Implications of Brazil's energy development

What does it mean for Brazil and for the world?

Highlights

- Brazil's energy sector undergoes a huge expansion between now and 2035. It has a wealth of energy resources to draw on, but faces stern challenges to develop them effectively. The country's emergence as a major exporter of oil, the tightening constraints on the expansion of domestic hydropower and the continued strong growth in energy demand create a new context for policymaking.
- Brazil plays a central role in meeting the world's oil needs through to 2035, accounting for one-third of the net growth in global supply. Such an increase in supply is heavily dependent on highly complex and capital-intensive deepwater developments, where Brazil is set to consolidate its position as the global leader. Brazil's rise means that it joins the ranks of the ten largest global oil producers around 2015 and is the sixth-largest in 2035.
- Brazil is a key player in any scenario for regional energy trade and integration. Although our projections do not suggest a large surplus for Brazil in either commodity, both natural gas and electricity offer promising perspectives to expand cross-border energy trade. In biofuels, Brazil is already a global player and its net exports grow to account for about 40% of global biofuels trade by 2035. This increase is contingent on policies favourable to biofuels trade being in place in the United States and Europe, the two largest export markets for Brazil.
- A pivotal factor in shaping Brazil's energy outlook will be the country's success in maintaining high levels of investment, with $90 billion needed per year to 2035. Almost two-thirds of this is required in the oil sector and more than a quarter to expand power generation and the transmission network. The heaviest burden lies with Petrobras, the world's largest deepwater operator, placing an emphasis on its ability to deploy resources effectively across a huge and varied investment programme.
- Brazil's energy sector remains one of the least carbon-intensive in the world, although the absolute level of energy-related CO_2 emissions grows by more than two-thirds to 2035, elevating the importance of this policy consideration. The high dependence of Brazil's energy system on climatic conditions, due to its continued high share of renewables, could increase vulnerability to the impacts of climate change, although the nature of these impacts remains uncertain.
- Opportunities exist to realise significant additional energy efficiency gains, sufficient to reduce final energy consumption in 2035 by 11% compared with the New Policies Scenario. This helps to relieve pressure on the power sector (a reduction of 100 TWh in 2035 power consumption, equivalent to 2012 output from the massive Itaipu hydropower plant), increase export earnings and mitigate the rise in emissions.

Context for Brazilian energy development

The Brazilian energy sector is changing, opening up a new landscape of choices, opportunities and potential vulnerabilities. Brazil has successfully developed over many years a range of policies aimed at limiting domestic reliance on oil and has very strong credentials on carbon-dioxide (CO_2) emissions, sustained in our projections by a low-carbon development strategy over the coming decades. Yet, within a few years, Brazil is also set to become one of the foremost international oil and gas producers, and a major net oil exporter, a development that redefines its place in the energy world.

Brazil also has to contemplate the implications of declining reliance on hydropower to meet its rapidly-growing demand for electricity. Unless satisfactory ways can be found to address social and environmental concerns about developing the hydropower potential of the Amazon region, limits to the further expansion of hydropower will come into view before 2035. A trend towards greater reliance on other technologies or fuels for new power generation is already visible in our projections and will develop further after 2035. Brazil will have to decide whether this need is to be filled primarily by renewable sources of energy, fossil fuels, nuclear, energy efficiency – or by a combination of all of the above.

A further shift in the context for Brazilian energy development comes from broader economic and social trends. As Brazil's economy more than doubles over the coming decades, the country will be making choices on mobility, infrastructure, social inclusion and economic development that will determine the relationship between rising incomes and energy consumption. The quality of energy services provided in Brazil, and the cost of these services, will also play a role in dictating the nature and speed of economic growth. The evident prospect of an oil and gas boom creates expectations of enhanced public services and economic opportunities, which may be difficult to fulfil. Beyond its own borders, Brazil will respond to, but also shape regional and global trends in both the energy sector and the broader economy (see Chapter 2).

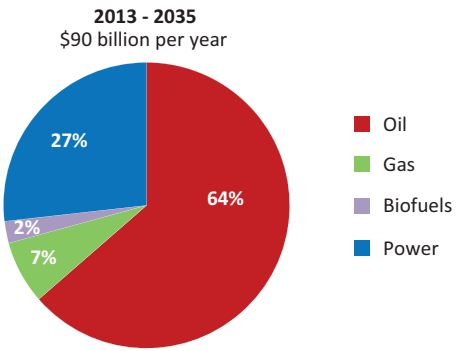
Against this shifting background, the focus of this chapter is to examine the implications of Brazil's supply and demand trends for the country itself, and for Latin America, but also to put Brazilian developments in a global energy and environmental context. We do this by considering three dimensions of Brazilian energy: its links with economic development, energy trade and security, and the environment.

Energy and the Brazilian economy

Brazil's need for energy at home and its ambitions to export oil and biofuels all require massive capital investment. To meet the energy supply projections in the New Policies Scenario, we estimate that Brazil requires a cumulative $2.1 trillion in investment across the different energy sectors, or $90 billion per year on average (Figure 12.1). The oil sector accounts for 64% of the total and an average of $57 billion per year, followed by the power sector (27% of the total), natural gas (7%) and biofuels (2%). As a component of overall

GDP, the share of investment in Brazil (in all sectors of the economy) is currently relatively low by international standards, at less than 20%, so an increase in capital spending in the energy sector would help to meet a broader policy priority. At the same time, Brazil will need to be wary of the risk that too high a concentration of investment in the oil sector may divert funds away from other productive sectors of its economy.

Figure 12.1 ▷ Average annual investment in Brazil's energy supply infrastructure in the New Policies Scenario



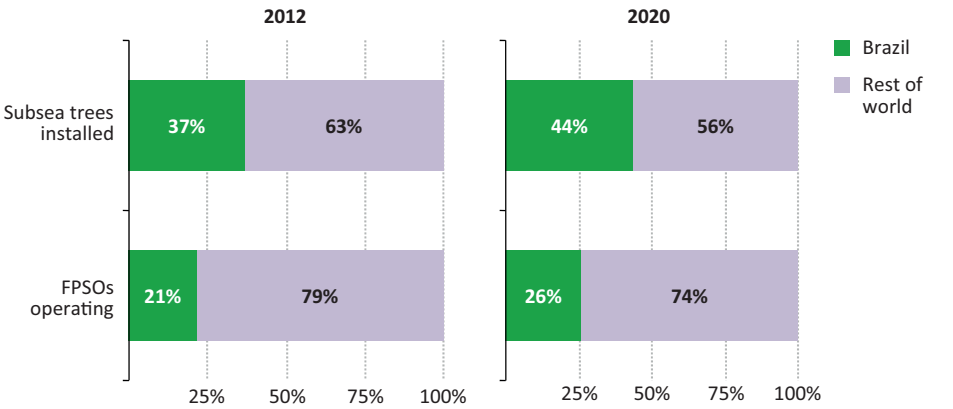
There are a number of mechanisms in place to bring the necessary capital investment into the energy sector, such as the bidding rounds for oil and gas licences, whether on a concession basis (as in the eleventh and twelfth rounds in 2013) or as production-sharing agreements (as in the first pre-salt round), and the auctions in the power sector for generation and transmission capacity. Concession-based schemes are also proposed to stimulate private investment in the transportation sector at large: the 2012 Logistics Investment Programme aims to bring private investment to a range of infrastructure projects, including highways, railways, and air and sea ports. More broadly, although direct allocations of public funds to the energy sector are limited (with health and education at the forefront of public spending plans), the government retains a major presence in shaping the environment for investment through the Brazilian Development Bank (BNDES). BNDES is the pre-eminent source of low-cost debt financing for energy projects and its lending criteria can be critical in determining the types of investment that are made. In all of these areas, there are ways to channel investment towards areas that serve government policy objectives but, to sustain a thriving mixed energy economy, it will be important that this does not occur at the expense of transparent conditions for the sector as a whole.

Our projections imply that Brazil becomes an important focal point for global spending on energy, deepwater production in particular. Brazil has the greatest impact on the global deepwater market in the early part of the projection period, when growth of deepwater production is quickest. By 2020, we estimate that 44% of all the subsea trees[1] installed in

1. A subsea tree (or "Christmas tree" as it is often called) is an assembly of valves which controls the flow from an oil or gas well situated on the sea bed.

the world in water depths more than 400 metres will be in Brazil (Figure 12.2). This implies that one in every two deepwater subsea trees produced between now and the end of the decade will be destined for Brazil. The story is similar for floating production, storage and offloading vessels (FPSOs): one in every three FPSOs brought into service between now and 2020 will be destined for Brazilian waters. A clear understanding of the plans of the government and of Petrobras, the national oil company, (including local content policy) is thus a critical input to business planning for the suppliers of such capital equipment.

Figure 12.2 ▷ Brazil share of installed deepwater subsea equipment and FPSOs in the New Policies Scenario, 2012 and 2020



Sources: Petrobras (2012); Offshore Magazine database (2013); Quest Offshore Resources (2013); McQuilling Partners (2012); IEA databases and analysis.

Over the projection period, a range of Brazilian and international players is set to increase their presence in the upstream (a development that increases the resilience of the sector); but the bulk of the anticipated investment will still be the responsibility of a single company, Petrobras. This is a function both of its traditional preponderance in the Brazilian upstream and also of the responsibilities reserved by legislation to Petrobras (a minimum 30% stake and role as operator) in areas deemed strategic, such as the new pre-salt developments. The company's business plan for the years to 2017 includes an investment programme of $237 billion, just over 60% of which is in the upstream. Annual upstream spending of $30 billion by Petrobras would represent around 5% of the anticipated global total, a massive commitment that would keep Petrobras in the highest echelon of companies committing capital to oil and gas production. The strain on resources that this implies (in terms of financing, skills and management capabilities) is amplified by the need for Petrobras, as a national oil company, to maintain a large and diverse portfolio of oil and gas sector activities upstream, midstream and downstream. Whereas international oil companies might typically sell off marginal assets in order to focus resources, Petrobras must allocate staff and spending across a very wide range of projects and is not necessarily

free to focus on the most profitable. Upstream, Petrobras retains operatorship of a very high percentage of fields in its overall portfolio, compared with other similar size oil and gas companies, creating heavier staff needs. Downstream, the structure of the market and the uncertainties over pricing mean that Petrobras is the only company investing in new refining capacity, but, as this is a capital-intensive business, it raises the question of whether new refineries can be built on the scale required at the same time as the company is developing Brazil's pre-salt resources (a similar point can be made in relation to the midstream and downstream gas sectors). Petrobras has thus far managed to raise money on domestic and international markets without difficulty, but this borrowing has occurred against fairly tough expectations for future oil production and revenue. A slippage relative to these targets could raise the cost of capital for the continued high investments required.

The scale of energy sector investment will ultimately be determined by the speed at which the Brazilian authorities choose to deplete their resources (Box 12.1). How this investment then affects the Brazilian economy will depend, to an extent, on how much of it is spent on domestically-sourced goods and services. As noted in the previous chapter, the government is seeking to secure spillover effects from the growth of the energy sector through local content requirements that are intended to stimulate the domestic supply chain, generating multiplier effects on employment and demand in the wider economy. However, the evidence from other countries on the benefits of such policies is mixed – they can result in a tighter and less competitive supply chain, especially while the necessary industrial capacity and skilled expertise is being developed. In Brazil's case, the possibility of labour shortages, and related inflationary and cost pressures, is already evident. Unemployment is low and energy projects are competing for skilled labour, not only with other industrial sectors, but also with the large-scale spending foreseen under the 2011-2014 Accelerated Growth Programmes (Programa de Aceleração do Crescimento), which includes the construction of major new transport infrastructure. The ultimate tests of the success of local content policies are whether they create domestic supply industries that can both meet local demand during the expansion phase and compete internationally after their domestic opportunities level off.

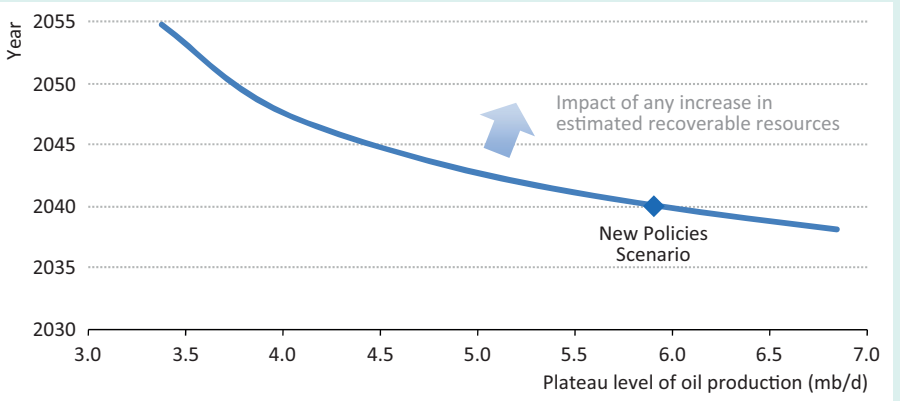
An additional way for investments in the domestic supply chain to bring broader economic benefits is via research and innovation. With this in mind, the government has introduced a levy on oil companies with concessions in Brazil's upstream that is earmarked for spending on research and development (R&D). The levy amounts to 1% of gross revenues, half of which goes to academic and research institutions. This has already borne some fruit, with a research hub now forming around Rio de Janeiro, involving a Petrobras technology centre and research units from leading international upstream, services and technology companies. ANP, the regulator, estimates that nearly $1 billion per year will be invested over the next decade as a result of the R&D provision included in oil and gas concessions.

Box 12.1 ▷ Choices for oil production beyond self-sufficiency

For a long time, the goal of self-sufficiency defined the limits of Brazil's ambitions for oil output. The most recent official long-term outlook (to 2030) for the energy sector dates from 2007 (EPE, 2007) and anticipates production rising to 3 mb/d during the current decade and then remaining at these levels for the rest of the period – enough to turn Brazil into a relatively small net exporter for much of the 2020s, before domestic demand catches up with supply. This forecast has been overtaken by higher medium-term prospects: the latest ten-year plan from the government sees oil production reaching 5.4 mb/d already by 2021 (EPE, 2013). This is broadly consistent with Petrobras' latest production forecast, which sees its own output reaching 4.2 mb/d in 2020. The level of ambition beyond 2021 has yet to be redefined.

Different considerations affect the choices Brazil has to make to maximise the value of its hydrocarbon resources. These involve longer-term assessments of market conditions and policies that may have an impact on demand for oil, the desire to maintain a steady flow of revenues and how best to develop and sustain domestic supply industries and employment. A key factor in these choices is the size of the resource base and the speed at which it is depleted. To illustrate this, we took the current estimate for Brazil's ultimately recoverable conventional resources (120 billion barrels) and calculated how soon different levels of plateau production might deplete 50% of these resources, the point at which it would be reasonable to assume that production starts to decline (see Chapter 13). These points can be shifted further into the future by increases in the size of the estimated resources (as has already happened in Brazil over the last ten years), or by technologies allowing higher recovery rates in discovered fields, but, in general, the higher the targeted level of production, the shorter the period for which this can be maintained. In the New Policies Scenario, production settles at between 5.5 mb/d and 6 mb/d and, at this rate of output, half of the Brazilian resource base (as currently estimated) will have been produced by 2040 (Figure 12.3).

Figure 12.3 ▷ Implications of different plateau production levels for the year in which 50% of Brazil's oil resources are depleted



Note: Oil resources are defined as ultimately recoverable resources of crude oil and NGLs.

Pricing

A key determinant of the interaction between the energy sector and the wider economy is the way that energy is priced. In the New Policies Scenario, the evolution of oil product demand (with the exception of liquefied petroleum gas [LPG]) and the competitiveness of ethanol relative to gasoline are based on the assumption that oil product prices in Brazil are aligned with international prices. Continuation of the current practice of holding gasoline prices below their international value would push up demand for this fuel at the expense of biofuels, compared with our projections, and continue to erode the financial resources of Petrobras, limiting its investment options.

For natural gas, the range of uncertainty over gas market development is substantial. We assume that domestic gas production will be priced in a way that finds and develops the domestic market, supplemented by imports at an average price of between $11-13 per million British thermal units (MBtu). There is clearly some momentum from national and regional policymakers, and from gas-consuming industry, to move to more open market models that would allow new, more transparent ways of pricing gas to emerge (see Chapter 10). With a well-functioning gas market, domestic production from a variety of sources, and imports via both pipeline and liquefied natural gas (LNG) (and, possibly, LNG export facilities), Brazil would be well placed to introduce open and efficient gas trading, allowing pricing signals to emerge that reflect the real supply-demand balance for gas (which is not the case today).

Counteracting pressures result in electricity prices remaining around current levels in real terms over the projection period. On one hand, the cost of renewable energy technologies, such as wind and solar photovoltaics (PV), are expected to decrease over time, transmission and distribution losses are expected to be reduced, and future growth in domestic gas supply could lead to lower average fuel costs for gas-fired power plants. On the other hand, concession rates for power from new hydropower projects will be higher than for existing hydropower to accommodate run-of-river designs and the requirement to repay capital costs. In addition, gas-fired power plants make up a growing share of the power mix in the New Policies Scenario and the cost of generating electricity from these plants is likely to be higher than from most other sources, even if average fuel costs come down.

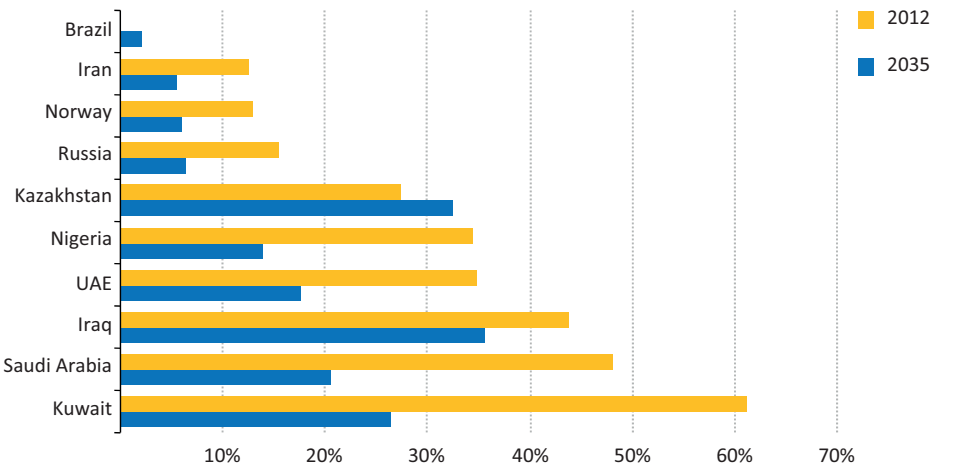
Revenues

The emergence of net oil exports post-2015 brings with it a notable boost to Brazil's export earnings, with oil export revenues estimated at close to $50 billion in 2020 and $120 billion in 2035 in the New Policies Scenario. This is an important source of national wealth, but needs to be seen in the context of the large and diversified Brazilian economy.[2] This export revenue amounts, at its peak, to around 2.5% of national gross domestic product (GDP), a level considerably below that of other leading exporters (Figure 12.4). One could conclude

2. Oil is the most important source of energy-related export earnings in 2035, supplemented by revenue from exports of biofuels (around one-tenth of the value of oil exports) and smaller amounts from natural gas.

from this that Brazil's oil exports do not, in themselves, create a major risk of "Dutch disease", *i.e.* of inflating the value of the currency in a way that harms other sectors, an ailment to which some resource-rich countries have succumbed. But the risk is higher if oil is considered in concert with Brazil's other commodity-based exports, particularly if energy commodities follow the same price cycles as other important export groups, such as mineral ores. This possibility is not to be excluded, given that the prospects for many commodities are tied closely to prospects in China and are highly correlated with global economic activity. A slowdown in demand and a dip in primary commodity prices could therefore be detrimental and indeed has been identified by the International Monetary Fund as a key economic risk for Brazil (IMF, 2012).

Figure 12.4 ▷ Oil export revenue as a share of GDP in selected countries in the New Policies Scenario



The oil and gas sectors represent a valuable source of fiscal revenue for Brazil, including signature bonuses, royalties, direct taxes and a complicated system of indirect taxes and social contributions levied by different levels of government. The expected increase in revenues has already made their allocation a hot topic in Brazilian politics, increasing the likelihood that a larger share of the revenues may be folded into current spending (with royalties earmarked specifically for education and healthcare), rather than to mitigate the effects of economic cycles.[3] Experience from other resource-rich countries offers some cautionary notes about the way that the promise of oil wealth can detract from the need to tackle structural economic problems, even though these are, in many cases, important determinants of the level of long-term welfare and economic growth.

3. The Brazilian authorities set up a sovereign wealth fund (Fundo Soberano do Brasil) in 2008 as a vehicle for saving a part of oil revenue. However, no money has been added to the fund since 2009 and its long-term role remains under discussion. Similarly, the Fundo Social was announced in 2009 as a sovereign wealth fund for the revenues that will come specifically from the pre-salt area.

Energy trade and security

In this section, we turn to Brazil's interactions with the wider world, how these might evolve over the projection period and how they might affect regional and international energy security. The focus is Brazil's net trade position in the various fuels, primarily oil, where net exports rise to 2.6 million barrels per day (mb/d) by 2035 from close to zero today, and biofuels, where net exports rise to 0.2 million barrels of oil equivalent per day (mboe/d) (Table 12.1).

Table 12.1 ▷ Brazil supply-demand balance by fuel in the New Policies Scenario

		2011	2020	2025	2030	2035	2011-2035	
							Delta	CAAGR*
Oil (mb/d)	Production	2.2	4.1	5.4	5.8	6.0	3.8	4.3%
	Demand	2.3	2.9	3.1	3.3	3.4	1.2	1.8%
	Net trade	-0.1	1.2	2.3	2.6	2.6	2.6	n.a.
Gas (bcm)	Production	17	38	60	78	92	76	7.4%
	Demand	27	45	61	75	90	63	5.2%
	Net trade	-10	-7	-1	3	2	12	n.a.
Biofuels (mboe/d)	Production	0.4	0.6	0.8	0.9	1.0	0.7	4.4%
	Demand	0.3	0.5	0.6	0.7	0.8	0.5	4.2%
	Net exports	0.1	0.1	0.2	0.2	0.2	0.2	n.a.

* Compound average annual growth rate.

Regional co-operation

As in many parts of the world (Europe is an exception), there has been a large and persistent gap in Latin America between the potential for regional energy co-operation and actual progress on the ground. This is not due to lack of political efforts to foster energy integration, nor to a lack of complementarities between the different energy systems. At a political level, for example, a Council of Ministers on Energy was created in 2007, under the Union of South American Nations (UNASUR in Spanish, UNASUL in Portuguese), which was followed in 2009 by the creation of a Council of Ministers on Infrastructure and Planning. A UNASUR energy treaty is also currently being prepared.[4] There are also examples of co-operation on specific projects, notably between Brazil and Paraguay on the huge bi-national Itaipu hydropower plant. But, overall, the amount of energy traded across borders in Latin America remains very small, relative to the size of the region's energy sector.

4. Other regional initiatives with an energy dimension or a specific energy focus include the Latin American Energy Organization (OLADE), South American Common Market (MERCOSUR) and the Andean Pact; there are also initiatives bringing together regional authorities and the private sector, such as the Commission of Regional Energy Integration (CIER), focusing on the power sector, as well as industry fora such as the Regional Association of Oil, Gas and Biofuels companies of Latin American and the Caribbean (ARPEL).

As the largest regional economy, Brazil is a key player in any Latin American energy integration scenario. One avenue for this could be the power sector, where – in addition to purchasing part of Paraguay's share of Itaipu output – Brazil already has transmission connections with Argentina, Uruguay and Venezuela. Further potential exists for cooperation on hydropower, where Brazil has been in discussions about new bi-national projects with Argentina, Bolivia and Peru. Another possibility is the natural gas sector, where an early wave of enthusiasm for integration in the 1990s led to the construction of the "Gasbol" pipeline from Bolivia to Brazil, along with several other pipelines across the Andes between Argentina and Chile. In addition, there are some joint initiatives in the oil sector, for example the commitment by Venezuela in 2005 to take a 40% stake in Brazil's Abreu e Lima oil refinery.

In each of these areas, though, there are questions over the prospects for deepening co-operation. The electricity sector is perhaps the most promising area for an expansion of cross-border ties, but the prospects for deeper integration are diminished by the disproportionate size of Brazil's power sector compared with any of its neighbours, meaning that the operation of any integrated network would be largely driven by the dynamics of the Brazilian system. Large new bi-national hydropower projects would be subject to the same public acceptance hurdles as purely domestic projects, but with added layers of political complexity arising from the need to negotiate and implement the projects in concert with a neighbour. Enthusiasm for cross-border gas pipeline projects faded significantly after the nationalisation of the upstream gas sector in Bolivia in 2006 and the failure of Argentina to fulfil its gas supply commitments to Chile since 2005. Experience in the oil sector has also been mixed. In the case of the joint refinery project, Venezuela has yet to provide financing for its stake, although Petrobras is committed to complete the project.

Over the *Outlook* period, it is projected that Brazil remains a modest net importer of electricity (at around 30-40 terawatt-hours [TWh] per year) and assumed that gas imports from Bolivia continue beyond the expiration of the current contract (in 2019), albeit with steadily decreasing volumes as Brazil moves to a position in which its own production can cover all of its domestic needs. Coal imports are likewise predominantly sourced from within the continent. But we do not assume a political breakthrough that would push forward the prospects for thorough top-down regional energy integration.

The prospects for increased trade, in Brazil's case, come in our judgement from a gradual process of expanding cross-border power links and also from a possible expansion in gas trade, notably LNG, which can be managed flexibly and without the political risk associated with fixed cross-border pipeline projects. In the power sector, Brazil's plans for expanding the electricity transmission network include new international interconnections with Bolivia, Guyana and Suriname and the expansion of existing interconnections with Argentina and Peru. Projects being considered or implemented under the Initiative for

Integration of the Regional Infrastructure of South America (IIRSA) include transmission projects with Paraguay and Uruguay.[5]

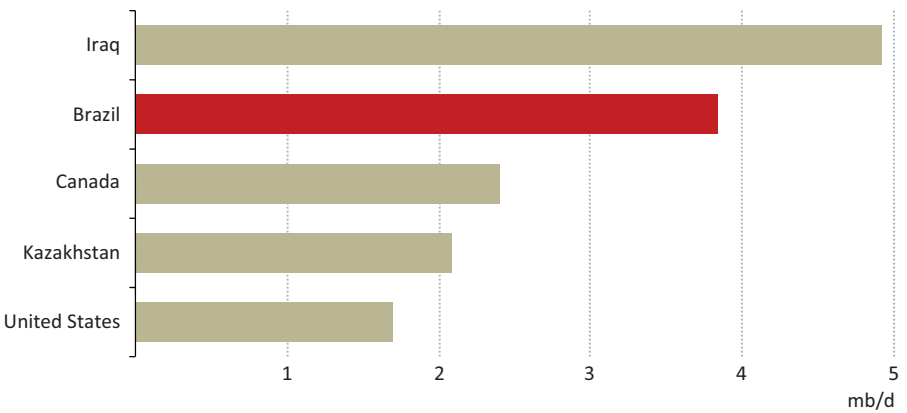
LNG trade can play an important role to fill in gaps in the regional gas infrastructure and could, with time, help to bring a degree of connectivity to the different gas markets in the region. Much will depend, though, on whether new regional trading and pricing hubs evolve to guide investment and gas flows (an issue in which Brazil can play an important role) and whether unconventional gas development in Argentina allows a restart of gas flows to Chile and also, potentially, the opening of a reversible link to Brazil that would provide for further balancing between the region's two largest gas markets.

Brazil and international oil and gas markets

Oil

In the period to 2035, Brazil becomes a major source of growth in global oil supply, with the highest anticipated rate of output growth among all oil producers. The 3.8 mb/d increase in production to 2035 is higher than that of global light tight oil, second only to Iraq among all oil producers and by far the largest among non-OPEC countries (Figure 12.5). The combined growth in output from Brazil and Iraq is equal to around 80% of the net increase in global production. Brazil's rise means that it joins the ranks of the ten largest global oil producers (crude oil plus natural gas liquids [NGLs]) around 2015 and becomes the sixth-largest producer by the end of the projection period, behind only Saudi Arabia, the United States, Russia, Iraq and Canada.

Figure 12.5 ▷ Major contributors to global oil supply growth in the New Policies Scenario, 2012-2035



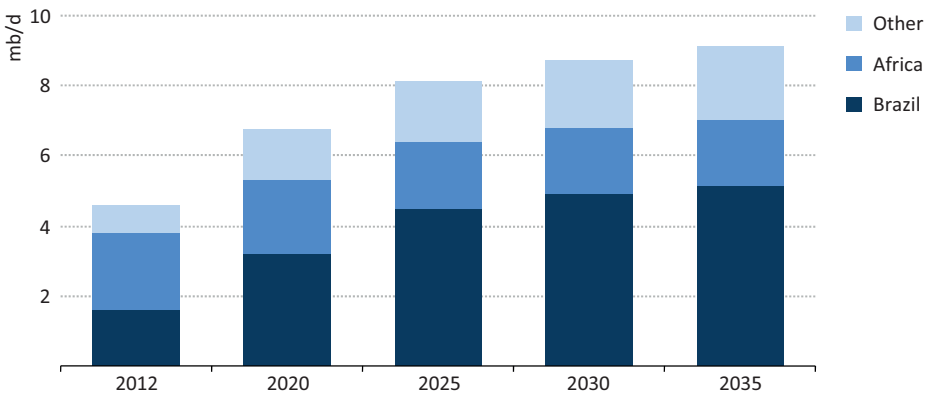
Growth of the magnitude projected for Brazil is not unprecedented for a single oil province. What makes this case stand out is the extent to which this growth relies on the performance of a single player: fields operated by Petrobras account for more than 80 % of Brazil's current

5. IIRSA is a technical forum under the Union of South American Nations Council of Ministers on Infrastructure and Planning.

oil production and, even though there were signs in the eleventh licensing round that the company was ready to take on non-operating roles in partnership with other companies, its position as operator of the main producing fields in the pre-salt is enshrined in legislation. We estimate that fields operated by Petrobras are responsible for around three-quarters of the increase in Brazilian output over the period to 2035.

Another distinguishing feature of Brazil's strong position in the global outlook is that it is almost entirely dependent on increases in deepwater production. The importance of deepwater is growing in the overall oil supply picture, its share of conventional crude output rising from 6% in 2012 to 11% in 2035, and Brazil accounts for more than 3.5 mb/d (nearly 80%) of the overall 4.4 mb/d increase from this source (Figure 12.6). This means that Brazil becomes the unrivalled leader in deepwater output and by far the largest market for all types of deepwater suppliers, a factor that is set to underpin a migration of deepwater suppliers to Brazil. It also suggests that, if Brazil can take on a position as technology leader in this area and develop a competitive local supply base, then there may be opportunities to export equipment and expertise in the second half of the projection period, when growth in deepwater output is expected to be spread more evenly across the various global basins. A second implication of our projections is that Brazil will be taking on the greatest share of deepwater risk. This type of oil production, it should not be forgotten, is consistently pushing at the frontiers of what the industry can undertake, and represents a relatively expensive source of oil. The repercussions of any serious accident or spill would be felt in Brazil, regardless of where it took place.

Figure 12.6 ▷ Global deepwater* oil production by region in the New Policies Scenario



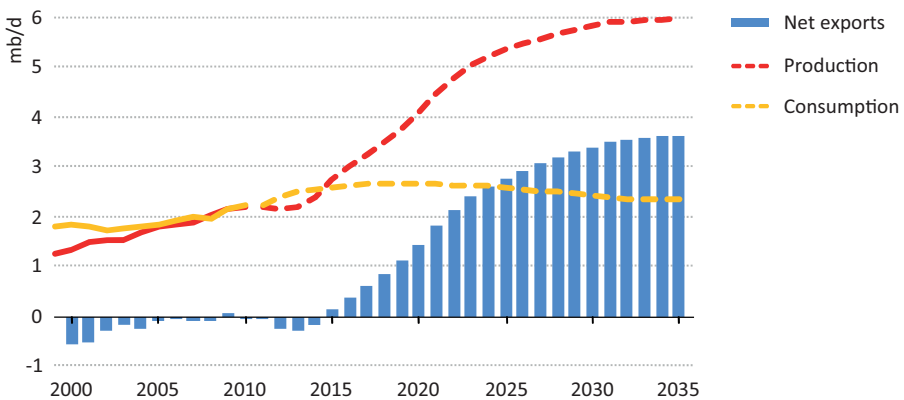
* Deepwater is defined as water with a depth in excess of 400 metres.

In the New Policies Scenario, Brazil becomes a net exporter of oil after 2015, becoming the first country since Canada, in the early 1980s, to go from being an importer to a major exporter of oil (Figure 12.7). The availability of crude oil for export is helped by Brazil's production of biofuels, which substitute for a part of the country's oil consumption. If all of

the domestic demand met by biofuels in our projections were instead met by oil products, Brazil's emergence as a net exporter would be postponed and its level of exports in 2035 would be reduced by one-third.

In our projections, the surplus is available as crude oil, since we do not assume any refinery capacity being built beyond that necessary to meet Brazil's domestic demand for products. A few years ago, the natural export market for Brazilian crude might have been North America, but this perspective is narrowing in our projections, as North America's requirement for imported crude shrinks substantially. Instead, we anticipate that a part of Brazil's crude exports go to Europe, but an increasingly large share of the total follows the global shift in demand and is drawn towards Asian markets.[6] Brazil's position is buoyed by its status as a supplier of medium-grade crudes, whose availability is squeezed by rising output of heavier crude and of NGLs (see Chapter 16).

Figure 12.7 ▷ Brazil oil balance in the New Policies Scenario



Natural gas

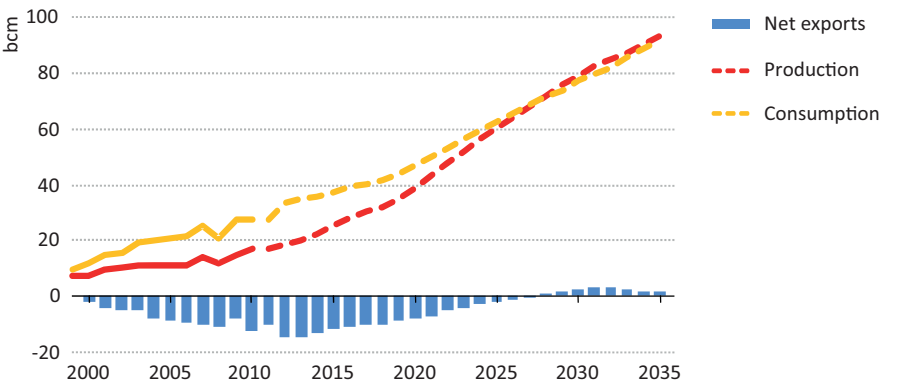
In the New Policies Scenario, the projected gradual increase in natural gas production brings Brazilian supply and demand into balance by the late 2020s, with a small net surplus of gas projected by the early 2030s (Figure 12.8). We assume in our projections that gas imports from Bolivia gradually tail off but, were they to continue at around 10 billion cubic metres (bcm) per year (as per the current contract), then Brazil could become a larger exporter earlier in the projection period. This would not affect Brazil's net gas position, but would provide an indirect route to international markets for landlocked Bolivian output.

At present, Brazil has two LNG import facilities, one in Pecem, a few miles north of Fortaleza in the northeast and one in Rio de Janeiro in the south, which is currently being expanded. A third is being built at Todos os Santos Bay in Bahia state, which would bring overall LNG import capacity to 15 bcm per year. These terminals provide Petrobras with

6. Sailing times from Brazil to Europe (Rotterdam) are around 22 days, ten days less than to Mumbai, although Asian premiums for crude oil are likely going to be high enough to cover the cost differential.

the necessary degree of flexibility to cope with fluctuations in gas demand from the power sector. Our projection that Brazilian supply catches up with demand could be understood to make these import terminals redundant, but this depends in practice on the extent to which other elements of flexibility are put in place, either on the supply side, such as storage or a substantial increase in non-associated gas production, or on the demand side, such as the development of market mechanisms that can absorb the fluctuation of power sector demand. Without these additional elements of flexibility, LNG import capacity would remain a useful insurance policy against swings in the supply-demand balance or temporarily adverse hydrological conditions.

Figure 12.8 ▷ Brazil gas balance in the New Policies Scenario



Gas export possibilities and prospects for Brazil are even more uncertain, arising on a sustained basis only towards the end of our projection period. Relatively small fluctuations in either supply or demand could have a large impact on the trade balance. Among the domestic circumstances that could precipitate pressure for export would be if gas discoveries exceed expectations, or, as discussed in Chapter 11, if gas injection proves to be less widespread or less successful than currently envisaged.[7] The construction of LNG export capacity could also be seen as a way to manage the possibility of temporary surfeits of gas, if these cannot be absorbed on the domestic market (although facilities for liquefaction are considerably more expensive to construct than those for regasification).

Brazil and international biofuels trade

Brazil is set to play the central role in the international biofuels market. It is one of the few countries that have both the resources and the intention to develop production capacity to meet the needs of international markets. In the New Policies Scenario, Brazil emerges as the largest net exporter of biofuels in the world early in the *Outlook* period, as its main

7. Floating LNG facilities, essentially a purpose-built barge that can liquefy gas produced from offshore fields, could also be an option for Brazil, providing a possible monetisation option for isolated new gas discoveries, for example in the Brazilian equatorial margin off the north coast of Brazil.

competitor, the United States, becomes a net importer. Brazil's net exports of biofuels (almost all consisting of ethanol) increase to around 0.2 mboe/d in 2035 and equate to about 40% of world biofuels trade at that time. At current prices, this level of exports would generate revenues well in excess of $10 billion per year.

The outlook for biofuels exports will be contingent on a range of factors, notably the level of investment in new capacity, the extent and impact of possible industry consolidation, inter-product price competition (both prevailing international sugar prices and domestic gasoline prices) and the success of individual harvests. International demand for biofuels will continue to be influenced heavily by government policies and regulations in specific markets. In the New Policies Scenario, the European Union and the United States are key export markets for Brazilian biofuels and have the capacity to alter the outlook significantly. The European Union has set ambitious goals for biofuels under its Renewable Energy Directive and these will be difficult to meet with domestic supply alone. The low-emissions credentials of Brazilian biofuels currently play in its favour. However, recent actions, namely the imposition of anti-dumping tariffs on biofuels from Argentina, Malaysia and the United States, suggest that unfettered future access to European markets is far from certain. Brazilian biofuels also seem well-placed to help meet the US Renewable Fuel Standard requirement to significantly increase consumption of "advanced biofuels" through to 2022. However, the US authorities are permitted to reduce this mandate if domestic production capacity falls short of the level required to meet the target and they have done so in the past. Such action could limit or close the opportunity for Brazil to sell into the US market.

Energy and the environment

The expansion of hydropower and of bioenergy use in Brazil have raised questions as well as plaudits on environmental issues, but they have been pivotal in enabling Brazil to achieve significant socio-economic development while keeping its energy-sector CO_2 emissions at relatively low levels. For many countries around the world, a key policy challenge is to decarbonise their energy sector. For Brazil, the task is different: to maintain its low-carbon profile and retain its strong environmental credentials, even as domestic energy demand grows rapidly.

Environmental considerations continue to appear on both sides of the debate over the future of Brazilian hydropower and biofuels. Concerns about large-scale inundation for hydro reservoirs are already a major consideration in Brazilian decision-making on new hydropower developments, tipping the balance in power sector planning towards run-of-river projects. New models for hydropower delivery and enhanced efforts to engage local communities can lessen the impact of construction and operation of projects in environmentally sensitive regions, such as the Amazon. But the balance of the argument could also be swayed if the result of constraints on hydropower is to increase the volumes of fossil-fuel generation and related CO_2 emissions. The projected growth in biofuels production raises concerns about changes in land use, although the government has

already acted to identify appropriate lands for sugarcane farming and processing (in effect, signalling to the industry that more than 90% of the country's territory should be considered unsuitable in the context of its expansion plans) as a means of avoiding an expansion of biofuels production taking place directly or indirectly at the expense of Brazil's forests.

There are other environmental hazards to be addressed across the Brazilian energy mix, as well as new risks that could emerge with a changing climate (Spotlight). Brazil is among the most bio-diverse countries in the world and its internationally recognised efforts to conserve this heritage have implications for any form of energy and infrastructure development, particularly in the Amazon region. The concentration of oil and gas production in the deepwater requires constant vigilance and the highest standards to avoid the risk of accidents and spills. The prospective expansion of the onshore production of unconventional gas requires a dedicated effort to ensure, similarly, that high standards are observed so as to avoid social and environmental damage.

SPOTLIGHT

How might climate change affect Brazil's energy sector?

Brazil has vast experience in managing an energy system that is influenced by seasonal and climatic variations, but the high share of renewables in the energy sector (combined with the country's already varied climate) mean that it may be particularly affected by climate change. The nature and scale of this challenge, though, is subject to a broad range of uncertainty. Existing climate models sometimes suggest negative effects on the energy sector and sometimes positive, complicating the task of policymakers and the energy sector in planning actions to mitigate or adapt.

The operation of Brazil's power sector is already affected by periodic droughts. For the future, global warming of about 2 °C by 2050 (compared with pre-industrial levels) would mean that more northern parts of Brazil, where much of the potential hydropower capacity is to be found, could see hydropower output decrease (IPCC, 2012), while the south of Brazil, where the majority of the existing capacity is located, could see an increase in output (Hamadudu and Killingtveit, 2012). These findings are broadly consistent with those of an earlier IPCC report (2011) that, examining the median results of twelve climate model projections, found a large-scale reduction in annual water run-off in the north but increases in the south by the end of this century. Large hydro reservoirs can help compensate for some additional seasonal variations in water inflow, and provide flexibility in freshwater supply for other purposes, while run-of-river projects become more vulnerable to variations in rainfall patterns.

Analysis of the effect of climate change on wind power also draws mixed conclusions: some find that wind resources in Brazil decline (Pryor and Barthelmie, 2010), while others suggest a substantial increase, particularly in coastal areas and the north/northeast regions (Lucena, *et al.,* 2010). As for thermal power plants, rising air

and water temperatures would affect their efficiency, either decreasing electricity output or increasing fuel consumption, though the overall effect on Brazil's thermal power output has been estimated at less than 2% (Lucena, Schaeffer and Szklo, 2010). As ambient temperatures increase, a warming climate could be expected to boost demand for cooling (see Chapter 10). Taking into account the combined effects on generation and peak electricity demand, higher temperatures are expected to result in a need for additional peak generation and transmission capacity or greater demand-side response at peak times.

Production of bioenergy (including biofuels) would likewise be affected: higher CO_2 levels and a limited temperature increase can extend the growing season, although more frequent extreme weather events or changes in precipitation patterns may reduce these positive impacts. Studies examining the impact of climate change on sugarcane production in Brazil suggest either little overall impact or a positive impact (Pinto and Assad, 2008). As well, any frequency in the incidence of tropical or sub-tropical cyclones (very rare at present in the South Atlantic) would have disruptive consequences for offshore oil and gas operations. Given the expected increase in the number of FPSOs and other offshore facilities over the coming decades, there is a risk that a rise in extreme weather events could become a new risk element for the offshore industry in Brazil.

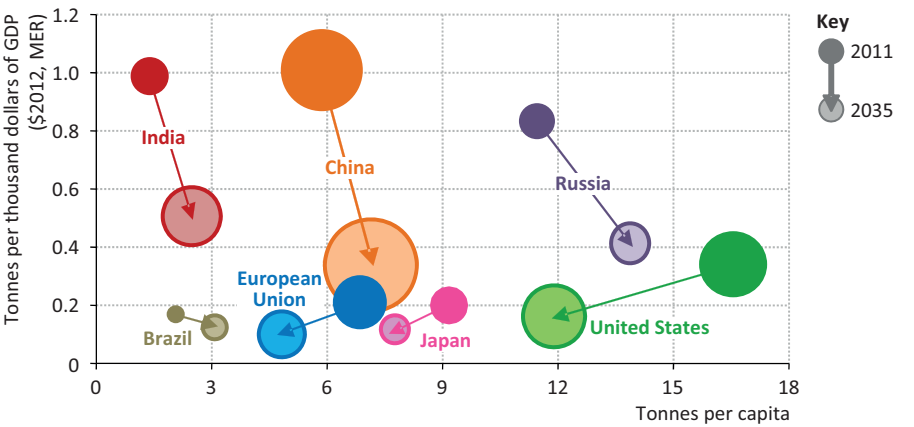
Energy-related emissions

As the source of more than two-thirds of global greenhouse-gas emissions (IEA, 2013), the energy sector is crucial to tackling climate change, but the energy sector in Brazil has, in the past, played a relatively small role in national greenhouse-gas emissions by international standards, behind emissions from land-use change and the agriculture sector. This is changing fast though, and the energy sector is becoming a more important source of emissions growth and, therefore, a more important target for future policy action (see Chapter 9, Figure 9.11).

Brazil has set a goal of reducing its greenhouse-gas emissions by at least 36% (compared with a business-as-usual baseline) by 2020 and has captured this commitment in domestic law. This implies, according to EPE, that emissions from the energy sector should remain below 680 million tonnes (Mt) by the end of the decade. This is achieved with room to spare in the New Policies Scenario; indeed, energy-related CO_2 emissions in our projections are only slightly above 700 Mt even in 2035. On one hand, this is a tribute to the way that the expansion of renewable sources of energy keeps emissions in check. On the other hand, it suggests that the baseline calculation, as currently formulated, makes generous allowance for emissions growth. Complementary actions to curb energy sector emissions are being taken at state level. For example, the São Paulo State Energy Plan aims to increase significantly the share of renewables in the state energy matrix, and Rio de Janeiro is seeking to introduce an emissions trading scheme.

In our projections, Brazilian energy-related CO_2 emissions increase by more than two-thirds by 2035. Oil accounts for nearly half of the growth (mainly in transport), gas for around 40% (mainly in industry and power) and coal the remainder. But the carbon intensity of Brazil's economy (measured as tonnes of CO_2 per $1 000 of GDP) remains one of the lowest in the world in 2035, slightly above the level of the European Union, three-quarters the level of the United States and less than half the level of China (Figure 12.9).[8] By 2035, Brazil accounts for nearly 4% of global GDP, but less than 2% of energy-related CO_2 emissions. Per-capita CO_2 emissions increase by 50% to reach 3 tonnes of CO_2, but this is still only 70% of the world average in 2035.

Figure 12.9 ▷ CO_2 per capita and CO_2 intensity of GDP in selected regions in the New Policies Scenario



Notes: Bubble area indicates total annual energy-related CO_2 emissions in that region. MER = market exchange rate.

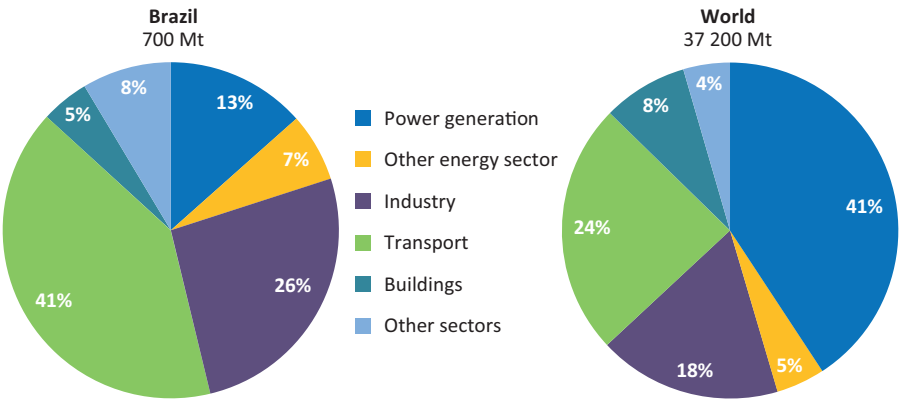
The share of renewable energy sources in Brazil's energy mix remains stable over the *Outlook* period at 43% (or 45% for low or zero-carbon energy, including the contribution of nuclear). This compares very favourably with a global average of 18% for renewables in 2035 (or 24% with nuclear). The power sector, which accounted for less than 10% of Brazil's energy-related CO_2 emissions in 2011, increases its share to 13% in 2035, still well below the global average (Figure 12.10). Even though the carbon intensity of the power sector increases, reaching 87 grammes of CO_2 per kilowatt-hour (g CO_2/kWh) in 2035, it remains a fraction of the OECD average of 265 g CO_2/kWh and the non-OECD average of 435 g CO_2/kWh.[9] The transport sector is already the largest source of energy-related CO_2 emissions in Brazil and its emissions increase by more than 55%, to reach 285 Mt in 2035, making it the sector responsible for the largest share of CO_2 emissions in Brazil. Road transport is the main contributor to this growth, which would be still higher if it were

8. GDP is measured at market exchange rate in year-2012 dollars.

9. This indicator does rise above 100 g CO_2 per kWh in our Low-Hydro Case (see Chapter 10, Box 10.2), as the gap left by hydropower is filled, in part, by the increased use of fossil fuels.

not for the projected increase in biofuels consumption. Biofuels meet around 45% of the increase in road transport energy demand and the level of CO_2 emissions per kilometre declines significantly over the projection period. If conditions are less conducive to biofuels development than we project, then substitution towards biofuels will be weaker, pushing transport sector emissions higher.

Figure 12.10 ▷ Energy-related CO_2 emissions by sector, 2035



Energy efficiency

In the New Policies Scenario, Brazil is assumed to make continued efforts to capture the available gains from energy efficiency policies, but primary energy demand in this scenario does not move significantly away from the level projected in the Current Policies Scenario, only around 5%, or 20 million tonnes of oil equivalent (Mtoe), lower by 2035. This suggests room for further concerted action to realise Brazil's economically viable energy efficiency potential. Government policies play a critical role in achieving efficiency gains as they can help lower market barriers and minimise transaction costs, unlocking the necessary investment.

To highlight the remaining potential for efficient energy use, not captured in the New Policies Scenario, we have conducted analysis of energy use in key end-use sectors – industry, transport and buildings – to assess the remaining potential for energy savings, and the policies that could unlock this potential.[10] No major technological breakthroughs are assumed, only use of the energy efficiency measures and technologies that exist today and are economically viable (assuming reasonable payback periods).[11] The payback periods are, in some cases, longer than those often required by lending institutions, households or firms, but they are always considerably shorter than the technical lifetime of the assets.

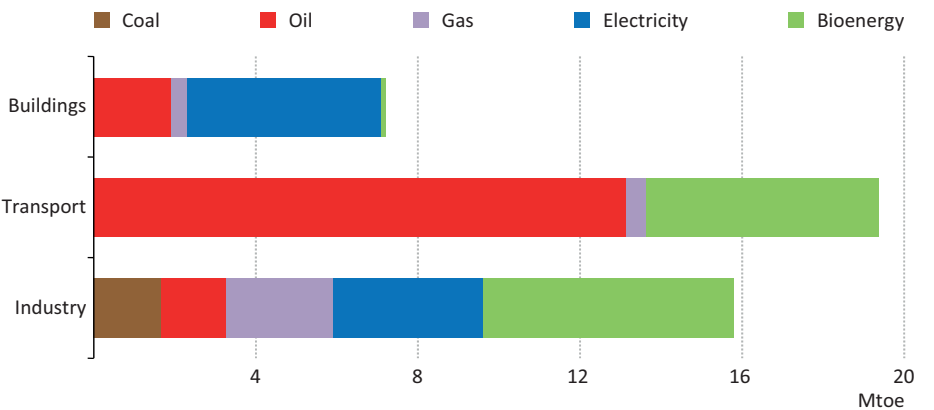
10. The analysis does not cover the potential for energy efficiency savings in energy supply, including power generation and transmission.

11. The methodology and assumptions used are the same as for the Efficient World Scenario in *WEO-2012*.

The policy measures in this Efficient Brazil Case go beyond the measures included in Brazil's National Energy Efficiency Plan, both in terms of their ambition and the assumed level of implementation. In the buildings sector, they include appropriate building codes for new buildings and minimum energy performance standards, enhanced over time, for all major appliances and equipment. In industry, we assume that all new equipment uses the best available technology and efficiency improvements are realised through better energy management and optimised operations. In the transport sector, the main change arises from deployment of the most efficient vehicles, pushed by policies such as mandatory fuel-economy standards and labelling.

The result of this analysis is that final consumption in 2035 is some 42 Mtoe (or 11%) lower than in the New Policies Scenario. The largest savings in absolute and in percentage terms are in the transport sector, mainly due to improvements in fuel economy (Figure 12.11). This analysis validates the importance of the efforts, now started in Brazil with the Inovar-Auto programme, to raise the efficiency performance of cars produced in Brazil. It does not, however, capture all of Brazil's potential in the transport sector, as there is still huge scope remaining in the New Policies Scenario to move freight transport off the roads and onto rail or waterways. The infrastructure projects launched with this aim are some of the most important energy efficiency projects in Brazil (even if they are not always seen in these terms).

Figure 12.11 ▷ Brazil potential for energy efficiency savings by end-use sector relative to the New Policies Scenario, 2035



In the industry sector, there are savings available among the large energy-intensive sectors, such as the iron and steel sector and chemicals production, but by and large these industries are typically already attentive to energy-saving opportunities, as energy makes up a large share of their production costs. It is rather in the less energy-intensive sectors that significant savings can be made, as existing opportunities can be overlooked because of a lack of awareness and know-how, or because financing for efficiency improvements is not available. In Brazil, savings of this sort could be made in areas like food processing, through improvements to steam systems and electric motors.

Overall, for the industry sector, we estimate that the additional investment required to realise the savings in the Efficient Brazil Case amounts to more than $15 billion over the course of the projection period. However, this produces much larger savings in terms of reduced spending on energy inputs: cumulative (undiscounted) savings on energy bills are more than $140 billion over the period to 2035. In terms of financing, the support available through the BNDES, such as PROESCO (which gives support specifically to energy efficiency projects) or the Climate Fund Programme, is an important instrument to support industrial energy efficiency. In the residential sector, energy use is already relatively low by international comparison (largely because of low heating requirements in Brazil), so the impact of new measures is relatively small, compared with the other sectors; the largest impact comes from the stringent application of standards for a range of energy-using equipment.

These gains in end-use efficiency are beneficial to Brazil in many ways. Electricity demand is reduced by some 100 TWh in 2035 (roughly equivalent of 2012 production from the massive Itaipu hydropower plant), reducing the need for new capacity and easing the task of addressing demand peaks. Brazil also frees up some 340 thousand barrels per day of oil, saving on refinery investments and increasing potential revenue from export by around $15 billion in 2035. The reduction in the use of fossil fuels means that emissions are further reduced by about 90 Mt, to a level 13% lower than in the New Policies Scenario. As they have in the past, robust and targeted energy policies can continue to shape Brazil's energy outlook for the better.