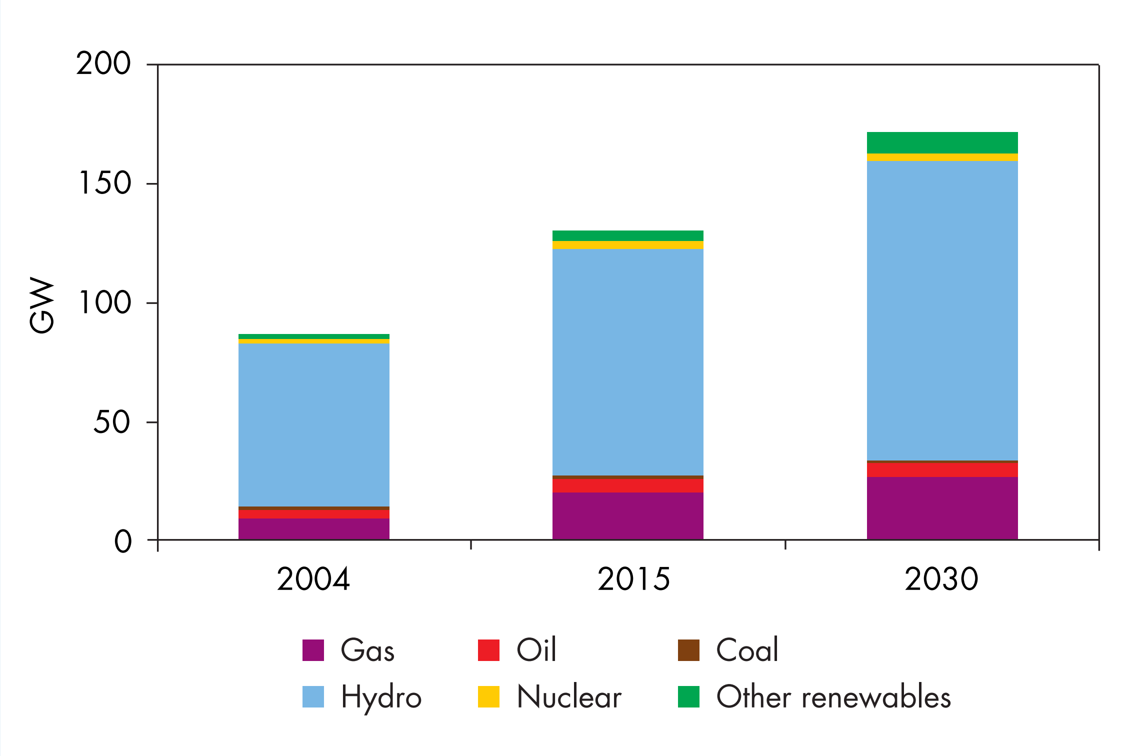
PROINFA is being implemented in two phases. In Phase 1, Eletrobrás had a target for 3 300 MW of renewable capacity by 2006. As of September 2006, 1 191 MW of small hydro, 1 423 MW of wind and 701 MW of biomass capacity had been accepted for PROINFA.[11] In Phase 2, Eletrobrás will be expected to lead the way to the fulfilment of PROINFA's 10% goal of electricity generation from renewables.

At 17% of total domestic supply in 2004, transmission and distribution losses in Brazil are among the highest in the world. They average only about 7% in OECD countries. Losses are high in Brazil because of the long distances over which power is transmitted, the old and poorly maintained systems with high losses and power theft. Insufficient investment in transmission and distribution facilities was one of the causes of the electricity crisis in 2001 and will be one of the major challenges over the *Outlook* period (see below).

In March 2004, the Brazilian government approved a new power-sector model. It is intended to address some of the regulatory concerns that had discouraged greater investment in expanding the country's power-generating and transmission capacity. Under the new regulations, two trading mechanisms will be established. The first is an electricity pool in which all distributors will be

11. See "Acompanhamento das Centrais Geradoras do PROINFA - Versão Agosto de 2006 at http://www.aneel.gov.br/37.htm.

Figure 16.14: **Power Generating Capacity in Brazil in the Reference Scenario**



able to participate. Supply contracts will be regulated. The second is an unregulated market which will be used by independent power producers and large consumers to negotiate bilateral contracts. The model also establishes new rules for the award of contracts for new generation plants to bidders who offer the lowest tariffs. The government is holding auctions for new electricity generation projects, including small and large hydro and biomass plants, with the aim of reducing power-supply risk and avoiding future supply shortages.

Although generating costs are low, electricity is considered very expensive for final consumers, particularly for households. Taxes and special charges to cover the cost of extending electrification make up more than 40% of the average electricity bill. The "Electricity for All" programme aims to give access to electricity to all households by 2015. The cross-subsidies involved in this programme increase tariffs for the non-subsidised population by 10%.

In the Alternative Policy Scenario, electricity generation is nearly 16% lower in 2030 than in the Reference Scenario and the fuel mix is different. There is much less gas and oil, and coal-fired generation almost disappears. Non-hydro renewables provide 49 TWh of generation, compared with 41 TWh in the Reference Scenario. Most of this increase is from bagasse cogeneration, which is boosted by more ethanol production in the Alternative Policy Scenario and stronger policies to connect bagasse producers to the grid. Nuclear power also increases its contribution by 41%, to 34.1 TWh in 2030, on the assumption that one more nuclear power plant is built after 2020. The share of hydropower generation remains broadly unchanged.

Environmental Issues

Environmental issues in Brazil have a very high profile, both domestically and internationally, where Brazil is a major player in discussions regarding the environment. Brazil's Amazon rainforest makes up 30% of the world's remaining tropical forests, provides shelter to at least one-tenth of the world's plant and animal species and is a vast source of freshwater.

Energy-related environmental problems include oil spills, air pollution, flooding, deforestation and induced occupation of areas cleared for transmission lines and pipelines. Oil spills cause severe environmental damage. Air pollution is mainly due to rapid urbanisation, industrial activities, poor fuel quality and biomass burning. The level of indoor air pollution from cooking with fuelwood is high in some areas. There are environmental pollution laws in place, with provision for sanctions. The government is working to enforce the requirements stemming from environmental impact assessments.

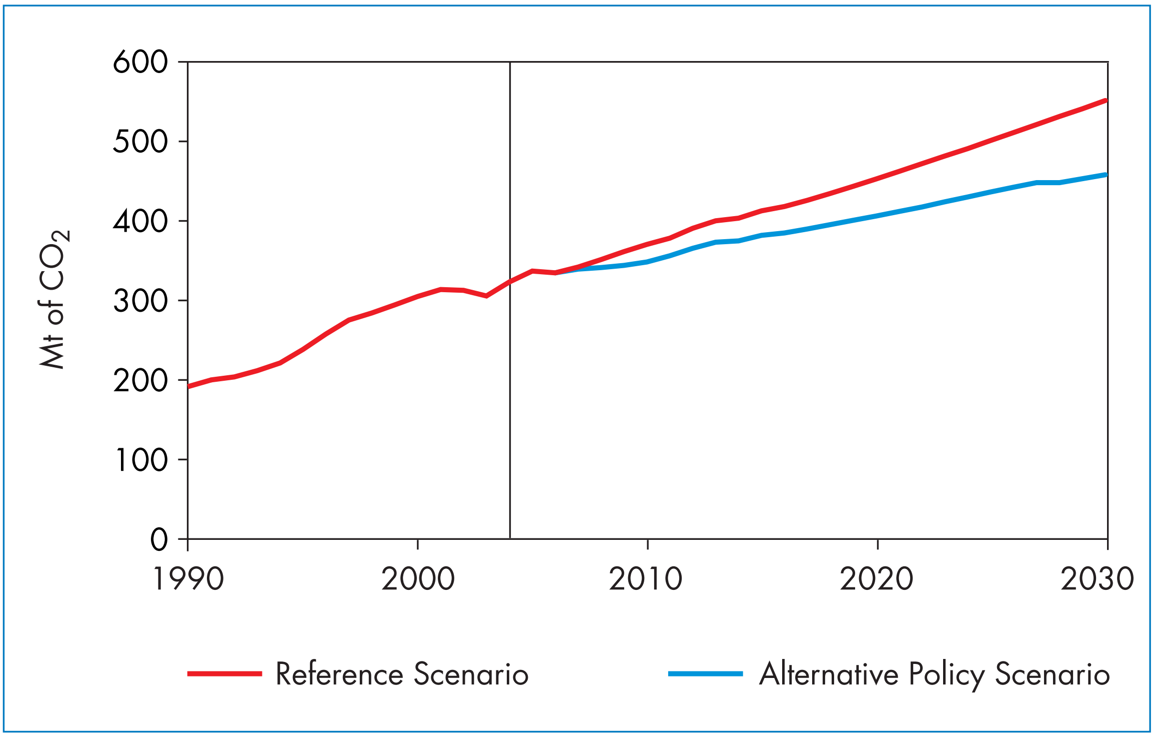
The construction of large dams is a major environmental issue. The Brazilian government favours the development of dams but there is considerable opposition. Because of opposition from environmental groups and weak institutional capacity at the federal level, hydropower generation projects have been delayed, despite the benefits these projects can offer when designed properly, such as multiple use of water and lower CO_2 emissions. If new dams are not constructed, the government may have no option but to invest in fossil-fuel plants and CO_2 emissions will rise.

Brazil's energy-related CO_2 emissions grew by 3.8% per year from 1990 to 2004. The carbon intensity of the economy grew, because of greater use of fossil fuels. CO_2 emissions per unit of GDP in PPP terms, however, were 20% lower than the average for the Latin American region as a whole in 2004 and 45% lower than in OECD countries. Use of hydropower and ethanol go some way to explaining this. Per-capita emissions in Brazil, at 1.8 tonnes in 2004, are among the lowest in the world and compare with 11 tonnes per capita in OECD countries.

Brazil ratified the Kyoto Protocol in 2002. As a developing country, Brazil is not currently required to reduce its CO_2 emissions, but like other developing countries, benefits from foreign investment encouraged by the Clean

Development Mechanism (CDM), to promote the development of energy sources that would lower carbon emissions. There were 66 CDM projects registered in Brazil as of September 2006.[12]

Figure 16.15: **Brazil's Energy-Related CO_2 Emissions in the Reference and Alternative Policy Scenarios**



In the Reference Scenario, energy-related CO_2 emissions are projected to reach 551 million tonnes by 2030, up from 323 million tonnes in 2004 and nearly three times higher than their 1990 level. Transport continues to contribute most to total emissions, its share increasing slightly from 42% today to 45% in 2030. The industrial sector's share of emissions remains flat. Those from power generation will decline slightly.

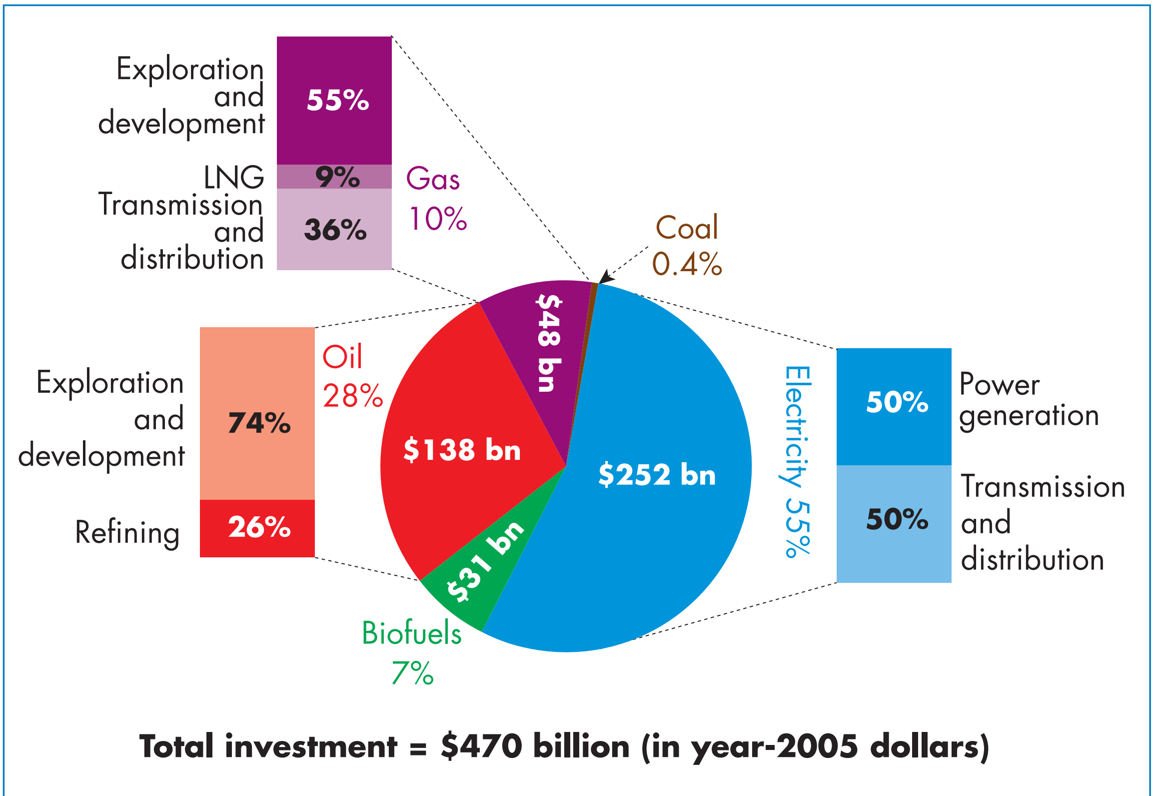
In the Alternative Policy Scenario, total CO_2 emissions reach 458 Mt in 2030, considerably lower than in the Reference Scenario (Figure 16.15). The decline is due to greater energy efficiency, more nuclear and renewables-based generation and more biofuels for transport. Emissions of CO_2 per unit of energy consumed are lower than in 2004. From a share today of 40% of primary energy use, the share of renewables remains flat in the Reference Scenario but rises by two percentage points in the Alternative Policy Scenario.

12. www.unfccc.int, accessed on 10 September 2006.

Investment

The cumulative amount of investment needed to underpin the projected growth in energy supply in Brazil is $470 billion (in year-2005 dollars) over the period 2005-2030 in the Reference Scenario. The electricity sector accounts for 54% of this spending, half for generation and the other half for investment in new transmission and distribution infrastructure (Figure 16.16). The $127 billion needed for generating capacity is two-thirds of that needed to meet all the additional demand in the rest of Latin America.

Figure 16.16: **Brazil's Cumulative Investment in Energy-Supply Infrastructure in the Reference Scenario, 2005-2030**



Note: See Chapter 2 for an explanation of the methodology used to project investment.

The private sector will be increasingly called upon to meet investment requirements. But that will require reform of the pricing structure and Brazil's regulatory regime to become more transparent and consistent. Investment in Brazil's transmission and distribution systems amounts to about $125 billion over the *Outlook* period.

Cumulative oil and gas investments amount to over $185 billion over the projection period. Upstream oil investment, at about $102 billion, or $4.1 billion per year, accounts for the majority of this. Expansion of the oil refining sector adds another $1.4 billion per year. These investments will be necessary to maintain self-sufficiency. Cumulative gas investments are projected at $48 billion, or $1.9 billion per year. Exploration and development of new fields needed to reduce dependence on gas imports will account for over half of total investment. Coal investment needs are negligible, because unit capital costs are low and new capacity needs minimal. To meet projected increases in biofuels demand, Brazil will need to invest some $31 billion over the *Outlook* period. This sum will represent nearly 20% of global investment in biofuels.

Required investments in the oil and gas sectors are lower in the Alternative Policy Scenario. Oil investment is $132 billion; $6 billion lower but still over $5 billion per year. Investments in the upstream oil sector will remain the same, but refinery investments fall. Cumulative gas investments are $47 billion over the *Outlook* period in the Alternative Policy Scenario. Reduced gas demand generates lower investment needs in the upstream and downstream sectors.

Lower electricity demand in the Alternative Policy Scenario reduces cumulative investment requirements to $206 billion, $47 billion less than in the Reference Scenario. Investments in transmission and distribution are considerably lower, at $82 billion. Generation investments are $3 billion lower. In the biofuels sector, some $6 billion more is needed to meet the demand expected in the Alternative Policy Scenario.

Total projected investment in the energy sector in the Reference Scenario is equal to around 1% of Brazil's GDP. Financing will be difficult, given the country's poorly developed domestic capital markets. External financing could account for a significant proportion of total capital flows to the Brazilian energy sector, especially in the oil and electricity industries if the right conditions were created.

On the demand side, the policies considered in the Alternative Policy Scenario lead to considerable increases in the amount of investment needed for energy efficiency improvements in the electricity and transport sectors. Cumulative investment requirements for more efficient electric equipment are $46 billion higher, compared with the Reference Scenario. In the transport sector, investment requirements are $42 billion higher.[13]

13. See Chapter 8 for a discussion of demand-side investments in the Alternative Policy Scenario.