International Energy Agency

CHILE

ENERGY POLICY REVIEW

2009

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Since 1990, Chile has been the fastest growing economy in Latin America thanks to sound economic management and integration into the global economy. Chile can also be proud of its energy policy achievements. The pioneering privatisation and liberalisation of its electricity sector in the 1980s was the foundation for a competitive energy sector, which has sustained the rapid growth of the Chilean economy over the past two decades.

Nonetheless, Chile faces the continuing challenge of finding additional energy supplies to fuel economic growth. Chile has limited fossil energy resources and depends on imports to meet three-quarters of its energy needs. The country's electricity sector has faced three periods of significant stress over the past decade. The last episode took place in 2007/2008, when the loss of natural gas imports from Argentina was further exacerbated by a drought in the central system, where hydropower normally accounts for over half of electricity generation.

Drawing on the experience of IEA member countries, the Review assesses Chile's major energy challenges and provides recommendations. Six main themes emerge: the successful liberalisation of the power sector in the 1980s; the essential role played by the state in ensuring energy security; the re-formulation of Chile's long-term energy policy; the proposed reorganisation of the institutional framework; greater independence for the system operators; and the need for a clear framework of regulation so that long-term investment decisions integrate social and environmental costs.

The *Chile Energy Policy Review 2009* is essential reading for all who are interested in Chilean energy issues and in learning about the important role sound energy policy can play in developing a nation's economic and social welfare.

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-eight of the thirty OECD member countries. The basic aims of the IEA are:

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- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies, including relating to climate change.

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

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FOREWORD

Chile can be proud of its energy policy achievements. The pioneering privatisation and liberalisation of its electricity sector in the 1980s, ahead of almost all IEA member countries, was the foundation for a competitive energy sector, which has sustained the rapid growth of the Chilean economy over the past two decades. These policies have helped sharply reduce the number of Chileans living in poverty, and lift Chile to the middle ranking of nations in terms of GDP per capita. Following a successful rural electrification programme, almost 99% of the Chilean population now has access to electricity.

However, in the past decade, energy security has come to the fore of the energy agenda. In 2007 and 2008, Chile faced a double crisis of energy supply, having lost most of its gas imports from its sole supplier, Argentina, at a time when its hydroelectric production was severely affected by drought. The government worked with industry to achieve a rapid adaptation of the power sector to ensure the continuity of electricity supply. IEA member countries, and other countries, can learn a great deal from the experience of Chile.

The IEA is very pleased to have been invited to conduct this *Energy Policy Review of Chile.* Given the country's distinct characteristics, the Review takes a comprehensive look at Chile's energy sector, including: the institutional framework, energy security, environmental sustainability, energy efficiency, as well as recent developments in sub-sectors such as fossil fuels, electricity, renewables, biomass, access to energy in rural areas, transport, and energy research and development. Chile is not a member of the IEA, although its application for membership to the OECD is at an advanced stage.

An immediate challenge facing Chile is to find additional energy supplies to fuel continuing economic growth and to replace the costly diesel oil that is now widely used in power stations that were built to run on gas from Argentina. Coal will also play a part in energy diversification, but new investment in coal should be placed in the context of an overall national strategy for the mitigation of greenhouse gas emissions to ensure sustainability in the longer term. This recommendation is also relevant to the transport sector, a challenge shared by many IEA member countries. Chile's National Action Plan for Climate Change, published at the end of 2008, presents a course of action for the next four years.

The IEA supports the government's effort to strengthen the institutional framework of the sector to improve policy-making instruments. Chile has recently put in place ambitious policies for the promotion of energy efficiency and for developing its outstanding natural potential for renewable energy. These measures should be taken even further. The IEA has also suggested some measures that could further enhance competition in Chile's gas and electricity markets. In many respects, therefore, the Review will serve to reinforce and encourage the government in the direction that it is already taking.

The Chilean government's invitation to the IEA to conduct this Review is a reflection of Chile's progressive and outward-looking approach to energy policy. This openness is very timely, given the rapid advances in energy policy and proposals for new Ministries of Energy and Environment before the Chilean Congress. I would like to pay particular tribute to Chile's current Energy Minister, Mr. Marcelo Tokman, for his leadership and personal engagement in the Review and to the many officials of the Chilean government, as well as outside commentators, who have contributed generously with their time and ideas.

Chile is due to hold presidential and legislative elections on 11 December 2009. I hope that the country's incoming energy policy-makers will find this report useful in framing the future energy policy of Chile. I am very pleased that the IEA and the government of Chile have already mapped out a programme of work for the coming two years, and I hope this presages a continued close and fruitful working relationship.

Nobuo Tanaka
Executive Director, International Energy Agency

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ORGANISATION OF THE REVIEW AND ACKNOWLEDGEMENTS

The 2009 IEA *Energy Policy Review of Chile* was undertaken by a team of energy specialists from International Energy Agency (IEA) member countries and from international organisations. The team visited Santiago from 30 March to 3 April, 2009 to hold discussions with government officials, energy companies, parliamentary committees, non-governmental organisations, and other stakeholders. The IEA Secretariat and review team members drafted this report based on those discussions, as well as the government of Chile's official response to the IEA energy policy questionnaire and other information provided by the government. This report is primarily based on information available as of July 2009.

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Organisations Visited

Chilean Government Institutions

- National Energy Commission
- National Commission for the Environment
- National Commission for Scientific and Technological Research
- National Council on Innovation and Competitiveness
- National Economic Development Agency
- National Energy Efficiency Programme
- Ministry of Finance
- Ministry of Housing and Urban Development
- Ministry of Public Works
- Ministry of Transport and Telecommunications
- Superintendence for Electricity and Fuels

Companies

- Chilean Association of LPG Distributors
- Chilean Association of Natural Gas Distributors
- Chilean Association of Renewable Energy Producers
- Chilean Association of Transmission and Distribution Companies
- Chilean Mining Council
- Chilean National Mining Society
- BHP Billiton
- Economic Load Dispatch Centres
- Federation of Chilean Industry
- Metrogas
- AES Gener S.A.

- Colbún S.A.
- Electroandina
- Endesa S.A.
- Pacific Hydro
- Chilectra
- Chilquinta
- Transelec
- Metro of Santiago

Other Public Institutions

- Civil Aviation Agency
- Energy and Mining Commission of the Chamber of Deputies
- Energy and Mining Commission of the Senate
- Advisory Group on Nuclear Energy
- Secretariat for Transport Planning
- Inter-Ministerial General Co-ordinator for Transportation in Santiago
- National Petroleum Company of Chile
- National Copper Corporation of Chile
- Catholic University of Chile
- University of Chile

International Organisations and IEA Member Countries

- Asia-Pacific Economic Co-operation Energy Working Group
- Organisation for Economic Co-operation and Development
- IEA member countries' embassies and representatives (Canada, France, Spain, the United Kingdom, the United States)

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Ghislaine Kieffer was the principal author and co-ordinator of this Review. Several individuals authored or made significant contributions to specific chapters: Kieran McNamara (energy security); Faith Corneille (environment); Nigel Jollands (energy efficiency); Paolo Frankl (renewable energy); Stephen Powell (fossil fuels and electricity); Teresa Malyshev (access to energy and biomass); Chris Zegras (transport); and Isabel Cabrita (energy R&D). Special thanks to Hartmut Schneider for his leadership and advice, as well as to Neil Hirst, Yo Osumi and Paolo Frankl for their continuous guidance and support.

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EXECUTIVE SUMMARY AND KEY RECOMMENDATIONS

Chile's energy sector has four distinctive characteristics. First, unlike many of its South American neighbours, Chile has limited indigenous fossil energy resources. Yet, fossil fuels account for almost 80% of the country's total primary energy supply (TPES). As a result, Chile imports close to 75% of its TPES in the form of oil, gas and coal. In the case of natural gas, this external dependence was concentrated almost exclusively on one supplier – Argentina – until the arrival of liquefied natural gas (LNG) in July 2009.

Second, Chile's unique geography – 4 300 km long and 175 km wide – has given it a varied climate, ranging from the world's driest desert (the Atacama desert) in the north, through a Mediterranean climate in the centre to a snow-prone Alpine climate in the south. Chile's geography has also shaped its electricity systems. The northern system (SING) comprises one-third of total installed capacity and covers an area equivalent to 25% of Chile's continental territory, in which only 6% of the population lives. Large industrial customers, mainly mining companies, account for around 90% of electricity consumption in the SING. The central system (SIC) is the country's main electrical system and provides electricity supply to more than 90% of the country's population of 17 million, including the country's largest consumption centre, the Santiago Metropolitan Region.

A third characteristic of Chile's energy matrix is the distinctive role played by combustible renewables and waste, accounting for 16% of Chile's TPES. Biomass – in the form of firewood mostly used for heating and cooking – accounts for 57% of energy consumption in Chile's residential sector, with potentially adverse health impacts. The market for firewood is largely informal, thus posing particular regulatory and policy challenges. Native forests are now protected by law and the government is planning to enact laws to certify wood production.

Last but not least, Chile's geography has also endowed it with significant renewable energy potential. This potential includes a wide spectrum of renewable energy sources, ranging from mature technologies such as small and large-scale hydropower and biomass, to emerging technologies, such as solar, ocean and wave energy. The Chilean government recognises the significant long-term potential of renewable energy in Chile and has recently adopted a wide-ranging approach, which includes assessment studies, a law for the development of non-conventional renewable energy (NCRE), specific financial support measures, and research and development activities.

Given these distinctive characteristics, this Review takes a comprehensive look at Chile's energy sector, with a special focus on the institutional framework, energy security, environmental sustainability and energy efficiency, as well as recent developments in sub-sectors such as: fossil fuels, electricity, renewables, biomass, access to energy in rural areas, transport, and energy research and development. Six main themes emerge from the Review.

Successful liberalisation of power sector

The first theme relates to the underlying principles of Chile's energy policy: private initiative, competitive markets and the subsidiary role of the state. For the past 30 years, energy policy in Chile has been founded on the premise that the best way to meet the demand for energy at prices that consumers can afford is: to rely on competition between privately owned entities wherever possible; to regulate where it is not (*i.e.* in the natural monopolies); and to limit the role of the state in entrepreneurial activities. Consistent with this approach was the assumption that competitive markets would deliver an appropriate level of security of supply.

Chile was the first country to institute a comprehensive reform of its electricity sector. It has rightly been hailed as a successful example of electricity market liberalisation, and has been emulated by other countries in the region and elsewhere. In common with many other countries in the early 1980s, the electricity supply industry in Chile was vertically integrated and state-owned. The enactment of the 1982 *General Law of Electric Services* created an unbundled and privately owned sector. The law recognised generation, transmission and distribution as separable activities; introduced a pool-type market in generation and third-party access to the transmission network; and set up a system operator to co-ordinate the operations of competitive generators. The privatisation process began in 1980 and was completed in 1998 when the last state-owned utility, Edelaysen, was sold.

Successes achieved in the electricity sector have been impressive. Growing demand over the past 20 years has been accommodated by a rapid increase in installed capacity, almost entirely financed and built by the private sector. Between 1982 and 2008, the share of households with access to electricity increased from 62% to 98.5% nationwide. Substantial improvements in labour and capital productivity in the sector since 1988 have reduced costs and prices. Distribution margins have fallen in real terms, and technical energy losses in the country's distribution system fell from 17% in 1988 to 8% in 2007. Aware of these achievements, other countries, beginning with the United Kingdom in the early 1990s, have followed Chile's example.

State plays essential role in energy security

The second theme to emerge is the essential role of the state in guiding the evolution of the energy sector, and in ensuring energy security and emergency response. The electricity sector has faced three periods of significant stress over the past decade. First in 1998/99, as a result of the worst drought in 40 years, which affected the SIC. From 2004 onwards, when natural gas supplies from Argentina, the sole supplier, were increasingly restricted. In 2007/08, the loss of natural gas imports from Argentina was further exacerbated by a drought in the SIC, where hydroelectric production normally accounts for over half of generation.

During the 2007/08 crisis, outages were successfully avoided through a combination of short-term measures. On the supply side, these included: the installation of fast-response emergency diesel-fired generation; the switching from natural gas to diesel oil in electricity generation; the more flexible use of water in reservoirs with inter-annual capacity; and reductions in transmission voltage. On the demand side, a government information campaign urged consumers to save energy; generators provided incentives to their customers to reduce consumption; and consumers reacted distinctly to higher prices. For example, industrial customers switched to back-up diesel generation to avoid having to pay as much as USD 350/MWh for grid-based electricity on the spot market.

In the medium term, the focus is on achieving greater fuel diversity as a means of increasing energy security through: the building of two LNG terminals to substitute for imported Argentine gas; the installation of additional coal-fired capacity; the promotion of NCRE sources; and a greater emphasis on energy efficiency.

Despite the short-term success in avoiding outages, from which other countries can learn valuable lessons, the experience of 2007/08 has shown that security of supply is a basic requirement of a well-functioning energy market. While investment decisions should continue to be made by the private sector, the government needs to take a more proactive position with regard to monitoring energy developments and systematic risk assessment. This could be done by strengthening prospective analysis and long-term scenarios. To this end, it is fundamental that the government continues to improve the quality of its energy statistics and develops modelling capabilities in the institutions in charge of energy policy.

The Chilean government has recently scaled-up its efforts to reduce and contain energy demand, not just in times of crisis, but as an essential feature of energy policy. The ability of the demand side to participate in the electricity and gas markets; the active promotion of energy efficiency measures; and the development of NCRE sources are all means of doing so without imposing significant costs on the consumer. The Chilean government should be commended for developing an energy efficiency policy portfolio with determination and vision in such a short time. Looking to the future, however, several areas warrant further attention when considered in relation to the broad suite of potential cost-effective energy efficiency policies recommended by the IEA.

Long-term energy policy re-formulation should be completed

The release of the National Energy Commission's *Energy Policy: New Guidelines* in 2008 is an important first step in policy re-formulation. The IEA recommends that the government finalises its new long-term energy policy as soon as possible. In recent years, the National Energy Commission (CNE) has greatly contributed to defining a more comprehensive energy policy, including the sustainable use of biomass, research and development priorities, stronger modelling capabilities, and the creation of a multi-dimensional rural energisation programme, among others. The proposed Ministry of Energy should maintain and expand its focus on these important energy issues, in close collaboration with relevant public agencies and other stakeholders.

Chile's long-term energy policy document should also set clear objectives and indicative targets to facilitate the monitoring of on-going policies and their *ex-post* evaluation. This will inform policy design and implementation in the future, and enhance public accountability. Finally, given the strategic importance of some of the energy projects currently under consideration in the country, including large coal-fired plants, large hydropower projects and the nuclear energy option, the government of Chile should address all the issues at stake in a national public debate with the aim of fostering support for such decisions across the political spectrum.

Reorganisation of institutional framework important step forward

The fourth theme to emerge from the Review is the need to assess the sector's institutional framework. A recent study of the existing structure reveals a number of shortcomings: the difficulty of co-ordinating policies where interests are shared across a number of ministries, commissions and agencies, which is a particular problem in the case of environment and energy policy; a legalistic approach to the regulation of the sector to the detriment of long-term public policies; and the institutional weakness of the CNE in relation to other entities in the sector. Draft legislation is currently before the Chilean Congress seeking to establish a clear separation of functions between policy formulation, technical-economic regulation, and enforcement and oversight in the energy sector. If it is enacted in its current form, it will create a Ministry of Energy and an Energy Efficiency Agency.

The creation of a Ministry of Energy will be a significant step forward and one which the IEA supports. As contemplated in the proposed legislation, the IEA recommends that the proposed Ministry of Energy be given the necessary human and financial resources to enable it to work effectively, with clear lines of authority and co-ordination mechanisms with other ministries and government agencies. At the same time, the CNE should be provided with the necessary resources to ensure the effective and efficient operation of its regulatory functions. It should be able to recruit suitably skilled labour and to take decisions independent of government. The hiring process for the Director of the CNE through the independent system of higher public administration is an important element in this reform.

System operators need greater independence

A similar theme arises with the governance of the system operators in the SING and SIC, the two main interconnected electricity systems in the country. The two system operators were originally controlled by the largest generators and the transmission companies in each system. Recognising the difficulties this could cause for other participants, the law was changed in 2005 to require the board of both system operators to include a representative of large industrial customers. This requirement was implemented by decree in August 2008.

The IEA recommends that the government take further action and consider transforming the two system operators into wholly independent entities. This could be along the lines of the independent system operator model found in the United States, Canada, Europe and Australia, where the boards of system operators have no financial interest or ties to any company doing business in the wholesale electricity markets they administer. This would ensure that the decisions of the two system operators are impartial and represent the interests of all users, including consumers.

Clearer regulation and incentives for investment must integrate social and environmental costs

A sixth and final theme to come out of the Review is the need for a strong framework of regulation and incentives to ensure that the competitive market internalises environmental and social costs. In common with many countries, Chile faces the difficult challenge of balancing economic growth, energy security and environmental objectives. Increasing concerns about climate change and the possibility of an international post-Kyoto climate agreement make energy and environment policy co-ordination in Chile even more important. Investment in new coal-fired power plants is expanding at a much faster rate than in renewable energy sources. Environmental externalities in Chile are partly internalised in the current environmental regulatory framework. But absolute emission standards for thermoelectric plants do not yet exist.

Chile has recently published a National Action Plan on Climate Change (PANCC). It contains useful analyses and presents a course of action, with accompanying measurable objectives, for the next four years. The government should now consider formulating a national greenhouse gas emissions mitigation strategy with indicative objectives, both nationally and at the sector level, to prepare Chile's economy for a possible post-Kyoto international climate agreement. This would avoid the risk of "locking-in" future CO_2 emissions in the electricity sector. This recommendation also applies to other sectors, such as transport. The application of fully cost-reflective pricing of transport fuels, roads and transport modes will facilitate the transition to a more sustainable energy system.

Key Recommendations

The government of Chile should:

- Continue to pursue diversification in terms of energy sources and suppliers to enhance energy security, in particular the active development of indigenous energy sources such as renewable energy and energy efficiency.
- Finalise Chile's long-term energy policy document by: adopting an integrated approach; setting clear targets and objectives; and building consensus around those objectives through broad public consultation mechanisms.
- Complete the reorganisation of the energy sector, especially the creation of the Ministry of Energy, with clear lines of authority and policy co-ordination.
- Create independent system operators in both the SIC and the SING to ensure that system operation decisions are impartial and take into account the interests of all users and consumers.
- Send clear investment signals to the private sector and create a framework to ensure that long-term investment decisions will be based on long-term cost/benefit analysis, including environmental externalities and the downward cost curve of certain technologies.

Map 1

Map of Chile

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.

Map 2

Chile's 15 Administrative Regions

Key	Region name	Capital
XV	Arica and Parinacota	Arica
I	Tarapacá	Iquique
II	Antofagasta	Antofagasta
III	Atacama	Copiapó
IV	Coquimbo	La Serena
V	Valparaíso	Valparaíso
VI	Libertador Bernardo O'Higgins	Rancagua
VII	Maule	Talca
VIII	Bío Bío	Concepción
IX	La Araucanía	Temuco
XIV	Los Ríos	Valdivia
X	Los Lagos	Puerto Montt
XI	Aysén del Gral. Carlos Ibañez del Campo	Coyhaique
XII	Magallanes y Antártica Chilena	Punta Arenas
RM	Metropolitana	Santiago

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Map 3

Chile's Electricity Grid

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1. GENERAL ENERGY POLICY

Political and Economic Overview

Country Overview

Chile, officially the Republic of Chile, is a country in South America occupying a long and narrow coastal strip tucked between the Andes mountains on the east and the Pacific Ocean on the west (see Map 1). It shares its border with Peru to the north, Bolivia to the northeast and Argentina to the east. The Pacific Ocean forms the country's entire western border, with a coastline that stretches over 6 435 kilometres (km). The Chilean territory includes several overseas territories, including Easter Island in Polynesia. Chile's population in 2009 is estimated at 17 million. Its gross domestic product (GDP) in 2008 was USD 236 billion (using purchasing power parities – PPP) ranking Chile the 43rd richest country globally.[1] Chile's GDP (PPP) per capita, at USD 14 500 is the highest in South America, ahead of Argentina and Brazil.

Chile's unusual shape, 4 300 km long and on average 175 km wide for a total surface area of 757 000 square kilometres (km^2), has given it a varied climate, ranging from the world's driest desert – the Atacama – in the north, through a Mediterranean climate in the centre, to a snow-prone alpine climate in the south, with glaciers, fjords and lakes. The Atacama desert contains great mineral wealth, principally copper. The relatively small central area where the capital, Santiago, is located, dominates the country in terms of population and agricultural resources. Southern Chile is famous for its pristine forests, volcanoes and lakes.

Chile is divided into fifteen administrative regions (see Map 2), each of which is headed by an *intendente* appointed by the President of Chile. Each region is further divided into provinces, with provincial *intendentes* also appointed by the President. About 85% of the country's population lives in urban areas, with 40% living in the Santiago Metropolitan Region. The largest agglomerations, according to the 2002 census, are the Santiago Metropolitan Region with 5.6 million people, Greater Concepción with 861 000 and Greater Valparaíso with 824 000. Chile's official language is Spanish. According to the 2002 census, 5% of the population also spoke native indigenous languages such as Mapudungun, Quechua, and Rapa Nui.

1. *Source: 2008* World Economic Outlook *Database – April 2009, International Monetary Fund (IMF).*

Political Developments

In March 1990, Chile returned to democracy after almost 17 years of military regime under General Augusto Pinochet. Since then, the country has been governed by a coalition of centre-left parties, the *Concertación de Partidos por la Democracía (Concertación).* The coalition comprises the centrist *Partido Demócrata Cristiano* (PDC) and three left-oriented parties, the *Partido Socialista* (PS), the *Partido Radical Social Demócrata* (PRSD) and the *Partido por la Democracia* (PPD). Michelle Bachelet, a member of the PS, was elected President in January 2006 and took office two months later, on 11 March 2006, for a four-year term, becoming the fourth consecutive *Concertación* President, and the first woman to win the presidency in Chile.

The constitution of Chile was approved in a national plebiscite in September 1980 under the Pinochet military regime. It was designed to strengthen the executive and to grant a supervisory role to the armed forces. The Constitution also provided for strong defence of property rights and commercial information while promoting a comprehensive programme of economic liberalisation. During the transition to civilian rule in 1989, the Constitution was reformed to allow for future amendments and to limit the powers of the National Security Council. In 2005, the government and the opposition agreed on a new set of constitutional amendments that had been debated since the early 1990s. The presidential term was shortened from six years to four to ensure that presidential and congressional elections coincide (consecutive presidential terms are still barred under the Constitution). All positions of appointed senators and senators-for-life were eliminated, and the President was granted the authority to remove the commanders-in-chief of the armed forces. At the same time, the power of the presidency was reduced by limiting its capacity to control the congressional agenda and by allowing the Chamber of Deputies greater powers to supervise executive decisions.

Chile's congress has a 38-seat Senate and a 120-member Chamber of Deputies. Senators serve for eight years with staggered terms, while deputies are elected every four years. The Congress is located in the port city of Valparaíso, about 140 kilometres west of the capital, Santiago. The current institutional arrangements balance Chile's strong presidential tradition with an independent central bank and an independent constitutional tribunal. Unless a candidate receives more than 50% of the vote in the first ballot, a second round opposes the two leading candidates from the first round. Presidential and congressional elections are due on 11 December 2009.

Chile's Economy

Chile's economic growth has been impressive. Since 1990, Chile has almost doubled its income per capita and has been the fastest-growing economy in Latin America. Chile's growth is export-driven and its main export goods are commodities. The impressive performance of the economy owes much to a sound institutional framework, tight monetary policies and integration into the global economy. In 2008, financial services accounted for 18% of GDP, manufacturing for 17% and mining for 7%.

Successive governments have focused on increasing the openness of Chile's economy through trade liberalisation and the pursuit of bilateral free trade agreements. By 2008, Chile had signed trade agreements with 58 countries, including the United States, Japan, China and the European Union, its main trading partners. These liberal policies have led to a profound change in the structure of Chile's economy. The share of exports of goods and services in GDP has increased from 26% in 1998 to 45% in 2006, owing both to market diversification and to the diversification of Chile's export products. Although copper remains dominant, the development of new export sectors has been a major engine of growth. These sectors include forestry products, farmed salmon, fruits, meat and wine.

Chile's economy is still dependent on commodity prices, in particular copper. The state-owned firm CODELCO is the world's largest copper-producing company. Foreign private investment has developed several new mines, and the private sector now produces more copper than CODELCO. According to Chile's Central Bank, in 2008 the mining sector accounted for 60% of Chilean exports (with copper accounting for 86% of the mining sector), agriculture 6% and industry 34%. China became Chile's biggest trading partner in 2008, accounting for 14% of Chile's exports, followed by the United States with 12% and Japan with 10%. Taken together, OECD member countries account for 48% of Chile's total exports.

Chile's solid fiscal accounts are one of its strengths in the face of the current international downturn. Successive governments have maintained a budget surplus. This was first implemented through an implicit fiscal rule, and from 2001 with an explicit fiscal surplus target (structural revenues – expenditure) of 1% of GDP. Public debt as a proportion of GDP has fallen from 45% in 1990 to only 4% in 2007.[2] Since 2006, surplus earnings are allocated to the Economic and Social Stabilisation Fund, and the Pensions Reserve Fund,

2. To Benefit From Plenty: Drawing Lessons from Chile and Norway, *Policy Brief N°37, OECD Development Centre, 2008.*

replacing the former Copper Stabilisation Fund. At the end of 2008, the two funds had savings amounting to USD 21.5 billion (12% of GDP) thanks to the rise in copper prices between 2006 and 2008. Sound macroeconomic management has enabled the Chilean government to run counter-cyclical fiscal policies. In January 2009, it announced a USD 4 billion stimulus package. The Chilean government derives the bulk of its revenues from non-resource sources, thereby maintaining a reliable source of public revenue, independent of commodity price volatility. While copper revenues have been important, the Chilean state received on average 72% of its income from tax revenues between 1994 and 2006.[3]

The United Nations Development Programme (UNDP) defines Chile as having a high level of human development, on a par with countries that include Hungary, Poland and Slovakia. At USD 14 500, its per capita GDP is still below that of lower-income developed countries such as Portugal (USD 22 200) and is similar to Portugal's per capita income in the mid-1990s.

Chile has been an observer to the OECD since 1996 and applied for full membership to the OECD in November 2003. The country officially became a candidate in November 2007. There are two outstanding issues to be resolved in negotiations: the Anti-Bribery Convention and bank secrecy. The government of President Michelle Bachelet hopes that Chile's acceptance will be formally confirmed before the end of her term in March 2010, and that membership of the organisation will give Chile access to new public-policy expertise that will facilitate its transition to full development.

According to the 2007-2008 Human Development Report, with a Gini coefficient of 55 Chile has a high level of income inequality compared with other countries.[4] However, after remaining relatively constant between 1990 and 2000, income inequality has fallen in Chile since 2000. According to the CASEN survey (*Caracterización Socio-Económica Nacional*, a socioeconomic survey used to shape the government's anti-poverty programmes), the proportion of the population living in poverty fell from 39% in 1990 to 14% in 2006. The percentage of poor in the year 2006 was only one-third of the 1990 level, which represents a sharp decline in poverty in a relatively short period of time. As well as reflecting economic growth, this was the result of well-targeted public policies. Chile is therefore poised on the threshold of development but now faces qualitative, rather than quantitative, challenges towards the goal of convergence with OECD member countries' economies.

3. Ibid.

4. A value of 0 represents absolute equality, and a value of 100 absolute inequality. See: http://hdrstats.undp.org/indicators/147.html.

Chile's Energy Matrix

Supply

Chile's total primary energy supply (TPES) stood at 30.8 million tonnes of oil equivalent (Mtoe) in 2007 (see Table 1.1). Chile's energy mix relies predominantly on fossil fuels, with oil representing 56%, and natural gas and coal both accounting for 11%. In total, renewables make up 22% of the energy mix, with biomass and hydro making up 16% and 6% of the total, respectively. Chile's primary energy intensity is low by comparison with some developed countries, but higher than that of Brazil and Mexico.[5] In 2007, Chile's energy intensity was 0.16 toe/thousand USD, very close to average intensity for IEA countries of 0.17 toe/thousand USD. In 2006, TPES per capita at 1.81 toe/capita was less than half the OECD average of 4.7 toe/capita.

Between 1997 and 2004, natural gas fully displaced the growth in coal consumption and some of the growth in oil (see Figure 1.1). Since 2004, however, there has been a steep fall in natural gas as a share of TPES, as a result of the progressive curtailment of natural gas supplies from Argentina. In 2004 when natural gas imports were at their peak, Chile imported 22 Mcm/day (million cubic metres), while imports barely reached 1 Mcm/day in 2008. This has been fully compensated by an increase in imports of oil products.

Table 1.1

Chile's Energy Balance, 2007 (Mtoe)

Supply	1973	1990	2000	2004	2005	2006	2007
Total production	**5.08**	**7.43**	**8.20**	**8.07**	**8.86**	**9.14**	**8.46**
Coal	0.96	1.45	0.24	0.13	0.27	0.26	0.10
Oil	1.79	1.13	0.43	0.38	0.34	0.33	0.55
Gas	0.53	1.41	1.60	1.37	1.61	1.55	1.08
Combustible renewables & waste[1]	1.33	2.68	4.26	4.30	4.37	4.49	4.73
Hydro	0.48	0.77	1.67	1.89	2.28	2.51	1.99
Wind	-	-	-	-	-	-	-
Net imports[2]	**3.39**	**6.99**	**18.27**	**21.29**	**21.04**	**22.17**	**24.13**
Coal	0.20	1.13	2.92	2.58	2.42	3.00	4.01
Oil	3.19	5.86	11.59	12.82	13.16	14.14	17.64

5. *Key World Energy Statistics*, IEA, 2009.

Table 1.1

Chile's Energy Balance, 2007 (Mtoe) (continued)

Supply	**1973**	**1990**	**2000**	**2004**	**2005**	**2006**	**2007**
Gas	-	-	3.67	5.72	5.27	4.82	2.34
Electricity	-	-	0.10	0.16	0.19	0.20	0.14
Total stock changes	**0.03**	**-0.60**	**-0.26**	**-0.46**	**-0.29**	**-0.85**	**-1.79**
Total supply (TPES)[3]	**8.50**	**13.82**	**26.21**	**28.90**	**29.61**	**30.46**	**30.790**
Coal	1.20	2.47	3.02	2.70	2.70	3.29	3.32
Oil	4.97	6.77	11.96	12.86	13.31	13.72	17.26
Gas	0.53	1.14	5.21	6.99	6.78	6.26	3.35
Combustible renewables & waste[1]	1.33	2.68	4.26	4.30	4.37	4.49	4.73
Hydro	0.48	0.77	1.67	1.89	2.28	2.51	1.99
Wind	-	-	-	-	-	-	-
Electricity trade[4]	-	-	0.10	0.16	0.19	0.20	0.14
Total final consumption	**6.52**	**11.43**	**21.36**	**22.95**	**23.24**	**24.56**	**24.55**
Coal	0.65	0.73	0.80	0.77	0.80	0.98	0.65
Oil	3.84	5.86	10.15	10.61	10.94	11.41	12.77
Gas	0.10	0.95	3.33	3.63	3.53	3.79	2.32
Combustible renewables & waste[1]	1.31	2.56	3.92	3.89	3.82	4.01	4.24
Electricity	0.63	1.33	3.16	4.05	4.16	4.37	4.56

Notes:

1. Comprises solid biomass and biogas.

2. Includes coal, oil, gas and electricity.

3. Excludes international marine bunkers and international aviation bunkers.

4. Total supply of electricity represents net trade. A positive number indicates that imports are greater than exports.

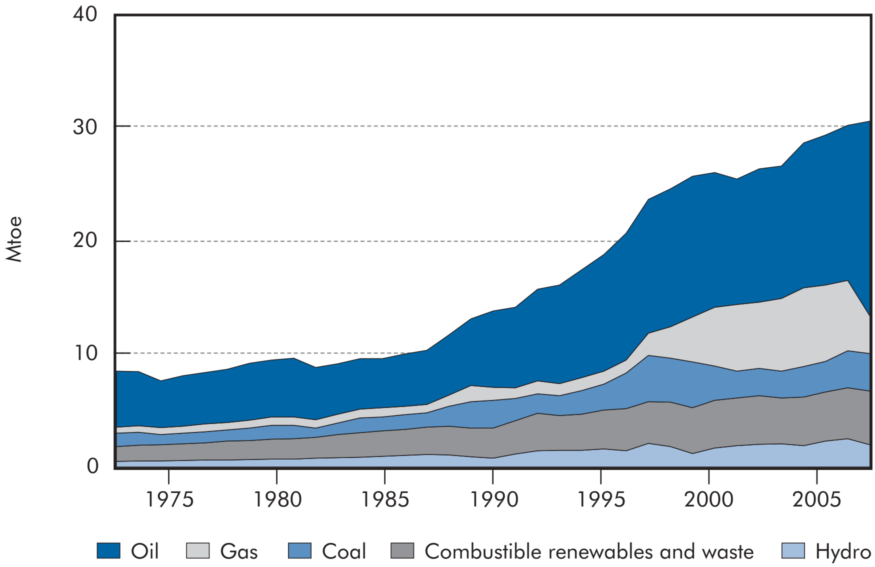
Source: Energy Balances of non-OECD Countries, IEA/OECD Paris, 2009.

Demand

Total final consumption of energy (TFC) in Chile has grown an average of 2.8% per year over the past 10 years. In 2007, TFC was 24.55 Mtoe with 42% of all consumption in the industrial sector (including the mining sector with 16%). The next largest share was transport with 33% almost exclusively petroleum derivatives (more than 70% of which were diesel and gasoline). The services-residential sector used 20%, with the remainder (5%) in the

Figure 1.1

Total Primary Energy Supply, 1973-2007



Source: Energy Balances of non-OECD Countries, IEA/OECD Paris, 2009.

commercial, public service, agriculture and fishing sectors (see Chapter 4: Energy Efficiency, Figure 4.5).

A key characteristic of Chile's energy matrix is the distinctive role played by combustible renewables and waste. Biomass in the form of firewood, which is used mostly for heating and cooking, represents approximately 50% of consumption in the residential and commercial sectors and 15% in the industrial sector (see Chapter 8: Biomass).

Import Dependence

A second characteristic of Chile's energy sector is its dependence on fossil fuel imports, which makes the country vulnerable to price volatility and supply interruptions. Unlike other countries in the region with abundant resources (Venezuela, Bolivia, Brazil and Argentina), Chile has few indigenous fossil resources, except for some coal and 1.65 Mtoe of domestic oil and gas production, mostly in the Magallanes Region. In 2007, Chile imported close to 80% of its total primary energy supply in the form of oil, gas and coal. This external dependence is exacerbated when it is concentrated almost exclusively on one supplier as was previously the case for natural gas; until the arrival of liquefied natural gas (LNG) in July 2009 Chile's natural gas came solely from Argentina. Crude oil imports in 2007 (approximately 230 000 barrels/day) came from Brazil (25%), Ecuador (23%), Angola (20%) and Colombia (17%), while coal imports (5.8 million tonnes) came from four major sources: Colombia (34%), Indonesia (26%), Australia (22%) and Canada (11%).

Chile's Electricity Grid

Chile's electricity grid comprises two main systems (see Map 3): the northern interconnected system *(Sistema Interconectado del Norte Grande – SING)* and the central interconnected system (*Sistema Interconectado Central* – SIC). The SING covers an area equivalent to 25% of Chile's continental territory and in which about 6% of the population of Chile lives. At the end of 2008, installed capacity in the SING amounted to 3 600 MW, almost all of which was thermal. Large industrial customers, mainly mining companies, account for around 90% of the load in the SING. The central interconnected system provides electricity supply to more than 90% of the country's population. The SIC includes the country's largest consumption centre, the Santiago Metropolitan Region. At the end of 2008, installed capacity in the SIC was almost 9 400 MW, of which just over 50% was hydro capacity. More than 70% of customers in the SIC are supplied under a regulated tariff.

Electricity Generation

Chile's generation mix has evolved significantly over the past decade. In 1996 and 1997, average electricity generation was 60% hydropower, 35% coal-based and 5% from oil and biomass. With increasing imports of natural gas from Argentina, the share of natural gas in electricity generation increased from 1% to 33% between 1997 and 2004, replacing coal and oil-based generation. However, beginning in 2005, the situation began to reverse in favour of coal consumption, gradually returning to the pre-1998 pattern, because of restrictions on gas exports by Argentina. The steep increase in oil-based electricity generation, particularly diesel, was also a consequence of the lack of availability of Argentine gas, as well as low hydrology. This switch was made possible by the conversion of power plants originally designed to operate with natural gas to dual-fuels.

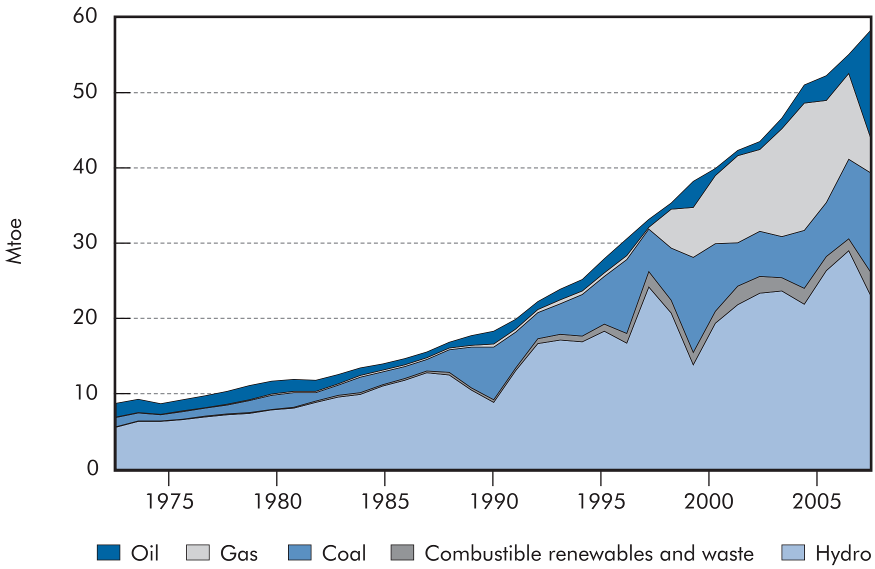
In 2007, Chile produced 58.5 terawatt-hours (TWh) of electricity (see Figure 1.2). Close to 40% of this electricity was generated from hydropower. The next largest share (24.6%) came from oil, followed by coal (22.7%) and natural gas (7.9%). Combustible renewables and waste supplied the rest of electricity (5.3%).

Strong Potential for Non-Conventional Renewable Energy

Based on CNE data, non-conventional renewable energy (NCRE) sources represented 2.4% of Chile's installed capacity in 2008. According to the CNE April 2009 *Plan de Obras*, total installed NCRE capacity is projected to reach 2 204 MW, equivalent to 20% of total additional capacity by 2020, from 345 MW at the end of 2008.[6] This would lead to a total NCRE electricity capacity share of 9.7 % by that date (see Chapter 7: Renewables).

Figure 1.2

Electricity Generation by Source, 1973-2007



Source: Energy Balances of non-OECD Countries, IEA/OECD Paris, 2009.

Energy Policy Institutions

Chile's energy institutional framework is based on the subsidiary role of the state and is embedded in the country's legal principles, which seek to encourage private initiative to foster competitiveness wherever possible, and to correct market failures when these occur. Chile's Constitution establishes the following as essential responsibilities of the state: to provide essential public goods for the functioning of society (*e.g.* the administration of justice); to promote equity and equal opportunity; and to facilitate the efficient and competitive operation of markets.[7] Accordingly, the structure

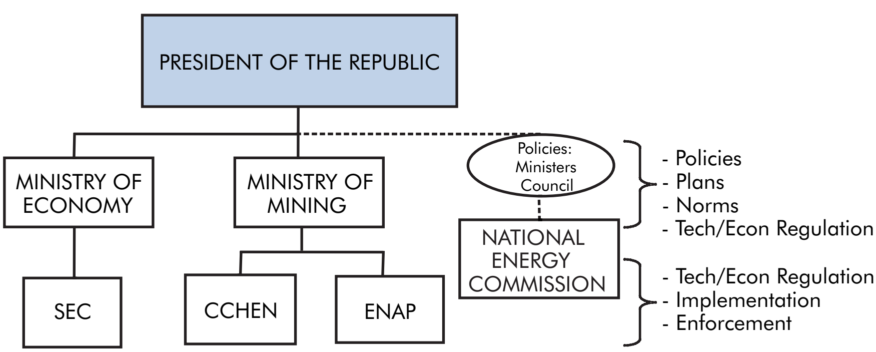
6. Energy Policy: New Guidelines, CNE, 2008, p.94.
7. Ibid, p.64.

of the energy sector does not currently reflect an integrated vision, but rather the co-existence of separate, technically specialised public institutions in charge of specific sub-sectors and reporting to different ministries (nuclear civil energy, electricity regulation, enforcement of fuel and electricity norms, and the National Petroleum Company, see Figure 1.3). Over the past 20 years, Chile's institutional structure has been adjusting incrementally to developments in the sector without any major reform of the overarching framework. In 2008, a bill was presented in Congress seeking to reorganise the institutional structure of the energy sector by clarifying the attributions of existing agencies and by reinforcing corresponding lines of authority and co-ordination mechanisms. In parallel, a bill was also proposed to reform the environmental framework.

The **National Energy Commission** (*Comisión Nacional de Energía* – CNE) was established by decree in 1978 as the regulatory supervisory authority and put in charge of preparing and co-ordinating plans, policies and standards for the proper operation and development of the sector, ensuring compliance and advising the government on energy-related matters. Its main responsibilities for the power sector include: (i) proposing sector norms and regulations; (ii) co-ordinating planning, policies and norms for efficient functioning of the market; and (iii) calculating and enforcing regulated prices in generation and distribution. The CNE consists of an Executive Council composed of one representative of the President of the Republic, who is the President of the CNE with the rank of Minister of State, as well as the ministers of: Mining; Economy, Development and Reconstruction; Finance; Defence; Planning; and the Ministry of the Presidency. The member ministries issue decrees to be implemented, while the CNE is responsible for preparing

Figure 1.3

Key Energy Policy Institutions of Chile in the Current Framework



Source: CNE.

relevant regulations and recommendations, and for ensuring policy co-ordination across key ministries. In the current institutional framework, the CNE depends administratively on the Ministry of Mining. Within the CNE structure, and subordinate to the Minister-President, is the National Energy Efficiency Program (PPEE).

The **Superintendence for Electricity and Fuels** (*Superintendencia de Electricidad y Combustibles* – SEC) was set up to oversee the proper operation of electricity, gas and fuel services, in terms of safety, quality and price. It is responsible for supervising enforcement of and compliance with existing laws, regulations and technical norms related to the generation, production, storage, transport and distribution of liquid fuels, gas and electricity. The SEC has responsibility for data collection for the purposes of enforcement and regulation, handling of customer complaints, and the implementation of service quality fines and customer compensations. It collects data on sector enterprises and sets the new replacement value for distribution assets. It may also impose penalties or recommend rescission of concession contracts. In regulation, the CNE uses data provided by the SEC on company costs. The President of Chile appoints the Superintendent of the SEC. In the current institutional structure, the SEC reports to the Ministry of Economy, Development and Reconstruction.

The **Chilean Nuclear Energy Commission** (*Comisión Chilena de Energía Nuclear* – CCHEN) is in charge of the production, acquisition, transfer, transport and peaceful use of atomic energy and its fertile, fissile and radioactive material. In the current institutional structure, the CCHEN reports to the Ministry of Mining.

The **Ministry of Mining** creates, promotes, disseminates and evaluates regulations and policies to optimise sustainable mining development in the country, to maximise its contribution to social and economic development, and to consolidate its position as an international leader. It has the authority to define policies, plans and regulations in the areas of hydrocarbons, nuclear energy and geothermal energy.

The **Ministry of Economy, Development and Reconstruction** promotes the modernisation and competitiveness of private initiatives and the efficient operation of markets, along with the country's productive structure, the development, of innovation and the consolidation of the international activity of the country's economy. In the current institutional framework, the Ministry of Economy dictates decrees on service prices, grants concessions, and determines energy transport systems and rationing in the electricity sector.

The **Ministry of the Presidency** (*Ministerio Secretaría General de la Presidencia de la República* – MINSEGEP) is the cabinet-level administrative office (equivalent to the president's Chief of Staff). It serves in an advisory role to the President of Chile and her or his ministers in the governments' relations with Congress, the development of the legislative agenda, and keeping track of the bills and other legislative activity in Congress as they pertain to the government.

The **Economic Load Dispatch Centres** (*Centro de Despacho Económico de Carga* – CDEC) are responsible for planning and co-ordinating load dispatch in each of the two large electricity systems (SING and SIC). The two CDECs are composed of representatives of generation and transmission companies and, since August 2008, of large users. The CDECs ensure the optimum operation of the system, based on least-cost dispatch, and determine values of economic transactions carried out between companies (see Chapter 6: Electricity).

The **Competition Tribunal** (*Tribunal de Defensa de la Libre Competencia* – TDLC) is a judicial entity pertaining to the Judiciary. It is also referred to as the Anti-monopoly Commission. The TDLC was established in 2004 to replace the Preventive and Anti-trust Commissions. It monitors implementation of anti-monopoly legislation and limits the concentration of economic power, including in the electricity sector. It has full powers to investigate possible cases of collusion or anti-competition practices, can impose penalties ranging from simple fines to the obligation of dissolving a company, and can also prohibit mergers

The **Panel of Experts** was created in 2004 as a *sui generis* independent institution, financed by sector participants and composed of five engineers or economists and two lawyers. Its members are appointed by the Competition Tribunal through a public, merit-based competition for a term of six years with overlapping terms to ensure continuity and receive competitive remuneration. The operational costs of the Panel are financed by the electricity generation and transmission companies and electrical energy public service distribution concessionaires, prorated according to their gross fixed assets. The Panel's decisions are final and cannot be appealed.

The **National Economic Prosecutor's Office** (*Fiscalía Nacional Económica* – FNE) is a decentralised public service from the Executive, a separate legal entity with its own financial resources. It is independent of any organism or service, and is supervised by the President of the Republic through the Ministry of Economy, Development and Reconstruction. Its mission is to prosecute and investigate anti-competitive conduct, merger policy, abuse of dominance and collusion, acting on behalf of the general interest. The *Fiscalía* can present cases to the Competition Tribunal. Its head is appointed by the President of the Republic, but has statutory independence from any authority.

The **National Energy Efficiency Programme** (*Programa País Eficiencia Energética* – PPEE) was created in January 2005 by a decree signed by the then Minister of Economy and Energy; the Secretariat General of the Presidency; and the ministers of: Public Works; Transport and Telecommunications; Education; Housing and Urbanism; and Mining. The PPEE is the main mechanism through which the Chilean government's energy efficiency policy and programmes are developed and implemented.

The **Chilean Energy Efficiency Agency** (*Agencía Chilena de Eficiencia Energética* – ACHEE) is proposed as part of the bill creating the Ministry of Energy. The Agency will be responsible for policy implementation and enforcement of energy efficiency standards. Its functions are likely to focus on technical assistance and the execution of programmes that require logistical expertise and co-ordination across different participants, leaving energy efficiency policy in the hands of the proposed Ministry of Energy (see Chapter 4: Energy Efficiency).

The **Chilean Centre for Renewable Energy** (*Centro de Energías Renovables* – CER) is envisaged as a clearinghouse for renewable energy developments, taking advantage of new developments in technologies around the world, identifying clean technologies and best international practices for renewable energies. The information collected will be systematised and disseminated in Chile to promote their development and use (see Chapter 7: Renewables). The CER was officially created in June 2009 as a committee within CORFO (see below), with technical support from the CNE.

The **National Commission for the Environment** (*Comisión Nacional del Medio Ambiente* – CONAMA) is the national institution responsible for environmental issues including in the power sector. Its responsibilities include administration of environmental impact evaluations and development of environmental norms. Compliance oversight is usually managed by the Health and Agriculture Ministries (see Chapter 3: Energy and Environment).

The **Regional Environment Commission** (*Comisión Regional del Medio Ambiente* – COREMA) is the regional institutions network extending from CONAMA, responsible for addressing the environmental issues in the corresponding regions. It administers the evaluation of the environmental impact of its regional projects and oversees the compliance with national environmental norms.

The **National Economic Development Agency** (*Corporación de Fomento de la Producción* – CORFO) is an agency administratively dependent on the Ministry of Economy. Its mission is to promote the country's economic development by supporting production companies. CORFO uses management tools, direct subsidies and financial instruments. With regards to renewable energy, CORFO handles subsidies for studies in pre-investment stage and long-term credits for financing. CORFO also plays a role in consortia to develop biofuels projects and solar energy pilot projects.

The **National Commission for Scientific and Technological Research** (*Comisión Nacional de Investigación Científica y Tecnológica* – CONICYT) aims to promote and strengthen scientific and technological research, the development of specialised human resources and new areas of knowledge and productive innovation, including renewable energy. It is administratively related to the government through the Ministry of Education.

The **National Petroleum Company** (*Empresa Nacional de Petróleo* – ENAP) is an oil and gas company fully owned by the Chilean state and is the country's leading hydrocarbon firm. It operates internationally and at all stages throughout the petroleum and gas business chain. ENAP promotes strategic alliances and partnerships with third parties that increase its scale and complement its business activities. The subsidiary Sipetrol S.A. was established in May 1990 for the purpose of exploring and developing hydrocarbon deposits outside of Chile. Sipetrol studies and develops new petroleum projects around the world but especially in its two focal regions of Latin America and the Middle East/North Africa (see Chapter 5: Fossil Fuels).

The **Regional Ministerial Secretariats** (S*ecretaria Regional Ministerial* – SEREMI) are devolved organisms representing each of the key central ministries at the regional level. Each SEREMI is controlled by a regional ministerial secretary who, not withstanding their position as the representative of the respective minister(s) in the region, collaborates directly with the *intendente*. The secretary is subordinate to this *intendente* when it comes to the creation, execution and co-ordination of policies, plans, budgets, development projects and any other matters that are controlled by regional governments.

General Energy Policy Direction

Electricity Sector Liberalisation in the 1980s

Since the late 1970s, Chilean energy policy has been structured around two crucial concepts: economic efficiency and the subsidiary role of the state. This reflects the belief that the best way to meet the demand for energy at prices that consumers can afford is to rely on competition between privately owned entities wherever possible, while the state should regulate potential market failures (*i.e.* natural monopolies). The state's subsidiary role is established in the Chilean Constitution and requires a law to create new public entities, thereby limiting the state's presence and its role in entrepreneurial activities. These concepts were embedded in the 1982 *Electricity Law*, which led to the vertical and horizontal unbundling and privatisation of the existing state-owned electricity system. Chile's electricity reform has been hailed as a successful example for the reform of electricity sectors around the world.[8]

This model has supported Chilean economic growth over the past 20 years with continuous, private sector-led expansion of generation capacity, as well as of transmission and distribution networks, and has achieved almost universal access to electricity in rural areas. Access to electricity nationwide increased from 62% in 1982 to 98.5% at the end of 2008.

However, the energy crisis which began in 2004 has shown that security of supply is a basic requirement of a well-functioning energy market and that the state should play a forward-looking and co-ordination role in the design of energy policy. With the benefit of hindsight, the restriction of gas imports from Argentina has also shown the necessity for a systematic evaluation of the risks involved in the long-term provision of energy.

2008 Energy Policy: New Guidelines

In the wake of the Argentine gas crisis and the 2007-2008 electricity shortages, the government of Chile is in the process of developing a new long-term energy policy, and the CNE has published new energy policy guidelines. The guidelines set out the country's six energy priorities:

- Strengthening institutions.
- Promoting energy efficiency.
- Optimising diversification.

8. *Pollitt, 2004.*

- Ensuring sustainable development.
- Supporting equal access.
- Contingency planning.

The institutional reform described in the guidelines will primarily impact Chile's general energy policy formulation.

Legislative Proposal for the Creation of a Ministry of Energy

The multiplicity of existing energy-related institutions generates significant co-ordination costs as well as the risk that political and institutional responsibilities will be weakened by the diverse political priorities and strategic alignments that exist. In addition, the CNE has no formal participation in environmental institutions (either in the Governing Council of the National Environmental Commission or in the Regional Environmental Commissions). The CNE has been unable to completely fulfil its forward-looking policy-making role because it has been focused on *ad hoc* crisis management, and on analysis and development of tariff-setting processes. As a result, it has been difficult for the CNE to focus on developing a more prospective, long-term vision for the energy sector that would enable it to prepare and carry out strategies to address the sector's challenges in a timely, effective and efficient manner.

The legislation's proposed institutional structure includes the following elements:[9]

- **Separation of functions**. All powers related to the design of policies, legal and regulatory provisions, plans and programmes will become the responsibility of the Ministry of Energy, which shall govern the country's energy sector. Functions related to technical and economic regulation of the energy sector will remain under the competence of the CNE.

- **Sectoral co-ordination and integration of Chile's regions**. The Ministry's highest authority will be the Minister of Energy. Internal administration and co-ordination of public energy services will be the responsibility of the Undersecretary of Energy. At the regional level, Regional Energy Ministry Secretariats (SEREMIs) will be established.

- **Co-ordination of environmental and energy policies**. The Minister of Energy will sit on the Management Committee of the National Environmental Commission and the Regional Energy Ministry Secretaries will be members of the Regional Environmental Commissions. This arrangement will enable the integration of energy and environment policies.

9. Energy Policy: New Guidelines, *CNE, 2008, p.66-67.*

- **Coherence in the actions of energy sector public services.** The sector is organised according to the structure set out in the *Organic Framework Law on Public Administration*, under which definition of policies, plans and standards in the sector will be the responsibility of the Ministry of Energy. As such, all energy sector public services will be overseen by this Ministry. The following services will report to the President of the Republic through the Ministry of Energy: the CNE, the Superintendency of Electricity and Fuels, and the Chilean Commission on Nuclear Energy (see Figure 1.4).

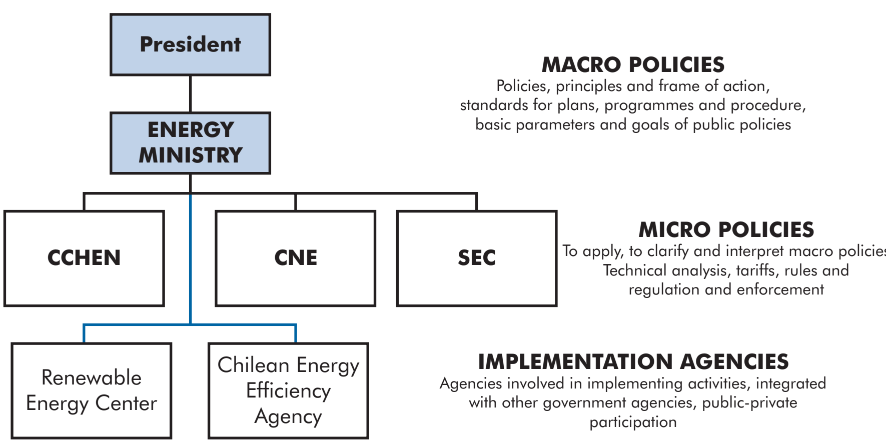
- **Strengthening regulatory capacity.** The CNE will be a decentralised public service charged with analysing prices, tariffs and technical standards that must be complied with by companies that produce, generate, transport and distribute energy. The procedures for regulating energy tariffs will remain the same as those currently in force.

- **An independent technical entity.** To ensure that the CNE complies with its mission to be an independent entity with technical expertise that is free from short-term political and private interests, both the Executive Secretary and second-level positions shall be filled according to the mechanism used for high-level public servants.

- **Human resources.** To ensure the competence of its staff, and attract and retain qualified professionals, remuneration paid will be competitive with the private sector.

Figure 1.4

Proposed Sector Organisation in the Energy Bill



Source: CNE.

International Collaboration

To enhance analysis of Chilean energy policies, closer ties have been forged with major international institutions such as the International Energy Agency (IEA), the International Atomic Energy Agency (IAEA) and the Asia Pacific Economic Co-operation (APEC) forum. Experts from these agencies have recently participated in various activities in Chile, two of the most notable being a Peer Review on Energy Efficiency carried out by APEC and this IEA Energy Policy Review.

Chile has taken an active role in international energy institutions, supporting from the start the creation of the International Renewable Energy Agency (IRENA) as a mechanism for promoting the worldwide development of renewable energy technologies.

Chile also actively participates in regional entities that analyse, co-ordinate and design energy policies, including: the Latin American Energy Organisation (*Organización Latinoamericana de Energía* – OLADE); the UN Economic Commission for Latin America and the Carribean (ECLAC), the Energy Experts Group of the Union of South American Nations (*Unión de Naciones Suramericanas* – UNASUR); the Commission for Regional Energy Integration (*Comisión de Integración Energética Regional* – CIER); the Ibero-American Association of Energy Regulators (*Asociación Iberoamericana de Entidades Reguladoras de la Energía* – ARIAE); and the Mercosur Energy Sub-group. Chile is also a member of the APEC Energy Working Group.

In addition, the Chilean government has signed various bilateral energy co-operation agreements with other governments including: a collaboration project on energy efficiency with the Spanish Energy Efficiency Agency; a renewable energy technical assistance project with Germany Agency for Economic Development; and a Memorandum of Understanding with the United States Department of Energy on renewable energy, concentrating in particular on solar power and biofuels.

Energy Statistics and Indicators

Chile's national energy balance is prepared by the CNE on the basis of annual surveys sent to the main companies in the energy sector, including producers, importers, exporters, distributors and large consumers in Chile. Currently, the directory of surveyed companies includes about 500 companies, covering the energy supply chain in Chile.[10]

10. The number of surveyed companies was expanded from around 200 in previous years as part of the effort of the CNE to improve its database.

To complement information from the surveyed companies, information from the Santiago Chamber of Commerce is also used to verify the import and export levels, and data from the National Statistics Institute (*Instituto Nacional de Estadísticas* – INE) provides additional details concerning electricity generation by self-producers. Information on biomass consumption is obtained partly from the estimates of annual electricity generation reported by the companies and partly from estimates of residential consumption using time series data.

The CNE currently lacks formal data collection authority to prepare the national energy balance. The CNE current practice is to send a letter signed by its executive secretary, indicating the importance of the national energy balance and guaranteeing confidentiality of the information provided. To date, this process has worked relatively well because many of the companies surveyed for the purposes of compiling the national energy balance operate in the energy supply chain and are thus likely to be regulated by the CNE.

The CNE is currently working to expand the number of companies surveyed to improve the disaggregation of industrial sector consumption. This increase in the number of companies is also being co-ordinated with Chile's Central Bank, to ensure that sector consumption figures are compatible with national accounts. One of the main challenges for this process will be obtaining responses from companies that have no direct relationship with the CNE.

Indeed, demand-side information in Chile is more limited. Some institutions measure energy consumption in specific ways for certain types of energy and for specific consumption sectors, as described below. However, the only statistics that currently measure supply and consumption for all energy sources and all sectors in the economy, on an annual basis, are those in the national energy balance.

- The Chilean Copper Commission (*Comisión Chilena del Cobre* – COCHILCO) conducts an annual survey of companies in the copper industry to measure energy consumption, establish indicators of consumption intensity by unit produced, and develop consumption projections for copper mining on the basis of expected production.

- ENAP estimates national sales of oil derivatives on a monthly basis, which can be considered as consumption.

- The CDECs provide monthly figures of the level of electricity sales, which can also be considered as consumption, once distribution losses are discounted.

- The Ministry of Planning (MIDEPLAN) conducts its annual CASEN survey, which collects information on residential energy consumption.
- The National Statistics Institute (INE) collects annual data on energy consumption in the industrial, retail and service sectors.
- The Ministry of Health will soon begin to keep records of fuel consumption for all greenhouse gas (GHG) emissions sources in the country.

All of these organisations and statistical instruments currently operate independently (except for the electricity sector, in which co-ordination among agents is embedded in regulation). As a result, there is no national database specifically designed to collect information about the national energy sector in a comprehensive manner. The creation of a Ministry of Energy should bring together the work of the CNE, SEC, PPEE and the ACHEE. This proposed institutional framework should enable the integration of these five institutions and the centralisation of national energy information. Accordingly, the proposed bill includes giving the authority to the Ministry of Energy to obtain statistical information from actors of the energy market. For other types of information, co-ordination with INE will be necessary.

In 2008 and 2009, with technical support from the IAEA, the CNE Energy Studies Department has been developing two models to forecast energy demand and to identify energy supply options. The demand model is based on the Model for Analysis of Energy Demand (MAED) and an energy supply optimisation model is being developed using the Model of Energy Supply Systems and their General Environmental Impacts (MESSAGE). Results from these models are expected to be available in the second half of 2009. In parallel, the CNE and PPEE plan to develop a set of key indicators of consumption intensity by sector, fundamental for the development of energy efficiency policies. Long-term indicative energy planning, whether through data collection, demand forecasts, long-term supply optimisation, or consumption intensity indicators, will be a new undertaking for the proposed Ministry of Energy.

Energy Prices, Taxes and Subsidies

Fossil Fuels

Chile has no price capping or subsidies for fuels. Prices for petroleum-based fuels are freely set by the refiner and throughout the distribution chain, including retail sales at service stations. There is an explicit government policy, however, to reduce price volatility for final consumers through two price stabilisation funds. The Oil Price Stabilisation Fund (FEPP) was established in 1991 and the Fuel Price Stabilisation Fund (FEPC) was created in 2005. Currently, the Oil Price Stabilisation Fund only covers fuel oil, while the Fuel Price Stabilisation Fund covers gasoline, diesel, LPG, LNG and kerosene. In practice, for each fuel subject to one of these funds, a price band is established that reflects its average import parity price level over the recent past. Every week, the CNE calculates the import parity price. If this price exceeds the price band ceiling, a credit is applied to benefit final fuel consumers and paid for by the fund. If, on the contrary, the import parity price of the week is below the price band floor, a tax is applied to make up the difference, paid for by final consumers. In this case, revenues generated are used to replenish the fund.

The aim of both funds is to reduce the volatility of end-user prices of these fuels from one year to another, while remaining neutral in the long term, with credits financed by the taxes generated. Over the 2.5 years from January 2007 to July 2009, credits outweighed taxes in the FEPC by USD 288 million (see Chapter 5: Fossil Fuels, Tables 5.4 and 5.5). To maintain a positive balance in the fund in the face of these outflows, the government injected a total of USD 760 million into the funds in 2007 and 2008. In the last quarter of 2008 and first two quarters of 2009, a positive balance of USD 486 million was recuperated following the fall in international oil prices.

The following taxes are paid on fuel in Chile: (i) import taxes on imported products; (ii) specific taxes for fuels used in transport vehicles; and (iii) a value-added tax paid on all fuels. Import taxes or tariffs are paid on all imported products, and current rates are around 6% under the general regime. This rate varies depending on the country of origin and whether it has signed a trade agreement with Chile. The specific tax for fuels used in transport vehicles is applied to gasoline, diesel oil, LPG and CNG. Gasoline is taxed at a fixed rate of UTM 6/cm[11] with a discount of up to UTM 2.5/cm until 1 April 2010 depending on the level of WTI crude prices.[12] Diesel oil is taxed at a fixed rate of UTM 1.5/cm, and companies that use diesel oil fuel for non-vehicular purposes can discount the amount corresponding to the specific tax from the amount of value-added tax that they pay. LPG and CNG are taxed with a

11. *UTM* (unidad tributaria mensual, *or monthly tax unit) is an inflation-tracking currency unit. The UTM was valued at CLP 37 000 in June 2009, equivalent to approximately USD 70.*

12. *If the average West Texas Intermediate (WTI) crude price over the previous 12 months is greater than USD 85/bl, UTM 2.5/cm is discounted; between USD 80/bl and USD 85/bl, UTM 2.0/cm is discounted; between USD 75/bl and USD 80/bl, UTM 1.5/cm is discounted; between USD 70/bl and USD 75/bl, UTM 1.0/cm is discounted; between USD 65/bl and USD 70/bl, UTM 0.5/cm is discounted. This law is in effect until April 2010, after which time the specific gasoline tax should revert to UTM 6/cm irrespective of the level of the WTI price.*

fixed component; they are set at 1.4 UTM/cm and 1.93 UTM/cm, respectively. The value-added tax (VAT) is a direct tax on consumption and the current rate is 19%.

Electricity

Chile's current electricity legislation establishes as a basic premise that tariffs must reflect the economic costs of generation, transmission and distribution of electricity. This aims to send the right signals both to private companies and consumers to optimise the economic efficiency of the system.

One of the key principles of electricity regulation is free pricing in those segments in which competitive conditions are observed. With regard to supply to end-users whose connected power is less than or equal to 2 000 kW, these are considered to be sectors in which the market may be characterised as a natural monopoly, and the law establishes that they are subject to price regulation. For supply to end-users whose connected power is greater than 2 000 kW, the law provides for free pricing, supposing that these users have the ability to negotiate and the possibility of obtaining electricity supply in other ways, such as self-generation or direct supply from generation companies. The first group of clients are known as regulated clients and the second group as free or unregulated clients, although clients that have connected power greater than 500 kW can choose which regime they wish to subscribe to (free or regulated).

The electricity bills of low-income residential users, both urban and rural, are now subsidised in certain circumstances. If electricity tariffs for urban and rural residential users undergo a real cumulative increase equal to or greater than 5% within a period of six months or less, a transitory subsidy is given in the form of a discount on the electricity bill of low-income households. The total cost of the subsidy thus far has amounted to USD 50 million following the high price of oil in the first half of 2008. For further discussion on electricity pricing, see Chapter 6: Electricity.

Critique

The government of Chile should be commended for having recently proposed a major re-foundation of Chile's energy policy, integrating the goals of economic growth, security of supply and environmental sustainability at least cost. This effort has been supported by two main instruments: a legislative bill and a long-term energy policy document. In March 2008, a legislative bill was introduced in the Chilean Congress seeking to reform the sector's institutional framework by clarifying the attributions of existing agencies and reinforcing co-ordination mechanisms. The Chilean government has also initiated a process to reformulate Chile's long-term energy policy, as outlined in the CNE *Energy Policy: New Guidelines* document released in January 2009.

The CNE recognises the importance of strong institutions in the country's energy policies. The *Energy Policy: New Guidelines* document states that "the ability to take action... will depend on having institutional, organisational and regulatory structures that are truly capable of handling these challenges... Well-functioning institutions are the foundation of any effective policy."

An assessment of Chile's existing institutional structure reveals a number of shortcomings: the difficulty of co-ordinating policies where interests are shared across a number of ministries, commissions and agencies, which is a particular problem in the case of environment and energy policy; the difficulty of gaining an overall view of the sector; a legalistic approach to the regulation of the sector to the detriment of long-term public policies; and the institutional weakness of the CNE in relation to other entities in the sector.

The legislation currently before the Chilean Congress seeks to establish a clear separation of functions between policy formulation, technical-economic regulation, and enforcement (see Figure 1.4). The proposed bill also puts forward the creation of a Ministry of Energy, thereby centralising the functions of formulation and evaluation of public policies.

The creation of a Ministry of Energy is an initiative which the IEA supports. As contemplated in the proposed legislation, the IEA recommends that the proposed Ministry of Energy be given the necessary human and financial resources to enable it to work effectively, with clear lines of authority and co-ordination mechanisms with other ministries and government agencies. The proposed Energy Ministry will be strengthened by action in specific areas such as energy efficiency and renewable energy, where two proposed executing agencies will work to ensure the implementation of energy policies by co-ordinating different agents: the Chilean Energy Efficiency Agency and the Centre for Renewable Energies. Similarly, giving the CNE the responsibility for the National Energy Efficiency Programme in 2008 was an important step in broadening the scope of the CNE energy policy-making functions.

The CNE should also be provided with the necessary resources to ensure the effective and efficient operation of its regulatory functions. It should be able to recruit suitably skilled labour and to take decisions independent of government. As proposed in the draft bill, the independent hiring process for the Director of the CNE through the system of higher public administration is an important element in this respect. All functions relating to the technical-economic regulation of the sector (tariff analysis and definition of technical and quality norms) will remain in the area of competence of the CNE.

The release of the *New Guidelines* document is an important first step in Chile's policy re-formulation effort. The IEA recommends that the government finalise its new long-term energy policy as soon as possible. The creation of an Energy Studies Department in 2007 within the CNE has greatly contributed to define a more comprehensive energy policy, including the sustainable use of biomass, research and development priorities, stronger modelling capabilities and assessment studies on the nuclear power option. The creation of the Rural an Social Energisation Programme is an important element in the formulation of Chile's multi-dimensional energy policy. The proposed Ministry of Energy should maintain its focus on these important energy issues (biomass and biofuels, rural energisation, statistics and modelling, energy research and development, NCRE, etc.) and should also consider a co-ordination role on transport as well as climate change issues, among others. Accordingly, the proposed organisation of the Ministry should be based on clear internal co-ordination principles to avoid duplication and inconsistencies. Finally, the Minister of Energy should be formally integrated into both the Ministerial Innovation Committee and the National Innovation Council for Competitiveness, with a view to articulating energy R&D policy in line with Chile's national economic development strategy.

Chile's long-term energy policy document should also set clear objectives and indicative targets to facilitate the monitoring of on-going policies and their *ex-post* evaluation. This will inform policy design and implementation in the future, and also enhance public accountability. Finally, given the strategic importance of some of the energy projects currently under consideration in the country, including large coal-fired plants, large hydropower projects and the nuclear energy option, the government of Chile should address all the issues at stake in a national public debate with the aim of fostering support across the political spectrum. This would ensure long-term consensus and share the associated political cost of such decisions.

There is broad consensus in Chile on the essential role of the state in guiding the evolution of the energy sector, given long lead times for energy investment, and in ensuring energy security and emergency response. This consensus acknowledges that energy security is a public good, which requires a unified, strategic analysis process. While investment decisions should continue to be made by the private sector, the government needs to take a more proactive position with regard to monitoring energy developments and systematic risk assessment to anticipate potential supply disruptions and minimise the potential cost of adapting to climate change. This could be done by strengthening prospective analysis and long-term scenarios. It is essential that the government continues to improve the quality of its energy statistics and to develop modelling capabilities in the institutions in charge of energy policy.

Reliable energy statistics are the foundation of informed policy making and market transparency. Accurate and timely data are a key instrument to correct information asymmetry across the public and the private sectors. Without quality information and data, policy makers cannot adequately monitor energy developments and identify emerging risks. Reliable official energy statistics are an essential tool to provide guidance for the future. There is currently a lack of human and financial resources allocated to energy statistics in Chile. An IEA survey conducted in 2004 showed that the number of people working on energy statistics in OECD member countries included on average between two and eight staff.

As a consequence, Chile faces major challenges in terms of monthly and annual reporting: incomplete energy balances, delays in data submission, lack of disaggregated data by end-use or product, etc. The lack of a proper energy statistical legal framework also contributes to the problems observed on energy balances and basic energy statistics. Not all companies are surveyed or respond to CNE requests for information. This leads to a coverage that is sometimes far from comprehensive. In short, the institutions for data collection in Chile are in place but need to be strengthened and given adequate authority and resources to carry out their mission.

The government of Chile should be praised for having identified data quality and transparency as a key energy policy issue and for having recently increased both human and financial resources dedicated to data collection and analysis in the CNE and the PPEE. The proposed bill explicitly seeks to provide mandatory authority for the proposed Ministry of Energy to collect data from all actors in the energy market. The government of Chile should create a dedicated department for data collection, processing and analysis, as well as energy modelling, including demand-supply and technology scenarios. Responsibility for compiling energy statistics should be located within the proposed Ministry of Energy, in a centralised unit closely connected to all Ministry departments and energy stakeholders, both public and private.

Furthermore, more disaggregated data at the end-use level are needed for Chile to support its energy efficiency policy. The IEA and APEC have produced a template to collect the data needed to prepare a minimum set of indicators common to all OECD member countries as well as APEC economies. Chile should be in a position to complete this template to better identify priorities and to compare Chilean indicators with other OECD member countries or similar economies.

In recent years, the government of Chile has demonstrated a strong commitment to work effectively on energy through APEC, and with the IEA, the IAEA, the IADB and OLADE, among others. The government should be praised for having given new momentum to Chile's participation in international institutions to add valuable insight to advance its energy policy and to provide key agents with information that can improve both public and private decision making. The country's experience could also provide valuable lessons to other countries in the region and emerging economies elsewhere.

Recommendations

The government of Chile should:

- Ensure that the reorganisation of the energy sector as currently under debate, and in particular the creation of a Ministry of Energy, is completed as soon as possible.
- Provide the Ministry of Energy with the resources needed to formulate, adopt and implement a coherent and long-term energy policy for Chile.
- Ensure that the institutions in charge of the technical-economic regulation of the energy markets are able to make independent and competent decisions.
- Finalise its new, long-term energy policy by:
  - Adopting an integrated approach to energy policy, such that it takes account not only of energy sector objectives (*e.g.* the requirement to secure energy supplies at affordable prices) but also of the needs of other sectors of the economy, including economic development, innovation, health, environment, transportation, mining, etc.

- Setting clear objectives and indicative targets to facilitate monitoring of on-going policies and *ex-post* evaluation.
- Building consensus around those objectives through broad public consultation mechanisms.

• Enhance data quality and transparency by:

- Creating a dedicated department for data collection, processing and analysis, as well as energy modelling, including demand-supply and technology scenarios, as contemplated in the bill to create a Ministry of Energy.
- Continuing to increase financial and human resources devoted to data collection and analysis.
- Providing mandatory authority for the proposed Ministry of Energy to collect data from all actors in the energy market.

• Deepen its international co-operation with a view to enrich its own energy policy development and share experiences with other countries.

2. SECURITY OF ENERGY SUPPLY

Overview

Unlike many of its South American neighbours, Chile has limited indigenous fossil energy resources. Proven crude oil reserves in January 2006 were estimated at 150 million barrels (Mb) (equivalent to 20 million tonnes or Mt), all located in the southern Magallanes Region. This is insignificant in comparison with annual domestic consumption of 11.7 Mt.[13] Estimates at the end of 2006 of natural gas proven reserves located in the Magallanes Region varied between 42 and 98 billion cubic metres (bcm) compared with annual consumption of 7.8 bcm in the same year.[14] The national petroleum company, ENAP, has explored other parts of the country for hydrocarbons without success. Chile has significant reserves of low-sulphur, sub-bituminous coal reserves mostly in Riesco Island in Region XII (Magallanes). These are estimated at between 200 Mt and 500 Mt, compared with coal consumption of 5 Mt and domestic production of 0.8 Mt in 2007.[15]

Chile has abundant hydropower potential in the central and southern regions, and plentiful non-conventional[16] renewable energy potential throughout the country. Its hydropower supply is not as geographically diverse as that of other countries in the region (*e.g.* Brazil), though there is undeveloped potential in the far south. Chile is therefore vulnerable to hydropower supply disruptions because of recurring weather patterns, which tend to cause droughts every two or three years.

Chile began to import natural gas for electricity generation from Argentina in 1996. When imported gas supplies reached their contracted levels of 8 bcm in 2004, gas-fired generation represented 33% of electricity output. The combination of a scarcity of domestic conventional energy resources, reliance on a single supplier of natural gas and the intermittency of hydropower left the country vulnerable to energy supply disruptions. This vulnerability was illustrated in 2007/08, when the combination of a drought in the central-south region and almost total restrictions by Argentina on natural gas exports to Chile resulted in an acute energy crisis.

13. *IEA Statistics, Oil Information 2008.*
14. Oil and Gas Journal. *Cedigaz estimates proven reserves at 42 bcm.*
15. *IEA Statistics, Coal Information 2008.*
16. *Non-conventional renewable energy (NCRE) sources include wind power, geothermal energy, solar energy (thermal and photovoltaic), biomass (solid, liquid and biogas), marine (currents, tides, waves and thermal gradients) and hydraulic energy (restricted to small hydro plants, defined in Chile as smaller than 20 MW installed capacity). See Chapter 7: Renewables.*

The experience of 2007/08 demonstrates that the Chilean government needs to take a more active role in energy security. The government's current role is to put in place contingency measures when market mechanisms fail, as well as to develop and maintain the necessary conditions to ensure that the market can deliver energy security in the short to medium term.

The country successfully survived the 2007/08 energy crisis without having to resort to blackouts through a combination of short-term measures, including: a significant switch to diesel-fired electricity generation as a substitute for gas from Argentina; the installation of fast-response diesel turbines; the immediate return of value-added tax on diesel; the more flexible use of water in two hydroelectric reservoir systems that are capable of inter-annual generation; a government information campaign urging consumers to save energy; the giving of incentives by generators to their customers to reduce consumption; reductions in transmission voltage; and a noticeable demand response on the part of consumers to high end-user prices.

In the medium term, the government aims to achieve a more diverse generation mix by encouraging greater penetration of non-conventional renewable energy (NCRE) sources and by facilitating the construction by the private sector of two liquefied natural gas (LNG) terminals. One of these plants is now operational in Quintero Bay, 155km northwest of the capital, Santiago. Generators are also building a significant amount of new coal-fired capacity partly in place of that which was previously fired on Argentine gas. Finally, the government has begun to develop a comprehensive policy framework to encourage greater efficiency in the end-use of energy.

While security of energy supply has moved up the Chilean energy policy agenda in recent years, more remains to be done if Chile is to sustain recent levels of economic growth.

Energy Security by Fuel and Source

Natural Gas

To meet increased energy demand from its growing economy in the early 1990s, Chile looked to Argentina as its sole potential supplier of natural gas. Following the signature of an *Economic Co-operation Agreement* in 1991 and a *Gas Integration Protocol* between the two countries in 1995, a decision was made by the private sector to invest in infrastructure that would allow the import of natural gas from Argentina.

The first pipeline connecting Argentina and Chile was commissioned in 1996 to serve the requirements of one customer, the Methanex methanol plant at Cabo Negro, near the city of Punta Arenas in the Magallanes Region. In 1997, the Gasandes pipeline, which connects the Neuquén basin in Argentina with central Chile, became operational. Further infrastructure followed in 1999 with the addition of two pipelines serving northern Chile *(Gas Atacama and Norandino)* and in 2000 by the *Gasoducto del Pacífico* pipeline serving the Concepción Region to the south. Most of the newly imported natural gas was used across the country for electricity generation and industrial consumption (of which more than half was attributable to *Methanex* as feedstock in its petrochemical plant).

Over a relatively short period, natural gas from Argentina became a significant source of primary energy in Chile. Between 1996, when imports from Argentina began, and 2004, when they reached their peak, consumption of natural gas in Chile increased from 1.9 bcm to 8.6 bcm, *i.e.* from 1% to 33% of total electricity generation. The arrival of Argentine natural gas had a positive impact on the Chilean energy sector and the number of connections increased from 40 000 in 1997, largely in Region XII, to 300 000 customers spread across five regions by 2003. Between 1997 and 2004, the private sector invested USD 4.9 billion in gas transportation infrastructure and gas-fired electricity generation facilities, resulting in greater diversification of primary energy supply and a more diverse electricity generation portfolio by fuel source.

Argentina began to impose restrictions on the export of natural gas to Chile on 1 April 2004, undermining the terms of the *Gas Integration Protocol*. These restrictions were partly the result of the Argentine government imposing price controls in the wake of the 2001 peso devaluation, which deterred investment in new oil and gas exploration and production in Argentina. When the Argentine economy rebounded in 2004, and demand for cheap natural gas surged, gas shortages followed. Argentine producers were required to give priority to internal demand before making any volumes available for export. Where volumes were made available for export, prices were higher and subject to significant increases in export taxes (see Table 2.1).

Table 2.1

Evolution of Price of Gas Imports from Argentina, 2000-2008

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
USD/ MMBTU	2.30	2.40	2.53	2.35	2.50	3.13	4.30	6.40	10.00

Since the beginning of the Argentine gas crisis, imports of natural gas have fallen by as much as 95% of contracted volumes, with adverse consequences for the Chilean energy sector and the wider economy. During periods in 2007 and 2008, imports from Argentina almost stopped completely except for 0.5 bcm for residential and commercial consumption in the Santiago Metropolitan Region. This minimal level was delivered as a direct result of negotiations between the Heads of State of the two countries in an effort to manage a supply crisis in the middle of a particularly cold winter.

Chile produces a small amount of gas from the Magallanes Basin in the far south and has plans to raise production in the coming years. Further discoveries may allow it to meet local demand and eventually the needs of the Methanex plant. The recent award of exploration permits to international oil and gas companies may also result in an expansion of the gas resource base. Nonetheless, future domestic production is unlikely to be sufficient to meet demand throughout the country.

Response to the Natural Gas Crisis

The progressive reduction in gas imports from 2004 onwards caused customers to switch to more expensive alternative fuels such as diesel and propane. Only the Methanex plant in the Magallanes Region had to curtail its production. The government was obliged to establish new regulations to define priorities for the distribution of natural gas in the event of continued restrictions. These regulations required distribution companies to give priority to the residential sector and hospitals in the event of a supply disruption, followed by power plants and then industrial plants. The industrial sector had to resort to more expensive and more environmentally damaging substitute fuels and facilities with no back-up energy supply. In both the SIC and the SING, combined-cycle natural gas-fired plants were converted to open-cycle running on diesel, thereby losing 20% of their operational efficiency on average. Attention was focused on building new emergency generating capacity and LNG import facilities.

In addition to these supply-side measures, the government of Chile also began actively to promote energy savings and efficiency measures. Energy saving measures announced by the government in February 2008 had positive results in terms of reducing consumption and helped to avoid power rationing. The measures included: the distribution of energy efficient light bulbs to the poorest 40% of the population; a 10% reduction in transmission voltage; the extension of the summer daylight schedule by several weeks; and plans to reduce power consumption in the public sector by 5%. In addition, generators offered special monetary incentives to consumers in exchange for reducing their electricity consumption. In early March 2008, the government also launched an energy efficiency campaign – *"Ahorra Ahora"* or "Save Now" – in various media, encouraging Chileans to save energy by unplugging electrical items when they were not in use and switching to more energy efficient light bulbs. As a result, electricity consumption in the SIC was 1.5% lower between March and December 2008 than during the same period in 2007, while demand growth had been expected to reach 6.5%, leaving total energy savings in the SIC at 8%. Higher end-use prices were also a significant factor in reducing demand. Wholesale electricity prices increased from USD 40/MWh in 2004 to USD 120/MWh in 2008/09, while spot prices reached USD 350/MWh in 2008. This encouraged a number of industries and copper mines that were purchasing energy at prices close to spot prices to generate with their own diesel-fired, back-up units rather than rely on grid-based electricity.

The development of two LNG regasification terminals was a direct response to the Argentine gas crisis. The first project is situated at Quintero Bay and began full operation at the end of August 2009. It was developed by GNL Quintero, a consortium made up of BG (40%), ENAP (20%), Endesa Chile (20%) and Metrogas (20%). The estimated total cost of the project is USD 1.2 billion. Gas send-out capacity in the initial phase is 2 bcm per year. The permanent capacity in the later phase will be 3.4 bcm per year, and there is an option to expand the terminal to a maximum send-out capacity of 6.8 bcm per year. This project should ensure that some generating plants will be able to operate on gas as originally planned, rather than oil.

In early 2008, GNL Mejillones, a joint venture company owned equally by shareholders Suez Energy International and CODELCO, obtained the environmental permit for its LNG project in Mejillones. Construction of the jetty and the on-shore LNG regasification terminal began shortly afterwards. First gas is expected to be delivered in 2010. The terminal will have a send-out capacity of 2 bcm per year. For LNG storage, the project will use a conventional LNG floating storage unit (FSU), which will be moored to the jetty as a transitional measure. Gas supply for Quintero will be sourced from British Gas and for Mejillones from GDF Suez, under long-term contracts linked to international oil prices.

Electricity

Chile's electricity sector in its current form has faced three periods of significant stress over the past 10 years: first in 1998/99, as a result of the worst drought in 40 years, which affected the central zone; from 2004 onwards, when natural gas supplies from Argentina, upon which the electricity generating systems in the SIC and the SING had come to depend, were increasingly restricted; and an extreme episode in 2007/08 when a drought further exacerbated the energy crisis. While the combination of hydropower and natural gas was certainly more diversified than previously, this proved insufficient to ensure a secure supply of energy because the provision of natural gas itself was not diversified while hydropower was subject to its own inherent risks. At peak, some 30% of the SIC capacity and 60% of the SING was fired by natural gas from Argentina.

Chile's largest electricity network, the SIC, is hydro-dependent and droughts are frequent. The severe drought of 1998/99 exposed a loophole in the market rules put in place in the 1980s. The original rules obliged generators to compensate distributors for supply curtailments in the case of drought, with an exception in the case of droughts as severe as one that occurred in 1968. The amendment to the 1982 *Electricity Law*, introduced in 1999, eliminated the exception of the "worst drought", thereby strengthening the incentives for generators to have sufficient back-up units.

Further changes to strengthen the incentives on generators were introduced in 2005. The law now requires the distribution companies (on behalf of regulated clients) to hold long-term contracts ensuring that their customers' energy needs are permanently covered for at least three years in advance. The law also makes it mandatory to hold periodic auctions to determine the prices in these long-term energy supply contracts between generators, including new entrants, and distribution companies. This will allow end-customers to express preferences for reliable (or firm) supplies of energy. The first such auctions took place in 2006, for supplies beginning in 2010. To ensure that the auctions attract the largest possible number of bidders (including new entrants), the law stipulates an interval of three years between the date of the auctions and the start of the resulting supply contracts. This period is intended to be sufficient to allow new plants to be built to service the contracts.

Further amendments to the 1982 *Electricity Law*, also introduced in 2005, allowed generators to offer incentives to regulated customers for reducing consumption. In the event of an energy shortage, a generator that secures a reduction in consumption from regulated customers will be allowed to credit this reduction against its contracts with the distributor, without the need to compensate users (except for the incentives offered to reduce consumption).

As intended, the reforms introduced in 2005 have helped to encourage greater investment in the electricity sector. Almost 4 000 MW of new capacity is currently under construction, all of which will be commissioned by end-2011 (see Table 2.2).

Table 2.2

Capacity Currently Under Construction by Fuel Type, April 2009 (MW)

Technology	SING	SIC	Total	Share (%)
Hydro	-	433	433	11
Coal	760	1 441	2 201	56
LNG	-	240	240	6
Diesel	5	750	755	19
Fuel oil	95	16	166	3
Wind	-	164	164	4
CHP		22	22	1
Total	**860**	**3 066**	**3 926**	**100**

Source: CNE.

Coal

In 2007, coal accounted for 3.3 Mtoe, or 11% of Chile's TPES. Chile imports almost 95% of its coal needs, largely from Colombia (40% of total imports), but also from Indonesia (30%) and Australia (15%). Coal imports have increased in recent years, from an average of between 2 Mt and 3 Mt per year between 2001 and 2006, to almost 5.5 Mt in 2007. This growth in coal consumption, largely driven by demand from the electricity sector, reflects the switch back to coal as a result of the collapse of Argentine gas exports to Chile.

Four regions have potential for coal production; Bío Bío/Arauco, Los Ríos, La Araucanía, and Magallanes (in particular Riesco Island). Should planned developments to produce Chilean coal proceed, on the basis of concessions awarded in 2007, forecasts indicate that dependence on external coal will fall from 96% in 2007 to 64% in 2012.

The electricity sector accounts for the majority (85%) of the country's coal consumption, with heavy industry accounting for most of the rest. At present, there is almost 2 050 MW of coal-fired electricity capacity in the SING and SIC combined. Given the likelihood of continued restrictions on gas imports from Argentina and the comparatively high price of LNG, electricity generators are now investing in new coal-based thermal generation. About 2 200 MW of coal-fired capacity is currently under construction. Coal accounts for more than half of total capacity currently being constructed.

Coal is one of the elements of Chile's energy security strategy through fuel diversification. However, planned coal-fired power plants are small in size and sub-critical and, for the time being, do not face pollutant emissions standards at the unit level. CNE projections show that installed coal capacity will rise from 16% in 2007 to 26% in 2020. Investments in coal-fired generation are not without disadvantages. Preliminary results of CNE projections show that Chile's GHG emissions are set to double between 2008 and 2025, partly as a result of the increase in coal-fired generation. This would risk locking-in a high percentage of Chile's capacity for 20 to 30 years, making it difficult for the country to adapt to any future GHG targets that might arise from a possible international agreement on climate change.

Oil

In 2007, oil accounted for 17.3 Mtoe, or 55%, of Chile's TPES. Indigenous sources provided just 1% of Chile's crude oil requirements and the country is also a net importer of oil products (of about 6 Mtoe in 2007). Two-thirds of final consumption of petroleum products in Chile are in the transport sector, with another 25% in the industrial and mining sectors. Total final consumption of oil in 2008 amounted to about 17 Mt, some 50% more than before the cuts began in natural gas imports from Argentina.

Since 2002, ENAP, the state-owned oil company, has pursued a strategy to diversify the sources of its crude imports. While in 2002, 74% of crude oil imports came from Argentina, in 2008, crude oil imports were fully diversified with 25% coming from Brazil, 23% from Ecuador, 20% from Angola, and 17% from Colombia (see Figure 5.1). Oil products are generally imported from countries in the region (Colombia, Ecuador, Peru, Argentina and Brazil) and from the United States. ENAP exports oil products mainly to Peru and Ecuador.

To reduce the country's reliance on imports, an international tender for hydrocarbon exploration in the Magallanes Region was recently launched, under the supervision of the Ministry of Mining. Of the ten blocks on offer, nine were awarded. Six will be operated exclusively by independent companies and consortia. In the three remaining blocks, the winning bidders will operate in partnership with ENAP.

Infrastructure for oil consists of storage plants, maritime terminals and oil pipelines. Internally, products are moved by sea between terminals located in the Antofagasta, Valparaíso, Bío-Bío and Magallanes regions, as well as through a network of pipelines that connect the refineries in the Valparaíso and Bío-Bío regions with the Santiago Metropolitan Region and some storage plants located in between. The same companies that distribute fuel manage coastal shipping operations. Pipeline transport is carried out by two systems that begin at the refineries and end at a storage plant in the Santiago Metropolitan Region (the ENAP storage facility in Maipú).

During the 2007/08 crisis, diesel storage capacity in Mejillones was increased by 0.6 Mcm. The number of ships used to import diesel into the country increased from 60 to more than 100 between 2006 and 2007, while a pipeline has been built to transport diesel between the distribution companies' Concón storage plant and the generation plants in Quillota. The efforts made to increase storage capacity and improve logistics for diesel were essential to avoid fuel shortages during a 12-month period when diesel consumption nearly doubled.

Refinery infrastructure is wholly owned by ENAP and has an approximate distillation capacity of 38 000 cm/day. ENAP has storage capacity for 1.2 bcm of crude oil, for 2.2 bcm of petroleum products and for 0.2 bcm of LPG. Pipeline transport is carried out by both ENAP and Sonacol.

Renewables

Renewables accounted for 79% of Chile's domestic primary energy production and 22% of its TPES in 2007 (see Table 1.1). Biomass is the second most important source of energy after oil. It supplied an estimated 16% of the total amount of energy consumed in the country, 55% of total domestic energy production and 70% of domestic renewable energy production in 2007. Combustible renewables and waste constitute 26% of TFC in the industrial sector and contribute to almost 5% of total electricity output (from CHP plants). Hydroelectric capacity constituted 38% of the country's installed electricity generation capacity at end-2008, of which 70% was reservoir based. Wind energy was non-existent in the main electrical systems until 2007. By the end of 2008, installed wind capacity totalled 20 MW. Wind power plants currently under construction are expected to bring total installed wind capacity to 193 MW by the beginning of 2010.

The potential for renewable energy in Chile is diverse and substantial, thanks to the country's unique geographical and natural conditions. Large and small-scale hydro is and will remain a significant component of its energy mix. Strong winds throughout the country make wind another attractive energy source. Chile has 10% of the world's active volcanoes, highlighting an abundant potential for geothermal energy. The north of the country is potentially rich in solar energy. Finally, Chile has more than four thousand kilometres of coastline, and possibly the greatest potential for ocean and wave energy of any country in the world.

The government of Chile has identified renewable sources of energy as a key element of energy security and electricity diversification. The 2005 amendments to the 1982 law, the enactment in 2008 of a specific law to promote the development of non-conventional renewables, and various incentives offered by CORFO should encourage greater investment in renewable energy projects. Since 2004, projects representing a total capacity of more than 2 050 MW have been submitted to the SEIA, although only a fraction of these will be developed. In addition to the 173 MW of wind power under construction, there were some 180 NCRE projects in the country at different stages of assessment or implementation at the end of 2008 (see Chapter 7: Renewables).

Energy Efficiency

As in many other countries, concerns over the security of energy supply and growing energy demand have resulted in energy efficiency becoming an increasingly important part of Chile's energy policy. Despite improving energy intensity across all sectors since 2000, there is still significant potential for energy efficiency in Chile. The CNE *Energy Policy: New Guidelines* document proposes an energy savings target of 20% of incremental demand to 2020 (see Figure 4.7 in Chapter 4: Energy Efficiency). Chile's approach to promoting energy efficiency has changed over time. Until recently, the government's main concern was to ensure that energy prices were determined as efficiently as possible. The predominant view was that an unfettered market, and fully cost-reflective energy prices would result in an optimally efficient use of energy. Nonetheless, the government made occasional attempts to promote energy efficiency through specific measures, although these were not long-lasting and did not have a major effect.

The general approach to energy efficiency changed in 2005, when the government began to develop an energy efficiency policy and included it as one of the central elements in its strategic priorities for energy. The government announced at the time that it would: establish an appropriate institutional framework for energy efficiency; build a suitable knowledge base; promote energy efficiency across all sectors; and regulate markets to provide incentives for energy efficiency. This policy is now being fully implemented (see Chapter 4: Energy Efficiency).

International Connections

Extending 407 km, the InterAndes 345 kV transmission line links Salta in Argentina to the Atacama sub-station in northern Chile and provides electricity to the SING. The Salta gas-fired CCGT plant injects power into both the Chilean system and the Argentine electrical system (SADI). The configuration of the busbars is such that Salta can supply both systems without creating an electrical interconnection between them.

Direct electricity imports from Argentina, Bolivia or Peru have been proposed from time to time, but they are not currently part of the Chilean government's plans for energy security. In response to an initiative on the part of Chile's energy minister and implemented through UNDP, a technical study into the feasibility of interconnecting the electricity networks of Bolivia, Colombia, Chile, Peru and Ecuador has been undertaken. In reality, however, the possibility of a regional power network remains unlikely in the foreseeable future.

It would seem logical for Chile to import LNG from its next-door neighbour, Peru, given the proximity of its Mejillones regasification terminal and Chile's critical need for LNG supplies. However, a long-standing border dispute that goes back to the late 19th century makes it difficult for Chile and Peru to seize this opportunity. On 16 January 2008, the Peruvian government formally presented a case to the International Court of Justice (The Hague, Netherlands) regarding a Chilean-Peruvian maritime dispute.

To the northeast, Chile shares a border with Bolivia, the holder of the second-largest gas reserves in the region. Bolivia and Chile have had strained relations since independence in the early 19th century, owing to a border dispute-dating back to the 1879-83 War of the Pacific. This makes gas exports from Bolivia to Chile unlikely in the foreseeable future.

Emergency Preparedness

Due to supply problems experienced with natural gas, Chile has developed measures to respond to potential energy shortages. Responsibility for implementing measures in response to natural gas supply emergencies rests with a Supervising Committee convened under the terms of Exempt Resolution

N° 754 of 2004, and its later modifications, for example SEC Exempt Resolution N° 1561 of 2007. Each Supervising Committee is made up as follows:

- Northern Committee: made up of representatives of each natural gas transportation company, Gas Atacama and Gasoducto NorAndino; each natural gas distribution and/or retailer, Distrinor and Progas; and the Director of Operations of the Economic Load Dispatch Centre of the Norte Grande Interconnected System (CDEC-SING).

- Central-South Committee: made up of representatives of each natural gas transportation company, Gas Andes and Electrogas; each natural gas distribution and/or retailer, Metrogas, GasValpo and Energas; and the Director of Operations of the Economic Load Dispatch Centre of the Central Interconnected System (CDEC-SIC).

In general terms, the Exempt Resolutions established an obligation for the sector to co-ordinate its actions by means of the Supervising Committee. In times of emergency, the group decides nominations and allocations of gas on a daily basis. Nominations are based upon the following order of priority:

- Supply of gas to residential and commercial consumers and hospitals.

- Supply of minimum gas needs to electricity generation plants, enabling them to operate safely and without rationing.

- Supply of gas to the industrial sector.

Furthermore, the Supervising Committee must ensure that natural gas distribution companies maintain mandatory security reserves in the form of natural gas stocks or line pack in the transport pipeline(s) to satisfy minimum demand requirements, in the order of supply priority, for at least three days.

Emergencies in the electricity sector are regulated by means of rationing decrees, which establish the procedures to which the country's entire electricity sector is subject when an electricity supply emergency occurs. In the case of electricity generation, the inspection, oversight and verification of matters concerning rationing, as well as the authorisation of the payment of subsidies, fall within the remit of the *Superintendencia de Electricidad y Combustibles* (SEC).

Regarding liquid petroleum-derived fuels, *Decree with Force of Law 1 of 1979* from the Ministry of Mining, Article 7, established that every producer or importer of liquid petroleum-derived fuels is obliged to maintain a stock of each product equivalent to 25 days of its average sales over the previous six months, or if imports are for self consumption, average import levels over the same period.

2008 Energy Policy: New Guidelines

The CNE *Energy Policy: New Guidelines* identifies specific challenges to be addressed in the short to medium term if the energy sector is to remain a pillar of long-term national development. The document presents policy proposals within the framework of the country's general economic and social development policy, which sees the market as the cornerstone of the economy and seeks efficiency in resource allocation through the promotion of free competition, with the state playing a subsidiary role.

The broad policy objectives set out in the document include: diversification of fuel sources; greater self-reliance; more efficient use of energy; the promotion of investment in LNG regasification facilities; and increased exploration and production of oil and gas in the southern Magallanes Basin. The document also recommends: the removal of barriers to large-scale renewable energy; the development and implementation of policies that would allow small-scale renewable energy producers access to markets; the development of energy efficiency measures; and, significantly, an examination of the potential for nuclear power (see section below). The CNE also recognises the potential offered by abundant coal reserves in the south and the diversification opportunities offered by coal-fired power.

The guidelines also recognise that contingencies represent an important energy security problem. Even if progress is made in adequate long-term development, unexpected situations may always arise and Chile must be prepared to minimise their impact. For this reason, the document recommends that existing requirements for security stocks of petroleum-derived fuels be strengthened. Furthermore, mechanisms need to be implemented to measure the degree of compliance with the provisions. The guidelines also recommend heavy investment in storage capacity for crude, petroleum derivatives and, if necessary, LNG.

Nuclear Energy Policy

In March 2007, the Chilean government set up an independent working group on nuclear electricity generation (*Grupo de Trabajo en Núcleo-Electricidad* – GTN) named the "Zanelli Commission" and headed by physics scientist, Jorge Zanelli. The group was mandated to look at the option of using nuclear power for the production of electricity in Chile and to advise the President on this matter. The Zanelli Report, presented at the end of 2007, concluded that nuclear power should not be ruled out as an option for Chile in the future on the strategic grounds that nuclear power could contribute to energy security through the diversification of energy sources. Because of the strategic nature of nuclear power, the working group recognised that the Chilean government would have to play an active role in the evaluation process, as well as in the selection of the technical options and in setting up adequate regulatory institutions.

The working group also concluded that the current sector legal framework and land-use planning in Chile would have to be changed if the nuclear power option was to be pursued. It made some specific recommendations regarding the country's current capability to cope with a radiological emergency and the need for strong support for the training of human resources in areas related to nuclear technology. Finally, the working group was of the opinion that, despite the inherent seismicity of Chile, anti-seismic technology and engineering available in Chile could guarantee acceptable safety levels for the installation of nuclear power reactors, though it was essential to have extensive information about seismic faults and reliable soil mechanic studies at potential sites to minimise risks.

In conclusion, the working group recommended further work on the nuclear power option, with the aim of defining the institutional, technical and economic viability of nuclear power. Following these recommendations, the Chilean government decided to commission further research so that the next administration might be able to make an informed decision. The CNE, in collaboration with CCHEN and the advisory group to the minister, worked to develop further studies.

In November 2008, the CNE launched a tender for four separate studies to analyse the possibility of developing nuclear energy in the country. The first study focuses on the role of the state and private agencies. The second study looks at the necessary nuclear regulatory framework. The third and fourth studies examine the life cycle of the fuel and the impacts and risks of nuclear electricity generation, respectively.[17] The studies presented their final reports during the first semester of 2009. In July 2009, the CNE tendered further studies related to: natural risks; barriers and potential impacts in

17. *The study on the role of the state and private agencies was assigned to a consortium consisting of* Universidad Adolfo Ibáñez *and SENES, a Canadian consulting firm. The nuclear regulatory framework study was assigned to STUK-Radiation and Nuclear Safety of Finland. The assessment on the life cycle of the fuel was assigned to AMEC-CADE, a Chilean-British consortium; and the study on the impacts and risks of nuclear electricity generation was assigned to* Corporaciòn Nuclear Eléctrica Chile *S.A., a Russia-based company.*

the electricity market; and legal modifications or adjustments that might be necessary to develop nuclear energy in the country

Critique

Over the past ten years, Chile has experienced three periods of major energy supply shortages. As a direct consequence, the country has become increasingly conscious of the challenge of securing energy supplies. Against this background, the government of Chile and participants in the energy sector are to be commended for having succeeded in taking short-term actions to avoid major disruptions that might otherwise have been imposed by successive energy crises, particularly that of 2007/08.

In its 2008 *Energy Policy: New Guidelines*, the CNE acknowledges that a new forward-looking strategy is required to increase energy security in both the short and long term, and to ensure environmental sustainability. Furthermore, the 2007/08 crisis prompted the country to take a comprehensive approach to energy security with an increasing focus on energy efficiency and renewable energy. This approach is fully in line with the *IEA Shared Goals*, which guide policy making by IEA member countries.

However, a strong regulatory framework is needed to ensure that private sector investment decisions take account not only of short-term private costs and benefits, but also of other long-term strategic considerations. The government therefore needs to link energy security and sustainability to send clear investment signals to the private sector and create a framework so that long-term investment decisions will be based on long-term cost/benefit analysis, including environmental externalities and the downward cost-curve of certain technologies.

While investment decisions should continue to be made by the private sector, the government needs to take a more proactive position with regard to monitoring energy developments and risk assessment. This could be done by strengthening prospective analysis and long-term strategic guidance. To this end, it is fundamental that the government continues to improve the quality of its energy statistics and develop modelling capabilities in the institutions in charge of energy policy (see Chapter 1: General Energy Policy). The government needs to be in a position to act when appropriate and to reinforce market-based signals should there be evidence that the private sector is not delivering secure, diverse and sustainable energy supplies in both the short and medium term.

The forecast growth in coal-fired installed capacity will strengthen the country's energy mix in terms of fuel diversification. But burning coal increases local pollution and produces large volumes of carbon dioxide (CO_2) globally. If coal-fired generation is to increase in the next decade in Chile, it must be accompanied by the widespread deployment of pollution-control equipment to reduce SO_2, NO_x and dust emissions at the plant level. Efforts must also focus on increasing the thermal efficiency of existing plants.

Environmental sustainability is an increasingly important feature of any energy security policy. In this regard, the Chilean government should send the right long-term signals to private investors by internalising environmental externalities, thereby containing the share of fossil fuels in electricity generation. As part of this sustainable strategy, the government should continue to actively promote fuel diversification through clean energy sources. Global GHG emissions reduction targets now called for by the international community will eventually require a significant reduction in CO_2 emissions from fossil-fired power plants. The Chilean government should be cognisant of the climate change implications of a substantial increase in coal-fired generation and plan ahead to avoid investments in assets today that may become stranded in the future. Unless an appropriate combination of these measures is adopted, Chile may lock-in inefficient technology for a period of 20 to 30 years over which international negotiations may produce an agreement on climate change, which may potentially result in high compliance costs for the country in the future (see Chapter 3: Energy and Environment and Chapter 5: Fossil Fuels).

The Chilean government should be commended for having recently scaled-up its focus on demand-side practices that reduce and contain energy demand, not just in times of shortages but as an underlying pillar of energy policy. The ability of demand to participate in the electricity and gas markets, the active promotion of energy efficiency measures, and the promotion of renewable energies are all means of doing so without imposing significant costs on the consumer. From this perspective, the Chilean government should pursue its efforts to establish a sound energy efficiency policy, with sufficient financial and human resources and implementation capability. Draft legislation currently before Congress, which will allow the proposed Ministry of Energy to formulate and implement mandatory minimum energy performance standards, should be passed as soon as possible.

The decisions of the government to incentivise oil and natural gas exploration and production, and to develop the potential of the country's coal reserves are welcome. The development of LNG importation terminals, of natural gas storage facilities, and of ongoing diplomatic engagement within the region are also to be welcomed. The present development of LNG regasification terminals increases diversity of supply and will allow the country to participate in global natural gas markets. LNG will also attract natural gas to the Chilean market from neighbouring countries. While access to LNG will strengthen gas security, it may be prudent for the Chilean government to develop more effective emergency policies to manage supply disruptions in the future.

With respect to emergency planning, the Chilean government should consider the introduction of a statutory obligation to hold a minimum number of days of oil stocks, in addition to the current legal obligation to hold commercial oil stocks, as well as ensuring the monitoring of oil stocks. For example, IEA member countries are required to meet two key obligations: to hold oil stocks equivalent to at least 90 days of their net oil imports and to maintain emergency response measures that can contribute to an IEA collective action during a severe oil supply disruption. Response measures available include: stock draw, demand restraint, fuel switching, surge oil production and, if necessary, the sharing of available oil supplies.

The development, implementation and maintenance of such measures have provided IEA members with the ability to respond efficiently and effectively at times of crisis, such as during the 1991 Gulf War and the 2005 hurricanes in the Gulf of Mexico. The Chilean government should move towards aligning itself with international best practices, in particular with its Pacific neighbours, Japan and Korea. The government should work with all stakeholders within the country to develop a coherent emergency plan that can be implemented in the event of a crisis.

The Chilean government should be commended for undertaking preliminary analyses of the scope for and potential timing of nuclear power within the country's energy matrix, thereby moving in the direction of a more rational debate on the issue. Consideration of this option under review is consistent given the future energy needs of the country and the likelihood that Chile will be required to reduce its GHG emissions over the longer term. Nuclear power has the potential to strengthen the country's electricity generation portfolio and energy supply diversification since fuel supplies are readily available from a variety of sources. The main objective of these analyses should be to assess the economic competitiveness and the risk profile of nuclear with respect to all competing technologies in the medium and long term.

Whatever the decision of Chilean society may be, the Chilean government will need to consider the long-term cost/benefit analysis of nuclear in comparison with other options with different discount rates and sensitivity analyses (including for a carbon price). This implies that when the nuclear option is considered, its costs should be compared with the projected generation costs of renewable electricity at the time when the first kWh of nuclear power will enter in operation, *i.e.* presumably between 2020 and 2025, at the earliest. Also worth considering is the potential inflexibility that even relatively small nuclear power plants (1 000 MW) may have on Chile's electricity system, including back-up capacity. This analysis should also take into consideration, as with all technologies, all hidden costs (including regulation, capacity building, etc.) as well as safety, waste management and decommissioning.

Finally, the Chilean government will need to convincingly address all these issues in a national public debate with the aim of fostering support across the political spectrum. This would ensure long-term consensus and share the associated political cost of such decisions. Public acceptance and safety are likely to be the topics that will define any decision on the future use of nuclear power in the country. A public debate should also foster a national consensus on the role the Chilean state should play in a potential nuclear programme, since this could represent a major departure from the prevailing deregulated approach to the energy sector since the 1980s. New institutions and facilities would need to be established, including those relating to safety, especially if Chile intends to develop a domestic capability for at least some steps in the nuclear fuel cycle. This should include preparing detailed plans for nuclear waste management and a long-term commitment to develop skills in both industry and government.

Recommendations

The government of Chile should:

- Continue to pursue diversification in terms of energy sources and suppliers to enhance energy security, in particular the active development of indigenous energy sources such as renewable energy and energy efficiency.
- Send clear investment signals to the private sector and create a framework to ensure that long-term investment decisions will be based on long-term cost/benefit analysis, including environmental externalities and the downward cost curve of certain technologies.

- Review the effectiveness and coherence of emergency measures currently in place, including the current legal obligation of holding commercial oil stocks and the improved monitoring of these stocks.
- Take account of international discussion of emergency preparedness and move towards harmonising the Chilean system with international best practices, including the current international co-operation centred on the IEA in terms of oil emergency response systems.

3. ENERGY AND ENVIRONMENT

Overview

The Chilean government recognises that Chile's energy development must be compatible with sustainable development and is taking steps to promote sustainable energy policies. Chile is a relatively low emitter of greenhouse gases (GHGs). It is not among the world's top 20 emitters, but emissions are rising as fossil fuel usage increases. Preliminary projections under review by the CNE predict a doubling of the country's GHG emissions between 2008 and 2025.[18] Greenhouse gas emissions from the electricity sector represented approximately one-third of total national emissions in 2008. Chile is vulnerable to climate change and launched a National Action Plan to address its impacts in December 2008. The plan assigns institutional responsibilities for action on adaptation, mitigation and capacity-building for the next four years.

The CNE *Energy Policy: New Guidelines* document, published in 2008, states that energy policy needs to "provide for economic and social needs, while protecting the environment" and reflects a commitment to minimise the local environmental impacts of energy development. The guidelines also acknowledge that energy policies should contribute "to the world effort to reduce GHG emissions without affecting energy development".[19] In common with many countries, Chile faces the difficult challenge of balancing economic growth, energy security and environmental objectives.

Environmental policy in Chile in recent years has been driven by concerns about the health impacts of local pollution, especially in the Santiago Metropolitan Region, and about the environmental performance of industries largely exporting to OECD member countries, as highlighted in the 2005 *OECD Environmental Performance Review of Chile.* According to the OECD Review, to implement its environmental policy, Chile "uses a wide range of instruments (...): environmental impact assessment (EIA), other regulatory instruments, economic instruments (including trading mechanisms), voluntary approaches and planning and information instruments".[20] The Review notes that when addressing air pollution, Chile's energy and environment policies should give more consideration "to the use of fiscal instruments to internalise environmental externalities in the transport and energy sectors".[21]

18. Projections of Greenhouse Gas Emissions in the Energy Sector, *POCH Consultores, July 2009.*
19. Energy Policy: New Guidelines, *CNE, 2008, page 108.*
20. OECD Environmental Performance Reviews: Chile, *2005, page 16.*
21. OECD Environmental Performance Reviews: Chile, *2005, page 19.*

The Chilean government has recently taken steps to encourage sustainable energy options. These include, but are not limited to:

- Regulating fuel quality, ambient air quality and emission standards.
- Drafting and implementing legislation to accelerate deployment of private sector investment in renewable energy in the electricity and transport sectors, as well as in solar thermal energy.
- Increasing financing for research and development in renewable energy technologies.
- Improving energy efficiency.
- Strengthening Chile's energy and environmental institutional framework.
- Finalising the 2006 National Strategy on Climate Change and the National Action Plan on Climate Change (PANCC) in 2008.
- Promoting rural electrification with non-conventional renewable energy (NCRE) sources.
- Deepening regional and international co-operation to share best practices on energy and environmental policies and technology co-operation.

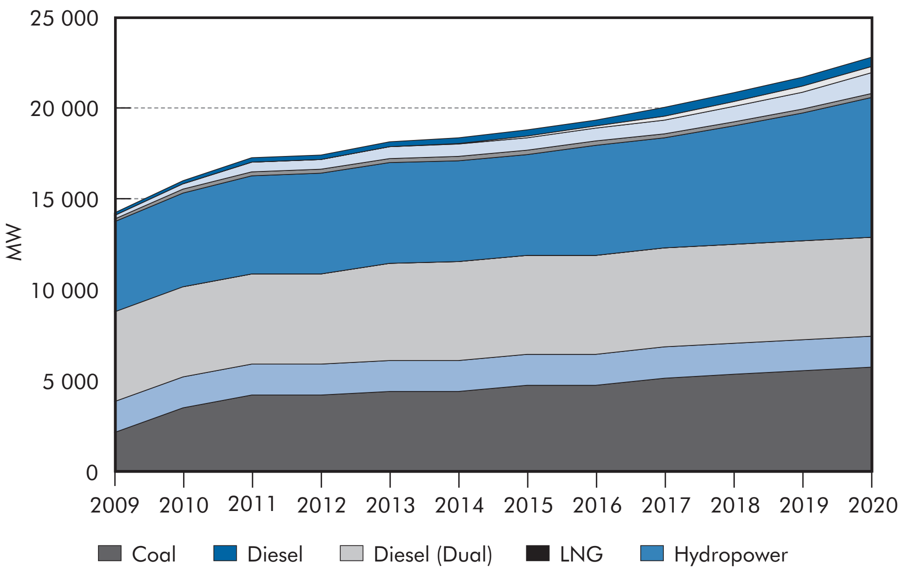
Chile successfully handled the energy crisis that began in 2004 (see Chapter 2: Energy Security). In spite of the crisis, the economy grew while energy consumption per capita fell, and blackouts were avoided. The medium- to long-term implications of the Chilean government's response to the gas supply shortages include an increased reliance on diesel and coal in the electricity sector, which both may have adverse effects on human health if pollution control measures are inadequate. Coal, relative to other fossil fuels, emits the greatest amount of GHGs as well as other contaminants.

The CNE estimates that coal will represent 26% of Chile's installed electric capacity by 2020, compared with 16% in 2008. According to CNE data, as of June 2009, 2 200 MW of coal-fired power plants were under construction (see Chapter 5: Fossil Fuels, Table 5.2), while an additional 4 700 MW were still under consideration. Although it is unlikely that all 4 700 MW will be constructed, these numbers illustrate the potential increase in Chile's coal-fired generation capacity in the near future.

Renewable energy, including large-scale hydropower, has the potential to reduce significantly the use of coal and other fossil fuels in power generation. The CNE April 2009 *Plan de Obras* shows that the rate of coal-fired capacity additions will slow down after 2011, while NCRE sources will see a steep increase throughout the period, and hydropower will substantially increase between 2015 and 2020 (see Figure 3.1). Coal power plants currently under construction are likely to be operating for the next 20 to 30 years, thus effectively "locking-in" future CO_2 emissions from the power sector. According to the same CNE projections, thermal generation will represent 57% of total electric capacity in 2020. The dynamic dimension of new capacity additions warrants close attention from the government to balance energy security and environmental sustainability.

Figure 3.1

Projected Capacity Additions in the SIC and SING to 2020, April 2009



Source: CNE.

Climate Change Impacts and Vulnerabilities in Chile

Several studies by the Intergovernmental Panel on Climate Change (IPCC) and the World Bank (WB) show that Chile is vulnerable to the effects of climate change.[22] These effects include:

- Lower rainfall in the central-southern part of the country.
- Greater variability of rainfall owing to more frequent recurrences of El Niño/La Niña phenomena.

22. *de la Torre, Fajnzylber and Nash:* Low Carbon, High Growth: Latin American Responses to Climate Change, *the World Bank, 2009.*

• Less snow peak accumulation in the high mountains. It is also anticipated that glacier melting will cause a drop in the level of glacial runoff, reducing the supply of water needed for hydroelectricity generation.

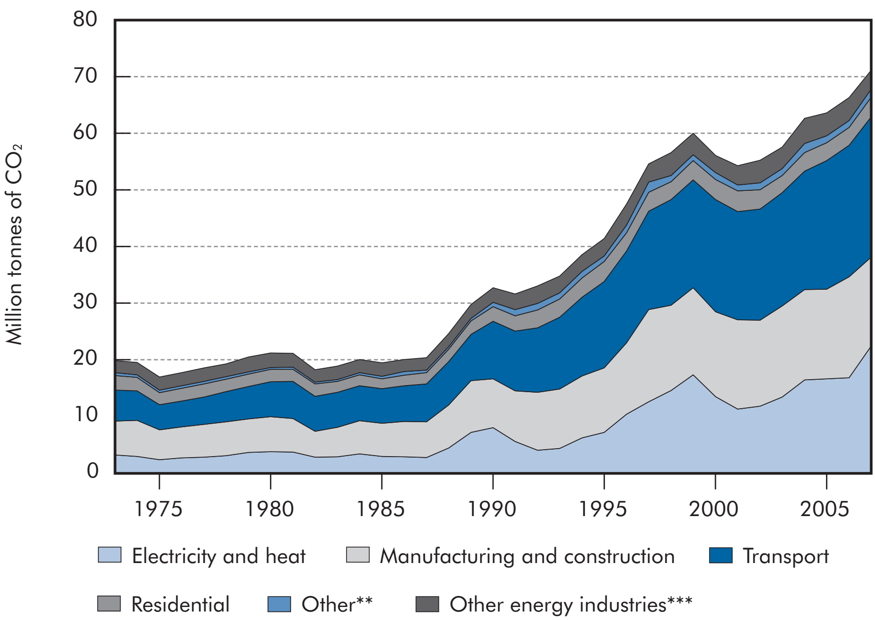
• Rising sea levels with adverse consequences for fish stocks and for yields in agriculture and forests, which are important export sectors.

• More consecutive dry days and longer heat waves by 2030, such that Chile's arid regions are likely to experience severe species loss by 2050.

According to IEA statistics, which exclude emissions from biomass use, total emissions from Chile's energy sector in 2007 represented 71 Mt of CO_2. Emissions per capita stood at 4.2 tonnes of CO_2.[23] Chile's emissions doubled between 1994 and 2007, corresponding to rapid economic growth (see Figure 3.2).

Figure 3.2

Chile CO_2 Emissions by Sector, 1973-2007*



** Estimated using the IPCC Sectoral Approach.*

*** Includes emissions from commercial and public services, agriculture/forestry and fishing.*

**** Includes emissions from fuel combusted in petroleum refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction, and other energy-producing industries.*

Source: CO_2 Emissions from Fuel Combustion, IEA/OECD Paris, 2009.

23. Energy-related CO_2 emissions have been estimated using the IPCC Tier I Sectoral Approach from the Revised 1996 IPCC Guidelines. In accordance with the IPCC methodology, emissions from international marine and aviation bunkers are not included in national totals. Energy-related CO_2 emissions only include emissions from oil, natural gas and coal combustion.

Electricity and heat represented approximately one-third of this total, while emissions from the transport sector accounted for 37%. Oil has historically accounted for the majority of emissions by fuel, and represented 70% of emissions in 2007 (Figure 3.3). GHG statistics from the National Commission for the Environment (*Comisión Nacional de Medio Ambiente* – CONAMA) for the whole economy indicate that emissions from biomass use represent an additional 22 Mt of CO_2 emissions, equivalent to 23% of the country's total emissions of 92.5 Mt in 2008.

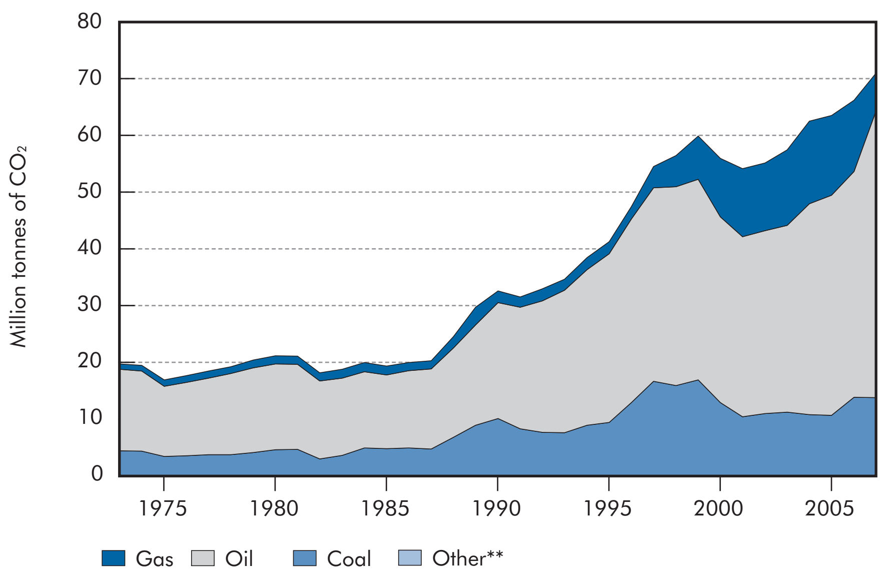
Preliminary projections from studies commissioned by the CNE predict a doubling of the country's GHG emissions between 2008 and 2025.[24] The increase in coal-fired generation will be partly responsible for the near tripling of CO_2 emissions from the electricity and heat sector.

Climate Change Policy

Chile ratified the Kyoto Protocol in 2002 and the United Nations Framework Convention on Climate Change (UNFCCC) in 1995. Chile currently has no

Figure 3.3

Chile CO_2 Emissions by Fuel, 1973-2007*



** Estimated using the IPCC Sectoral Approach.*

*** Includes industrial waste and non-renewable municipal waste (negligible)*

Source: CO_2 Emissions from Fuel Combustion, IEA/OECD Paris, 2009.

24. Projections of Greenhouse Gas Emissions in the Energy Sector, *POCH Consultores, July 2009.*

binding international or national obligations to reduce GHG emissions. The country is an active member in UN-led global climate change negotiations and embraces the principle of common but differentiated responsibilities for a post-Kyoto framework. In a national context, the Chilean government has said that measures to address climate change will not impede economic growth; government policies will only slow the rate of emissions growth, primarily via energy efficiency measures.

Chile participates in extensive bilateral, regional and global co-operative efforts on energy, reflecting an outward-looking approach to energy development. Examples of Chile's multilateral engagement include APEC, IRENA, IAEA, OECD, IEA and UN-led efforts on energy and the environment. At the regional level, Chile participates in UNASUR, ECLAC, MERCOSUR and OLADE initiatives. Chile also developed various bilateral energy co-operation agreements with Spain, Germany, the United Kingdom and the United States, among others. Additionally, there is a range of international private companies operating in Chile's energy sector, and the government has worked to attract private investment to bring renewable and energy efficient technologies to Chile. The Chilean government should be commended for its commitment to learn from and adapt international best practices in Chile.

Chile also participates in market-based mechanisms such as the Clean Development Mechanism (CDM), through which Chile has secured financing for small hydropower projects, landfill gas capture, methane digester and wind projects.

Clean Development Mechanism Projects

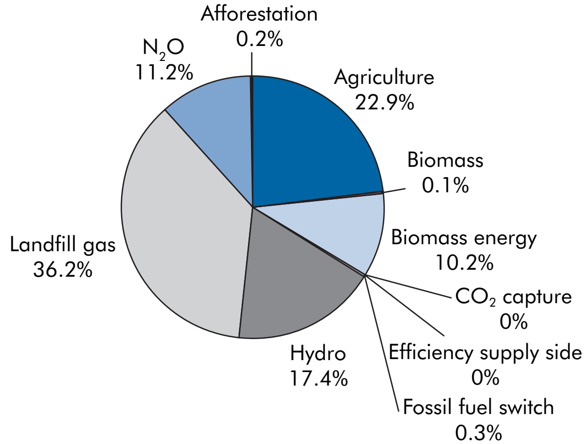
Chile has developed one of the most dynamic portfolios of CDM projects in the world (see Figure 3.4). As of 1 June 2009, some 32 registered projects were expected to deliver about 27 Mt of CO_2 emissions reductions by 2012. In addition, there are 35 projects undergoing validation or awaiting registration. These projects are expected to deliver an additional 11 Mt of CO_2 emissions reductions by 2012. Attesting to the sound establishment CDM mechanisms in the country, Chile currently ranks sixth globally for the volumes of CDM emissions reductions, behind China, Brazil, India, Mexico and Malaysia.

National Action Plan for Climate Change

In December 2008, the Chilean government published a 2008-2012 National Action Plan on Climate Change (PANCC), prepared by CONAMA. The

Figure 3.4

Chile's CDM Projects (Total Pipeline) by Project Type, June 2009



Source: UNEP/Risoe CDM database, updated June 1, 2009.

PANCC complements the 2006 National Strategy on Climate Change and assigns institutional responsibilities for action on adaptation, mitigation and strengthening Chile's capacity to address climate change. Financial resources to support these activities include a guarantee fund of USD 400 million for energy efficiency and renewable energy projects, in addition to public funding for relevant government agencies.

Regarding adaptation, the PANCC identified hydro resources, food production, urban and coastal infrastructure and energy supply as the four areas most vulnerable to climate change.

On the mitigation side, the PANCC details Chile's strategy to transition toward an economy that is less carbon-intensive and that contributes to sustainable development in Chile and to global efforts in reducing the rate of GHG emissions growth. This strategy identifies tangible steps to reduce emissions by targeting sectors with the highest levels of GHG emissions, such as electricity generation, transport, mining, and agriculture. It also includes some efforts in research and development, such as the idea of capturing CO_2 through microalgae.

To strengthen Chile's ability to address climate change, the Chilean government highlights the importance of educating its citizens on environmental issues and climate change. The PANCC seeks to enhance the quality and accessibility of climate change information, and the accuracy of information used in public and private sector decision making. It also calls for a national climate change educational and awareness plan.

Table 3.1

Priority Actions Identified in the PANCC

Action programme 2008-2012 Adaptation	2008	2009	2010	2011	2012	Responsible institution
Generation of climate scenarios at local level	•	•	•			**DMC**
Definition of impact and methods for adaptation when facing climate change in:	•	•	•			
Water resources: determine the level of vulnerability at watershed level		•	•			DGA, CONAMA, INIA, CNR
Biodiversity: identify vulnerable ecosystems, habitat and species		•	•			CONAMA, IGM
Forestry and agriculture: update knowledge of sectors vulnerability in relation to climate scenarios	•	•				MINAGRI, CONAMA, INFOR
Energy: determine the vulnerability of hydroelectric power in Chile	•	•	•			CNE
Infrastructure in urban and coastal areas: evaluate the impact on major infrastructure, coastal and riverside areas and incorporate into planning models		•	•	•	•	MOP, MINVU, DIRECTEMAR, SSM
Fisheries: estimate vulnerability of fish stocks		•	•			ECONOMIA
Health: strengthen health systems in the face of climate change			•	•	•	MINSAL
Formulation of National and Regional Plans for Adaptation to Climate Change			•	•	•	**CONAMA / SECTORES**
Mitigation						
Update emissions data	•	•				
Create a system to annually update national and regional emissions statistics and GHG emissions	•	•				CONAMA, MINMINERIA

Evaluation of the potential for GHG mitigation		•	•			
Determine potential total and regional estimates of emissions reductions	•	•				CNE, MTT, MINECOM, MINVU, MINAGRI, CONAMA
Develop a proposal on potential indicators to monitor the impact of introducing different plans, policies and strategies	•	•				CNE, MTT, MINECOM, MINVU, MINAGRI, CONAMA
Generation of mitigation scenarios in Chile		•	•			
Develop GHG mitigation scenarios for different time horizons (2015, 2020, etc.)		•	•			CNE, MINAGRI, CONAMA
Formulation of National and Regional GHG Mitigation Plans	•	•	•			**CONAMA / SECTORES**
Creation and development of capacities						
Introduction of a national programme of climate change education and awareness		•	•			MINEDUC
Creation of a national research fund on biodiversity and climate change	•	•				CONICYT
Technical and economical evaluation of GHG monitoring network		•	•			DMC, INIA, DIRECTEMAR, SHOA
Develop a national registry of glaciers	•	•	•			DGA, CONAMA, MINDEFENSA
Development of negotiation strategies for Chile in post-Kyoto scenarios		•	•	•	•	CNACG
Strengthening of national institutions for tackling climate change	•	•				CONAMA, MINREL
Design of development instruments to reduce emissions and for adaptation		•	•			CORFO, CONAMA, CNE, INIA, CIREN, INFOR, MTT
Preparation of the Second National Communication	•	•	•			CONAMA

Source: PANCC, CONAMA.

Institutional Framework for Environment Policy

Chile's Regulatory Framework for Environment

There are two main components to Chile's environment system. At the central level, the National Commission for the Environment (CONAMA) is a co-ordinating commission headed by a council of 14 ministers. It is responsible for proposing environmental policies, co-ordinating the formulation and enforcement of environmental norms by various public services, and administering the Environmental Impact Assessment System (SEIA).

At the regional level, Regional Commissions for the Environment (COREMAs) are chaired by regional *intendentes* and include the *intendentes* of the region's provinces, the four regional counsellors, the regional representatives of the main Santiago ministries, and CONAMA. These regional commissions are in charge of approving Environmental Impact Declarations (DIA) or Environmental Impact Studies (EIA) for projects submitted to the SEIA in their region. In case of rejection of an EIA, project developers have the right of appeal to the ministerial council of CONAMA. Chile's Environmental Impact Assessment System is therefore fully decentralised at the regional level.

Although CONAMA and its ministerial council have served as a useful forum to debate and resolve conflicts across sectors, they have not been as effective in proposing environment policies. Moreover, as noted in the 2005 *OECD Environmental Performance Review*, they have been slow in co-ordinating the issue of emission standards and other environmental norms. Furthermore, CONAMA does not have the legal mandate to enforce regulation directly.

The Chilean government recognises the need to reform both the energy and the environmental frameworks to establish a clear separation of functions between policy formulation, technical-economic regulation, and enforcement and oversight. In this regard, two separate legislative bills were introduced in the Chilean Congress in April and June 2008.

The bill to reform Chile's environmental regulatory framework contemplates the creation of a Ministry of Environment with clear policy-making and co-ordination responsibilities, and an Environmental Assessment Service that will administer the SEIA. To enforce environmental regulation, a new Superintendency of the Environment would be empowered to impose higher penalties for compliance failures and, in the case of projects that have received approval for their DIA or EIA, would have exclusive enforcement powers. This is in line with the recommendations of the *OECD Environmental Performance Review.* Finally, the reform would strengthen the Strategic Environmental Assessment (SEA) process by establishing a system for the *ex-ante* evaluation of the environmental impact of public policies to be managed by the Ministry of Environment. The bill also considers the creation of a Ministerial Sustainability Council, which would ensure the integration of environmental concerns in sectoral policies at the government level.[25]

To advance these reforms, President Bachelet appointed new environment and energy ministers on 27 and 29 March 2007, respectively. Both bills were approved by the Chamber of Deputies in the first half of 2009 and are currently being discussed in the Senate.

Regulatory Instruments for Environment Policy

The 1992 *General Environmental Framework Law* establishes a series of environmental management instruments with different objectives such as: establishing environmental quality and emission standards; managing prevention, correction, and compliance; promoting education, research and citizen participation; and generating information.

The key environmental management instruments created in the law include: (i) environmental quality and emission standards; (ii) prevention and decontamination plans; and (iii) the Environmental Impact Assessment System (SEIA).

Environmental Quality and Emission Standards

These procedures seek to establish environmental primary and secondary quality standards,[26] standards for the preservation and conservation of national heritage, and emission standards. CONAMA is responsible for proposing, co-ordinating and approving these standards through its Governing Council. Environmental standards can be characterised as follows:

- Standards should define the levels that warrant the declaration of an emergency and should be promulgated by supreme decree.

25. The Ministerial Sustainability Council has further responsibilities that allow for the integration of environmental concerns in sectoral regulations, including proposing. sustainable policies to the President to be included in sectoral regulations to the President.

26. Standards are considered primary when they protect human health and secondary when they protect other environmental aspects.

- Given that environmental quality objectives do not only respond to technical criteria, they must also be aligned with political concerns reflecting economic, ethical, moral and social aspects. Supreme decrees must carry the signature of the President of the Republic as well as the Ministry of the Presidency and, in the case of primary standards, the Minister of Health. In the case of secondary standards, they carry the signature of the corresponding ministers (agriculture, economy, etc.).

- The mandatory procedure for the approval of standards comprises several stages, including technical and economic analysis, development of scientific studies, consultations with competent public and private organisms, analysis of observations and publicity.

Chile's primary environmental quality standards regulate emissions including: carbon monoxide (CO), sulphur dioxide (SO_2), ozone (O_3), nitrogen dioxide (NO_2), and particulate matter (PM_{10}). CONAMA is now developing a standard for particulate matter of diameter less than 2.5 µm ($PM_{2,5}$), and studying an emission standard for thermoelectric plants that would regulate SO_2, NO_x and PM. Chile currently has no CO_2 reduction targets or CO_2 national emission standards.

In addition, Chile regulates fuel quality and pollutants from the transport sector, including from mobile sources such as motor vehicles and public transport buses. Standards for stationary sources of emissions from incineration and co-incineration are also in place.

Prevention and Decontamination Plans

Pollution prevention and decontamination plans are designed to address pollution in specific areas. The first step for the development of these plans is to declare a particular zone either "latent" or "saturated". A zone is declared latent when the measure of the concentration of pollutants in the air, water or soil reaches between 80% and 100% of the value of the relevant environmental quality standard. An area is declared saturated if measured levels exceed at least one of the environmental standards.

Prevention plans are implemented in latent zones to avoid exceeding environmental quality standards, while decontamination plans aim to rapidly lower pollution levels in saturated zones.

The latent or saturated classification is based on measures carried out or certified by competent public agencies. The procedure is overseen by CONAMA and follows the same process as for the approval of environmental quality and emission standards. These plans are required to: set a target date for achieving the plan's emission reduction goal; identify the parties responsible for compliance and the authorities responsible for supervision; estimate economic and social costs; and propose, when possible, emission compensation mechanisms.

CONAMA is responsible for the development of these plans and must include public and private participation during the design process. They may utilise the following regulatory or economic instruments, as appropriate:

- Emission standards.
- Negotiable emission permits.
- Taxes on emissions or user tariffs incorporating the environmental cost implicit in the production or use of certain goods or services.
- Other incentives to promote actions to improve and restore environmental quality.

Environmental Impact Assessment System (SEIA)

The *General Environmental Framework Law* provides a comprehensive SEIA framework applicable to all public and private investment projects or activities. It states that the projects or activities outlined within the law may be implemented or modified only after an evaluation of their environmental impacts, and that all permits or environmental decisions will be granted according to current legislation or by public agencies through the SEIA.

The law creates a system that includes environmental requirements from all public agencies, known as the "single window" approach. This is made possible through the co-ordination efforts of the respective COREMAs or by CONAMA itself depending on the case, and is formalised through a resolution that certifies that a particular project or activity does (or does not) comply with all applicable environmental requirements. Article 10 of the law establishes that energy projects requiring evaluation include: electricity generation above 3 MW high voltage transmission lines and sub-stations; gas or oil pipelines; resource exploitation; and marine terminals.

The SEIA certificate also indicates the conditions under which the specific permits will be granted during the implementation of the project, including potential mitigation and restoration efforts. If the evaluation is favourable, no public agency may deny the applicable environmental authorisations. If it is negative, public agencies must deny them. It should be noted that environmental resolutions issued by COREMAs or by CONAMA are based on the opinion of involved agencies on the environmental acceptability of a project following review of the documents contained in the Environmental Impact *Declaration* or Environmental Impact *Study*.

There are no uniform emission limits for power plants; however, if a new plant is built in an area with a decontamination or prevention plan, emissions compensation can apply. Operators are then required to report air emissions, which the Health Ministry monitors and publishes on its website. CONAMA is currently co-ordinating the drafting of Emission Standards for Thermal Power Plants *(Norma de Emisión para Centrales Termoeléctricas)*, which aim to regulate emissions – excluding GHGs – from the combustion of fossil fuels, including coal.

Chile regulates a number of air pollutants including: SO_2, arsenic and PM_{10} through decontamination plans. The government is currently developing standards for the use and combustion of biomass in the form of firewood (see Chapter 8: Biomass). As in other countries, the quality of solid fuels such as coal and coke is not regulated, except in designated smoke-control zones.

The process for developing standards and regulations governing emissions, air quality and prevention and decontamination plans must include citizen participation. The *General Environmental Framework Law* also requires that all projects entering the SEIA through EIAs include citizen participation. This is usually the case for large projects. For projects entering the SEIA through DIAs, citizen participation is not mandatory. Throughout the SEIA process, all public and private information regarding the environmental assessment of a specific project is available on the internet (www.e-seia.cl/), ensuring a high level of transparency.

Critique

In common with many countries, Chile faces the difficult challenge of balancing economic growth, energy security, environment and climate objectives. Chile is a developing, middle-income country, but it seeks to further develop its economy and join the OECD. Chile's *General Environmental Framework Law* provides a comprehensive framework for the environmental impact assessment of all public and private investment projects or activities. Furthermore, Chile's environmental regulatory framework is one of the most sophisticated, rigorous and transparent in the developing world.

The CNE *Energy Policy: New Guidelines* clearly acknowledge that energy policy needs to "provide for economic and social needs, while protecting the environment" and show awareness of the need to minimise the local environmental impacts of energy development. The guidelines also recognise that energy policies should contribute "to the world effort to reduce GHG emissions without affecting energy development".[27] In this regard, the Chilean government should be praised for its demonstrated commitment to sustainable energy sources through the active promotion of energy efficiency measures and the development of renewable energy sources in recent years. To be particularly commended is the focus on end-use energy efficiency, which will yield the double benefit of alleviating the pressure to expand generation capacity while avoiding carbon lock-in.

However, the current lack of any formal inter-governmental policy, co-ordination mechanism between the CNE and CONAMA reveals substantial room for improvement in the strategic articulation of energy and environment policies. The CNE currently has no formal participation in environmental institutions in Chile, since it does not participate in the Governing Council either of CONAMA or of the COREMAs. The same is true for CONAMA, which does not formally participate in the CNE Executive Committee. Officials from both organisations recognise that the success of policy co-ordination often depends on personal relationships, which can contribute to a less formal, and at times, *ad hoc* process. Moreover, co-ordination usually occurs at a project level, which may not lead to strategic-level policy development consistent with or supporting Chile's economic, energy and environment objectives.

Formal institutional arrangements, as envisioned in the two legislative bills currently under debate in the Chilean Congress, should be praised as they seek to integrate energy policy with sustainable development at a strategic policy level. To establish formal channels of communication between the two sectors, the Ministry of Energy will be represented into the Governing Council of CONAMA, just as the Energy SEREMIs will be incorporated into the COREMAs and as such will participate in the Environmental Impact Evaluation System. The integration of energy and environment policies should also be clearly articulated in Chile's long-term energy policy document. In this regard, the IEA supports the two bills currently debated in the Senate.

As evidenced by the CNE April 2009 *Plan de Obras*, investment in new coal-fired capacity additions is currently expanding at a much faster rate

27. Energy Policy: New Guidelines, *CNE*, *2008*, *page 108*.

than investiment in renewable energy sources. Environmental externalities in Chile are partly internalised in the current environmental regulatory framework. However, while air quality standards define targets, they do not clearly define emission limits for individual plants to achieve these targets systematically, especially in areas with multiple sources of pollution. Absolute emission standards for thermoelectric plants do not yet exist in Chile.

Emission standards for thermal power plants, which aim to regulate emissions (excluding GHGs) from the combustion of fossil fuels, have been under debate since 2004. Such standards, if uniformly applied to thermoelectric plants would provide a sound basis for effective pollution control.The government of Chile should therefore introduce without delay uniform and enforceable pollutant emissions standards for thermoelectric plants. In addition, as contemplated in the proposed environment bill, the government should also strengthen the enforcement of current air quality standards, as well as technical capacity to monitor and evaluate their impact. In this regard, the IEA supports the underlying principles of the proposed creation of a Ministry of Environment with clear policy-making and co-ordination functions, as well as the proposed creation of a Superintendency of the Environment in charge of ensuring environmental compliance.

In the longer term, the harmonisation of energy and environment policies will need a strong framework of regulation and incentives to ensure that the competitive market internalises environmental and social costs. This will send clear signals to the private sector so that long-term investment decisions will be based on long-term cost/benefit analysis, including environmental externalities and the downward cost curve of certain technologies. This recommendation also applies to the transport sector, where the application of fully cost-reflective pricing of transport fuels, roads and modes is also important to facilitate the transition to a more sustainable energy system. In general terms, the IEA notes that the full cost of power generation will not be internalised until GHG emissions and carbon abatement costs are reflected in the SEIA or through other means.

Increasing concerns about climate change and the possibility of an international post-Kyoto climate agreement make energy and environment policy co-ordination in Chile even more important. The National Action Plan on Climate Change is a step in the right direction, as it contains useful diagnostic information, highlights specific consequences from Chile's emissions, and presents a course of action for the next four years with measurable objectives.

Preliminary projections under review by the CNE predict a doubling of the country's GHG emissions between 2008 and 2025.[28] The increase in coal-fired generation will be partly responsible for the near tripling of CO_2 emissions from the electricity and heat sector. The government of Chile should consider formulating a national GHG emissions mitigation strategy with indicative objectives, both nationally and at the sector level as contemplated in the PANCC. Such a strategy would avoid the risk of locking-in future CO_2 emissions in the electricity sector and prepare Chile's economy for a possible post-Kyoto international climate agreement. This is especially relevant since consumers in export markets may progressively demand environmentally sustainable goods and services from Chile (*i.e.* with lower carbon footprints). OECD member countries currently account for 48% of Chile's total exports.

Like other countries in the world, Chile faces the challenge of defining sound approval processes for strategic projects. A number of electricity megaprojects (*i.e.* larger than 1 000 MW) are currently under evaluation in the Environmental Impact Assessment System, including: HydroAysén (2 759 MW, hydro); Castilla (2 350 MW, thermal); Energía Minera (1050 MW, thermal); and Río Cuervo (1 000 MW, hydro). Power projects of this scale can test public acceptance and can lead to significant opposition and political polarisation. Government, projects developers, stakeholders and local communities can all experience unnecessary, lasting, negative consequences as a result of not gaining public acceptance, or worse, invalidation of environmental permits to build those projects, causing significant project delays and financial losses. As pointed out by the CNE, part of the complexity involved in such projects stems from the fact that "while the project may benefit the system as a whole, the impacts and costs are local".[29] Moreover, in some cases such as nuclear energy power projects, megaprojects may have national strategic and defense implications, and are therefore unfit for environmental evaluation at the regional level. Such projects may also put undue long-term political pressure on the SEIA, which is founded on technical evaluation and does not include public consultation instruments at the national level.

Given the strategic importance of some of the electricity projects currently under consideration in Chile, including large fossil-fired plants, large

28. Projections of Greenhouse Gas Emissions in the Energy Sector, *POCH Consultores, July 2009.*
29. Energy Policy: New Guidelines, *CNE, 2008, page 111.*

hydropower projects and the nuclear energy option, the government should conduct a review of international best practice regarding environmental evaluation processes of this type of projects (as has been done in countries such as the United States, Japan, the United Kingdom, France and Norway, among others). Given the issues at stake, the government should take a leadership role in developing national public consultation mechanisms with the aim of fostering support across the political spectrum. This would ensure long-term consensus and share the associated political cost of such decisions.

Recommendations

The government of Chile should:

- Regularly evaluate the effectiveness of Chile's inter-governmental ministerial policy co-ordination in integrating economic growth, energy security and environmental sustainability goals. Chile should create a formal, inter-ministerial co-ordination process that considers strategic decisions and involves all relevant ministries.
- Send clear investment signals to the private sector and create a framework so that long-term investment decisions will be based on long-term cost/benefit analysis, including environmental externalities and the downward cost curve of certain technologies.
- Introduce without delay uniform and enforceable pollutant emissions standards for thermoelectric plants, and strengthen the enforcement of current air quality standards and technical capacity to monitor and evaluate their impact.
- Formulate a national GHG emissions mitigation strategy with indicative objectives both nationally and at the sector level to prepare Chile's economy for a possible post-Kyoto international climate agreement.
- Conduct a review of international best practice regarding environmental evaluation of strategic electricity megaprojects.

4. ENERGY EFFICIENCY

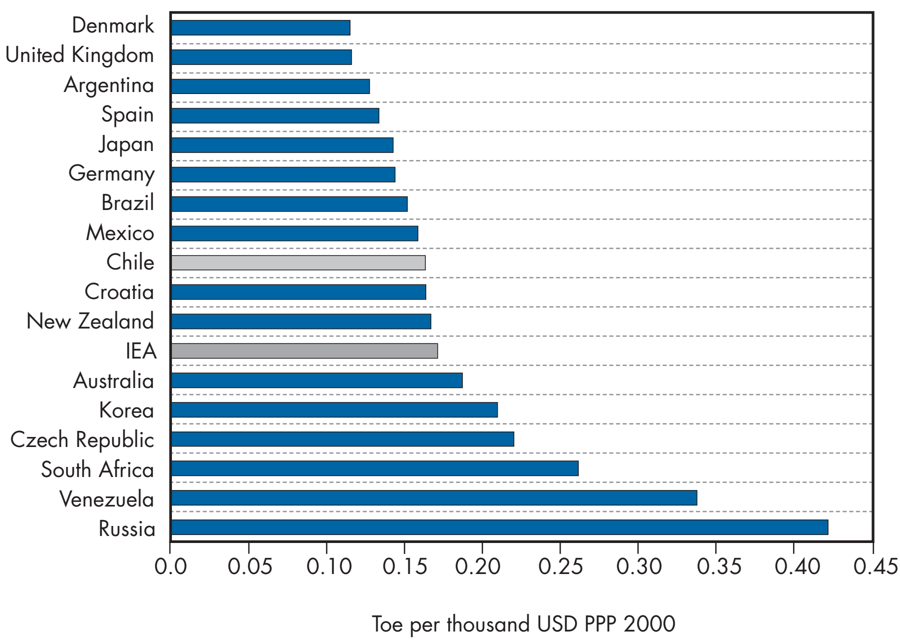
Overview of Energy Efficiency Trends

As in many other countries, energy security concerns and growing energy demand mean that energy efficiency is becoming an increasingly important part of Chile's energy policy. Chile has experienced significant growth in energy consumption over the past few decades, particularly in the electricity sector. Final energy consumption grew by 2.8% per year on average over the past ten years, while electricity consumption increased on average by close to 6% per year.

Chile's primary energy intensity is low by comparison with some developed countries, but higher than Brazil and Mexico.[30] In 2007, Chile's energy

Figure 4.1

Total Primary Energy Supply per GDP (PPP) in Selected Countries, 2007



Source: Energy Balances of OECD and non-OECD countries, IEA/OECD, 2009.

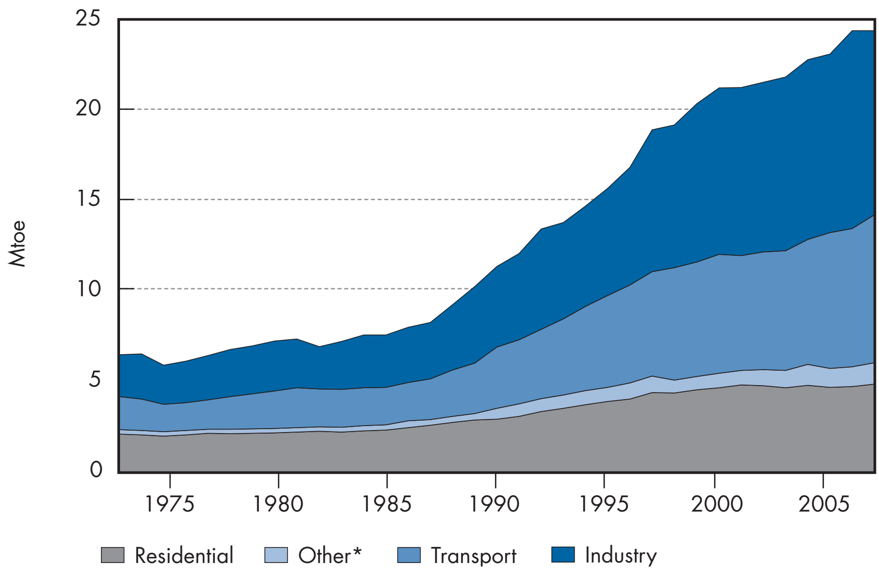
30. Energy intensity is the amount of energy used per unit of activity. It is commonly calculated as the ratio of energy use to GDP in real terms. Energy intensity is often taken as a proxy for energy efficiency, although this is not entirely accurate since changes in energy intensity are a function of changes in several factors including the structure of the economy, impacts of changes in economic activity and final energy use in different sectors. For a detailed discussion of the energy efficiency indicators, please see Energy Use in the New Millennium, *International Energy Agency (2007).*

intensity was 0.16 toe/thousand USD[31] close to average intensity for IEA countries of 0.17 toe/thousand USD (see Figure 4.1).

According to IEA data on the energy balance of Chile, total final energy consumption (TFC) in the country amounted to 24.55 Mtoe in 2007. The industrial sector, including the mining sector, consumes the most energy with 42% of TFC (see Figure 4.2). The transportation sector is the second highest, at 33%, while the services-residential sector accounts for 20%. Other sectors, such as commercial, public service, agriculture and fishing, make up the remaining 5%.

Figure 4.2

Chile's Total Final Consumption by Sector, 1973-2007



** Includes commercial, public service, agricultural, fishing and other non-specified sectors.*

Source: Energy Balances of non-OECD Countries, IEA/OECD Paris, 2009.

Industrial and Mining Sector

In 2007, the industrial sector, including mining, consumed the most energy with 42% of TFC. Petroleum derivatives (33%), electricity (24%) and biomass (26%) accounted for 83% of total sector final consumption. Industrial sector energy intensity has followed a similar path to other

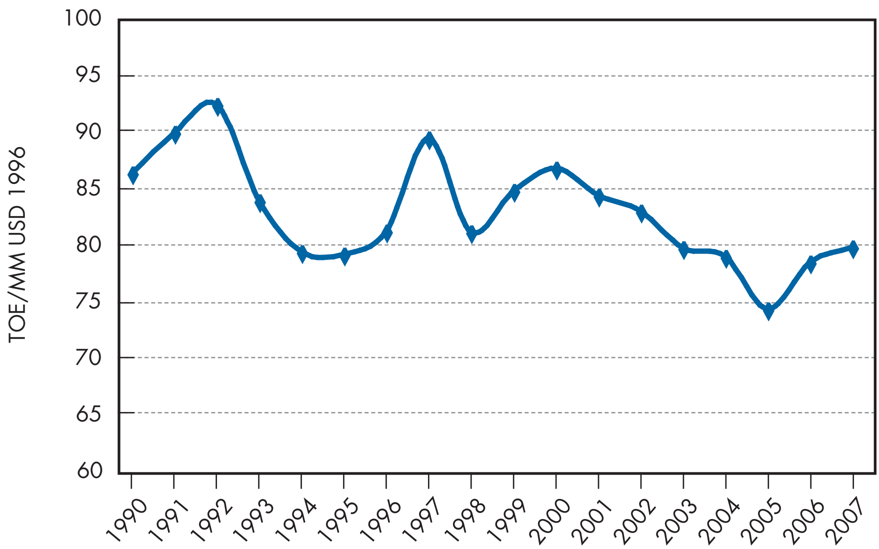
31. Key World Energy Statistics, IEA, 2009.
Tonne of oil equivalent per thousand USD at 2000 prices and exchange rates.

sectors and has declined progressively since 2000. Interestingly, industrial sector energy intensity in 2000 was similar to its 1990 level. Detailed data on structural changes in the economy and specific end-use consumption are required to fully analyse these trends.

The mining sector is a key industrial sector in Chile and accounts for 16% of TFC. Electricity is the most significant energy source for the mining sector, accounting for 50% of total consumption. Petroleum derivatives constitute 46% of the sector's consumption.

Figure 4.3

Energy Intensity in the Industrial and Mining Sector, 1990-2007



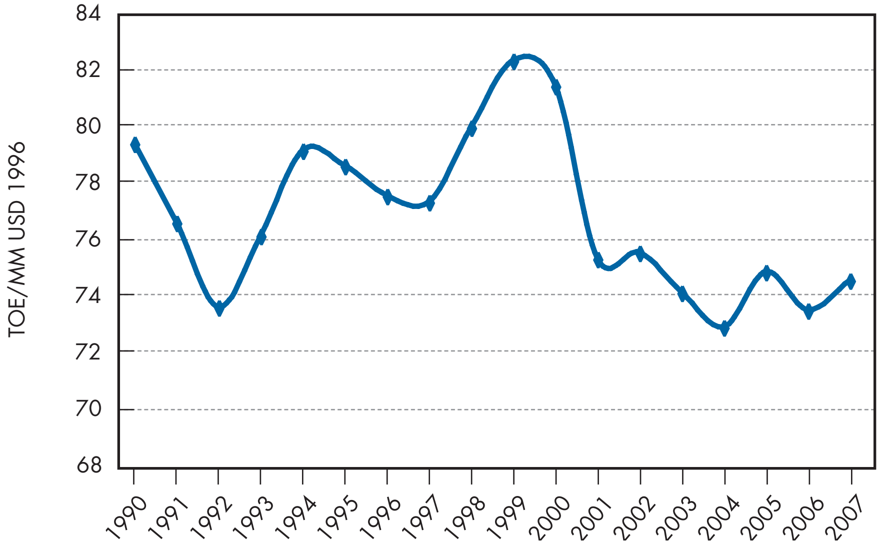
Source: Prepared by the CNE based on data from the Central Bank (industrial and mining sector GDP) and CNE (industrial and mining sector energy consumption)

Transport Sector

Sectoral trends show a fall in energy intensity in the transport sector since 2000. In 2007, transport was Chile's second-largest energy consumer, accounting for 33% of TFC, the majority of which is derived from petroleum derivatives (99% of total transport energy demand). Energy intensity in the transport sector fell by 10% from 1999 to 2004, and has since remained relatively stable (see Figure 4.4).

Figure 4.4

Energy Intensity in the Transport Sector, 1990-2007



Source: CNE based on data from the Central Bank (transport GDP) and CNE (transport sector consumption).

Residential Sector

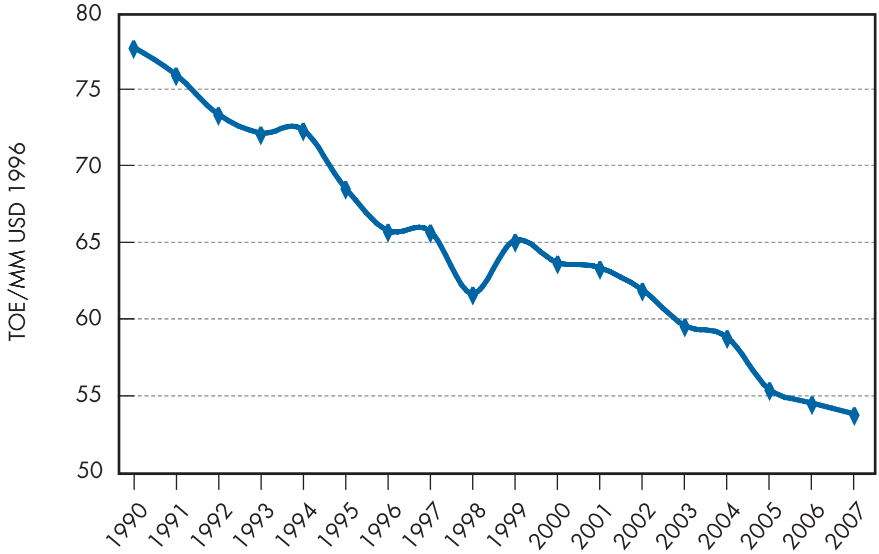
In 2007, the residential sector accounted for 20% of TFC. A distinctive aspect of this sector is the significant role of biomass in the form of firewood as an energy source. Firewood accounts for 57% of total residential energy consumption and is used mostly for heating and cooking. It should be noted that biomass consumption data are still grossly estimated due to the complexity and informal nature of the biomass market, and is therefore subject to wide margins of error. Electricity and petroleum derivatives are of almost equal importance in terms of final sector demand (15% and 20%, respectively). Natural gas has increased in importance, now representing 8% of final consumption in the residential sector. The energy intensity of Chilean homes has tended to fall since 1990 (see Figure 4.5).

Outlook

Despite improving energy intensity across all sectors since 2000, there is still significant potential for enhancing energy efficiency in Chile. A recent study by the Energy Studies and Research Programme (*Programa de Estudios e Investigaciones en Energía*, or PRIEN) at the *Universidad de Chile* estimated the potential for energy efficiency in the economy's largest

Figure 4.5

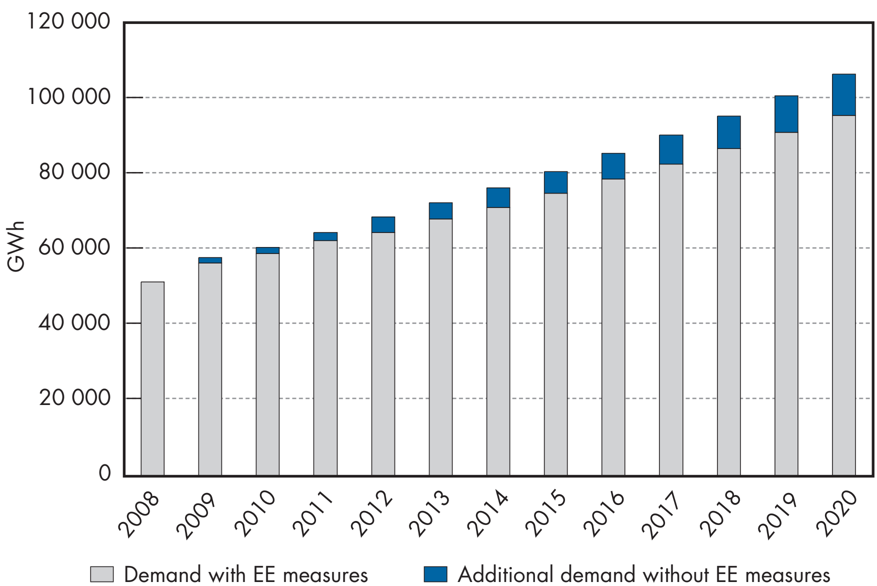
Energy Intensity in the Residential Sector, 1990-2007



Source: CNE based on data from the Instituto Nacional de Estadísticas (number of residents) and CNE (energy consumption in the residential sector).

Figure 4.6

Energy Demand Projection to 2020 with Energy Efficiency Measures



Source: CNE.

consumption sectors. The study estimated that incorporating energy efficiency measures could reduce total demand by about 20% in 2021.

Based on this analysis and an understanding of the current energy efficiency situation in Chile, the CNE *Energy Policy: New Guidelines* document proposes an energy savings target of 20% of incremental demand to 2020 for the electricity sector alone (see Figure 4.6). The CNE estimates that reducing incremental consumption by 20% in the 2008-2020 period will reduce the additional installed capacity needed by 1 600 MW (or slightly more than 11% of the total).[32]

Energy Efficiency Policy Direction

Chile's approach to promoting energy efficiency has changed over time. Until a few years ago, the government's main instrument to encourage energy efficiency was to ensure that energy pricing mechanisms were as efficient as possible. The predominant view was that an unfettered market and fully cost-reflective energy prices would result in an optimally efficient use of energy. In this situation the marginal benefit to an end consumer of using an additional unit of energy would be equal to its marginal cost. Nonetheless, the government made occasional attempts to promote energy efficiency through specific measures (*e.g.* the Conservation and Rational Energy Use Programme, known as CUREN) – although these were not long-lasting and did not have a major effect.

The general approach to energy efficiency changed in 2005, when the government began to develop an energy efficiency policy and included it as one of the central elements in its strategic priorities for energy. In 2008, the government announced that it would establish an energy efficiency policy by taking four steps:

1. Establish the institutional framework for energy efficiency.

2. Build a suitable knowledge base.

3. Promote energy efficiency across all sectors.

4. Provide incentives for energy efficiency, particulary in the electricity market.

Current Institutional Framework

The CNE recognises the importance of strong institutions in the country's energy policies. The CNE *Energy Policy: New Guidelines* document states that "the ability

32. *CNE, 2008, p.77.*

to take action... will depend on having institutional, organisational and regulatory structures that are truly capable of handling these challenges... Well-functioning institutions are the foundation of any effective policy".

In December 2005, the National Energy Efficiency Programme (*Programa País de Eficiencia Energética* – PPEE) was created by a decree signed by the then Minister of Economy and Energy; the Secretariat General of the Presidency; and the ministers of: Public Works; Transport and Telecommunications; Education; Housing and Urbanism; and Mining. The PPEE is the main mechanism through which the Chilean government's energy efficiency policy and programmes are developed and implemented.

In early 2008, the PPEE was officially transferred to the CNE as part of the institutional reorganisation of the sector (see Chapter 1: General Energy Policy). Since the creation of the PPEE, energy efficiency has become one of the central elements of the government's energy policy and has gathered increasing momentum since early 2008. Strong political support for energy efficiency in recent years has made possible a new institution for energy efficiency. Indeed, the annual budget allocated to the PPEE has grown from USD 1 million in 2006 to more than USD 34 million in 2009.

From the outset, a strong relationship and involvement with the private sector has been a key feature of the PPEE. In developing the PPEE, a committee was created that included representatives from the most relevant state institutions, the private sector, local government and civil society. The mission of the PPEE is "to consolidate energy efficiency as a source of energy that contributes to Chile's sustainable energy development." To achieve this, the PPEE has defined a series of strategic objectives:

- Establish the institutional foundations and regulatory framework for energy efficiency.
- Develop incentives and support tools for energy efficiency.
- Develop useful and accessible information for making public and private decisions, as well as collective and individual ones.
- Position and introduce energy efficiency in all levels of training, both formal and informal.
- Take advantage of international experiences and instruments to accelerate the development of energy efficiency and measure the reduction in generated emissions.
- Strengthen institutional management through process quality.

The PPEE functions with an Executive Secretary, an Advisory Council and an Operating Committee. The Advisory Council, which meets twice a year, includes ministerial representatives and high-level representatives from the private sector. It provides continuous advice to relevant ministries on the focus of energy efficiency policies. The Operating Committee, which meets periodically, is comprised of representatives from various public sector, civil society and private sector institutions. It provides guidance to the PPEE on policy formulation and operational functioning.

One of the key tasks of the PPEE during 2009 will be the development of the ten-year Energy Efficiency Action Plan (EEAP) for 2010-2020. The EEAP will further articulate priority interventions, goals, evaluation tools and the corresponding financing. Stakeholder participation in the development process will be a key element in achieving broad-based support for the priorities identified in the EEAP.

Baselines for the main energy consumption sectors will be determined as an input for this plan. The Lawrence Berkeley National Laboratory (LBNL) is providing technical support to the PPEE to develop the methodologies for the construction of energy savings cost curves, the analysis of public policy instruments derived from the results, and the development of long-term capacity in this area.

Future Energy Efficiency Institutional Framework

Chile is currently reforming its energy institutional framework. The main reform is the creation of a Ministry of Energy, which will centralise the functions of developing, proposing and evaluating public policies related to energy. This will include defining objectives, regulatory frameworks and strategies and developing public policy instruments. While the proposed Ministry of Energy will be responsible for developing policies and regulatory functions including those related to energy efficiency, new agencies such as the *Agencía Chilena de Eficiencia Energética* (ACHEE) will be responsible for energy efficiency programme delivery and implementation. The legislation creating the Ministry of Energy will also establish ACHEE.

Since the bill is currently under debate in Congress, it is unclear what the exact form of ACHEE's governance structure will be. The agency's functions are likely to focus on activities for which it has a comparative advantage, such as technical assistance and the execution of programmes that require logistical expertise and co-ordination across different participants, leaving energy efficiency policy in the hands of the proposed Ministry of Energy.

Sectoral Energy Efficiency Policies

Commercial, Residential, Public Sectors

The initial focus of Chile's energy efficiency activities after 2005 was on the residential sector. Based on available end-use data, it achieved the following results:

- A reduction in electrical demand through widespread adoption of compact fluorescent lamps (CFLs) for residential lighting.
- Energy labelling for refrigerators, incandescent light bulbs and CFLs.
- Development of minimum mandatory standards for roofs since 2000 and minimum mandatory standards for envelope insulation in new homes since 2007, with planned revision of the standards by 2015.
- Design tools for energy efficient new buildings, including energy consumption simulation.
- Insulation retrofit programmes for existing homes.
- An energy certification programme for residential buildings.

In the public buildings sector, energy efficiency programmes have been restricted to energy audits and initial data gathering. Energy audits have been conducted on more than 20 buildings, with measures taken to implement the recommendations from the audits in two facilities. One audit assessed the La Moneda Palace, seat of the President of the Republic of Chile, which will serve as a demonstration project. Data collection on public buildings energy use continues and will be used in the development of energy efficiency guidelines. Recently, a working group including the PPEE and the ministries of Housing and Urbanism, Public Works, Health, and Education, has been established for this purpose.

Industrial and Mining Sectors

Energy efficiency programmes in the industrial and mining sectors have focused on conducting energy audits and implementing their recommendations. Audits and implementation projects are co-funded with public resources and are directed at all but the largest companies (*i.e.* those with more than USD 30 million in revenues).

Together with the Chilean Economic Development Agency (CORFO), the National Energy Efficiency Programme created the *Programa de Preinversión* *en Eficiencia Energética* (Energy Efficiency Pre-investment Programme–PIEE), which enables companies with net annual sales of up to approximately USD 37 million to hire consultants or conduct audits to quantify potential energy savings and to develop an improvement plan. CORFO covers up to 70% of the total cost of the audit, up to a maximum of CLP (Chilean Peso) 6 million (USD 11 000). Between January 2007 and January 2009, 192 projects were evaluated and 67 were completed.

Transport

Chile is almost totally dependent on imported oil and the transport sector is expected to experience one of the largest increases in energy consumption by 2030 (see Chapter 10: Transport). Current policies and measures to improve efficiency in the transport sector are primarily directed at three segments: freight transport, light-duty vehicles (private cars and collective taxis) and non-motorised transport.

Policies relating to freight transport energy efficiency have focused on three aspects: incentives to promote the renewal of the freight transport fleet (through subsidies and soft credit with the aim of replacing 500 trucks in 2009-2010); eco-driving training (with the aim of training 1 000 drivers by the end of 2009); and the provision of technical assistance in terms of maintenance and fleet management for urban and inter-urban freight transport companies. Chile expects a reduction of between 5% and 10% in the fuel consumption of those participating in eco-driving.

There are two main elements of the energy efficiency policy for light-duty vehicles: an incentive programme for the purchase of hybrid vehicles and planned vehicle fuel economy labelling. Labelling regulations and their implementation schedule are pending. To promote non-motorised transport, studies have identified places for bicycle parking, along with promotional campaigns to students. For further analysis see Chapter 10: Transport.

Appliances

In the past two decades, IEA countries have tended to adopt two main policies to improve the energy efficiency of energy-related appliances and equipment:

- ***Energy information labelling:*** product labels that identify the efficiency and/or usage of products for sale, sometimes in relation to similar models.

- ***Minimum energy performance standards (MEPS):*** regulatory restrictions that require models for sale to be no less efficient than a designated level.

Since 2005, Chile has started to develop a product labelling programme. The programme uses the European comparative labelling scheme, which divides all similar models of a product into one of seven efficiency categories, A (most efficient) through G (least efficient). This has been applied to five product types in Chile (two-door refrigerator-freezer, one-door refrigerator, freezer, incandescent light bulbs, and CFL with ballast), with another five to six planned in 2009 and 2010 (single and double casket fluorescent lamps, squirrel-cage 3-phase induction motor, standby for microwave ovens, and air conditioners). Products covered so far are strictly for residential applications, with future coverage aimed at residential to small commercial applications. There are currently six certifying entities authorised by the SEC, and three testing laboratories for energy efficiency protocols.

Chile has not yet implemented a mandatory minimum energy performance standard. However, the bill that proposes the creation of the Ministry of Energy incorporates the authority for the minister to establish labelling programmes and set minimum energy performance standards for a broad set of appliances and equipment. The authority given to the minister represents a clear mandate in the way forward on energy efficiency policy. Additionally, a senator recently presented a bill to Congress to establish MEPS for light bulbs, which considers the phase-out of low efficiency light-bulbs in a period of six years.

Retrofit Projects and Project Financing

Retrofitting of existing buildings and facilities, especially when coupled with strong project financing schemes, has proven to be an effective energy-savings approach in most IEA member countries. The National Energy Efficiency Programme has attempted to promote retrofit projects in public sector facilities, as well as small- and medium-sized enterprises. The heart of the strategy has been the subsidy of energy audits, and the creation of a low-interest loan programme by CORFO. However, uptake of loans has been slow (only two banks have signed contracts in the eight months since the programme's inception) and a revised loan guarantee programme is being developed that will aim at still lower interest rates.

Fundación Chile is leading a project with financing from the Multilateral Investment Fund of the Inter-American Development Bank (IADB) to promote performance contracting with small- and medium-size energy service companies (ESCOs), along with third-party financing. Loans for this initiative are also available through the CORFO-backed lending programme described above. As with the PPEE retrofit initiative, this effort is generating strong interest from energy consultants, with 30 audits completed. However, it has similarly encountered barriers with prospective lenders.

The PPEE is also developing a Global Environment Facility (GEF) project to address energy efficiency project financing.[33] This project seeks to establish the foundations for the development of an energy efficiency market. Its main components include the development of financial instruments to promote the energy services market, technical assistance and pilot projects (technological and financing models).

Engagement in International Energy Efficiency Policy

Chile seeks to participate actively in international energy organisations. It recognises that this participation will help domestic policy making by enabling Chile to learn from the experiences of other countries and to share its own experience. As a result, Chile has forged closer ties with a range of national energy efficiency agencies (in Spain and France, for example) as well as with international institutions including the IEA and the Asia Pacific Economic Co-operation Forum. The Chilean government is directly incorporating policy lessons in the design of the institutional framework and policy formulation for energy efficiency in Chile. Additionally, from its beginning, the PPEE sought the advice of world-leading institutions on energy efficiency, such as the Lawrence Berkeley National Laboratory and the Regulatory Assistance Project, for its technical and public policy decisions. The country is also considering joining the newly established International Partnership on Energy Efficiency Collaboration (IPEEC), as well as some of Implementing Agreements focused on end-use technologies that are part of the IEA international technology network.

Critique

The Chilean government should be praised for developing an emerging energy efficiency policy portfolio with determination and vision. Looking

33. PROJECT CH-X1002 "Promoting and strengthening an energy efficiency market in the industrial sector in Chile" (total grant amount of USD 5.5 million).

to the future, however, several areas warrant further attention when considered in relation to the broad suite of potential cost-effective energy efficiency policies recommended by the IEA (see Box 4.1).

Data, Monitoring and Evaluation

Robust, accurate and timely energy statistics are essential for developing and monitoring a high-quality energy efficiency policy. Chile has a useful set of energy statistics and is attempting to use them as extensively as possible. However, primary indicators are not sufficient for understanding the driving forces behind the changing patterns of energy consumption or for analysing the role of energy efficiency in the economy. In Chile, disaggregated energy end–use data fundamental for energy efficiency policy are still patchy. Lack of data – or not having the right data – may lead to misinformed policy decisions and sub-optimal choices that prove to be far more costly in the long term. Chile is therefore planning to address this in part by conducting decomposition analysis to understand sectoral and activity changes on energy intensity.

There is potential to improve significantly the quality and coverage of energy statistics in Chile. On the demand side, the PPEE and the CNE are working to fill the energy efficiency data vacuum through sector studies and to improve the energy balance, aggregate and sectoral energy intensity data. The institutions for data collection are now in place to improve data quality. However, they need to be strengthened and given adequate authority and resources to carry out their mission. In this regard, the bill to create a Ministry of Energy and the proposed institutional reorganisation of the sector should facilitate the centralisation and harmonisation of all energy information. In this new framework, the proposed Ministry and the PPEE should collaborate closely on the collection and analysis of end-use consumption data to avoid duplication and inconsistencies.

The PPEE current design process for energy efficiency programmes includes an *ex ante* evaluation of their impacts. However, Chile urgently needs to develop systems and capacity for independent monitoring of on-going programme performance and *ex-post* verification of energy savings. This is especially important to provide feedback for designing and implementing public policies, and for public accountability on the use and impact of resources invested in energy efficiency given the scaling-up of the project in recent years.

Box 4.1: The IEA 25 Energy Efficiency Recommendations

The IEA recommends that countries adopt and urgently implement a package of 25 measures across seven priority areas: cross-sectoral activity; buildings; appliances; lighting; transport; industry; and power utilities:

- The IEA recommends action on energy efficiency *across sectors*. In particular, the IEA calls for action on:
  - Measures for increasing investment in energy efficiency;
  - National energy efficiency strategies and goals;
  - Compliance, monitoring, enforcement and evaluation of energy efficiency measures;
  - Energy efficiency indicators;
  - Monitoring and reporting progress with the IEA energy efficiency recommendations themselves.
- *Buildings* account for about 40% of energy used in most countries. To save a significant portion of this energy, the IEA recommends action on:
  - Building codes for new buildings;
  - Passive energy houses and zero-energy buildings;
  - Policy packages to promote energy efficiency in existing buildings;
  - Building certification schemes;
  - Energy efficiency improvements in glazed areas.
- *Appliances and equipment* represent one of the fastest-growing energy loads in most countries. The IEA recommends action on:
  - Mandatory energy performance requirements or labels;
  - Low-power modes, including standby power, for electronic and networked equipment;
  - Televisions and "set-top" boxes;
  - Energy performance test standards and measurement protocols.
- Saving energy by adopting efficient *lighting* technology is cost-effective. The IEA recommends action on:
  - Best practice lighting and the phase-out of incandescent bulbs;
  - Ensuring least-cost lighting in non-residential buildings and the phase-out of inefficient fuel-based lighting.

- About 60% of world oil is consumed in the *transport* sector. To achieve significant savings in this sector, the IEA recommends action on:
  - Fuel-efficient tyres;
  - Mandatory fuel efficiency standards for light-duty vehicles;
  - Fuel economy of heavy-duty vehicles;
  - Eco-driving.
- To improve energy efficiency in *industry*, action is needed on:
  - Collection of high quality energy efficiency data for industry;
  - Energy performance of electric motors;
  - Assistance in developing energy management capability;
  - Policy packages to promote energy efficiency in small- and medium-sized enterprises.
- *Energy utilities* can play an important role in promoting energy efficiency. Action is needed to promote:
  - Utility end-use energy efficiency schemes.

Implementation of IEA energy efficiency recommendations can lead to cost-effective energy and CO_2 savings. The IEA estimates that if implemented globally without delay, the proposed actions could save around 8.2 Gt CO_2/year by 2030. This is equivalent to one-fifth of global reference scenario energy-related CO_2 emissions in 2030. Taken together, these measures set out an ambitious road map for improving energy efficiency at a global scale (for more information visit: www.iea.org/textbase/papers/2008/cd_energy_efficiency_policy/index_EnergyEfficiencyPolicy_2008.pdf).

Institutional Framework

The establishment of the PPEE in 2005 was a positive step for Chile's energy efficiency policy. The PPEE has since established co-operative relationships and links with relevant government agencies, including the Ministry of Housing, the Ministry of Transport, the Ministry of Public Works and CORFO, as well as with a range of companies and organisations in the private sector.

In part because of the PPEE, there is currently broad-based support for energy efficiency in Chile. This support extends from the Minister for Energy to the general public who responded positively to an energy efficiency information and education campaign during the energy supply crisis of 2008. Since the inception of the PPEE, strong government support for energy efficiency has been reflected in a progressive increase in the annual PPEE budget – from USD 1 million in 2006, USD 2.4 million in 2007, USD 9 million in 2008 to USD 34 million in 2009.

The proposed bill proposes the restructuring of the PPEE along two main functions: energy efficiency policy advice and formulation will be transferred to an energy efficiency department within the Ministry of Energy, while the Chilean Energy Efficiency Agency (ACHEE) will be responsible for programme execution. The PPEE as such will no longer exist.

The establishment of ACHEE will therefore strengthen the institutional framework for energy efficiency by providing a dedicated implementation arm to the Ministry of Energy. Founding the agency through legislation should also ensure its long-term support despite shorter-term changes in political, economic and market-operating environments. A legislative mandate should also provide the agency with necessary authority to conduct its business. However, two areas of potential concern remain.

First, the government of Chile must ensure that it establishes the most appropriate governance structure for ACHEE. One option under consideration includes the direct involvement of private sector representatives on ACHEE's Board. Experience has shown that the direct involvement of the private sector may put the design and implementation of the programme at risk of being biased or undermined by the vested interests of the private sector. The IEA, in line with the APEC energy efficiency review, recommends that the responsibility for governance of the agency should be located entirely within the public sector. Aware of this risk, the government has included various controls in the proposal under consideration in Congress and has limited the private participation to a minority in the Board in order to minimise that risk. Special attention should also be given to this risk during the implementation of the new agency.

However, it is important for ACHEE to have direct and continuing access to advice from the private sector, alongside diverse expertise and experience from academics, NGOs, consultants and other groups with a stake in accelerating the uptake of energy efficiency measures. Accordingly, a permanent advisory committee should also be established with wide representation from the private sector, civil society and consumer organisations to provide ACHEE with expert advice on energy efficiency programme operationalisation and implementation.

Second, it is critical that the new energy efficiency institutions be established without delay, so that broad-based support for energy efficiency in Chile continues through the forthcoming period of political change. It is essential that the current momentum in developing and implementing energy efficiency programmes, including the Energy Efficiency Action Plan, continues after the December 2009 elections.

Energy Efficiency Action Plan

The Chilean government should be commended for its current efforts to develop an Energy Efficiency Action Plan (EEAP). An EEAP is an essential element in any country's portfolio because it can help guide and encourage energy efficiency policy development and implementation, capturing synergies between policies and avoiding duplication, while also prioritising resource allocation across the energy efficiency portfolio.

However, in developing an EEAP, Chile should ensure that it sets clear policies, targets and responsibilities, each of which should be specified for relevant sectors. In addition, the EEAP should ensure that it:

- Places energy efficiency policy within the broader policy context, *i.e.* it should support economic, energy and environmental policies.
- Is consistent with international best practice, *i.e.* it should address a range of issues including setting clear goals, acknowledge the full range of benefits from energy efficiency, and clearly allocate responsibility for implementation.
- Uses appropriate levels of stakeholder engagement in both policy development and implementation.
- Builds long-term, broad-based political support for energy efficiency.

Capacity Building and Education

Capacity building and education are important foundations for capturing energy efficiency potential. Chile has made significant progress in educating consumers about the importance of energy efficiency – particularly during the energy supply shortage in 2008. In addition, there are numerous opportunities for training energy efficiency and related professionals, including courses offered in 19 universities, and two engineering associations with sub-groups focused on energy.

However, achievement of Chile's energy efficiency goals will require substantial expansion of human capacity in this area. Chile will require skilled workers across all sectors of the economy to help implement energy efficiency improvements. For example, construction companies will need to understand how to implement new building regulations, engineers will be needed to test equipment and ensure it meets minimum energy performance standards, etc. Chile urgently needs to increase resources allocated to building technical energy efficiency capacity across critical sectors of the economy.

Sectoral Critique

Appliances

Chile has now established an energy appliance labelling scheme. However, appliance energy labelling is only one part of a package of appliance policies common in other countries. In particular, Chile has yet to establish minimum energy performance standards (MEPS) for energy-related equipment and appliances. MEPS are perhaps the most successful energy-saving strategy in IEA member countries, in terms of both total savings and cost-effectiveness. Numerous evaluations worldwide conclude that MEPS have delivered substantial benefits at low, and even negative, cost. Establishing MEPS to cover both residential and commercial electric, gas and wood-burning appliances and equipment would be effective in reducing energy use and electricity demand in Chile. The choice of products to be covered by the standards should be based on total energy savings potential as well as cost-effectiveness.

Buildings

Chile's buildings' energy efficiency policies need considerable attention in three areas. First, although Chile has energy requirements for residential buildings, the stringency of these requirements needs to be strengthened. It should be acknowledged that the current envelope standards represent a 20% improvement over the previous design code for indoor temperatures. However, the next review cycle should strengthen these requirements even further.

Second, Chile has no energy standards for commercial buildings, which form an important component of the building sector in urban areas. The government of Chile should urgently develop and implement mandatory energy efficiency standards for commercial and public buildings.

Finally, it is imperative that Chile expands and upgrades its data on energy use in buildings, particularly commercial buildings. These data are essential for developing effective energy efficiency policies for buildings in Chile.

Industry

In general, Chile has accomplished successful energy efficiency programmes in the industrial and mining sectors. However, there is room for improvement. Based on international experience, one key factor is the appointment of an accredited energy manager and the establishment of energy management systems by large energy-consuming companies. One effective model is a continuous improvement process. This starts with detailed data collection and benchmarking, and moves on to reporting and analysis of energy usage, with designated energy managers responsible for project implementation. This integrated resource management approach has been applied to large industry for many years in a number of countries, such as Japan.

Because of the large number of small- and medium-sized firms in the Chilean industrial and mining sectors, there is a shortage of qualified technicians to provide the necessary energy efficiency services. This situation could be improved if ACHEE established a technical service centre devoted to these activities.

Transport

Improving energy efficiency in the transport sector is challenging. The current government-led actions to encourage the purchase of energy efficient vehicles, driver training, provision of light vehicle fuel efficiency labelling, and better traffic management are a start, and these should continue to be pursued and extended where appropriate.

Looking to the future, it is important that Chile expands its transport energy efficiency policy portfolio. As a first step, Chile should take a comprehensive and systematic approach to integrating transport energy efficiency policies into transport and environmental policy at a strategic level. Also critical is the development and implementation of a diverse range of practical measures addressing:

- Improvements in transport fleet energy efficiency through fuel economy standards for vehicles and regulations addressing non-motor components that affect vehicle energy efficiency (*e.g.* tyre rolling resistance and tyre pressure).

- Support for more energy efficient transport modes, including public transport, rail, shipping, cycling and walking, and for integrated transport/land-use management.
- The development and adoption of renewable and emerging transport fuels and technologies.

The application of fully cost-reflective pricing of transport fuels, roads and modes (including the progressive introduction of the cost of externalities such as environmental and health impacts) is also important to facilitate the transition to a more sustainable energy system for transport. A differential vehicle taxation regime could usefully be extended to provide an even stronger support for transport energy efficiency (see Chapter 10: Transport).

Recommendations

The government of Chile should:

- Establish the proposed Energy Efficiency Agency (ACHEE) with its governance and accountability under public sector control.
- Foster long-term, broad-based political support for energy efficiency so that it remains a political priority.
- Establish within the proposed Ministry of Energy an energy efficiency data collection and monitoring team with relevant skills to establish data collection systems, conduct regular energy efficiency benchmarking studies for key sectors, and provide relevant information on past and current trends in energy efficiency and the potential for future improvements.
- Develop systems and capacity for independent monitoring of on-going programme performance and *ex-post* verification of energy savings.
- Ensure that the Energy Efficiency Action Plan 2010-2020 currently under development sets clear policies, targets and responsibilities for industrial, residential and service sectors already covered, and gradually integrates remaining sectors, including transport.
- Significantly increase resources allocated to building technical energy efficiency capacity across critical sectors of the economy by establishing clear priorities, including for energy efficiency research and development.

- Continue its appliance energy labelling programme and implement minimum energy performance standards (MEPS) covering electric, gas and wood-burning appliances and equipment. Prioritisation of products should be based on total energy savings potential and cost-effectiveness.

- Increase and regularly update mandatory energy efficiency standards for residential buildings, and extend these standards to commercial and public buildings.

- Require large industrial and commercial enterprises with energy demand above a set level (*e.g.* 1 000 kW) to appoint an accredited energy manager and establish an energy management system.

- Adopt strong and increasingly stringent vehicle fuel economy standards or GHG standards, and introduce a vehicle purchase or registration fee structure that incentivises the purchase of fuel efficient vehicles.

- Develop full multi-modal (air, road, rail and water) inter-urban transport planning capability (for both passenger and freight) to enable better forecasts and option analysis, seeking in particular to induce shifts to less energy-intensive modes.

5. FOSSIL FUELS

Overview

With few domestic resources of its own, other than some natural gas and coal deposits in the far south of the country, imports supply most of Chile's fossil fuel consumption. The import, production, transport, refining, distribution and commercialisation of oil products was deregulated in the late 1970s, and market prices tend to reflect the import-parity prices of these fuels. Under the Constitution, the exploration for and production of crude oil and natural gas can be carried out either directly by ENAP, the national petroleum company or by private companies through exploration and exploitation contracts (CEOP) established with the Chilean state.

The transport and distribution of natural gas by pipeline requires a non-exclusive concession, which gives specific rights and obligations to the concessionaire. Chile started importing natural gas from Argentina in 1996. At the peak, Chile imported about 80% of its natural gas requirements from Argentina. But supplies were increasingly restricted by Argentina from March 2004 onwards. Chile has now placed a high priority on security of supply. Two LNG processing terminals are now being built to replace some of the gas that was previously imported from Argentina. A significant increase in coal-fired electricity generation is projected using imported coal and, possibly, domestic coal.

Coal

Supply and Consumption

In 2007, coal accounted for 3.3 Mtoe, or 11% of Chile's total primary energy supply (TPES). The electricity sector accounts for about 85% of the country's coal consumption, with the cement, iron and steel, and sugar sectors using most of the rest. CNE 10-year projections show electricity generation accounting for over 90% of total coal consumption by 2018.

Table 5.1 shows the installed capacity of the existing coal-fired power stations in the SIC and the SING. Most power plants are of conventional design, burning pulverised coal (PC), although some of the older, smaller plants use antiquated chain-grate stokers. Most plants are fitted with particulate control equipment, but none have flue gas desulphurisation to reduce sulphur dioxide (SO_2) emissions. Plants must be operated in a way that meets local air quality standards in the case of saturation: emission limits are not applied to individual plants. One 75 MW cogeneration plant owned by Petropower S.A utilises fluidised bed combustion to burn petcoke at the Talcahuano oil refinery in the Bío Bío Region.

Table 5.1

Coal-fired Power Plants, end-2007

Plant	Owner	System	Installed capacity (MW)	No. of units	Technology	Commissioned
Laguna Verde	AES Gener	SIC	55	2	CG	1939/1949
Ventanas I	AES Gener	SIC	120	1	PC	1964
Ventanas II	AES Gener	SIC	220	1	PC	1977
Bocamina	Endesa	SIC	128	1	PC	1970
Huasco Vapor	Endesa	SIC	16	2	CG	1965
Guacolda	Guacolda S.A.	SIC	304	2	PC	1995/1996
Tarapaca	Celta	SING	158	1	PC	1999
Mejillones	Edelnor	SING	341	2	PC	1993/1998
Nueva Tocopilla	Norgener	SING	277	2	PC	1995/1997
Tocopilla	Electroandina	SING	429	4	PC	1983-1990
Total			**2 048**			

Note: PC = pulverised coal combustion; CG = chain grate stoker.
Sources: CDEC-SIC and CDEC-SING.

Several new coal-fired power plants are under construction, as shown in Table 5.2 . All are conventional PC, subcritical designs, given their size.

Three regions have potential for coal production: Bío Bío-Arauco, Valdivia, and Magallanes (including Riesco Island). Most of Chile's coal mines were closed in the late 1990s due to high production costs. Chile now relies on imports for more than 95% of its requirements. These come mainly from Colombia (which accounts for 40% of total imports), Indonesia (30%) and Australia (15%). Coal imports have increased in recent years from an average of 2 Mt to 3 Mt per year between 2001 and 2006 to almost 5.5 Mt in 2007. This reflects the switch to coal as a result of the restrictions by the Argentine government on gas exports to Chile.

In 2005, BHP began to assess coal prospects in Chile. It acquired the Estancia Invierno (Riesco Island) concession in 2006. Interest in developing coal reserves in the far south was revived in 2007 and 2008 by the rise in fossil fuel prices on world markets, the shortage of natural gas and the projected increase in coal demand. Proven reserves in the area are estimated at around 500 Mt. A project with a value of USD 300 million for the exploitation of sub-bituminous coal deposits on Riesco Island in the Magallanes Region was officially awarded in April 2009 by CORFO, following a bidding process. The winner was Sociedad Minera Isla Riesco, a joint venture between domestic shipping company Ultramar and fuels distributor COPEC. The project consists of three main proven coal deposits (Estancia Invierno, Rio Eduardo and Elena), together with the building of associated port infrastructure.[34] The first stage of the project is expected to be completed by 2011 and should see coal production reach 4 Mt per year (according to information provided by Ultramar). Full production is estimated at 6 Mt per year, to be reached in 2013.

There is an open import-export policy in place in Chile. There are no assigned quotas for imports and only the general import tax (6%) is charged. The port infrastructure for imports and exports is privately owned.

Table 5.2

Coal-fired Power Plants under Construction, June 2009

Plant	System	Installed capacity (MW)	Completion date
Guacolda 03	SIC	135	2009
Nueva Ventanas	SIC	240	2010
Guacolda 04	SIC	139	2010
Santa María	SIC	343	2010
Bocamina 02	SIC	342	2010
Campiche	SIC	242	2011
CT Andina	SING	150	2010
Hornitos	SING	150	2010
Angamos I	SING	230	2011
Angamos II	SING	230	2011
Total		**2 201**	

Source: CNE

34. Only two of the three properties (Elena and Rio Eduardo) were sold outright. The sale of the third, Estancia Invierno, will be completed in 2017, when the rights of the existing owner (BHP Billiton) lapse.

Chile imports bituminous steam coal with a gross calorific value (GCV) of between 6 000 and 6 800 kcal/kg, and sub-bituminous steam coal with a GCV of between 4 500 and 5 500 kcal/kg. Users mix both types in proportions on the basis of the technical specifications of their combustion equipment to maximise the technical benefit at the lowest cost, while complying with cumulative environmental restrictions. Bituminous coal imports amounted to 5.2 Mt in 2008, with a CIF value of USD 625 million (*i.e.* USD 120/tonne), with the principal suppliers being Colombia (80%) and the United States (11%). Sub-bituminous coal imports reached 0.9 Mt, with a total CIF value[35] of USD 75 million (*i.e.* USD 89/tonne), with Indonesia being the principal supplier.

Given the restrictions on natural gas imports from Argentina and the expected high price of liquefied natural gas (LNG), electricity generation companies are now favouring coal-based thermal generation. There are 35 plants with a combined installed capacity of just over 3 300 MW currently under construction in Chile, which will be commissioned by the end of 2011. Of these, coal-based generation projects represent about 60% by capacity (see Table 5.2).

Projections

The most recent 10-year indicative plan drawn up by the CNE envisages that coal-based power plants would account for 26% of total installed capacity in the electricity sector by 2020, compared with 16% in 2007. Even with this projected growth in coal use, Chile would remain a small consumer in global terms. Today, it ranks behind 40 other countries, accounting for 0.1% of global hard coal consumption on a tonnage basis.

Oil

Supply and Consumption

In 2007, oil accounted for 17.3 Mtoe, or 55%, of Chile's TPES. Only 1% of Chile's crude oil requirements were from indigenous sources. Chile is also a net importer of oil products, of about 6 Mtoe in 2007. About 65% of the final consumption of petroleum products in Chile is in the transport sector, with

35. Cost, insurance and freight (CIF) is a common term in a sales contract that may be encountered in international trading when ocean transport is used. It must always indicate the port of destination, i.e "CIF Shanghai". When a price is quoted CIF, it means that the selling price includes the cost of the goods, the freight or transport costs and also the cost of marine insurance. CIF is an international commerce term.

another 25% in the industry and mining sectors. In 2008, TFC amounted to about 17 Mcm, some 50% more than before the cuts in natural gas imports from Argentina began.

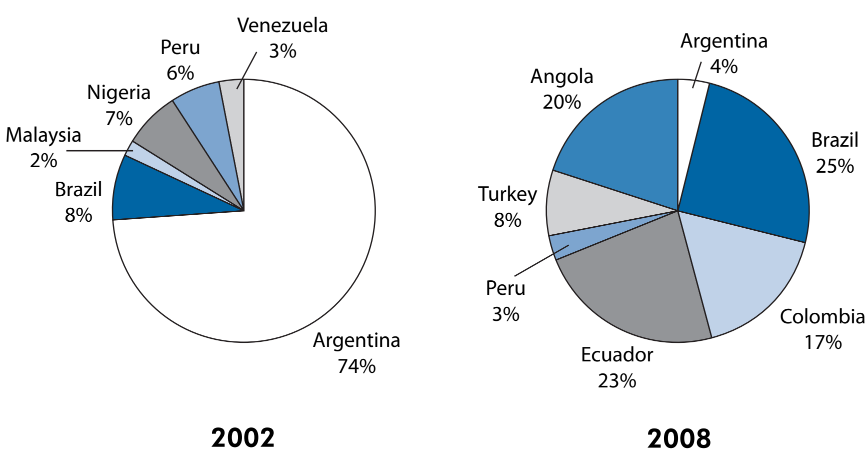
As can be seen in Figure 5.1, ENAP has diversified the source of its crude imports between 2002, when total imports amounted to 9 Mt, and 2008 when they reached 10.1 Mt. Imports of crude currently come from a variety of sources, including Argentina, Brazil, Ecuador and Angola. Oil products are imported from countries in the region (Colombia, Ecuador, Peru, Argentina and Brazil) and from the United States. ENAP exports products mainly to neighbouring countries (Peru and Ecuador).

Domestic production of crude oil is currently about 0.1 Mtoe. To reduce Chile's reliance on imports, an international tender for hydrocarbon exploration in Magallanes was recently launched, under the supervision of the Ministry of Mining. Of the ten blocks on offer, nine were awarded. Six will be operated exclusively by independent companies and consortia. In the three remaining blocks, the winning bidders will operate in partnership with ENAP. Proven reserves of oil in January 2006 were 150 million barrels (equivalent to 20 Mt).

Even though ENAP has no monopoly over the production, import and refining of crude oil, nor for the import and distribution of refined products, it controls Chile's upstream oil sector. Crude oil and refined product prices are not regulated and private companies are allowed to import crude oil,

Figure 5.1

Shares of Crude Oil Imports by Country of Origin, 2002 and 2008



Source: ENAP.

develop refineries and import and commercialise refined products. ENAP has historically been the sole producer of crude oil and refiner in the country, but Geopark has recently been producing crude oil and natural gas in Fell Block (Magallanes Region), a productive block operated under a Special Oil Operating Agreement (CEOP) with the Chilean state. In 1990, ENAP formed an international subsidiary, Sipetrol, to seek foreign production that could offset declining domestic production. Sipetrol has pursued investments in places such as Argentina, Colombia, Ecuador, Egypt, Venezuela, Iran and Yemen.

Downstream Sector

Wholesale Market

The downstream sector comprises ENAP, which participates in refining, importing, storage and maritime transport, as well as pipeline transport in partnership with other companies. ENAP owns the country's three refineries: Aconcagua, Bío Bío and Gregorio (the southernmost refinery in the world). Together, they have an approximate distillation capacity of 230 000 barrels/day, equivalent to about 80% of domestic consumption of refined products. Table 5.3 shows the market share of ENAP in 2007 by product. ENAP reported a loss of USD 960 million in 2008. This compares with a profit of USD 98 million in 2007 and of USD 104 million in 2006.

Transport through pipelines is carried out through lines that belong mainly to ENAP and Sonacol (shared ownership among ENAP, COPEC, Petrobrás

Table 5.3

ENAP Market Share, 2007

	ENAP sales (thousand cm)	Domestic consumption (thousand cm)	Share %
Liquefied Petroleum Gas	1 238	2 114	59
Gasoline	2 812	3 121	90
Kerosene	1 068	1 063	100
Diesel	6 693	9 485	71
Fuel oil	2 638	2 704	98
Industrial products and others	620	619	100
Total	**15 068**	**19 106**	**79**

Source: ENAP.

and Shell). Maritime transport is carried out by the distribution companies, including ENAP. Rail transport is practically non-existent, with the exception of operations by Norgas in the north. Finally, the distribution companies (COPEC, Petrobrás, Shell, Terpel, Abastible, Gasco and Lipigas) transport product by road, in their own trucks or those rented from private companies. Distribution companies are also active agents for the import and commercialisation of refined products and LPG. ENAP and the distribution companies have storage facilities, as does Gasmar, an LPG importer that operates a storage terminal in Quintero Bay.

Storage capacity currently amounts to just under 7 Mb of crude, 11 Mb of petroleum products and 0.2 Mcm of LPG.

Distribution and Retail

ENAP sells petroleum products to private companies operating in the distribution sector. It does not compete directly in the retail sector. Private companies also import refined products. The main companies operating in the retail sector are COPEC (a Chilean company), which has a 60% market share, Petrobrás, Shell and Terpel (a Colombian company). In the LPG sector, all companies are local: Abastible (affiliated with COPEC), Lipigas, Norgas (owned by Lipigas and ENAP), Gasco and Gasmar, which is affiliated to Gasco and which imports only LPG.

The distribution and retail infrastructure is privately owned and there are no third-party access obligations. None of the downstream activities in the oil industry are subject to concession and there are no restrictions on imports. Any interested party can import and sell fuels, as long as they comply with the current quality specifications.

Retail prices of refined products are freely determined by the market. ENAP has to compete with importers of similar products. The company sets its wholesale prices at parity with the price of imported products. These prices are adjusted weekly to ensure they remain competitive with the price of imported supplies. ENAP uses United States Gulf Coast indices and adds elements to cover the cost of freight to Quintero Bay, insurance and a margin to cover vapour losses, demurrage, customs duties, terminal and storage costs, and the cost of using its pipeline to get the product to Concón. The retailers then independently determine retail prices.

Oil and Fuel Price Stabilisation Funds

The only influence that the authorities have over these retail prices (other than through the specific tax on road transport of liquid fuels) is through the credit or tax that they decide on a weekly basis using: the Oil Price Stabilisation Fund (FEPP) (created in 1991 in the wake of the Gulf War), which currently covers only fuel oil; and the Fuel Price Stabilisation Fund (FEPC) created in September 2005, which covers gasoline, diesel, domestic kerosene and LPG. The government recently extended the coverage of the FEPC to include LNG regasified within the country. According to the government, this will allow LNG to receive credits or to be taxed to maintain parity with import prices of alternatives fuels, thereby avoiding distortions that could arise with other fuels covered by the funds, including diesel and LPG. The FEPC does not cover natural gas imported by pipeline.

The operation of these two stabilisation funds is based on the assumption that internal prices of petroleum products should reflect import parity prices. A price band is set by the CNE on the basis of the particular fuel's medium-term import parity price level. The Legislation defines the methodology to be used to set the price band, on the basis of a combination of past and future prices. The CNE has some discretion over the length of the period over which the historical average price is calculated and how far to look into the future. The funds operate by:

- Charging a tax when the import parity price is lower than the price band's lower limit. The tax is equal to the difference between the two values.
- Paying a credit when the import parity price is greater than the price band's upper limit. The credit is equal to the difference between the two values, but depending on the amount remaining in the Fund, credits can be reduced.

Table 5.4

Quarterly Balance of Chile's Fuel Price Stabilisation Fund - FEPC (USD Million)

	Government transfer	Tax	Credit	Movement	Balance
Q1/2007	0	1.5	0.8	0.7	15.7
Q2/2007	60	0,0	15.4	44.6	60.3
Q3/2007	0	0.0	4.6	-4.6	55.7
Q4/2007	0	4.0	48.1	-44.1	11.6
Q1/2008	200	2.1	28.9	173.3	184.9
Q2/2008	500	0.9	109.1	391.8	576.8
Q3/2008	0	10.1	254.9	-244.9	331.9
Q4/2008	0	119.8	4.9	114.9	446.8
Q1/2009	0	54.0	0.0	54.0	500.8
Q2/2009	0	6.5	20.9	-14.5	486.3

Table 5.5

Quarterly Balance of Chile's Oil Price Stabilisation Fund - FEPP (USD Million)

	Government transfer	Tax	Credit	Movement	Balance
Q1/2007	0	0.7	0.4	0.4	0.4
Q2/2007	0	0.0	0.0	0.0	0.4
Q3/2007	0	0.1	0.2	-0.2	0.2
Q4/2007	0	0.1	0.2	-0.1	0.1
Q1/2008	0	0.0	0.0	0.0	0.1
Q2/2008	0	0.0	0.0	-0.0	0.1
Q3/2008	0	0.0	0.0	-0.0	0.1
Q4/2008	0	32.0	6.1	25.9	26.0
Q1/2009	0	29.2	13.9	15.2	41.2
Q2/2009	0	4.3	0.7	3.6	44.9

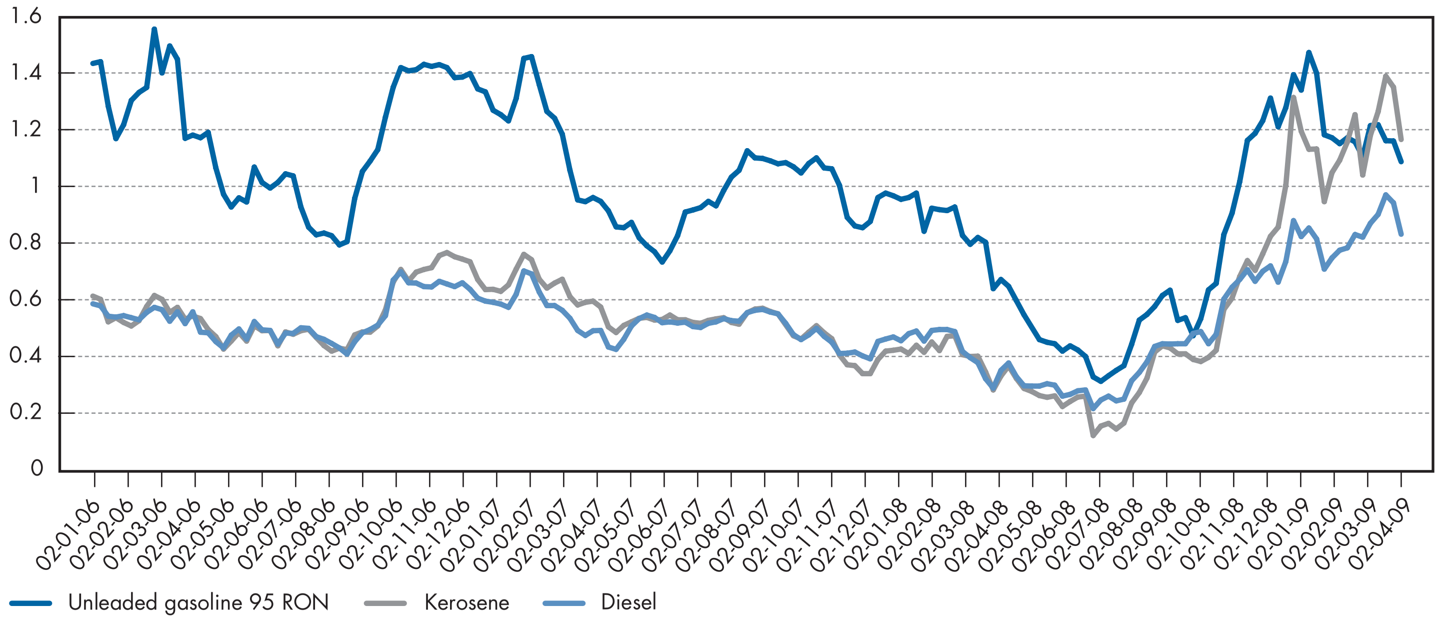
If the import parity price lies within the price band, no credits or taxes are applied.

The aim of both funds is to reduce the volatility of end-user prices of these fuels from year to year, while remaining neutral in the long term. Credits are financed by the taxes generated. Over the 2.5 years from the beginning of 2007 to July 2009, credits outweighed taxes in the FEPC by USD 288 million (Tables 5.4 and 5.5). To maintain a positive balance in the fund in the face of these outflows, the government injected a total of USD 760 million into the funds in 2007 and 2008. In the last quarter of 2008 and the first two quarters of 2009, a positive balance of USD 486 million was recuperated following the decrease in international oil prices.

Figure 5.2 shows the effect of the operation of the funds from the beginning of 2006. The differential between the retail price and the import parity price as a proportion of the import parity price fell from its long-term average of around 150% to less than 30% in July 2008. The equivalent figures for diesel were 70% and 20%, and for domestic kerosene 52% and 10%. All three percentage differentials have since recovered and, in the case of diesel and kerosene, are now well above their medium-term averages.

Figure 5.2

Proportionate Difference between Retail and Import Parity Prices, 2006-2009



Source: CNE

Natural Gas

Supply and Consumption

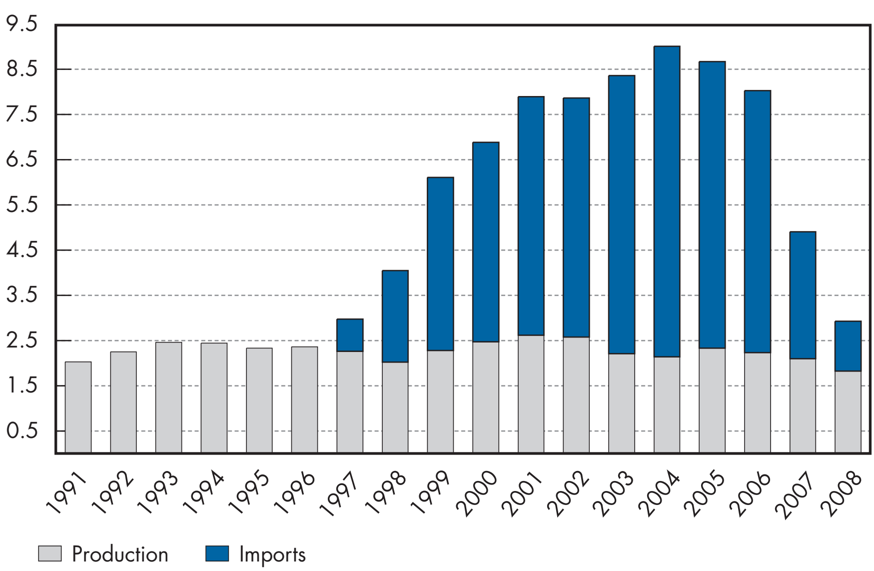
Figure 5.3 compares indigenous production, imports and domestic consumption of natural gas since 1991. Between 1996, when imports from Argentina first arrived, and 2004 when they reached their peak, consumption of natural gas in Chile increased by 4.5 times, from around 1.9 bcm to 8.6 bcm.

This large increase in consumption was met entirely from imports. Domestic production has remained relatively constant since the early 1990s, at between 2 bcm/year and 2.5 bcm/year. Domestic gas production supplies an isolated network in the Magallanes Region in the far south, which includes a natural gas-based methanol plant that can process a total of close to 4 bcm/year of gas, mainly for export. The rest of the country is entirely dependent on Argentina for its gas, at least until the two LNG facilities come on line. At the end of 2006, estimates of natural gas proven reserves located in the Magallanes Region varied between 42 bcm and 98 bcm.

The increasing availability of a cheap, clean and plentiful fuel from 1996 onwards, in the central and northern areas of Chile, was reflected in a

Figure 5.3

Production and Imports of Natural Gas, 1990-2008 (bcm)



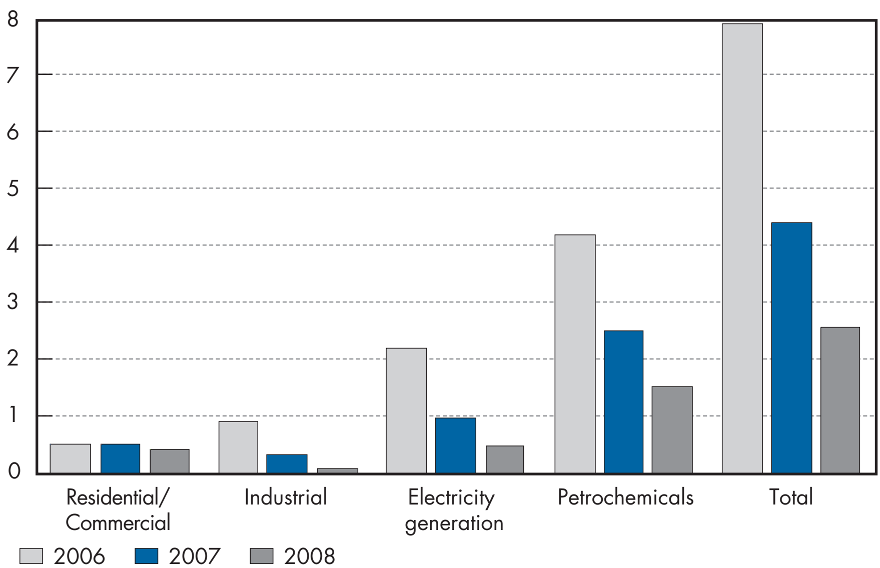
Source: CNE.

significant switch towards gas for electricity generation (particularly in efficient combined-cycle gas turbine plants) and in an increased penetration of natural gas in the industrial, residential and commercial sectors. As a result, the number of gas customers grew from 38 850 in 1996 to more than 478 000 in 2006. More than 97% of these customers were households.

The effects of cuts in supplies of gas from Argentina were felt primarily in the petrochemicals and electricity generation sectors, as shown in Figure 5.4. The authorities expect that the 1.5 bcm/year to 2 bcm/year currently imported by pipeline from Argentina cannot be relied upon to continue.

Figure 5.4

Consumption of Natural Gas by Sector, 2006–2008 (bcm)



Source: CNE.

Industry Structure

Upstream

Gas interconnection between Chile and Argentina was facilitated by the signing of the 1995 Gas Protocol between the two countries. The first gas pipeline was built in Magallanes in 1996. In the central area of the country, the *Gas Andes* gas pipeline began operation in August 1997. It was the first pipeline to be built entirely by the private sector. In the southern part of the country, the *Gaspacífico* gas pipeline was built in 1999. In the north, two competing pipelines were built in 1999. Both are connected to the Argentine

Northeast Basin and transport gas to the generating plants and industrial and mining clients in the region. The two pipelines are not interconnected. Other than in Magallanes, the main stimulus for the construction of gas pipelines came from the electricity sector, which had experienced annual average growth in demand for electricity of 7% during the first half of the 1990s.

Table 5.6 shows the gas pipeline networks in the north, central/southern and far south regions of the country.

Table 5.6

Gas Pipeline Networks, 2005

Pipeline[1]	Owner[2]	Capacity (thousand cm/day)[3]	Length (km)[4]
Northern Region			
Gasatacama (International)	Gasoducto Atacama Chile Ltda.	4.50	950
Norandino (International)	Gasoducto Nor Andino S.A.	4.50	1 070
Taltal (National)	Gasoducto Taltal Ltda.	2.50	229
Central/Southern Region			
GasAndes (International)	GasAndes S.A.	10.70	540
Electrogas (National)	Electrogas S.A.	6.10	138
Gas Pacífico (International)	Gas Pacífico S.A.	4.30	568
Red Innergy (National)	Innergy Transporte S.A.	2.60	77
Far South Region			
Bandurria (International)	ENAP	2.40	83
Dungeness Monte Dinero (International)	ENAP	1.20	11
Condor-Posesión (International)	ENAP	2.30	9
Posesión - Cabo Negro (National)	ENAP	6.30	177
Posesión - Cabo Negro[2] (National)	ENAP	2.90	177
Red ENAP (National)	ENAP	4.00	106

Notes:
(1) Information as of 2005.
(2) In the case of international pipelines the owner indicated is the owner of the Chilean section.
(3) Corresponds to the capacity of the largest section.
(4) Refers to total length including lateral sections and sections located in foreign countries.
Source: CNE.

Tariffs in the gas transport sector are unregulated. Competition to build pipelines has worked well. Each time a potential demand for gas emerged, at least two groups of investors showed interest in building the necessary infrastructure. Competition to win long-term, take-or-pay contracts with generation companies and gas distributors were sufficient to secure finance for the successful completion of the projects.

Downstream

Natural gas is distributed through networks owned by seven companies in various cities: Metrogas in Santiago and Rancagua; Gasvalpo and Energas in the Greater Valparaíso area; GasSur in the Greater Concepción area and Los Ángeles; Intergas in Chillán and Los Ángeles; Lipigas in Calama; and Gasco Magallanes in Punta Arenas, Puerto Natales and Porvenir.

These distributors vary greatly in size. Metrogas is the country's largest in terms of number of customers, with more than 405 000 customers in 2007. It owns a network that is capable of supplying most of the districts in Greater Santiago and part of Region VI (Rancagua). Gasco has a controlling stake in Metrogas; the other partners are COPEC and Trigas. All three companies have LPG distribution businesses in the same region. As a back-up for the supply of natural gas, Metrogas has propane-air installations with 30 000 gallon storage tanks, to supply residential and commercial clients. The propane-air can be distributed using the same network of natural gas pipes if supply from Argentina is insufficient to satisfy residential demand in Santiago. Similar propane-air plants were built in Greater Valparaíso and Concepción.

Gas Market Regulation

In Chile, the import of natural gas is not regulated, but transport and distribution of natural gas by pipeline requires a non-exclusive concession, which gives specific rights and obligations to the concessionaire. The *Gas Law* establishes that, with the exception of the Magallanes Region, distribution concessionaries are free to set tariffs for gas distribution service, with the limitation that these tariffs must be non-discriminatory, *i.e.* the same for all consumers with the same demand characteristics. Prices of gas to the end-user are not set directly by the authorities, on the grounds that gas competes with other substitute hydrocarbons (*e.g.* LPG distributed in cylinders or domestic tanks), even though consumers may incur significant fixed costs in switching from one to the other.

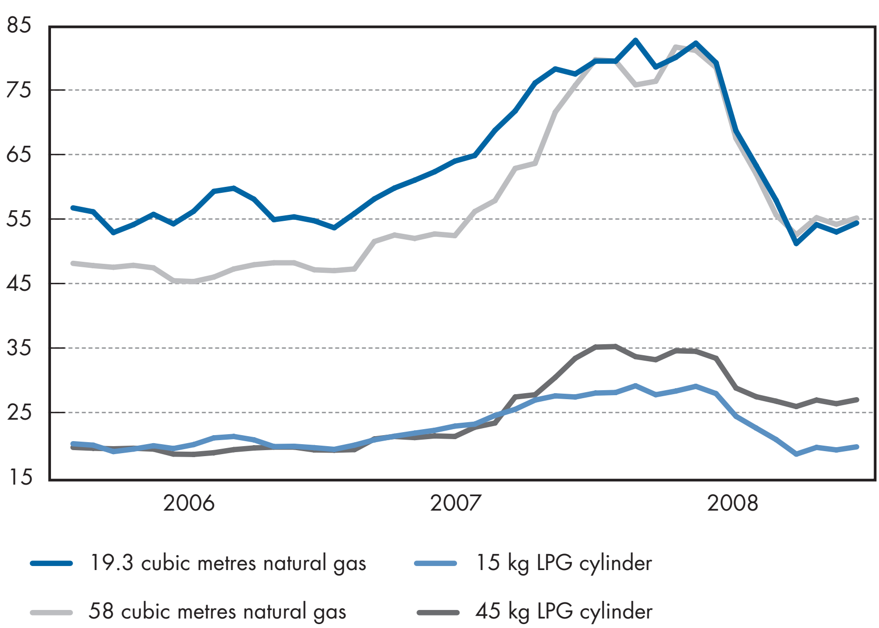
However, the law establishes a ceiling on the profitability that the gas distribution concessionaries may earn. This ceiling is defined as 5 percentage points above the cost of capital. The cost of capital is set by the Ministry of the Economy and cannot be less than 6%. The Competition Tribunal can ask the Ministry of Economy to regulate prices paid by users that consume less than 100 Gj of gas, if the distributor's profitability exceeds the ceiling in a given year. To date, no such requests have been made.

Prices

The tariff policy of the distribution companies has generally been to follow the price of substitutes (*e.g.* LPG in cylinders or tanks, or diesel oil in the case of large consumers) by tranche of consumption. Figure 5.5 compares the prices (in USD) of natural gas with that of an equivalent 15 kg cylinder of LPG and an equivalent 45 kg cylinder of LPG, for the Santiago Metropolitan Region since the beginning of 2004. In the case of the prices of natural gas and a 15 kg cylinder of LPG, the correlation between the two prices was close until the end of 2007. Since then, natural gas has tended to be consistently and considerably more expensive than LPG. A similar pattern can be seen in the case of the prices of natural gas and a 45 kg cylinder of LPG. The consistent differential of USD 10 to USD 15 between the two disappeared in mid-2008 and has not reappeared since.

Figure 5.5

Prices of Natural Gas and LPG in Santiago for Equivalent Energy Supply (USD), 2006-2008



Source: CNE.

Liquefied Natural Gas

In 2009, Chile will become the third-largest LNG importer in South America and the largest on the Pacific Coast of South America. The building of two LNG receiving terminal projects is a direct response to the Argentine gas crisis. Given the urgency of the situation, the government agreed to the participation of two state-owned companies, ENAP in the central region and CODELCO in the north, as the main sponsors and developers of the Quintero and Mejillones projects respectively, on condition that private companies also agreed to participate in ownership of the terminals and as off-takers. This agreement was reached within a few months.

The first phase of the GNL Quintero receiving terminal in the central region, located 114 km from Santiago, opened at the end of August 2009. In an initial, fast-track phase, the terminal will use unloading vessels as tanks to store the liquefied gas until it can be converted back into gas and injected into pipelines linking the terminal to the consumers in central Chile. This will involve discharging directly from the ship into the onshore vaporisers with only a small 14 000 cm storage tank available as buffer. This has allowed the project to begin operation about one year early, given that two larger 160 000 cm tanks will be operational only in the second semester of 2010. The estimated total cost of the project is USD 940 million.

Gas send-out capacity in the initial phase is 2.4 bcm/year. Gas will be injected into the existing pipeline network of Electrogas and Gasandes for power generation and industrial, residential and commercial consumption. The Electrogas pipeline extends from the Valparaíso Region to the Santiago Metropolitan Region, where it connects to the Gasandes pipeline that supplies the Metrogas grid and then to the Bernardo O'Higgins Region. The permanent capacity in the later phase will be 3.6 bcm/year. There is an option to expand the terminal to a maximum send-out capacity of 6.8 bcm/year. This project should ensure that some generating plants will be able to operate on gas as originally planned, rather than on oil.

GNL Quintero S.A. was formed for the Quintero project. It is a joint venture between Endesa Chile (20%), ENAP (20%), Metrogas Chile (20%) and BG Group (40%) and will own the Quintero sea terminal and regasification plant. A related company, GNL Chile S.A., will be responsible for LNG purchase and re-sale. GNL Chile is owned by ENAP (33.3%), Endesa Chile (33.3%) and Metrogas (33.3%). GNL Chile has a contract to buy up to 2.3 bcm/year of LNG from BG Group's global portfolio.

The country's second import terminal, GNL Mejillones, is expected to open early in 2010. The project is a 50-50 joint venture between Suez Energy and state-owned mining company, CODELCO. GDF Suez is expected to provide about 0.8 bcm/year of LNG for the first three years from its global portfolio, including Yemen LNG. Located in the country's northern interconnected electricity system (SING), the project is a priority for the mining sector and the off-takers will be a consortium of mining companies. The SING system, with no hydro resources, is heavily dependent on gas and other fossil fuels, mainly coal.

GNL Mejillones will have a send-out capacity of 2 bcm/year, enough to satisfy the demand of 1 100 MW of gas-fired electricity generation. The first stage of the project will use an LNG vessel for storage, as well as a jetty and onshore regasification plant. The total cost is estimated at USD 500 million. In 2009, a decision will be made on whether to build permanent storage tanks on land, which would take three years to complete. The decision will depend on the generators' willingness to enter into long-term LNG purchase contracts, given that new capacity from cheaper coal-based generation will start coming online on the SING grid in 2012.

The opportunity cost of LNG relative to other sources of power will be critical for the development of Chilean LNG imports. Chilean gas consumers may agree to pay a premium for supply security, given the risk involved in Argentine gas imports. However, since much of the gas will be used for electricity generation, LNG will need to be competitive with other fuel sources, particularly coal.

It would seem logical for Chile to import LNG from its next-door neighbour, Peru, given the proximity of its Mejillones regasification terminal and its critical need for LNG supplies. However, a long-standing border dispute that goes back to the late 19th century is making it difficult for Chile and Peru to seize this opportunity.

In the northwest, Chile also shares a border with Bolivia, the second-largest gas reserves holder in the region. Bolivia and Chile have had strained relations because of a border dispute dating back to the 1879-83 War of the Pacific, which als o makes gas exports from Bolivia to Chile also unlikely in the foreseeable future.

Critique

Chile's dependence on coal is set to increase as a result of the restrictions on Argentine natural gas exports to Chile and coal's attractiveness (in terms of price and availability) relative to other fuels used for power generation. Coal installed capacity at the end of 2008 reached 2 048 MW. According to the CNE April 2009 *Plan de Obras* based on projects currently under construction, it is projected to double by 2011, reaching 4 244 MW. The rate of capacity additions is anticipated to slow down between 2011 and 2020, when it will reach 5 783 MW, equivalent to 26% of total installed capacity.

This projected rise in coal-fired capacity could set Chile on an unsustainable path with regards to climate change, in comparison with both OECD member countries and Latin American countries. The IEA *2008 World Energy Outlook* (WEO 2008) considers a scenario corresponding to long-term stabilisation of GHG concentration at 450 parts per million of CO_2 equivalent, which would limit the increase in global temperatures to about 2°C. The 450 policy scenario requires substantial reductions after 2020 in global GHG emissions.

According to the 450 policy scenario, OECD member countries would see their share of electricity generation from coal fall from 38% in 2006 to 11.5% in 2030, while Latin America as a region would see a reduction from 3.1% to 0.4% by 2030 (Table 5.7). The WEO 2008 Reference Scenario, which assumes no new policies are implemented, describes an unsustainable scenario that OECD member countries should aim to avoid through policy action and technology change. Chile should similarly consider what steps are needed to limit its own emissions. Without a credible climate change strategy to mitigate emissions, the CNE current coal capacity projections would become increasingly untenable.

The Chilean government is aware of the GHG implications of the substantial increase in dependence on coal. The global GHG emissions reduction

Table 5.7

Shares of Coal in Electricity Generation in OECD and Latin America

	2006		2030	
	OECD	Latin America	OECD	Latin America
Reference scenario	37.6%	3.1%	34.2%	8.6%
450 Policy scenario	37.6%	3.1%	11.5%	0.4%

Source: 2008 World Energy Outlook, IEA/OECD, 2008.

targets now called for by the international community will eventually require a significant reduction in CO_2 emissions from coal-fired power plants. The Chilean government should be cognisant of this need and establish a strong framework of regulation and incentives to ensure that the competitive market internalises environmental and social costs and avoids near-term investment in assets that might become stranded in the future. Large coal-fired plants should at least be built with sufficient space for the later retrofit of CO_2 capture equipment and with some confidence that underground storage sites for the captured CO_2 exist within a viable transport distance. As Chile does not appear to have suitable storage sites, at least on initial inspection, more work is needed to assess CO_2 storage potential, perhaps drawing on work in Japan, which faces similar problems.

When granting permission for new coal-fired power plants, the government should ensure that high energy efficiency is achieved. At larger plants with unit sizes above 500 MW, particularly those using imported coal, commercial drivers usually make high-efficiency (greater than 42% lower heating value - LHV), supercritical plants the natural choice. At smaller, subcritical plants with efficiencies below 38% LHV, such as those under construction in Chile given the current size of the country's electrical system, combined heat and power (CHP or co-generation) can offer significant efficiency gains. However, this option typically requires government co-ordination due to the infrastructure requirements of district heating and cooling. For industrial applications, carbon pricing (or targeted incentives) can drive project developers towards CHP. In any event, an assessment of CHP options should be included as an obligation in EIAs, which would require a change in legislation.

With respect to local air pollution, the current system of emissions abatement, which comes into effect once the local ambient concentration of pollutants exceed 80% of air quality standards, needs to be supplemented by clearly defined and uniform emission limits for individual thermal plants. While air quality standards define targets, they do not always provide the means to achieve these targets, especially in areas with multiple sources of pollution. Enforceable emission standards, uniformly applied to thermoelectric plants, would provide a sound basis for effective pollution control (see Chapter 3: Energy and Environment).

Chile's oil sector is characterised by the dominant position of state-owned ENAP. The company owns the country's three refineries, imports petroleum products, and participates in storage and maritime transport, as well as pipeline transport in partnership with other companies. Some 80% of domestic demand for oil products is currently met by the output of ENAP refineries and net imports of oil products by ENAP. The other 20% is accounted for by four private companies, which are responsible for imports, as well as pipeline, road and maritime distribution, and storage and retail. In some cases, the market share of ENAP is 100% or close to it. Companies are free to set prices for their products, while ENAP sets its own wholesale prices on a weekly basis to match the price quoted by Platts of the same product imported into Chile from a market of reference, such as the United States Gulf Coast.

These pricing arrangements may be appropriate for a sector that is both concentrated and dominated by a state-owned company and in which market prices are set on a weekly basis with reference to prices of petroleum products in the region. However, it requires ENAP to take on the costs of hedging its foreign currency and refined product price exposures, a role it may not be well placed to undertake. ENAP can hedge its risks to some extent by simultaneously buying crude spot and selling products. Although importers of refined products also face price and foreign exchange risks, ENAP is exposed for much longer, owing to its role as the country's only refiner.

Moreover, the way in which the price stabilisation funds work has interfered in these import parity price arrangements, particularly over the 2.5 years from early 2006 to mid-2008, which saw a steep increase in oil prices. The authorities argue that the funds successfully stabilised prices over a period of volatility in world oil prices and have not prevented the long-term trend in prices from reflecting market signals. They also insist that the methodology for setting the price bands is designed to be neutral if international prices follow a random walk over a period of time. However, if international prices do not regress quickly, the funds will inevitably subsidise fuel prices. According to the FEPC methodology set out in the law, once the fund becomes exhausted subsidisation should be reduced and eventually stop. In 2008, this built-in safeguard was circumvented when the Chilean Congress voted to grant additional funds to maintain and even increase the subsidisation until international prices fell. As a result, prices did not fully reflect opportunity costs for some time.

The IEA is opposed to administered price regimes of this kind, for two reasons. First, they inhibit demand-side responses to changes in prices. If schemes of this kind were in widespread use, this lack of a demand response would exacerbate swings in oil prices. Second, however well designed or circumscribed, such schemes expose governments to political pressures to use them for the purposes of subsidisation rather than the simple stated aim of reducing volatility.

Chile faced significant challenges after 2004 when Argentina first began to restrict exports of natural gas. The government and private sector participants in the energy sector are to be commended for the way in which the crisis was handled, particularly since the gas crisis coincided with a drought and at a time when world energy prices were rising steeply.

Restrictions of gas imports from Argentina starkly illustrated Chile's need for an independent and secure supply of natural gas. Given Chile's distance from major global natural gas producers on the continent and further afield – and the political difficulty of importing gas from its neighbours, Bolivia and Peru – the only viable alternative to improve diversification was to develop LNG projects. Given the urgency of the situation, two state-owned companies, ENAP in the central region and CODELCO in the north, acted as the sponsors and developers of the Quintero and Mejillones projects. ENAP and CODELCO were soon joined by private partners. The two commercial consortia negotiated LNG contracts with potential suppliers for over twelve months.

The downstream gas sector has wholly unregulated tariffs (with the exception of the Magallanes Region), but concessions impose a number of obligations on companies with respect to public services. While distributors of natural gas are free to charge what they like, they tend to set natural gas prices with reference to the price of LPG for residential customers and to diesel oil and other alternatives for industrial customers. This is an appropriate policy provided that the market for LPG and diesel oil is effectively competitive, and that competing suppliers of natural gas can enter and compete with incumbent distributors to supply their customers.

With no third-party access arrangements in place in the downstream gas networks, these conditions are not met. Customers connected to the gas distribution networks have no choice but to buy their gas from the distributor or to switch to LPG. The distributor can afford to sell gas at the LPG price (or higher) and not lose customers because of the high cost of switching. Giving other gas suppliers the right to use the distribution network to compete against the distributor in the supply of gas would be a step towards a competitive market provided that there is a diverse source of gas available. This could be the case when the LNG plant at Quintero is commissioned, though it is recognised that LNG will be the only source of natural gas, and at a price and with risks that will not make the development of retail competition particularly attractive.

Recommendations

The government of Chile should:

- Ensure that energy efficiency is maximised by insisting, where feasible, on co-generation (combined heat and power or CHP) when approving new coal-fired power plants to supply heat for industrial processes.
- Introduce without delay uniform and enforceable pollutant emission standards for thermal plants, and strengthen the enforcement of current air quality standards and the technical capacity to monitor and evaluate their impact.
- Consider the IEA position of discouraging administered price regimes, bearing in mind that such regimes weaken demand-side responses to price changes.
- Consider options to eliminate the exposure of ENAP to price and foreign exchange risks.
- Take steps to create a regulated, open-access regime in gas distribution and the opening of competition for gas consumers to third parties.

6. ELECTRICITY

Overview

Chile was the first country to institute a comprehensive reform of its electricity sector. It has rightly been hailed as a successful example of electricity reform in a middle-income developing country and has been emulated by other countries in the region and elsewhere.

Reforms were first planned in 1978 when the CNE was established. The original legislation in 1982 led to the vertical and horizontal unbundling of the sector and its commercialisation. The law also put in place a spot market for electricity and a contracts market in which generators and large industrial customers could freely negotiate supplies. The privatisation of what was then a wholly state-owned sector began in 1986 and was completed in 1998, when the last state-owned utility, Edelaysen S.A., was sold to the private sector. Sector participants are now almost entirely privately owned.[36]

Legal Framework

• 1982 Electricity Law

The main law that governs the operation and regulation of the electricity sector in Chile is the *Ley General de Servicios Eléctricos* (General Electric Services Law) of 1982, which was amended principally by the *Ley Corta I* and *Ley Corta II* (Short Laws) of 2004 and 2005.[37] The 1982 law created two types of customers: non-regulated and regulated. Non-regulated customers are those with a connected capacity of more than 2 000 kW who must freely negotiate for the supply of their energy directly with a generation or distribution company.[38] Regulated customers have much lower consumption and have no choice but to be supplied by their local distribution company. The law also:

- Created a system operator: the CDEC (*Centro de Despacho Económico de Carga*).

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36. The minor exceptions include the system on Easter Island.

37. The amended text of the 1982 Law has been enacted as DFLN°4 of May 12, 2006. The law that promotes the development of renewable energies is a separate law (Law N° 20257 of April 2008) and is also an amendment of the Ley General de Servicios Eléctricos.

38. Customers with a connected capacity of between 500 kW and 2 000 kW can now choose to be supplied by someone other than their local distribution company. This change was introduced in the Ley Corta No. 19,940 of January 2004. Eligibility is determined by the capacity of the customer's connection, rather than peak measured demand or average load over a given time period.

- Set out how the spot market for electricity would work and how spot prices would be determined.
- Regulated the transactions between generators and distribution companies for the supply of customers obliged under the law to buy from their local distribution company (*i.e.* regulated customers).
- Determined the mechanism for setting transmission tolls.
- Determined the mechanisms for passing prices on to end-users.

The spot market was designed for trading the differences between the contractual commitments of the generators with their clients and their actual (*i.e.* constrained) dispatch quantities. Involvement in the spot market is therefore limited to generators, who effectively sell energy and capacity into the market and buy energy and capacity out of it to satisfy their contracts with non-regulated customers and with distributors. Distributors and non-regulated consumers must purchase their energy requirements in the contract market and do not have access to the spot market.

Changes have been made to the 1982 law to reflect developments over the past 25 years. One was necessitated by the severe drought of 1998/1999, which was exacerbated by the delay to the commissioning of a new large, gas-fired combined-cycle gas turbine (CCGT). Outages began in November 1998 and continued for six months, and electricity supplies had to be rationed in the first half of 1999. Disputes then arose over the question of compensation due to regulated customers who had been cut off. The generators argued that droughts more severe than those considered in setting regulated prices were *force majeure* events and exonerated them from paying compensation. Generators who were long in the contracts market argued that imbalanced prices should be set at the failure cost, not at the system marginal cost. It was recognised that the existing framework provided insufficient incentives to generators to install sufficient back-up units to avoid shortages of supply in case of extreme droughts. The 1982 law was amended in 1999 such that extreme droughts were ruled out as *force majeure* events and penalties for failing to satisfy electricity supply contracts would apply even in cases of extreme drought.

Short Law I

Ley Corta I of March 2004 (*Short Law I*) amended a number of other provisions of the 1982 law. First, the framework of transmission charging was changed to ensure that owners of the trunk transmission system could recover the costs of existing transmission lines. Second, the amount by which the node price for the regulated market was allowed to differ from prices in the non-regulated market was reduced from 10% to 5%, thereby reducing the price risks faced by generators supplying the regulated market. Third, any customer with a connected capacity in excess of 500 kW was given freedom to choose to be supplied by a retailer other than their local distribution company, though they are not obliged to change suppliers.

Short Law II

Ley Corta II of May 2005 (*Short Law II*) reformed the regulation of transactions between generators and distributors for the supply of regulated customers. This was in response to the crisis precipitated by the restrictions on the supply of natural gas to Chile from Argentina, which began in 2004 and which threatened new investments in new generating capacity. A new framework for the sale of energy to regulated customers was put in place to give generators the necessary confidence to invest.

This framework replaces that of node prices established in the 1982 law. The prices at which generators sell to distributors for resale to their regulated customers must now be set through open and competitive tenders, overseen by the CNE and awarded to the bid with the lowest price. Bidders are free to choose what base energy price to bid, though bid prices are capped at between 26% and 56% above the average price during the previous four months of the non-regulated contracts then in force. The specific cap will depend on the difference observed between the average price of these non-regulated contracts and the average expected value of wholesale spot prices over a four-year horizon. The cap is set by the CNE using a formula set out in the law. The base capacity price over the duration of the contract is that which exists at the time of the tender.

If the bidding process fails, owing to insufficient interest on the part of generators or a failure to comply with the bidding terms of reference, the CNE can approve an additional increase of 15% over the initial cap. Distributors are obliged to hold long-term contracts (of up to 15 years in length) to ensure that their customers' energy needs are permanently covered for at least three years in advance. To ensure that the auctions attract the largest possible number of bidders (including new entrants), the law stipulates an interval of three years between the date of the auctions and the start of the resulting supply contracts. This period is intended to be sufficient to allow new plants to be built to service the contracts. The first of these auctions was held in late 2006 for contracts to run from 2010 to 2024.[39]

39. *Tenders for Supply Contracts with Chilean Electricity Distributors*, Empresas Eléctricas *A.G. July 2006*

Demand and Supply

Reflecting the country's geography, the electricity sector in Chile comprises four distinct electrical systems: the SING, which supplies the north of the country; the SIC, which supplies the populous central regions; the Aysén System in the south, which has three separate systems; and the Magallanes System in the far south, which has four separate systems.[40] The relative sizes of the four systems (as at end-2008) are shown in Table 6.1.

Table 6.1

Installed Capacity by Type of Plant and Energy Source, end-2008 (MW)

Technology	SING	SIC	Aysén system	Magallanes system	Total[1]	Share (%)
Hydroelectric	13	4 910	21	-	4 943	38
Reservoir	-	3 393	-	-	3 393	26
Run-of-River (> 20 MW)	13	1 516	21	-	1 550	12
Mini Hydro (< 20 MW)	13	125	21		159	1
Thermal	3 589	4 458	28	99	8 173	62
Coal	1 206	838	-	-	2 043	16
Natural Gas	2 112	2 547	-	84	4 743	36
Oil[2]	272	907	28	14	1 220	9
Biomass[3]	-	166	-	-	166	1
Wind	-	18	2	-	20	0
Total	**3 603**	**9 385**	**51**	**98**	**13 137**	**100**

Notes:

1. Excluding autoproducers, co-generators or other generators that are not connected to the systems.

2. Oil includes oil derivatives, diesel and intermediate fuel oil.

3. Biomass includes forest waste.

Source: CNE.

Northern Interconnected System

The SING supplies the northern part of Chile between the city of Arica and the port of Coloso. It covers an area equivalent to 25% of Chile's continental territory and in which about 6% of the population lives. Most of the population is concentrated in extensive urban areas on the coast, whereas

40. In Aysén and Magallanes, the various separate systems have installed capacities between 1.5 MW and 20 MW each.

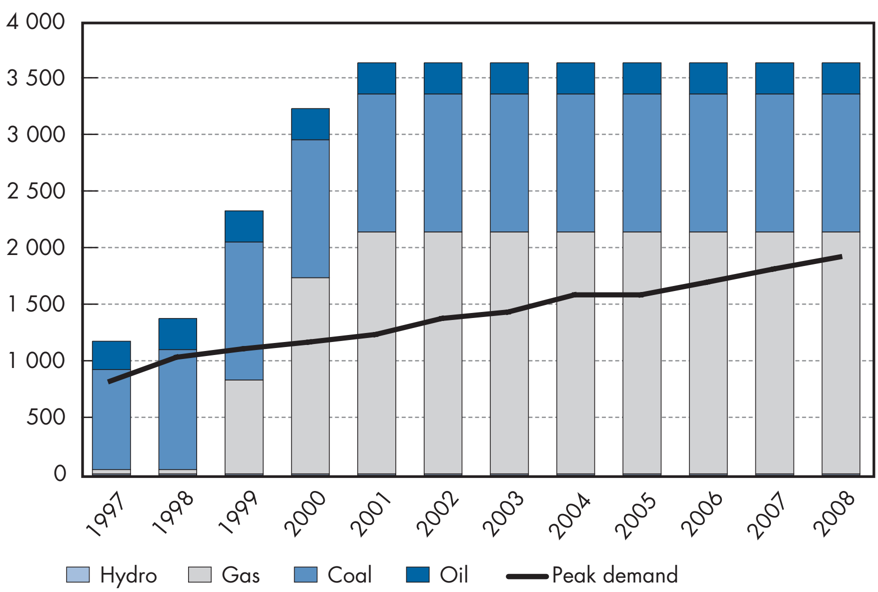
most of the industrial activity, essentially mining, is concentrated in the interior and towards the mountainous areas.

Installed capacity in the SING amounted to 3 600 MW at end-December 2008, almost all of which was thermal. Gas-fired plants accounted for 60% of total installed capacity and coal for 33%. System maximum demand was around 1 900 MW in December 2008, implying a simple reserve margin of 47%.[41] Gross generation in 2008 was about 14 500 GWh, implying a system load factor of more than 85%. Sales of electricity in the SING have grown at an annual rate of about 5.5% since 1999. Large industrial customers, mainly mining companies, account for around 90% of the load in the SING. Regulated customers in the residential and commercial sectors account for just over 10% of sales.

Figure 6.1 shows the evolution of installed capacity and peak demand in the SING since 1997. The remarkable increase in installed capacity in the SING from 1997 to 2002 is clearly visible and is entirely accounted for by the installation of around 2 000 MW of CCGTs built to take advantage of the arrival of cheap and plentiful supplies of natural gas from Argentina. The chart also shows that, without the conversion of 800 MW of those gas-fired

Figure 6.1

Installed Capacity and Peak Demand in the SING, 1997-2008 (MW)

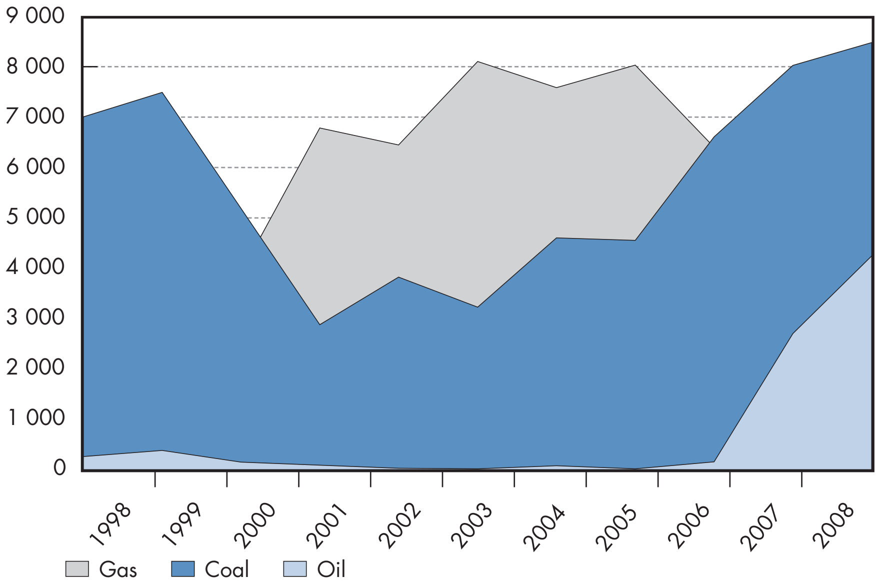


Source: CNE.

41. The reserve margin is defined as net capacity as a proportion of peak demand.

Figure 6.2

Generation by Fuel Type in the SING, 1997-2008 (GWh)



Source: CNE.

plants to run on diesel when supplies of gas from Argentina were cut off, generation capacity in the SING would have been insufficient to meet the peak demand.

Chile is not electrically interconnected with neighbouring countries. However, the Salta CCGT plant, located in Argentina, is electrically part of the SING and was not connected to the Argentine grid until 2007. From then on, Salta began to inject energy into the Argentine system. The configuration of the busbars is such that the power plant has some components dedicated to the SING while others are reserved for the Argentine system. This ensures that there is no electrical connection between the two systems. At its peak in 2006, the Salta plant supplied 2 284 GWh to the SING, or about 20% of the SING requirements.

Figure 6.2 shows generation in the SING by fuel since 1997. The dramatic effect of the arrival of gas from Argentina and its subsequent withdrawal can be seen quite clearly in the use of coal and oil over the decade.

There are four distribution companies operating the SING, supplying about 275 000 customers. However, the Emel Group, which owns three of the four companies, has close to 100% market share of sales and customers supplied.

Central Interconnected System

The SIC is Chile's main electrical system and provides electricity supply to more than 90% of the country's population. It includes the country's largest consumption centre, the Santiago Metropolitan Region.

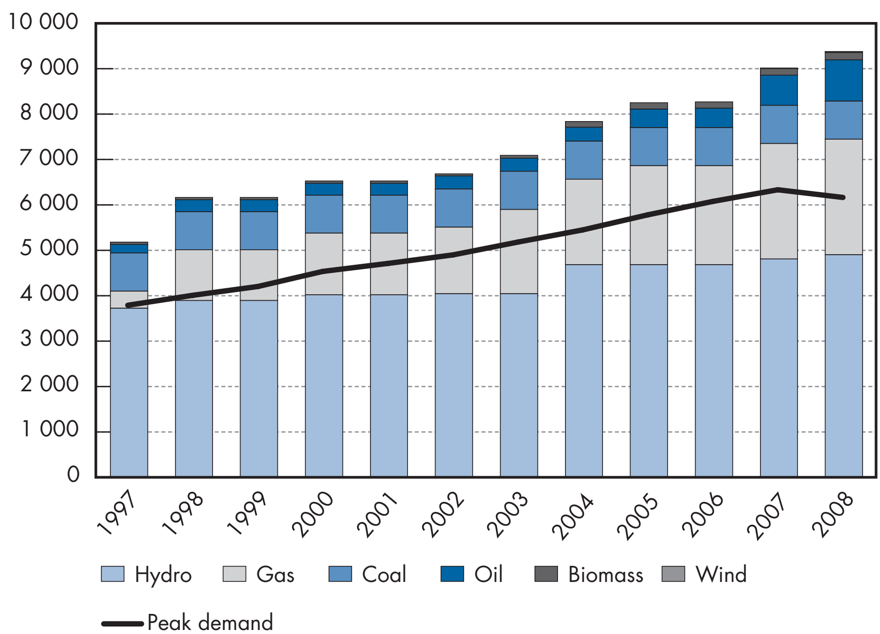
Installed capacity in the SIC at end-2008 was almost 9 400 MW, of which just over 50% was hydro capacity. Maximum demand reached 6 313 MW in March 2007, implying a reserve margin of 33%. Gross energy generation in 2008 was around 41 800 GWh, of which 56% was from the hydroelectric plants and 44% was thermal. The system load factor was just over 75%.

Figure 6.3 below shows the evolution of installed capacity and peak demand in the SIC since 1997. Sales of electricity in the SIC grew by more than 6% per year on average between 1986 and 2008. More than 70% of customers in the SIC are supplied under a regulated tariff.

Figure 6.4 shows generation by technology and fuel type since 1997 in the SIC. The effect of the gas restrictions on gas exports by Argentina and the drought in 2008 can be clearly seen.

Figure 6.3

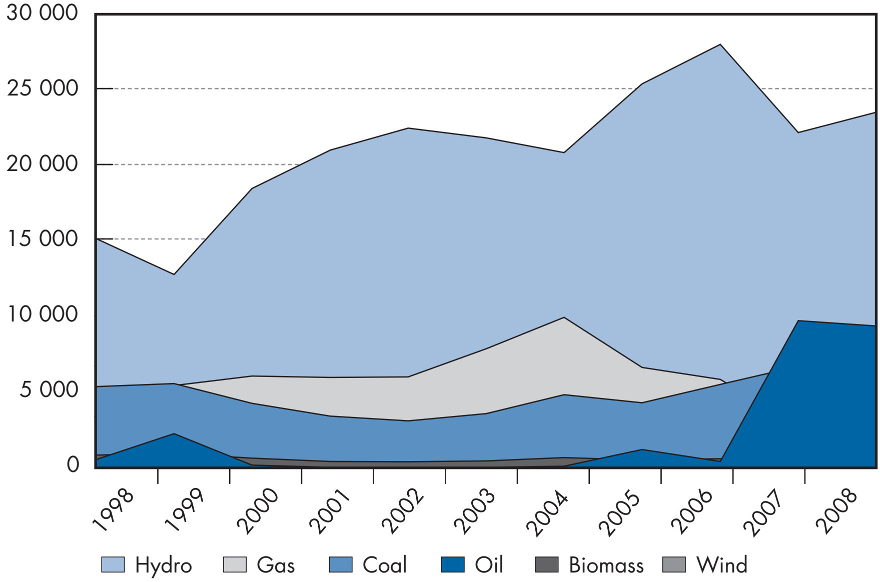
Installed Capacity and Peak Demand in the SIC, 1997-2008 (MW)



Source: CNE.

Figure 6.4

Generation by Fuel/Technology in the SIC, 1997-2008 (GWh)



Source: CNE.

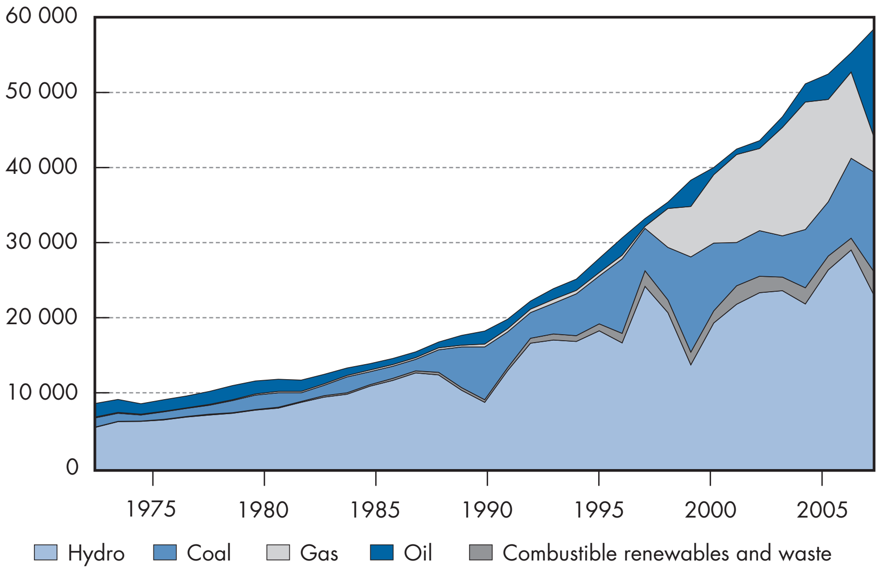
Figure 6.5 shows the evolution of electricity generated by fuel over a longer period, since 1973, for all four systems. The increased importance of gas imports from Argentina in the late 1990s is clearly apparent, as are the effects of the droughts in the late 1990s, in 1998/99 and again in 2008.

Projections

The latest projections by the CNE show significant changes in the composition of installed capacity over the period to 2020. Figure 6.6 compares installed capacity at end-2005 with that projected for 2020 and the mix of generation sources by capacity. The relative sizes of the circles reflect the expected near doubling in installed capacity over the period, from 11.9 GW at end-2005 to 22.8 GW by end-2020. The expected changing shares of the various generation technologies is also apparent, with a decline in the relative importance of oil, duel-fired gas and large hydro capacity, an increase in non-conventional renewable sources (wind, geothermal, biomass and small hydro), and an increase in the share of coal in total installed capacity, from 17% in 2005 to 26% by 2020.

Figure 6.5

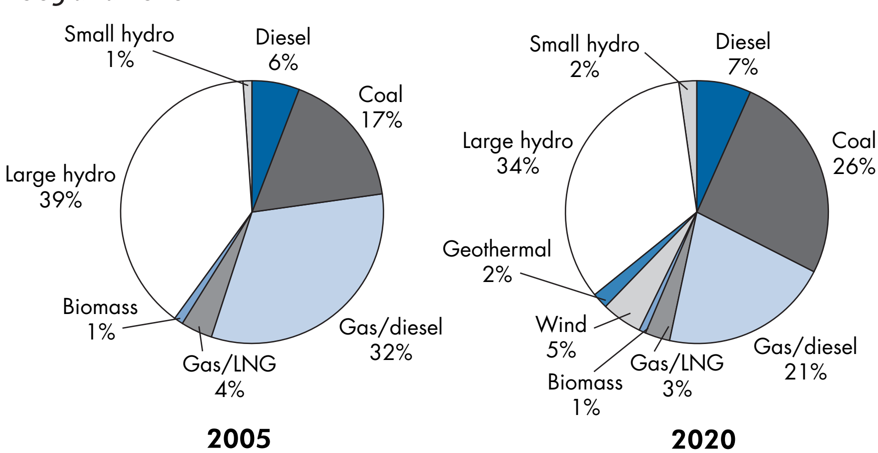
Generation by Fuel/Technology, 1973-2007 (GWh)



Source: Energy Balances of non-OECD Countries, IEA/OECD Paris, 2009.

Figure 6.6

Projected Evolution of Installed Capacity in the SIC and SING, 2005 and 2020



Source: CNE: Energy Policy: New Guidelines, 2008.

Market Design, Competition and Regulation

Regulatory Framework

The regulatory framework for Chile's electricity supply industry is based on the principle of competitive markets for generation and supply. Distribution and transmission are considered natural monopolies and are subject to a regulatory framework that establishes investment requirements, ensures third-party access, and sets prices for access to and use of the networks. Environmental norms and rights-of-way for transmission lines also apply for these activities.

Sector Structure

Generation, transmission and distribution are unbundled horizontally in both the SIC and the SING. The sectors are, however, integrated vertically: generators in the SIC also own transmission assets and distribution networks in the SIC. For example, Enersis owns both Endesa, which currently generates around half the SIC electricity, and Chilectra, which supplies around one-third of the regulated customers in the SIC.

Generation

Thirty-five generation companies currently operate in the SIC. But the market is concentrated with almost 90% of the capacity belonging to three large holding companies: Endesa, AES Gener and Colbún. Endesa alone owns 50% of the SIC total installed capacity as well as 75% of water rights, while Colbún and AES Gener own another 40% of total installed capacity. Six generating companies currently operate in the SING. Again, the sector is concentrated: three companies (AES Gener, Gas Atacama and Suez/CODELCO) own almost 95% of the SING total installed capacity.

Transmission

There are currently 14 500 km of transmission lines (from 33 kV to 500 kV) in the SIC, owned by around 20 companies. Two companies – Transelec and CGE Transmisiòn – own 50% and 17% of the lines respectively. Transelec used to be owned by Endesa but, following a long dispute with the National Economic Prosecutor's Office, the CNE encouraged Endesa to sell Transelec to Hydro-Quebec in 2000. Hydro-Quebec subsequently sold 100% of its shares in Transelec to a consortium led by Brookfield, which includes the Canadian Pension Plan Investment Board, and the British Columbia Investment Management Corporation, among others.

There are 6 200 km of transmission lines (from 66 kV to 345 kV) in the SING, owned by 24 companies. Four companies – Transelec Norte, AES Gener, Codelco/Suez and Minera Escondida – own 75% of the lines.

Distribution

Twenty-nine distribution companies currently supply just over 4.6 million customers in the SIC, of which 60% are supplied by two companies, Chilectra (with around 1.5 million customers) and CGE. Chilectra is owned by Enersis, of which Endesa is part. Four distribution companies operate in the SING, supplying nearly 275 000 customers. The Emel Group, which owns three of the four distribution companies in the SING, has close to 100% of the market in terms of both sales and customers supplied.

Wholesale Market

The wholesale markets for electricity in the SIC and the SING comprise two separate markets: a spot market and a contracts market.

Spot Market

The SIC and the SING are mandatory pools, into which generators are required to sell all their hourly generation at the corresponding hourly marginal cost projected for the injection node. Generators are also required to buy their hourly contracted demand at the corresponding hourly marginal cost projected for the demand node. The only participants in the spot market are generators, who perform two roles: as generators and as retailers to both distribution companies and to non-regulated customers. The demand side, in the form of large industrial customers, plays no part in the spot market.

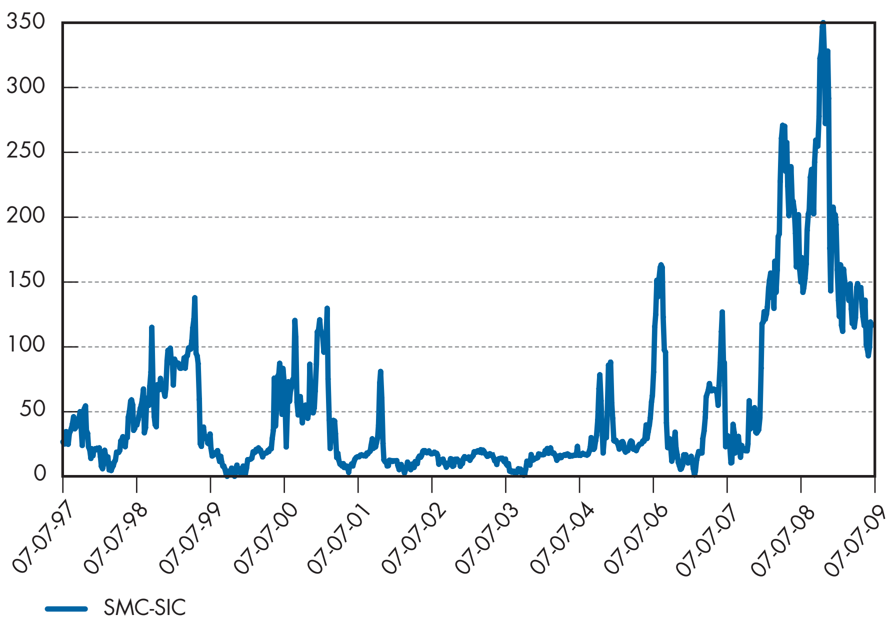
Dispatch and prices are based on an economic merit order in which the lowest marginal cost generator is used to satisfy demand before the next lowest marginal cost producer is dispatched. The dispatch schedule takes account of transmission constraints, so that the prices that come out of the process include the cost of dispatching the system to alleviate constraints. Generators therefore directly bear the cost of transmission constraints.

In common with spot electricity markets in other Latin American countries, generators in the two Chilean systems are not free to bid what they like to be dispatched. They are instead dispatched, in the case of thermal generators, on the basis of their audited variable generating costs (fuel plus variable operation and maintenance costs). The price of water in reservoirs (in the SIC) is calculated by CDEC on a weekly basis, using a model based on information provided by the generators on water levels and inflows into their reservoirs. The opportunity cost is normally equal to the expected operating cost of the thermal plant that can be replaced in the future by a marginal release of water in the reservoirs. If there is a shortage of available capacity in the system, the spot price at which imbalances are cashed out becomes the outage cost.[42]

Hourly imbalances between generation and contracted demand in the spot market are settled at the marginal cost at the respective node. Figure 6.7 shows the behaviour of the system marginal price at one node (Alto Jahuel) in the SIC over the ten years from end-June 1997 to end-June 2009. The spike in prices in the early part of the period (1998/99) reflects the effects of the drought on the system marginal cost, as high-cost, less efficient thermal plants were called into service to replace the lack of water. Prices again became more volatile from March 2005, as the initial restrictions on gas exports from Argentina to Chile began to be felt. The rapidly rising prices in 2007 reflect the combination of further (and by late 2007 almost total) restrictions on gas exports to Chile by Argentina, rising oil prices on world markets and, in 2008,

Figure 6.7

System Marginal Cost in the SIC, 1997-2008 (USD/MWh)



Source: CNE.

42. The outage cost is equal to an amount based on consumer willingness to accept compensation for a planned outage of a particular magnitude. For a less than 10% demand restriction it is between 4 and 5 times the normal spot price.

the effect of the drought in the SIC. System marginal prices reached a peak of almost USD 350/MWh in March 2008, at the height of the crisis, before falling back to around USD 100/MWh in June 2009. Figure 6.8 shows the proportionate cuts in supplies of gas from Argentina over the period from the beginning of 2004.

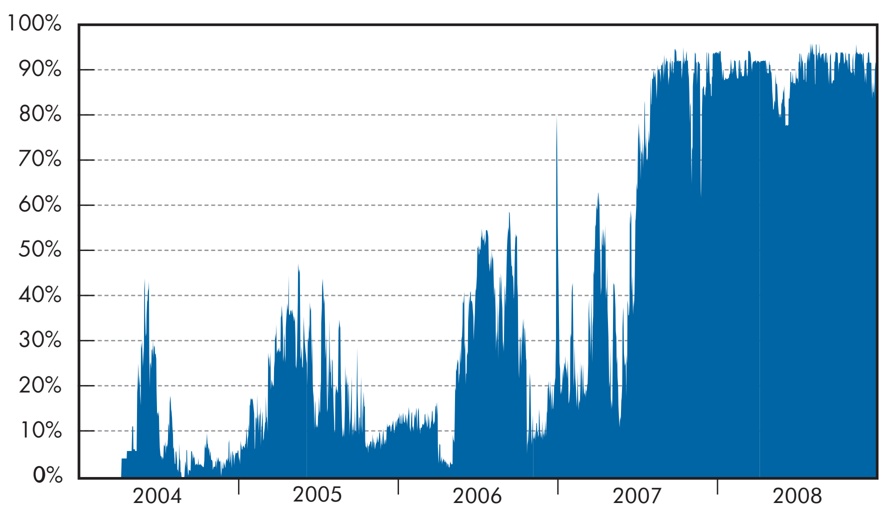
Income from energy sales is complemented by capacity income. All generating units receive a capacity payment, on the basis of their *potencia firme* (firm power). A generator's firm power is calculated as the capacity that it can, with a high probability, make available at times of peak demand.

The price paid for peak power is determined every six months by the CNE on the basis of the annualised cost of a reference efficient peaking unit. An open cycle gas turbine has been chosen since 1982 as the least-cost peaking unit. Its capital costs are annualised using a 10% real discount rate and the cost includes annual fixed operation and maintenance costs. The reference peaking unit is currently a diesel-fired gas turbine with an installed capacity of 70 MW for both the SIC and the SING.

The peak power price is currently about USD 106/kW per year in the SIC and USD 102/kW per year in the SING. In general, revenue for firm power constitutes between 20% and 30% of the total annual revenue that a generating unit receives from its participation in the spot market.

Figure 6.8

Restrictions on Argentine Gas Exports, 2004-2008, (% reduction on normal requirements)



Source: CNE.

Contracts Market

Generators can sign financial contracts with distributors and with non-regulated customers to hedge price risks in the spot market. The nodes at which energy and firm power are injected onto the transmission system by the generator and withdrawn by the generator to supply the non-regulated customer or distributor are specified in the contract. While the spot markets in the SIC and SING have uniform system marginal prices, different prices apply at different nodes. The differences reflect marginal transmission losses or transmission constraints.

Node Prices

Prior to *Short Law II*, sales by generators to distributors for resale to regulated customers were subject to price regulation under a system of node prices. This system was put in place to insulate regulated customers from fluctuations in the spot price of electricity by allowing distributors to pass through a smoothed price that would respond only slowly to changes in supply conditions. There were two types of smoothed (or node) prices: the peak power node price and the energy node price, respectively.

The energy node price is calculated in April and October each year, and is set equal to the average of the expected marginal costs of each electricity system over the following four years.[43] It is then fixed for the subsequent six months. The peak power node price is calculated by the CNE as the cost per installed unit of capacity of the unit able to supply peak demand most efficiently. Node prices are derived from system-wide prices by applying an energy and a capacity modulation factor, which reflects marginal transmission losses and transmission constraints at each node.

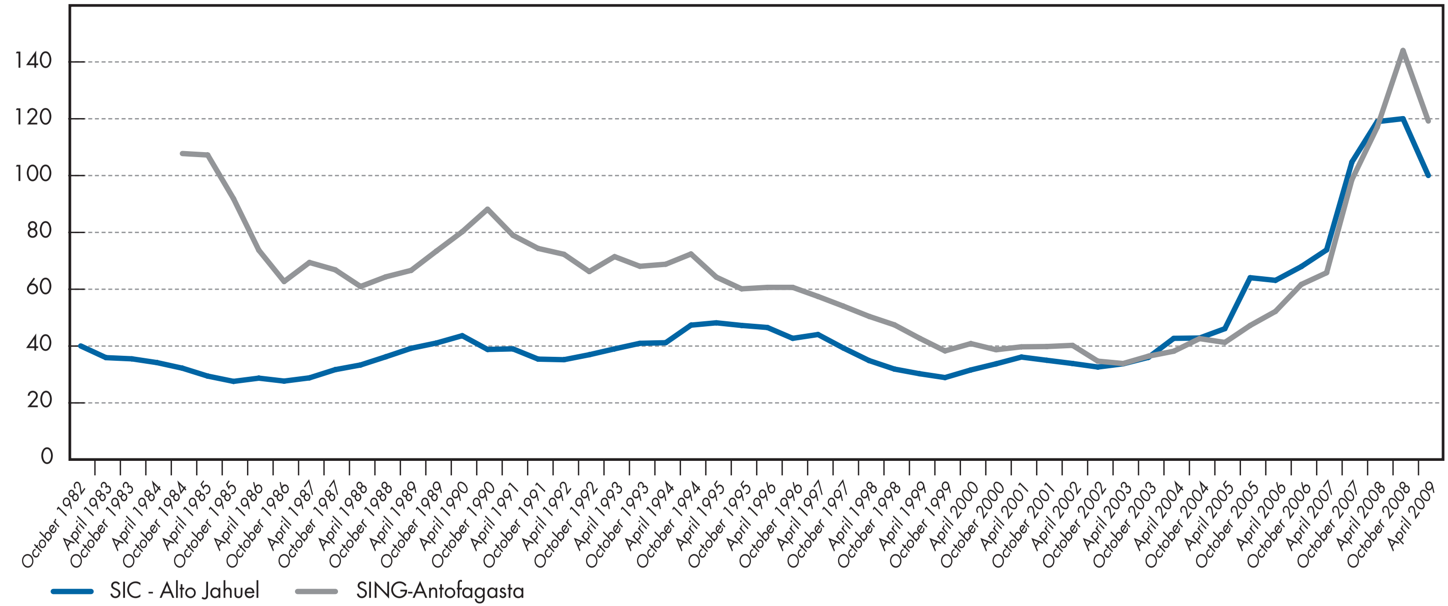
Before prices established in this way can come into force, they are compared with the average non-regulated price in contracts signed between generators and non-regulated customers over the previous four months.[44] If this basic average price differs from the average non-regulated price by no more than a given percentage in either direction, the node prices are accepted and come into force. But if the difference is larger than that percentage, the node prices are adjusted up or down, until the difference is equal to that percentage. Subject to these limits, the node price is constrained by prices

43. The CNE can choose a time period of between 24 and 48 months. Currently, the CNE uses 48 months but this could be changed.

44. The percentage variation was originally set at 10% in the 1982 Law. It was reduced in Short Law I *to 5%. Given the experience in 2004/05 with the restrictions on gas imports from Argentina, an acceleration factor was introduced in* Short Law II *to be used when the price deviation between the node price and average price in the non-regulated market was 80% or more. In this case, the band around the node price increased to 30%.*

Figure 6.9

Monomic Node Prices in the SIC and SING, 1982-2009 (USD/MWh)



Source: CNE.

in the non-regulated market. The latter tend, however, to be indexed to the node price, thereby limiting the usefulness of the cap and collar.

Figure 6.9 below shows the evolution of monomic node prices (a combination of energy and peak power prices) in nominal USD terms since the early 1980s. It shows the disparity between prices in the SIC and SING in the 1980s and 1990s, which reflected the different generating technologies in the two systems (hydro and thermal, respectively), as well as the convergence in prices by October 2003, by which time gas from Argentina had become an influence on energy node prices in both systems. The re-emergence of the disparity in the second half of 2008 reflects the differing effects of the restriction of gas exports by Argentina in the two systems.

System Operation

The system and market operators in the SIC (CDEC-SIC) and the SING (CDEC-SING) were created in 1985 and 1993, respectively. Their main duties are: to maintain service quality in their respective interconnected systems; to dispatch generation at least cost; to calculate spot prices and perform settlements between generators for their transactions with the spot market; and to guarantee open access to the trunk transmission and sub-transmission systems.

There is currently no market in ancillary services. The establishment of a market for ancillary services, which was addressed in *Short Law I* in 2004, is still under development. The regulation that will define the prices to be paid and the modalities of cost recovery has yet to be drafted.

The CDECs are governed by a board with representatives of the generators, transmission companies and large users.[45] The boards are responsible for establishing the regulations required to ensure that the CDEC fulfils its statutory duties. The increasing number of disputes between participants which were referred to the CDEC for resolution (primarily with respect to energy and capacity transfers and to transmission pricing) created problems for the CDECs. This has now been addressed by the creation in 2004 of a Panel of Experts, an independent entity financed by sector participants and composed of five engineers or economists and two lawyers. The experts are appointed by the Competition Tribunal through a public, merit-based competition for a term of three years (with overlapping terms to ensure continuity) and receive competitive remuneration. The Panel's decisions are final and cannot be appealed.

45. Prior to July 2008, the boards included representatives of only the generation and transmission companies.

Retail Market

The Chilean regulatory model is designed from the perspective that wholesale supply is carried out by the generation companies themselves, although the law does not prohibit the existence of independent retailers, as long as they have a minimum (9 MW) generation capacity. Thus, in practice, retailers in the Chilean market are either generation companies taking on this role or distributors that buy from generators and sell to both regulated and non-regulated customers connected to their distribution systems.

Network Access and Regulation

Transmission

Transmission is generally treated as a natural monopoly and a public service in Chile and revenues are regulated. *Short Law I* defines three categories of transmission: trunk systems, sub-transmission systems and additional systems.

The trunk system is the backbone of the high voltage transmission systems in the SIC and the SING. Reinforcements (or extensions) and expansions (or new facilities) of the system are mandatory, once identified by the CNE. The CNE draws up a ten-year generation and transmission expansion plan every four years, with the help of industry participants. In the intervening years, the expansion plan is revised by the CDECs, and the CNE proposes a yearly expansion programme. The relevant CDEC has the power to challenge the CNE proposals and delay their implementation. Extensions of the existing system are carried out by the existing owner. For new facilities, construction and subsequent operation of the lines are to be carried out by the successful company in an international tender.

The annual revenue received by the owner of a new trunk transmission facility is defined in the international tender mentioned above. These revenues are fixed for 20 years, after which they are updated by the value determined in the main transmission study supervised every four years by the CNE.

The law establishes that owners of non-conventional renewable generating plants (*i.e.* geothermal, wind, solar, biomass, tidal, small hydroelectric plants, co-generation, etc.), and whose power surpluses supplied to the system are less than 20 MW, are exempt from paying all of or a portion of the injection tolls for use of the trunk transmission system. In effect, non-conventional renewable units with capacity of less than 9 MW do not pay transmission tolls, and units with capacity of between 9 MW and 20 MW pay only for the power exceeding 9 MW. Units with power equal to or greater than 20 MW pay the normal toll amount.

The sub-transmission system is used to supply demand in specific distribution areas. In common with the trunk system, the sub-transmission system is considered a public service and owners are obliged to ensure third-party access and to expand or reinforce the system in such a way as to meet the growth in demand in an efficient manner.

The additional transmission system is defined as the infrastructure required to connect a generating station or a large industrial load to the sub- or trunk transmission systems. The use of these "shallow" assets is paid for under agreements freely reached between the generators and large industrial customers. Alternatively, additional transmission systems may be constructed and paid for by the users themselves.

System Operation

The CDEC decides and co-ordinates operation of generation units, regardless of their ownership or the characteristics of the respective contracts, with the sole objective of minimising overall operation costs while also complying with service quality and safety provisions. The existence of the CDEC thus guarantees that units will be dispatched efficiently in accordance with system capability requirements.

The CDECs in the SIC and SING were originally controlled by the largest generators and the transmission companies. But *Short Law II* required that the board of each of the CDECs should include a representative of the large industrial clients. This requirement was implemented by decree in August 2008.[46]

Distribution

Distribution in Chile is considered a natural monopoly and a public service and is regulated. Within its concession area, a distribution company serves both regulated and non-regulated customers. The end-user tariff paid by regulated customers is calculated as the sum of the price at which the distributor buys energy and capacity from generators, the transmission toll and a distribution margin known as the *Valor Agregado de Distribución* (VAD). The VAD is intended to remunerate the distribution company for the distribution and retailing services it provides, as well as a profit margin.

46. This was one of a number of regulations required to be implemented under Short Laws I *and* II. *Some.* e.g. *on the establishment of a market in ancillary services, are yet to be implemented.*

In the case of non-regulated customers connected to the distribution networks, distributors compete with generators (in their role as retailers) to supply non-regulated customers. Generators supplying a non-regulated customer in a distributor's concession area must pay the distributor a toll for the use of the distribution network. The toll is set in such a way that the final price paid by the non-regulated customer (including energy, capacity, transmission tolls and the distribution toll) should be equal to the end-user price a non-regulated customer pays to be supplied by the distributor. This means the distribution toll is broadly equal to the VAD.

The VAD is set every four years, based on the estimated efficient costs of a model distributor operating in an equivalent area (in terms of length of lines, density of customers, etc.). The law mandates the CNE to commission an independent consultant to model the optimal network of a distributor, with given demands and sources of supply. The law allows the distribution companies to hire their own independent consultant(s) to undertake the same exercise. The VAD is then set by averaging the estimates of the efficient costs, with weights of two-thirds for the estimates of the CNE consultants and one-third for that of the distributor's consultants. The CNE can reset the VAD after the first year of the control if the rate of return on assets of a distribution company falls below 5% or exceeds 15%.

Quality of Supply

The Superintendence for Electricity and Fuels (SEC) compiles each year a weighted average ranking of the quality of service provided by distribution companies. This indicator comprises three elements: the number and duration of outages (with a 50% weight); the results of a quality of service and value for money customer survey (with a 37.5% weight); and an indicator based on the number of service quality complaints made by consumers to the SEC and upheld by the SEC (with a weight of 12.5%).

According to this weighted indicator, the sector's performance was markedly worse in 2008 (with a value of 7.0) than in 2007 (8.4). This deterioration partly reflected the failure of some distribution companies to provide the necessary data in a timely fashion, which affected the average. But it also reflected a deterioration in the satisfaction of customers with the quality of service provided by the companies (in a survey of more than 15 600 customers) and a significant increase in the proportion of customers formally complaining to the SEC about the service provided by their local distribution company (up from 5% in 2007 to 10% in 2008).

This was only partly offset by two factors: a fall in the proportion of distribution lines (feeders) with outage frequencies above the standard, from 16% in 2007 to 10% in 2008; and a fall in the proportion of customers affected by feeders outside the standards for frequency and duration of outages, from 18% in 2007 to 9% in 2008.

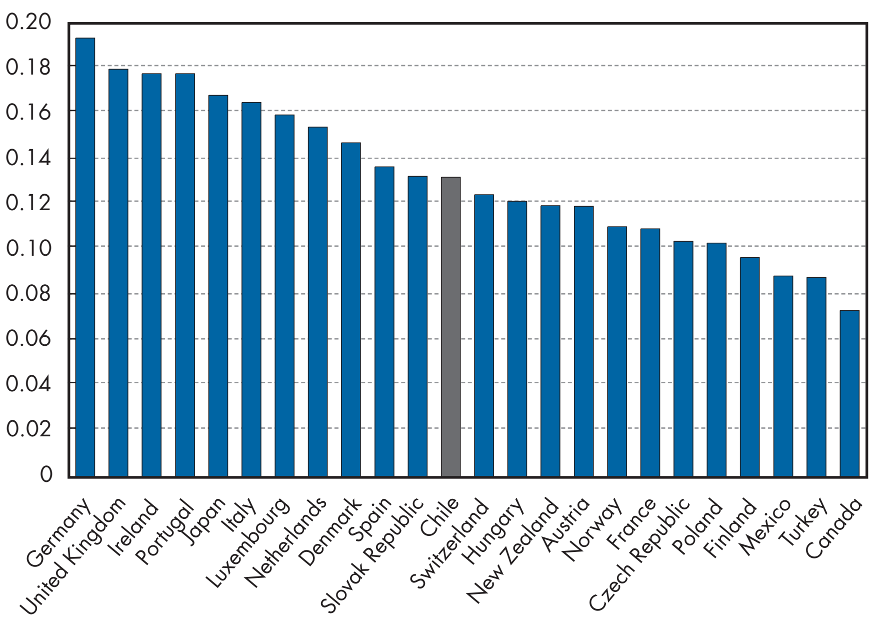
Tariffs

Tariffs for non-regulated customers are determined freely between retailers (*i.e.* generators and distributors) and their customers.[47] Tariffs for regulated customers are made up of the cost to distributors of buying energy from generators, the transmission toll and the VAD.

Figure 6.10 compares the average residential tariff (excluding taxes) in Chile in 2006 with those in OECD member countries in 2006 (in USD/kWh). Chile's residential tariff compared favourably with those in a number of developed countries.

Figure 6.10

Average Residential Tariffs, Excluding Taxes, 2006 (USD/kWh)



Source: IEA statistics.

47. Approximately 15% of the energy sold by distributors is sold to non-regulated consumers, at negotiated prices.

The electricity bills of some residential customers are now subsidised in certain circumstances. If electricity tariffs for urban and rural residential users undergo a real cumulative increase equal to or greater than 5% within a period of six months or less, a transitory subsidy is now given in the form of a discount on the electricity bill of low-income households. The total cost of the subsidy thus far has amounted to USD 50 million following the high price of oil in the first half of 2008.

Critique

The electricity sector in Chile has scored some notable successes over the past 20 years.

Between the beginning of 1982 (when the reforms began) and the end of 2008, installed generating capacity in the SIC system expanded from 2 713 MW to 9 386 MW (equivalent to an annual average growth of almost 5%), while installed capacity in the SING expanded from 428 MW to 3 602 MW (*i.e.* more than 8% per year). In transmission, the route length of transmission lines in the main SIC system (at 500, 220, 154 and 110 kV) expanded from 4 310 km in 1982 to 8 004 km at end-2007 (an average increase of 2.5% per year) and from 363 km and 6 202 km (an average increase of 11.5%) in the SING. Between 1982 and end-2008, the percentage of households with electricity supply increased from 38% to 94.5% in rural areas and from 95% to almost 100% in urban areas.

Distribution margins have been falling in real terms since 1988. The VAD for Chilectra fell by 18% in the tariff setting process of 1992, by 5% in 1996, by 18% in 2000 and by 8% in 2004, reflecting substantial improvements in labour and capital productivity over the period. In Chilectra, labour productivity improved from 1.4 GWh sales per worker in 1987 to 14.1 GWh sales per worker in 2003.[48]

Technical energy losses in the country's distribution system fell from 17% in 1988 to 8% by 2007. Technical losses in Chilectra's system were as high as 16% in 1989, they had fallen to 5.6% by 2002 and 5.4% by 2007. In the Transelec transmission system, the average of supply interruption was 6.4 minutes in 2007, down from an average of 6.6 minutes over the previous ten years.

The high rates of investment, falling prices in distribution and significant improvements in the quality of supply have been accompanied by strong financial performance by the companies involved. For example, Chilectra's

48. See Pollitt, M.G, Electricity Reform in Chile: Lessons for Developing Countries, *Cambridge Working Papers in Economics, January 2005.*

annual average nominal historic cost return on equity was 32% between 1996 and 1999. The average real rate of return on capital at replacement cost in the distribution sector was 14% in 2002, at the high end of the range of rates of return permitted by law (between 5% and 15%).[49]

At the same time, the sector has faced three major crises over the past decade, which have called into question the ability of the electricity market as designed to respond to events flexibly and efficiently.

The first crisis occurred in 1998/99 when the SIC experienced a severe drought at a time when the commissioning of a new CCGT, equivalent in size to 5% of the SIC installed capacity, was delayed. Outages began in the autumn of 1998 and continued for six months. Electricity had to be rationed in the first half of 1999. It was recognised that the existing framework provided insufficient incentives to generators to install sufficient back-up units to avoid shortages of supply in case of extreme droughts. The 1982 law was amended in 1999 such that extreme droughts were ruled out as *force majeure events* and penalties for failing to satisfy electricity supply contracts were increased substantially.

The second crisis stemmed from the substantial and rapid growth in installed capacity in the SING (see Figure 6.1), which resulted in two blackouts in the SING in July and September 1999. The crisis originated in the uncoordinated entry and exit of large generating units and large loads on the system combined with an inadequate provision of the ancillary services required to maintain stability and to guarantee reliability. This highlighted the need for a well-defined ancillary services market and a pricing system that adequately recognised the characteristics of each particular type of ancillary service.

The third crisis was triggered by the progressive reductions from 2004 onwards in the supply of gas from Argentina, on which the Chilean generating systems in the SIC and the SING had come to depend. In 2008, this coincided with another drought in the SIC as well as a major plant failure. At its peak, some 30% of SIC capacity and 60% of the SING was dependent on natural gas from Argentina. While the authorities took measures to avoid outages and rationing, replacing Argentine gas has been costly. In the short term, it was costly because companies had to convert gas-fired plants to operate on oil (diesel) and because of the higher cost of diesel. In the longer term, it will be costly to partially replace piped natural gas from Argentina with LNG imports.

49. See Pollitt, ibid.

A second concern is the high level of concentration in both the SIC and the SING generation markets. A sector with three firms with respective market shares of 45%, 25% and 15% would have a Herfindahl-Hirschman Index (HHI) of almost 3 000.[50] The US Department of Justice (DOJ) considers a market with a HHI of less than 1 000 to be competitive; one with an HHI of between 1 000 and 1 800 to be moderately concentrated; and one with an HHI of 1 800 or more to be highly concentrated. Participants in concentrated markets have market power, defined by the DOJ as the ability of a market participant, acting independently, to raise market prices consistently and profitably above competitive levels for a sustained period of time. Market monitors in electricity markets (*e.g.* in the PJM market[51] in the United States and in the Office of Gas and Electricity Markets or OFGEM in the United Kingdom) typically use the HHI as a screening tool for evidence of market power.

This definition refers to a capability and not to the likelihood of the exercise of market power. But if a market participant has the capability to substantially affect price, this warrants mitigation measures on the part of the authorities. One such measure is the design of the spot market. The spot market in Chile is not a market in the same sense as the spot markets in the United States and Europe. Generators are dispatched on the basis of regulated estimates of their marginal costs. They are not free to compete on the basis of price in the market. A spot market in which generators can compete on the basis of price is unlikely to be viable in Chile until concentration levels are far lower than at present. Competition will necessarily be restricted to entry into the market rather than for a share of the market once in. It is possible that spot markets with HHI around the 2500 to 3000 mark can still produce competitive results – but only if they are subject to the genuine threat of competitive new entry. Such a situation is a function of several factors including levels of spare capacity, degree to which the system is capacity/energy constrained, levels of incremental demand growth, etc. Chile's regulatory institutions thus have an important role to play in monitoring competition in the market.

The perception of a concentrated market can be a barrier to new entry in its own right. It is encouraging that two new entrants participated in the most recent tender process for long-term contracts with distribution companies: a wind power company belonging to the French group Suez Energy and a thermal generating company belonging to Southern Cross. But entry on this small scale is unlikely to pose a competitive threat to the incumbents,

50. Monitoring Analytics, State of the PJM Market January through April, 2009, June 2009

51. PJM Interconnection is a regional transmission organization (RTO) that co-ordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia. http://www.pjm.com/

even though the design of the auction for long-term contracts between the distribution companies and generators to supply regulated customer favours new entrants.[52]

The authorities are aware that the structure of the spot and contracts markets requires close and constant oversight to protect the interests of customers. While this is essential in current circumstances, the challenge is to encourage further reform to develop a truly competitive wholesale market that uses transparency and genuine horizontal and vertical competition to create strong commercial incentives for efficient behaviour, based on efficient price formation. This kind of market would be self-regulating to a large degree. It would allow the authorities to reduce their regulatory interventions, and would reduce compliance costs and the risk of regulatory failure while at the same time improving incentives for more efficient, flexible and innovative investment, operation and end-use.

This process could begin with the creation of a market participant called a retailer, whose function would be to buy electricity from generators and sell to non-regulated and regulated customers. Distributors would then formally be authorised as retailers, as would independents.[53] Retailers would be given access to the spot market, into which generators would now sell and from which retailers would buy. This might encourage independent retailers (including distributors) to buy in the spot market and compete with existing generators in the retail market, although the high level of concentration in generation and supply currently constitutes a significant barrier to entry. Giving the demand side (*e.g.* large industrial and mining customers), the right to participate directly in the spot market would also be appropriate as a way of limiting the market power of the generators.

A further step would be the divestment by generators of any interest in distribution, to avoid conflicts of interest. Where generation and distribution are part of the same group (*e.g.* Endesa and Chilectra), it is unlikely that competition to supply Chilectra's non-regulated and regulated customers will develop. There is scope for greater competition in supply: 70% of customers in the SIC are still obliged to buy their energy from their local distributor and switching rates are low. In the SIC, only one customer has changed supplier since 2006, out of a total of 13 customers who had the option on the expiry of their long-term contracts during this period. In the SING, six customers changed supplier out of a total of eight customers who have had the option

52. The current interval of three years between the award of a long-term contract and its coming into force may be long enough to incentivise new entrants building gas-fired plant and renewables. But it is insufficiently long for new coal or large hydro plants.

53. Distributors are already retailers for non-regulated end customers.

since 2006. Finally, the threshold above which customers can choose to be supplied by an entity other than their local distributor, which has recently been reduced from 2 000 kW to 500 kW, could be reduced further.

Opening up the retail market in this way will be of little value if competing generators have no scope for contesting the market. As part of the response to the gas crisis, distribution companies are now required to sign long-term contracts with generators to cover the anticipated load of their regulated customers. This runs the risk of limiting the scope for greater competition in the retail market in the years to come. The greater the proportion of existing supply that is tied up under long-term contracts, the more closed the market will become.

Finally, while improvements to the governance arrangements of the two CDECs have been made, the government should consider transforming the status of the two CDECs into entities that are independent of other entities in the sector. This could be along the lines of the independent system operators in North America and Europe, whose boards have no financial interest or ties to any company doing business in the wholesale electricity market they administer. This would ensure that the decisions of the boards of the two CDECs are impartial and represent the interests of all users.

Recommendations

The government of Chile should:

- Monitor closely competition in the spot market, and in the regulated and non-regulated contracts markets.
- Conduct a review of current best practice in wholesale electricity market design in other countries, with the aim of transforming the current wholesale markets in the SIC and SING by creating "retailers" to ensure real competition among generators, thereby empowering customer choice.
- Take progressive steps, including separating distribution from supply and eliminating the distinction between non-regulated and regulated markets, to create workable competition in the market for customers below 2 000 kW.
- Create an independent system operator in both the SIC and the SING to ensure that system operation decisions are impartial and take into account the interests of all users, not just the generators, transmission companies and large users.

7. RENEWABLES

Overview

The potential for renewable energy in Chile is diverse and substantial, thanks to the country's distinctive geographical and natural conditions. Chile has abundant water resources and good slopes to exploit them. Hydropower is and will remain a significant component of its energy mix. The southern part of the country is rich in biomass. While the traditional use of biomass in the form of firewood is likely to diminish in favour of more efficient bioenergy and/or of less polluting fuels, biomass will remain an important energy source thanks to the residues of Chile's large forestry industry. Strong winds throughout the country are another attractive energy source. Chile has 10% of the world's active volcanoes, highlighting an abundant potential for geothermal energy. The north of the country lacks water resources, but is rich in solar energy, which could be used both for thermal energy and electricity production. Finally, Chile has more than 4 000 km of coastline, and possibly the greatest potential for ocean and wave energy of any country in the world.

Current Use of Renewables

In 2007, renewable energy sources, including large hydro and bioenergy from firewood, accounted for 79% of Chile's domestic primary energy production and 22% of its total primary energy supply (see Table 1.1: Chile's Energy Balance), highlighting the importance of renewable energy in Chile.

Biomass plays an important role in Chile's energy matrix. It is the second most important source of energy after oil. In 2007, it contributed 16% of the total amount of primary energy supplied in the country, 55% of total domestic energy production and 70% of domestic renewable energy production (see Table 1.1). A large proportion of total bioenergy, corresponding to 40% of total domestic renewables production, is used for heating and cooking in the residential sector in the form of firewood. (The use of firewood is discussed in detail Chapter 8: Biomass).[54] Combustible renewables and waste constitute 26% of total final consumption in the industrial sector and contribute almost 5% of total electricity output (from auto-producer combined heat and power [CHP] plants). Chile does not currently use a significant amount of biofuels.

54. More detailed data are needed to assess the quantity of bioenergy produced and used in a sustainable manner.

Hydroelectricity is one of Chile's principal energy resources, owing to the geographical characteristics of the country, which allow large waterfalls over relatively short distances. This results in hydroelectricity costs that are competitive for both large and small projects. In 2007, hydroelectricity accounted for almost 40% of total electricity generation and for 37% of total installed capacity (see Table 6.1: Installed Capacity by Type of Plant and Energy Source).[55]

Wind energy was non-existent in the main electrical systems until 2007.[56] At the end of 2008, installed wind capacity totalled 20 MW. Wind plant installations under construction or planned are expected to bring total installed wind capacity in the SIC to 193 MW by the beginning of 2010.

In 2007, solar photovoltaics (PV) made a negligible contribution to Chile's energy mix, while other renewable energy sources including geothermal, concentrated solar power (CSP) and wave energy were not yet exploited.

Potential for Renewables

Chile has the potential to develop a diversified portfolio of renewable energy technologies. It is useful to discuss this potential separately for the various types of renewable technologies: conventional hydro; non-conventional renewable energy (NCRE), as defined by Chilean law; renewable heating (in particular solar); and biofuels for transport.

Conventional Hydropower

Chile's conventional hydro resource potential is far from having been fully developed. This potential could amount to as much as 20 000 MW of installed capacity.[57] In the past three years, new hydroelectricity projects have been approved with a total capacity of around 900 MW. Environmental Impact Assessments (EIAs) are currently being conducted for an additional 3 700 MW of hydro capacity, out of a total of 10 500 MW.[58] According to

55. *The production of electricity from hydro sources is heavily dependent on weather and hydrological variability. Hydrological data from the past few decades have shown that generation in a rainy hydrological cycle can be up to three times higher (around 30 000 GWh) than in a dry cycle (around 10 000 GWh). Source:* Energy Policy: New Guidelines, *CNE, 2008, p.35.*

56. *The first project (2MW) in Chile was installed in October 2001 in the Aysén system.*

57. Energy Policy: New Guidelines, *CNE 2008, p.93: Considering those projects which have entered the Environmental Impact Assessment System (SEIA) in recent years, plus other concrete initiatives that are being studied by generating companies, there is already projected availability of 10 500 MW, which corresponds to the doubling of the current total installed hydro capacity.*

58. *Including the 2 750 MW HidroAysén project in the south of the country, which is currently under evaluation in the SEIA system.*

projections made by the CNE, more than one-third of the capacity expansion in the SIC and SING systems by 2020 will be accounted for by conventional hydroelectricity projects (amounting to more than 4 400 MW, out of a total of nearly 13 000 MW to be installed).[59] Furthermore, this is a technology in which there is a high level of knowledge in the country, which minimises development costs.

Nevertheless, hydrological variability and environmental concerns are important constraints. Chile's energy policy must take into account the implications of such a large expansion in conventional hydro for energy security and local environmental impacts.

From an energy security perspective, three potential impacts of global warming will be important for the strategic planning of hydroelectric generation in Chile. The first is a reduction in average rainfall in south-central Chile (north of Chiloé Island). The second is less snow accumulation in the high Andes. The third is the increased frequency of the El Niño and La Niña phenomena, which will increase hydrological variability in the south-central zone. To deal with these potential impacts, reservoir capacity will need to be regulated to allow an accumulation of energy (and water resources in general) in line with new climate conditions.[60] Constructing hydroelectricity projects in areas with more availability and less variability of the resource will be equally important.

To exploit the significant potential of conventional hydropower it will be important to fully address potential environmental and social impact issues associated with hydropower projects, also duly taking into account the multipurpose use of water resources for non-energy applications. It will be essential to integrate various mitigation measures that contribute to the resolution of environmental and social issues – as well as measures that enhance the potential social and environmental benefits – at the early stages of project planning. Since potential impacts are dependent on the specific natural and social conditions of the affected region, the proposed measures will have to be tailored in the case of large projects. In this regard, it will be important to learn from international experience when considering appropriate planning and action.[61]

59. Energy Policy: New Guidelines, *CNE, 2008, p.94.*

60. *This would increase the overall flexibility of the system and ease the integration of other renewable variable power sources (e.g. wind) into electricity grids, provided that the relevant interconnections are built.*

61. *See 60 Good Practice cases from 20 countries worldwide in* "Hydropower Good Practices: Environmental Mitigation Measures and Benefits", *IEA Implementing Agreement for Hydropower Technologies and Programmes, Annex VIII, 2006, retrievable at (http://www.ieahydro.org/annex8.htm) and (http://www.hydropower.org/sustainable_hydropower/HSAF_IHA_Sustainability_Assessment_Protocol.html)*

Non-Conventional Renewable Energy

As defined in the Chilean law, "non-conventional" renewable energy (NCRE) refers to those energy sources, or combinations of energy sources and technology, which are not generally used in Chile at present. The definition includes wind power, geothermal energy, solar energy (thermal and photovoltaic), biomass (solid, liquid and biogas), marine (currents, tides, waves and thermal gradients), and hydraulic energy (restricted to small hydro plants, defined in Chile as having less than 20 MW installed capacity).

According to the CNE, cumulative installed capacity of NCRE sources (including small-hydro and co-generation from forestry waste) in 2008 was less than 3% of total installed capacity (see Table 6.1). According to CNE projections, some 2 206 MW of new NCRE capacity might be added between 2009 and 2020, leading to a total NCRE electricity capacity share of 9.7% in 2020. However, other CNE estimates show that in the longer term, a total capacity of more than 12 000 MW could be installed using existing technologies.[62] Another recent study assessing three different scenarios for renewables penetration estimates that economically feasible electricity generation from NCRE sources could amount to between 17% and 28% of the total expected demand of 105 000 GWh in 2025.[63]

Wind Energy

Wind is among the most cost-competitive renewable electricity generation technologies, and is expected to contribute to a large share of additional NCRE capacity. As of end-March 2009, the list of wind projects currently under evaluation in Chile's environmental impact assessment system (SEIA) and those approved in the period 2006-09 totalled potential new capacity of around 1 500 MW. Of course, only a fraction of those projects will be developed in the coming years.[64]

Geothermal Energy

Chile is part of the so-called "Pacific Ring of Fire" and has 10% of all the active volcanoes in the world, giving it a comparative advantage for geothermal energy. The National Petroleum Company (ENAP) estimates

62. Energy Policy New Guidelines, *CNE, 2008, p.95*

63. Aporte potencial de Energías Renovables No Convencionales y Eficiencia Energética a la Matriz Eléctrica, *2008-2025 Universidad Técnica Federico Santa Maria and Universidad de Chile, 2008. It is worth highlighting that this study uses a different methodology so its results cannot be directly compared with those of CNE.*

64. *List of wind projects approved or submitted to SEIA as of 30 March 2009, CNE, April 2009*

that the country has the potential to produce 3 350 MW of electricity from this source. Geothermal energy is particularly interesting from the point of view of security of supply, given the high number of full-load hours and low maintenance, which make it ideal for base-load generation.

Solar Energy

Solar energy is potentially abundant over a large part of the country, with exceptional levels of solar radiation available especially in the north of Chile. This makes it competitive for providing hot water for a large portion of the population. Studies have indicated that it is cost-effective in most parts of the country – the savings from solar-powered hot water far outweigh the cost of the equipment required. However, a number of barriers currently hinder the exploitation of its market potential, including lack of awareness among consumers, lack of trained installers and maintenance service providers, different quality and reliability level of products on the market, etc.

There is also potential for solar space heating and cooling in residential, commercial and other buildings, which needs to be economically assessed. Furthermore, there is probably a large potential for solar heat for industrial process heat at various temperature levels, *e.g.* in the copper mining industry in the northern part of the country.

In the longer term, the potential of solar for electricity generation in Chile is immense, owing to technical advances and the scale of the primary resource. A recent study estimates the gross potential at between 40 GW and 100 GW, and a potential of 1 GW for solar photovoltaics, capable of being exploited in small power systems for the residential, industry and service sectors.[65] These numbers reflect the large technical potential of solar energy in the country. The economic potential over time will obviously be a fraction of these numbers, and will depend both on the expected economic competitiveness of solar and the actual capability of introducing large amounts of solar energy in the electric system. The latter will also depend on concurrent measures to increase the flexibility of the electric system, including – among other aspects – improved grid planning and management, use of smart grids and new interconnections.

Biomass and Biofuels

While firewood is the principal biomass energy source available in Chile, it is not the only one. A biogas plant producing city gas from sewage came into

65. Universidad Técnica Federico Santa Maria and Universidad de Chile, ibid.

operation in October 2008. This plant can supply up to 4% of the daily gas consumption of Santiago's households. Several studies are evaluating the electricity generation potential from waste produced by forest management and harvesting.

The potential for domestic production of first-generation biofuels in Chile is limited. Manufacturing from animal fat and marginal production of traditional crops is just being developed. A more logical approach for Chile would be to import biofuels at competitive prices from nearby countries, with more developed markets, such as Brazil. However, thanks to its available natural resources and the latest technological advances, there is considerable potential in Chile for the production of second-generation biofuels from forestry residues in the south and from algae all along the coast. If current R&D activity is maintained and produces new developments, biofuels will be increasingly incorporated into Chile’s liquid fuel market. A Decree published in January 2008 authorised the sale of bioethanol-gasoline and biodiesel-petroleum diesel mixtures composed of 5% biofuel, which can be used without making any adjustments to vehicles.[66] Currently available technical and economic information suggests that biofuels could account for as much as 10% of motor vehicle fuel consumption by 2020.[67]

Renewable Energy Policy Direction

Characteristics of Non-Conventional Renewable Energy

The formulation of a renewable energy policy in Chile is a recent development. The first measures supporting renewables were introduced only in 2004. The Chilean government is now implementing a comprehensive policy framework for renewables, which includes the improvement of the electricity market regulatory framework, specific measures supporting investment in renewables, and initiatives at the demonstration and R&D level. The policy framework addresses all types of renewables and specific regulations have been or are about to be introduced for solar thermal energy and biofuels.

The Chilean government recognises the value of generation from NCRE sources as an option that supports supply increases (with potentially competitive resources) while addressing energy security and fulfilling environmental and equity goals. Moreover, NCRE sources are generally significantly less environmentally invasive than traditional sources. In

66. *Supreme Decree 11, Ministry of Economy, Development and Reconstruction (January 2008).*
67. Energy Policy: New Guidelines, *p.89.*

addition, they are compatible with or complementary to other economic activities, allow development throughout the country, and help to mitigate the impacts of energy consumption on the global climate. Finally, the availability of different resources in different parts of the country enhances the potential for local solutions in areas where traditional energy supply is not viable owing to infrastructure limitations or high costs.

The Chilean government recognises the significant long-term potential of renewable energy in Chile. More importantly, it considers that NCRE sources are potentially cost-competitive, even in the short term. Energy price levels in 2007 and 2008 showed that many of these projects are competitive and will become even more so in the coming decade, as equipment supply companies expand worldwide and the service industry in Chile consolidates.

The government's renewable energy policy strategy is based on the recognition that a number of barriers prevent the exploitation of both the short-and long-term potential of NCRE sources. This is because the nature of many NCRE projects, and some of their developers, prevent them from assuming risks associated with the final sale of energy in the way that traditional projects can. These projects are also hindered by their small scale and by the risks involved in the introduction of innovative technologies (see Box 7.1).

In the case of geothermal energy, the high risk of exploration presents a specific barrier. As with oil exploration, geothermal exploration requires large investments at successive stages. Although the initial costs of geothermal exploration are relatively low, the likelihood of locating a commercially

Box 7.1: Typical Barriers Faced by NCRE

- Lack of information on energy resources.
- Uncertainty in processing permits for new technologies.
- Regulatory framework under development (first drafts started only in 2004).
- Weak infrastructure (especially access to some resources).
- Difficulty of accessing credit (capital-intensive with long pay-back periods).
- Uncertainty regarding technological options, their costs and performance.
- Need to adapt systems to operate with more intermittent sources.

viable geothermal reserve is also low. In the exploration stage with deep wells (two or more), drilling to confirm the existence of the resource is expensive, amounting to several million dollars per well.

The strategy for incorporating NCRE technologies into the Chilean electricity system aims to reduce these barriers as much as possible. Particular emphasis is put on reducing the excessive risks associated with NCRE technologies so that they can compete on equal terms with other technologies. Some of these barriers will be overcome as experience with implementing NCRE projects develops. Others will require specific measures to remove them.

Renewable Energy Policies and Measures

Two main lines of action have been pursued to reduce barriers faced by NCRE: improving the electricity market regulatory framework; and introducing direct support instruments for NCRE investment projects.

The first seeks to ensure that the rules under which the electricity market operates take NCRE particularities into account so that they can be incorporated into the electricity market. This began with the modification of the *1982 General Electrical Services Law* with *Short Law I* and *Short Law II* in 2004 and 2005, and was consolidated with the enactment of the *2008 Law for the Development of NCRE*.

The second seeks to mitigate specific barriers to each type of NCRE source and enable all types of NCRE to compete on equal terms. Some NCRE technologies face fewer barriers to development in Chile (such as small-scale hydroelectric generation), while specific barriers limit others. This line of action includes specific measures to promote private investment, as well as providing public information to reduce investment risks.

Improving the Electricity Market Regulatory Framework

Under *Short Law I*, a subsidy for NCRE sources was established for the first time by exempting them from payment of toll charges for the trunk transmission system. Barriers to NCRE entering the electricity generation market were also eliminated. All sources of generation, regardless of size, ownership or level of connection, now have the right to participate in electricity transfers co-ordinated by the two Central Economic Dispatch Load Centres (CDECs). This guarantees that all generators have access to the same markets to sell their electrical products: spot, non-regulated customers and distribution companies. In particular, the 2004 modification means that:

- Plants smaller than 9 MW that sell their products on the spot market are entitled to an energy price stabilisation mechanism in this market.
- Operators of distribution networks must allow plants smaller than 9 MW to connect to their networks. This complements the open access to transmission networks previously established.
- Plants that use NCRE sources are exempt from payment of the trunk toll charge. The exemption is complete for plants with capacities smaller than 9 MW and partial for plants between 9 MW and 20 MW.

Short Law II of 2005 allowed long-term supply contracts to be signed between generator and distribution companies, which stabilises energy payments over the contract period. In this way, traditional companies can include capital-intensive, low operating cost generation projects (such as NCRE) in their portfolios with lower risk.

Moreover, in 2008, the government passed a special law to promote NCRE sources. The *Law for the Development of NCRE* of April 2008 obliges electricity companies that sell energy in the SIC and the SING to demonstrate from 2010 onwards, that a percentage of their commercialised energy each year is generated from NCRE sources. Only new NCRE projects connected to the electricity grid after 1 January 2007 are eligible.[68] Traditional generators can meet this obligation either from their own plants or from NCRE plants owned by others and under contract. The obligation applies to generators that supply non-regulated clients and distribution companies under contract from 31 August 2007 onwards. The obligation lasts until 2034 and will increase over time, starting at 5% of supply between 2010 and 2014, and increasing by 0.5% per year from 2015, reaching a maximum of 10% in 2024.

Companies will be penalised if they fail to obtain the required percentage of their supplies from NCRE sources. The penalty will be proportional to the amount of mandated renewable energy that they failed to procure. The charge will amount to UTM 0.4 for each non-supplied MWh (equivalent to USD 29/MWh in June 2008).[69] The charge will be increased to UTM 0.6/MWh (equivalent to USD 42/MWh) for companies that fail again to comply with the obligation within three years from the first non-compliance. The revenues

68. A linearly decreasing proportion of the energy production from hydropower plants up to 40 MW is accepted as well: 100% of energy for a 20 MW plant, 50% for a 30 MW plant, down to 0% for a 40 MW plant.

69. These amounts are low compared with those in other countries. The equivalent penalty price in the United Kingdom's similar Renewables Obligation Certificate scheme is GBP 35.76/MWh in 2008/09, equivalent to USD 55/MWh using the July 2009 exchange rate.

collected through these penalties will be recycled to the clients of the suppliers who met the obligation.

According to the government, the objective of the law is to create the conditions for the implementation of NCRE projects and to stimulate a market for those technologies. It follows four general principles:

- **Efficiency and competition:** the implementation of the most efficient renewable energy projects will be encouraged because traditional generators will internalise the cost of meeting the obligation into their offers in the wholesale market.

- **Effectiveness:** by guaranteeing the incorporation of NCRE projects into the electricity market. According to CNE, the estimated impact of the law in terms of additional capacity is 200 MW by 2010 and 1 400 MW by 2020.

- **Equity:** by not discriminating between regulated and non- customers, the law should not significantly affect the cost of energy or alter the competitive environment in the supply market.

- **Legal simplicity:** it is compatible with the *1982 Electricity Law* and encourages competition and free enterprise by allowing new entrants with NCRE projects to sign contracts with established companies.

Finally, a modification has been proposed to the existing *Law on Geothermal Concessions*. The objective is to increase efficiency in the allocation of geothermal concessions by improving the terms and conditions through which they are granted, and to ensure the sustainable productive use of geothermal resources. The role of the state in promoting and inspecting commitments will be improved as well.

Direct Support Instruments for NCRE Investment Initiatives

Since 2004, the government has developed various instruments to promote private investment and make information available to guide and facilitate investment decisions through various public agencies. In 2008, the NCRE Development Support Programme was created to extend this work and complement government efforts in eliminating barriers that limit the development of NCRE.

Promotion of Private Investment

Since 2005, the Chilean Economic Development Agency (*Corporación de Fomento de la Producción* – CORFO), with technical support from the CNE, has been providing subsidies for pre-investment stages of NCRE projects through co-funding of pre-feasibility studies for such projects.[70] The maximum subsidy is USD 60 000, with a limit of 50% of the study cost and 2% of the estimated investment. By 2008, some 130 projects based on wind power, biomass, biogas, geothermal energy and small-scale hydroelectric plants received support from CORFO. Some of these projects have already been implemented; others are currently under construction or in the process of obtaining permits.

CORFO also provides grants for pre-investment studies under advanced stage of development. This incentive finances part of the costs of advanced engineering studies such as basic and detailed engineering, studies of electrical connections, and environmental impact studies. These grants can provide up to 50% of the total cost of the study, with a maximum of 5% of the estimated investment and not surpassing USD 160 000 per project submission. This instrument does not apply to studies measuring the availability of resources or to pre-feasibility studies.

CORFO also offers support for foreign products and service providers for renewable energy projects through the High Technology Investment Programme. The programme delivers grants for the pre-investment phase for fixed assets, as well as incentives for the start-up of a company, settlement and human resources. The programme applies to ancillary services and products for renewable energy generation such as: wind power logistics, maintenance, off-shoring of engineering, manufacturing of turbines, laboratories, etc.

In parallel, CORFO also provides funding for NCRE investments. Through their financing lines in the local banking system, investors can apply for specialised credits for NCRE projects with preferential conditions on rates and periods.[71] This has also facilitated the involvement of the local banking system. In addition, CORFO can provide risk capital for investment funds for NCRE projects.

Other instruments to be implemented in 2009 are:

- A dedicated instrument to encourage transmission line owners to connect several NCRE projects to stimulate inter-connectivity between such projects and improve their technical and economic viability.

70. This includes, among others, conceptual engineering, prospection and environmental impact assessment studies.

71. CORFO provides long-term credit lines with attractive interest rates for investment projects, including an "environmental line" for projects with a positive environmental impact, including renewable energy with a maximum loan amount of USD 5 million per project, with 12-year payment term and 30-months grace period. It also has a financing line for renewable energy and energy efficiency projects with a maximum loan amount of the equivalent of about USD 13.5 million, with 12-year payment term and 36-month grace period. The funds are provided with resources from CORFO complemented by a loan granted by the German government to the Chilean government for this purpose.

- A proposed fund to guarantee bank loans for NCRE projects applied to electricity generation and other areas, and for energy efficiency.
- For geothermal energy, a mechanism has been designed that allows the Chilean government to share with the private sector the risk in the final stages of well drilling. This mechanism would apply to concessions already granted and will be a contingent subsidy to cover part of the exploratory costs in the wells that would be paid out if the geothermal reserve fails to meet expectations.[72]
- Regarding solar energy, the CNE announced in April 2009 that an international tender would be launched in the second semester of 2009 for the construction of two solar plants in the north of Chile: a 0.5 MW PV power plant and a 10 MW CSP plant. The plants are expected to be operating, respectively, in 2010 and 2012. The tendering scheme will allow minimising total investment costs, part of which will be subsidised by the government.

InnovaChile, a specific programme established within CORFO, supports the development of pre-competitive initiatives and technology transfer, thereby supporting the creation of new products, services and business models in the energy sector. Through these lines the following results have been obtained:

- Since 2005, InnovaChile has supported 68 innovation projects in the energy area (34 during 2008).
- This represents a total contribution of CLP 6 900 million (USD 13 million) by the government to the sector, with 75% of funding allocated to biofuels projects.
- One-third of these 68 projects are related to biofuels.

Among the beneficiaries are national R&D centres developing projects jointly with the private sector, as well as private companies.

Investment Information

Lack of appropriate information for investors has been identified as a key barrier for NCRE. The CNE and other government institutions, aided by technical co-operation from the German government and UNDP, are gathering more information to fill in the gaps on the potential of NCRE projects and their associated technologies, as well as on technical,

72. Conditional upon the return of the concession and the delivery of all the information from the drilling operation.

economic, administrative and authorisation procedures. Information currently in the public domain includes the following:

- Evaluation of Chile's potential for generating biogas from biomass.
- Evaluation of the availability of wood industry waste used to produce energy.
- Evaluation of electricity generation potential from forest management and harvesting waste.
- Database on wind measurements in Chile.
- Wind-power resource measuring campaign in the Atacama, Coquimbo and Maule regions.
- Manuals for environmental assessment of wind-power and biomass projects.
- Manual for project application to the Clean Development Mechanism (CDM) of the Kyoto Protocol.
- Evaluation of generating potential of hydraulic projects associated with irrigation works, including registry of projects with flows greater than 4 cm/second.
- Investment guidelines for projects associated with irrigation and for their environmental processing, together with a programme to advertise these business opportunities with irrigation organisations and hydroelectricity companies.
- Guidelines for NRCE in the Chilean electricity market.
- Programme to characterise the wind-power potential in government-owned land located in the SING area.
- Measurement of solar radiation using technical requirements to assess the feasibility of solar thermo-electric projects, together with modelling of solar radiation in the north of the country.

As a complementary initiative, CORFO organises an annual international renewable energy investment meeting. During these events, project sponsors can meet the international investment and financing community and establish contact to reach a financial agreement. Since the first investment meeting in 2006, more than 2 000 formal meetings have been organised by CORFO and numerous agreements have been reached. In parallel, a Renewable Energy Project Directory with relevant information on approximately 40 projects is issued every year. This information provides an overview of the Chilean renewable energy market to international investors and facilitates the process of identifying attractive projects.

For geothermal energy, in 2007 a resource identification and evaluation programme was initiated in Chile. The programme is implemented by the National Geology and Mining Service in areas where there are no current geothermal concessions, and is financed with public funds and financial co-operation of the German government. This complements the work of companies such as ENAP, Antofagasta Minerals, and Geotermía del Pacífico, among others, in the development of geothermal projects.

Research and development on NCRE must take account of international assessments of alternatives and their possible adaptation for Chile. In this context, CORFO, InnovaChile and the National Commission for Scientific and Technological Research (CONICYT) are currently implementing activities and are connecting to some regional initiatives. The proposed Centre for Renewable Energies will complement these efforts.

An important step towards the provision of comprehensive information to investors and other stakeholders, as well as the co-ordination of R&D and promotion activities, will be the establishment of the Renewable Energy Centre (*Centro de Energías Renovables* – CER). The Centre has the purpose of acting as an antenna (or a clearinghouse) for renewable energy development, identifying technological advances and best practices around the world to organise and make available information within Chile. In addition, the Centre will review experience with various types of incentives for alternative energy projects, generate systematic reviews of available natural resources, provide capacity building, orient potential investors, administer direct financing instruments, and create networks with other specialised centres of R&D and incentives in renewable energies.

Renewable Heating Policies (Solar Thermal)

Although solar thermal domestic hot water is already competitive with traditional alternatives in several parts of Chile, several barriers hinder the broader exploitation of this market.

One barrier is the reliability and quality of the installations. As thermal solar panels are installed in individual homes, collective dwellings and other buildings, users need a certification system that guarantees the technology's reliability. Minimum quality standards for the equipment are also useful to guarantee that effective use will be made of the resources available and to maximise the economic profitability of installations.

Secondly, equipment and qualified installers are needed to expand the market and offer alternatives tailored to each home. Some technical training institutes in Chile are already training personnel to install solar collectors.

Finally, in July 2009 the Chilean Congress approved a bill providing tax credits for the installation of solar thermal collectors in new housing units. Houses valued up to UF[73] 2 000 (USD 80) will be credited with a 100% tax rebate for such installations; houses costing between UF 2 000 and UF 4 500 (USD 80 and USD 175) will receive a progressively smaller rebate. The bill will also establish technical standards and a certification system. This support scheme seeks to boost market development, encourage the training of solar panel installers and establish a certification system. The tax incentive will last for five years only, in the expectation that once the proposed objectives are achieved, the private cost-effectiveness of installing this technology should ensure that the market is sustainable without publicly-funded incentives.

Biofuels Policies

Chile currently has no quota obligation or other mandatory measures for biofuels. However, the government recognises the value of biofuels as an instrument to increase energy security, reduce the exposure to oil price volatility, and reduce local and global environmental impacts. It has therefore introduced a number of regulatory, technical and institutional measures. The biofuels policy proposes that the equivalent of 10% of vehicle fuel consumption is provided by biofuels by 2020. This supply is most likely to be achieved through imports from other countries (*e.g.* Brazil), as Chile does not have a significant potential for domestic production of first-generation biofuels.

An initial measure was the authorisation of the sale of bioethanol-gasoline and biodiesel-petroleum diesel mixtures composed of 5% biofuels, which can be used without making any adjustments to vehicles.[74] Implementing this standard, including defining certification and retail procedures, requires an oversight institution capable of supervising its application. A law was passed in 2008 to grant supervisory powers on these matters to the SEC.[75]

73. The Unidad de Fomento *(UF) is a unit of account that is used in Chile for determining principal and interest in bank loans, subject to revaluation in line with price inflation. The exchange rate between the UF and the CLP is adjusted so that the value of the UF remains constant in real terms. It has become the preferred and predominant measure for determining the cost of construction, values of housing and any secured loan, either private or public. It is currently set at around UF 1 = CLP 21 000.*

74. Supreme Decree 11, Ministry of Economy, Development and Reconstruction (January 2008).

75. Decree 128, Ministry of Mining (August 2008).

To foster the uptake of biofuels, a tax incentive was established, exempting biofuels from taxes applied to petroleum derivatives for transportation.[76] In addition, pilot tests have been carried out and an agreement was signed with Brazil for technical co-operation on biofuels.

As biofuels use increases, more information will be needed to assess the scope and implications of the proposed standards, as well as any possible adjustments that must be made. Progress has been made by ENAP in analysing the environmental impacts of the proposed mixture and the desired qualities of the gasoline to be used.[77] Fuel distribution logistics are also being analysed.

Chile has considerable potential for producing second-generation biofuels from non-food feedstock chains. This potential is especially important for ligno-cellulosic material and algae, as well as some exotic crops (such as jatropha and castor oil plants). In addition to standard R&D efforts supported by entities such as CONICYT, a competition financed by InnovaChile was launched in 2008 to establish research consortia to study ligno-cellulosic biofuels. The competition was funded with CLP 4 billion (USD 7.5 million) in public resources. The outcome of the competition was the establishment of two consortia composed of: Chile's principal forestry companies and some of its main universities (University of Concepción and University of Valparaíso); and ENAP and the University of Chile, supported by a total investment of CLP 7 billion (USD 13 million). A new tender has recently been launched to establish consortia for studying biofuels from microalgae. A fund of USD 12 million has been committed to finance at least two research groups. Applications are expected at the end of 2009.

From an industrial perspective, the development of biofuels bears implications across various sectors of the economy. To co-ordinate policies and measures for developing biofuels' value chain, Chile created the Inter-ministerial Advisory Commission on Biofuels Matters (*Comisión Asesora Interministerial en Materia de Biocombustibles en Chile*) in mid-2008.[78]

Critique

Chile has a large and diversified potential for renewable energy, thanks to its distinctive geographical and natural conditions. This potential includes a wide

76. Resolution 30 (April 2007) from the Chilean Internal Revenue Service (Servicio de Impuestos Internos).

77. CODELCO is conducting tests to determine the impact of using biofuels in certain machinery utilised in underground mining.

78. Decree 128, Ministry of Mining (August 2008).

spectrum of renewable energy options, ranging from mature technologies such as hydropower and biomass CHP, to emerging technologies such as solar power and ocean and wave energy. This constitutes a strategic resource for Chile's long-term energy security and a key option to achieve a more sustainable energy mix. It can also make an important contribution to economic development, innovation and job creation.

The Chilean government has taken concrete measures to exploit this potential. The Chilean government's all-encompassing approach, which includes assessment studies, a law for the development of NCRE, specific support measures through CORFO and strengthening R&D activities through CONICYT, is to be commended. The focus on identifying barriers and developing measures to overcome them is particularly pertinent. The IEA considers tackling barriers as the first and perhaps the most important principle for the design and implementation of effective and efficient renewable energy support policies. In this specific respect, Chile is doing better than several IEA member countries.

Observed results are encouraging. It is estimated that by mid-2008 there were some 180 NCRE projects in the country at different stages of assessment or implementation. Between January 2005 and March 2009, projects representing a total capacity of more than 2 050 MW have been submitted to the SEIA, bearing in mind that only a fraction of those will be developed. The installed capacity of wind generators is expected to amount to 193 MW by the beginning of 2010. Projections suggest that at the end of 2009, NCRE capacity in the SIC and the SING will reach around 4% of total capacity, doubling NCRE total installed capacity from 2006.

At this stage, it is difficult to determine the extent to which this trend is the direct result of measures taken by the government as opposed to the effect of high fossil fuel prices in 2007-08. While the measures taken to reduce or eliminate the barriers to NCRE deployment are to be welcomed, it will be crucial to monitor the deployment of renewables during the current financial and economic crisis and, over the next few years, to evaluate the effectiveness of the measures taken to promote NCRE.

Despite these encouraging developments, there are concerns. The installation of new coal power plants in Chile is expanding much faster than NCRE. This reflects an energy system based mainly on short-term, private cost orientation and one in which the externalities of fossil-fuel based generation or other long-term strategic considerations are only partially taken into account. Environmental externalities in Chile are partly internalised in the current environmental impact assessment system. But absolute emission standards for thermoelectric plants do not yet exist. Moreover, while Chile currently has no CO_2 reduction targets or national emission standards under the Kyoto Protocol, this situation may change in the case of a global, post-Kyoto agreement. In general terms, the IEA notes that the full cost of power generation will not be internalised until GHG emissions and carbon abatement costs are reflected in the SEIA or through other means.

Other barriers exist, particularly for new market entrants and small participants, who have to compete in a highly concentrated power market (see Chapter 6: Electricity). While forthcoming implementation of specific measures introduced by the NCRE Development Support Programme may ease the situation (*e.g.* loan guarantees by CORFO to ease access to credit), they are unlikely to be sufficient to overcome all existing barriers.

In this context, the government can play a crucial role by sending clear medium- to long-term signals to the market. IEA analysis highlights that explicit targets (either indicative or mandatory) are an important component of effective renewable energy support policies. Such signals should be consistent with other key policy objectives, *e.g.* the National Action Plan on Climate Change, environmental objectives, and innovation and socio-economic development goals. Signals should be based on continuing technical and economic analysis, and should also address the heating and transport sectors.

The Chilean government should be applauded for establishing the obligation to commercialise a certain share of NCRE. The 2008 *Law for the Development of Non-Conventional Renewable Energy Sources* is one such signal. However, some of its specific features and implementation aspects raise concern and deserve particular attention, specifically with respect to the obligation level and the penalty charge.

The main objective of the law is to enable the development of those NCRE projects that are profitable at current and anticipated market prices, but which face business entry barriers other than price. The issue here is the appropriateness and the effectiveness of the long-term target of 10% from NCRE electricity generation by 2024. The IEA acknowledges the assessment studies carried out in this respect, but underlines that the cost-competitive potential of renewables is dynamic. It will therefore depend on the concurrent development over time of fossil fuels and other conventional energy prices compared with the prices of renewables. The latter are generally decreasing – in some cases quite rapidly – thanks to technological advances and to economies of scale achieved through the deployment of the global renewables market. As a consequence, if the NCRE target is to reflect the anticipated mid- to long-term cost-competitive potential of renewable electricity in Chile, it is imperative that the assessment of both global and regional NCRE costs and prices be continuously updated, taking into account global renewable energy market trends.[79, 80] NCRE targets should be revised on a regular basis (*e.g.* every five years). Too low a target could be a counter-productive signal to the market and detrimental to the deployment of the cost-competitive potential of NCRE.

Moreover, the current penalty fees for non-compliance may be too low. This has been an important reason for failure in other countries applying quota obligation/renewable portfolio standard systems. Experience shows that an obligation only works in the presence of penalty fees that are substantially higher than market values. Otherwise, it is no more effective than an indicative target. In a context of lower fossil fuel prices and a penalty level of between USD 29/MWh and USD 42/MWh, suppliers may prefer to pay the fee in preference to investing in NCRE. The effectiveness of the penalty fee mechanism should be carefully monitored over time, and the level should be increased if necessary.

The new legislative regime is intended to create a market for renewable electricity and attract new entrants to the market, by requiring distribution companies to negotiate long-term contracts with generators for the supply of energy. However, the current conditions of high market concentration and the lack of internalisation of environmental externalities may hamper such a process. Competition in the wholesale and retail markets should be carefully monitored, and should be encouraged as an explicit policy goal. NCRE support measures should be reinforced accordingly, if necessary.[81]

Additional measures to involve distributors could be envisaged, for instance by modifying the bidding rules or extending the NCRE obligation to distributors.[82] The latter would create a much stronger and more straightforward incentive for new generators to enter the market.

The current policy framework supporting NCRE is an important step in the right direction. Together with other initiatives, it has contributed to creating a marked improvement in terms of deployment of a cost-competitive

79. See the latest IEA world scenarios published in 2008, more specifically the BLUE Map scenario of Energy Technologies Perspectives 2008 *and the 450 Policy scenario of the* World Energy Outlook 2008. *These scenarios identify the energy technology transition paths on which the world will have to be to satisfy growing energy needs without harming the environment and causing irreversible damage due to climate change. The IEA clearly states that the Reference scenario (business as usual) is unsustainable in environmental, economic and social terms.*

80. This also implies that when the nuclear option is considered, its costs have to be compared with the projected generation costs of renewable electricity at the time when the first kWh of nuclear will enter in operation, i.e. presumably between 2020 and 2025.

81. The law will be subject to verification for the first time in 2010. However, the Decree for Application of the law was still not published as of July 2009.

82. Including the option of introducing separate bidding process for conventional and non-conventional energy sources.

potential of renewables. However, given the country's large potential, the Chilean government may consider accelerating this process even further. In addition to monitoring progress and changing the obligation targets and penalty levels as proposed above, Chile may consider joining the large numbers of OECD and non-OECD countries worldwide that provide market-based incentives to renewables to enhance energy security and the sustainability of their energy matrix.

Several market-oriented incentive mechanisms could be applied, *e.g.* a combination of the renewables obligation with production tax credits as adopted in several states of the United States, or the introduction of tradable green certificates, possibly with technology banding, as in the United Kingdom and in Italy. To be effective and cost-efficient, and to foster

Box 7.2: Principles for Effective Renewable Energy Policies According to the IEA

The 2008 IEA publication: *Deploying Renewables: Principles for Effective Policies* provides a comparative assessment of renewable energy policy effectiveness and cost efficiency in OECD member countries and BRICS (Brazil, Russia, India, China and South Africa). The study concludes that the effectiveness and efficiency of renewable energy policies are determined by the adherence to five key policy design principles, *i.e.*:

i) The removal of non-economic barriers.

ii) The need for a predictable and transparent support framework to attract investments.

iii) The introduction of transitional incentives, decreasing over time, to foster and monitor technological innovation and move technologies quickly towards market competitiveness.

iv) The development and implementation of appropriate incentives guaranteeing a specific level of support to different technologies based on their degree of technology maturity, in order to exploit the significant potential of the large basket of renewable energy technologies over time.

v) The due consideration of the impact of large-scale penetration of renewable energy technologies on the overall energy system, especially in liberalised energy markets, with regard to overall cost efficiency and system.

innovation and the deployment of the best technology options, the incentives should be transitional in nature and decrease over time (see Box 7.2). This is the same principle as that followed in the proposed bill for solar thermal collectors recently approved. Three main reasons justify a change of this sort to the policy framework: the urgency to act to avoid the risk of a lock-in with currently cheaper but more polluting technologies; the large renewables resource potential in Chile; and the risk that investors may prefer to invest in other countries that offer more attractive support schemes.

Chile has long-term potential in emerging renewable energy technologies, including solar, deep-drilling geothermal and wave energy. The government has introduced commendable specific risk-sharing measures for geothermal and funding for solar demonstration plants, which could be replicated for other NCRE projects with a high potential. However, experience in other countries has shown that an appropriate combination of technology development and market deployment is key to attracting large private investments, triggering innovation and driving down costs. Taking early action would have the advantage of preparing for future market integration of these technologies and of reducing their adaptation costs to the Chilean framework. It would also contribute to creating jobs in the relevant supply chains, triggering innovation and economic development.

The comprehensive approach taken by the Chilean government to support renewable heating and biofuels (beyond renewable electricity) is to be commended. The option of the direct use of geothermal energy, as well as its use in heating and cooling heat pumps, is an option that deserves examination. It is also advisable to elaborate a policy to assess and eventually support the use of solar heat for industrial process heat, which may rapidly become economically profitable.

The sound approach followed for biofuels, *i.e.* focusing R&D efforts on those technology areas in which the country has the largest potential (second-generation biofuels from forest residues and microalgae) could be extended to other technologies, such as solar heat and electricity, and ocean and wave energy.

Recommendations

The government of Chile should:

- Continue and deepen the technical and economic assessment of renewable energy potential, taking into account global trends, technology improvements and expected cost reductions.

- Evaluate the full socio-economic benefits of renewables in the electricity, heating and transport sectors in terms of energy security, emissions reductions, creation of innovation, and employment.
- Send clear, long-term investment signals to the private sector on the basis of this assessment. Monitor actual deployment and consider the opportunity to revise NCRE obligation targets accordingly at appropriate times. Monitor and assess the effectiveness of the non-compliance penalty fee over time, and modify the fee level accordingly, if needed.
- Facilitate the access of new market entrants, including small- and medium-size enterprises, and support the realisation of small-size projects by strengthening action in identifying and overcoming barriers. Carefully monitor the implementation and results of the NCRE Development Support Plan and reinforce measures, if necessary. Consider the opportunity to introduce measures involving distributors. Accelerate action to introduce emerging renewable technologies, by:
  - Continuing and reinforcing support measures through CORFO.
  - Considering the opportunity to combine those measures with specific transitional provisions for deployment, to prepare those technologies to compete in the future market.
  - Focusing on those technologies with high potential and in which Chile has a competitive advantage in terms of possible creation of innovation and industrial activities.
  - Strengthening co-ordination between involved agencies through the Centre for Renewable Energy currently under development.

8. BIOMASS

Overview

Biomass, mostly wood, is a valuable resource for Chile. It represents more than half of total domestic energy production and is used by households and industry for heating and cooking. About 5.7 Mt of wood are drawn from Chile's forests every year. The market for firewood is largely informal and thus unregulated. Many of the appliances that use wood are inefficient and the burning of wood (particularly wood with a high level of humidity) results in high levels of local air pollution and adverse health impacts.

The Chilean government is beginning the process of formalising the wood market.[83] It also plans to focus on the demand side of wood use for energy. Recognising that there is a cultural affinity for wood use and that wood is an integral part of the energy mix, the Chilean government has explicitly chosen to encourage a more sustainable use of wood for energy. There are currently no plans to incentivise fuel switching. Native forests are protected by law [84] and the government is planning to enact new laws to regulate the use of firewood. Despite the introduction of decontamination plans in some cities, measures to reduce emissions from wood use are less advanced compared with other decontamination measures. Proposals to limit emissions from residential firewood in cities with decontamination plans are currently under review.

Biomass Supply

Forestry Resources

Forests have long been an important resource in Chile, but have not always been managed in a sustainable manner. Because forestry resources make such a significant contribution to the current energy mix – and will continue to do so in the future – some background on the forestry sector in Chile is provided here.

From the mid-19th century until about 1950, the use of native forest in Chile was based on selective logging, with the best species selected for use as

83. Bulletin 6616-12 "Proposed Law for the regulation of devices for the combustion of wood and other wood fuels as well as those fuels" (2009).
84. Law 20.283 "On the recovery of native forests and afforestation".

firewood and timber. This selective logging led to the deterioration of forests in the central valley and in the accessible Andean areas. Although there were a large number of sawmills, there was no established forest industry and there was little interest in the regeneration of exploited species. Large estates, which were the usual form of land tenure, led to the expansion of land for agriculture.

Government policies implemented from 1974 to promote planted forests and private investments resulted in a diversified forest industry. The national development strategy promoted financial incentives for industrial forest plantations. Legal instruments defined subsidies and regulated logging, favouring small- and medium-sized landholdings and plantations in degraded areas. However, the initial effect of the new regulations was the creation of large forestry companies. The 1974 Decree also had unintended adverse consequences, which were formally addressed in the 2008 *Native Forest Law* (see Box 8.1).

The *Native Forest Law*, passed in 2008,represents a major improvement in the management of Chile's forests (Box 8.1). Today, Chile has more than 15 million hectares (ha) of forest, covering 17% of the country's territory. Native forest covers 13.4 million ha and is estimated to contain 123 different tree species. Plantations cover some 2 million ha.

Firewood demand has led to local deforestation around urban centres, independent of size and latitude. Although demand for wood for heating is lower in the north of Chile, deforestation of bushland has also occurred in these regions. Figure 8.1 shows Chile's wood balance by region.

Box 8.1: Laws Governing the Use of Forests in Chile

The *Forestry Law of 1931* regulated the use of firewood and allowed farm land, including the existing national parks, to be selectively logged. Timber companies established their own land, with plantations of fast-growing species, mainly pine. Plantations were started in farming and grazing areas, and on eroded and abandoned land, but soon spread to large areas of secondary forests or those degraded by selective logging.

The Chilean government, through *Decree Law 701 of 1974*, began to subsidise the cost of establishing plantations of exotic species, mainly in degraded areas that had lost their original forest cover. But a loophole in government regulation resulted in native forests being replaced by exotic trees such as Monterrey pine and eucalyptus. As a result, the native forests were severely affected in several areas (see Map A.2). Pine plantations currently occupy nearly 2 million ha in central-southern Chile, mostly in the Los Ríos (Region XIV) and Los Lagos (Region X).[85]

In December 2008, the Chilean Congress approved a law to preserve the country's forests while promoting their sustainable use and fostering related scientific research. *The Native Forest Law* had been in negotiation for 15 years. A key aspect of the law is the creation of an initial fund of USD 8 million per year for forest conservation, recovery and sustainable management projects. The law will also protect water sources by strictly regulating the felling of native forests located near springs, rivers, glaciers, wetlands and lands with steep slopes. An Advisory Council (involving government authorities, forestry and biology academics, NGOs and native forest owners) will be set up to advise on the law's application and propose modifications. According to the Ministry of Agriculture, the law is likely to allow 500 000 ha of native forest to be preserved over the next 15 years. It will also assist in the recovery of 600 000 ha for productive use, and create 38 000 new jobs in and around the forestry sector.

There is an abundance of forests in the far south, but the transport of firewood to other regions is difficult owing to high costs (see Map 2). The Santiago Metropolitan Region is in severe wood deficit. Wood supply comes from Region V, mostly plantations. The dominant species in terms of use depends much on the region. Destruction of native forests in Regions V to VII means that firewood consumption is mostly from eucalyptus plantations. Wood supply from native bushland is consumed from Regions IV to VII, especially in rural areas.

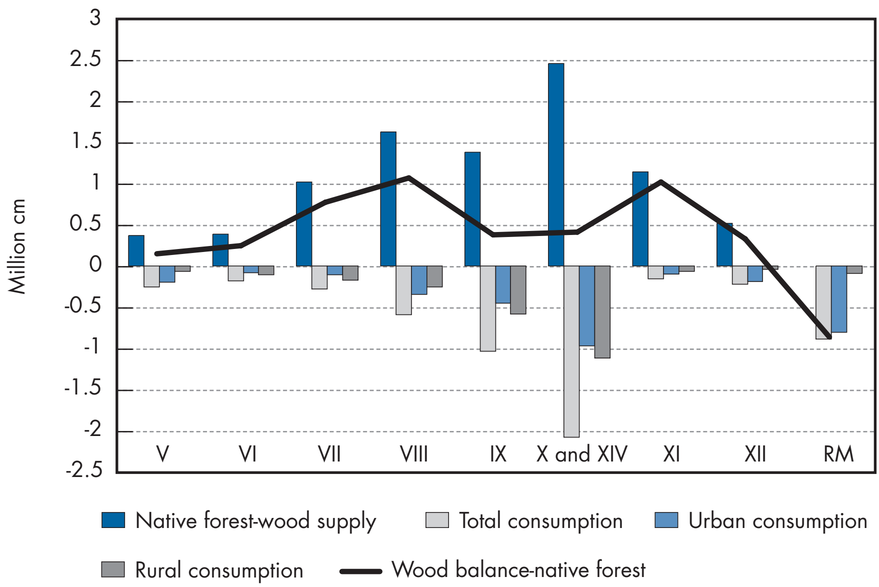
One hectare of forest cleared in Region X produces some 750 cm of firewood. The city of Valdivia alone requires about 400 ha each year to meet its firewood requirements. The exploitation of forests in Region X has resulted in secondary forests, anthropogenic grasslands and forest plantations, because of the proximity to population centres and road networks.

85. "Strategic Analysis of the Potential of Fuelwood in the Chilean Energy Matrix", *"Chile Ambiente" (commissioned by the National Energy Commission).*

Regions in Figure 8.1 with a negative balance of firewood also exhibit fragile areas, which further limits the availability of firewood. Close analysis in the central region shows a serious risk of degradation of the area covered by bushland. The growing pressure for firewood prevents the regeneration of vegetation and subsequent erosion accelerates desertification in certain areas.

Figure 8.1

Wood Energy Balance by Region, 2008



Notes: 1) See Map A.2 for a definition of each region; 2) Dark blue bars refer to sustainably managed forests.
Source: Preliminary results from CNE biomass studies carried out in 2008.

Forestry Management

The National Forestry Corporation (CONAF), with in the Ministry of Agriculture, was created in 1973 to contribute to the conservation, management and increased utilisation of forest resources in Chile. Its primary tasks are to manage Chile's forest policy and to promote sector development.

CONAF objectives are to:

- Strengthen the National System of Government Protected Areas, incorporating modern tools of management and optimising Chile's forestry resources.

- Encourage the creation and management of forest resources for the generation of environmental goods and services, with emphasis on small and medium landowners, through the administration of forest law that allows incentives for afforestation and sustainable forest management.
- Protect forest ecosystems from harmful agents and processes such as fires, desertification and other forms of deterioration, through the system of protection against forest fires, the National Plan to Combat Desertification and Drought, and forestry management measures.
- Strengthen citizen and local stakeholder participation in protecting wildlife areas and forest ecosystems, through the implementation of programmes and mechanisms for education and community development.

CONAF has offices and agencies in all regions and provinces, and manages a total of 95 sites in national reserves, national parks and natural monuments. It has a staff of about 1 800 people who serve as technicians, managers and assistants in promoting forestry conservation, and preventing and combating forest fires.

The implementation of the *Native Forest Law* is vested in CONAF, which is responsible for controlling illegal logging in forests that do not have a government-approved management plan. A fine is imposed on illegal logging, based on the value of the cut. The minimum fine is USD 350. In the Santiago Metropolitan Region, there are 11 employees responsible for the administration and approval of forestry management plans. Half of the team works in the field while the other half focuses on administrative duties.

Secondary Wood Supply

Chile is a major producer and exporter of wood and wood products, mainly pulpwood, roundwood, wood chips and pellets. There are currently three companies producing pellets with an installed capacity of over 100 000 tonnes: Andes Bio Pellets; Ecopellets; and Ecomass (a Japanese company). Potential production is 130 000 tonnes per year, but production has not exceeded 30 000 tonnes, of which 90% is exported, since early 2008. High transport costs appear to be the greatest impediment to exporting pellets. The domestic market for pellet consumption is underdeveloped.

Wood pellets are a solid fuel made of by-products of wood production and wood waste such as sawdust and shavings, timber left in the forest after logging, and used paper. Pellets are CO_2, meaning that when burned, they neither increase nor decrease CO_2 levels. Wood pellets are dry, and easy to store. Because of the efficiency of the production process and the low price of the materials used, pellets are economical. They are suitable for automated equipment because they are uniform in shape and moisture content. Accordingly, they can be used as a fuel for a variety of equipment, from boilers for power generation to heaters and cookers for home use.

Policies Affecting Wood Supply

According to the United Nations Food and Agriculture Organisation (FAO), only 6% of the production of wood for energy in Chile is commercially traded. While other wood products are bought, sold and exported on a commercial basis and thus regulated, wood for cooking and heating is usually traded in informal markets. The Ministry of the Interior has requested that all government facilities should purchase certified dry wood. However, the requirement to certify wood does not exist yet and there is currently no official certification process. In the absence of government oversight, the National Firewood Certification System (SNCL) has stepped in to certify wood on a voluntary basis (Box 8.2). It should be noted that the plan to regulate wood as a fuel is quite recent.

Box 8.2: The National Firewood Certification System (SNCL)

The goal of the National Firewood Certification System (SNCL) is to guarantee the quality of wood through certification related to calorific value and harvesting practices. It aims to ensure that consumers are able to buy high quality products from forests that adopt a strict management plan. The system is voluntary and levies only an evaluator's fee and the annual certification fee (USD 0.35/cm of certified firewood sold) to meet its administrative costs. The firewood dealer is given up to two years to comply with the standards, which stipulate that all firewood must contain no more than 25% humidity and must come from a forest that follows a management plan.

SNCL is a public-private initiative, currently financially supported by the European Commission. This voluntary certification system has been in place for five years and is supported by CONAF, CONAMA, the Chilean Tax Administration (SII) and the National Consumers' Association (SERNAC). It has a staff of 20.

The government has recently presented a bill to Congress that would require the use of dry wood in pollution-saturated areas in Chile and the certification of new woodstoves. The Chamber of Deputies and the Senate have introduced their own bills aimed at certifying firewood and heating systems with double combustion chambers used in saturated areas. These bills include requirements for wood or wood products to come from forests with certified management plans and stipulate a moisture content of less than 25%. The proposed legislation also includes fines for non-compliance.

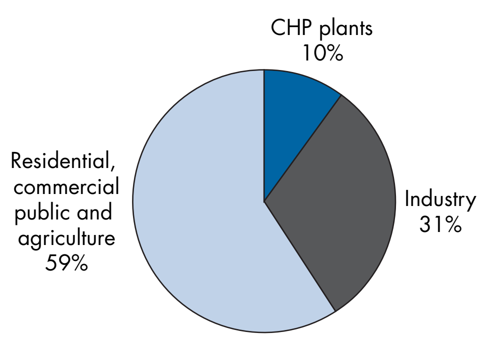
Biomass Demand

Biomass Energy Balance

Biomass, mostly wood, represents some 16% of TPES in Chile. It is used for cooking and heating in cities and in villages, for process energy in small industry, and for heating in schools and public buildings. Biomass resources are also used to produce electricity, primarily in CHP plants. Biomass demand in the residential, commercial, public and agricultural sectors represents about 60% of total biomass demand in Chile (Figure 8.2). The CNE estimates that demand in the residential sector has grown by about 3% per year since 1990. In the south of Chile, the share of wood in energy demand for heating is estimated to be over 90%, based on survey information showing that 90% of homes in southern Chile have wood heating systems. Many homes have a cooking device that also provides heat, but are usually equipped with a specific device for heating.

Figure 8.2

Biomass Demand by Sector, 2007



Note: Biomass includes wood, wood wastes and other solid waste. Chile does not have a mechanism in place to accurately measure annual consumption of wood in these sectors. Demand, particularly in the residential sector, is likely underestimated.

Source: CNE.

Wood Prices

Wood sold on the market in Chile is less expensive in calorific terms than kerosene and LPG (Table 8.1). Wood is usually traded in informal markets. Poor, rural households tend to collect wood "freely", although there are costs associated with the time required in collection. In many rural areas, local producers sell wood in informal markets, usually at prices far below those prevailing in cities. Many landowners in the south of Chile produce firewood for their own use. The lack of government oversight in the market has led to an inefficient consumption of wood that is not socially desirable, and has resulted in high air pollutant levels and associated health risks.

Table 8.1

Prices of Wood, Kerosene and LPG, May 2009

	Price per unit (USD)	Kcal per unit	CLP per Kcal
Wood (kg)	0.07	3.50	0.01
Kerosene (litres)	0.85	8.99	0.05
LPG (kg)	1.47	12.10	0.07

Note: Prices include taxes for kerosene and LPG.
Source: CNE.

Appliances Using Wood

Many Chilean households, even in cities, rely predominately on wood for heating and cooking especially in the south of Chile (*i.e.* south of Rancagua). Firewood is often preferred for cultural reasons, even in wealthier households. Table 8.2 shows the efficiencies, emissions and costs for a range of technologies. Clearly, the certification of wood and its enforcement is important, because dry wood is more efficient and emissions are lower. Pellet stoves reduce emissions by a factor of ten over traditional stoves using dry wood.

In OECD member countries, such as Sweden and Japan, pellets are commonly used both for industrial and household purposes. Pellet stoves are heavily subsidised for household use in Sweden. In Chile, most consumers cannot afford pellet stoves, which are mainly imported from Europe. Only 60 to 70 units were sold in Chile in 2008.

Table 8.2

Comparison of Stoves and Boilers

	Efficiency (%)	Emissions (milligrams/MJ)	USD/kW
Open fire stove	10	50 000	0
Traditional stove (wet wood)	45	5 000	30
Traditional stove (dry wood)	60	500	30
Pellet stove	90	50	200
Industrial boiler (wood)	70	250	100
Industrial boiler (pellets)	95	30	200
Co-generation plant (wood chips)	85	20	2 000

Source: CNE.

According to a study by the CNE, Chilean consumers have no incentive to switch from a wood stove to a pellet stove, because the payback period is too long. Even when the lower fuel cost of pellets – given efficiency gains – is taken into account, it is estimated to take 15 years to recover the initial cost of the stove and its installation.

Policies Affecting Wood Demand

Chile does not yet have policies in place to regulate the use of wood-based appliances. There are, however, plans to implement specific standards. The SEC is responsible for guaranteeing that fuels used for energy are not hazardous to people. It was not called upon to regulate wood in the past, because its legal mandate was limited to liquid and gas fuels and did not include solid fuels such as wood. However, the Chilean government has now decided that there is a need to certify appliances that use firewood to reduce emissions, improve efficiency and ensure safety of the equipment. The CNE worked with the SEC on a legislative proposal that would regulate appliances that use firewood. In the current legal framework for the energy sector, only the SEC can set certification standards although other agencies can collaborate in the process.

The Prevention and Decontamination Plan of Santiago and the Decontamination Plan of Temuco both include decontamination measures to control emissions from firewood combustion. Possible measures for technology improvement and replacement are currently under analysis.

Environmental and Health Impacts of Wood Use

Particulate Emissions

Burning wood in Chile produces high concentrations of particulate matter (PM). The Chilean government has set air quality standards for PM_{10}. The standard for the annual concentration of PM_{10} is 50 micrograms per cubic metre (50 µg/cm). Daily (*i.e.* 24 hour) concentrations are not allowed to exceed 150 µg/cm. Despite the standards, in Temuco and in many other cities in the south of Chile, daily PM_{10} concentrations average between 200 and 250 µg/cm during the winter. Comparatively, the 24-hour concentration standard for PM_{10} in European Union countries is 50 µg/cm, which can be exceeded on no more than 35 days per year. The EU standard for annual concentration is 40 µg/cm.

Currently, Chile has no standards in place to control emissions of $PM_{2.5}$. Some studies estimate that $PM_{2.5}$ ambient concentration levels in most Chilean cities exceed 200 µg/cm. The European Union norm for these emissions is 50 µg/cm. In the United States, the 24 hour $PM_{2.5}$ standard is 35 µg/cm. A $PM_{2.5}$ standard has been under discussion in CONAMA since 1998.

Decontamination Plans

CONAMA estimates that among cities where pollution levels have been measured to date, there are five cities/areas with major PM concentrations directly related to the use of firewood: Temuco, Padre las Casas, Concepción Metropolitano, Region VI (including Rancagua, San Francisco de Mostazal and Codegua), and, to a certain extent, Santiago. CONAMA has set up decontamination plans in some of these areas; for example Santiago has had a decontamination plan in place since 1998. The residential sector is estimated to account for 11% of PM_{10} emissions. Temuco and Padre las Casas were declared PM_{10}-saturated zones in March 2005. In June 2007, a preliminary decontamination plan was introduced in these cities, which indicated that the residential sector accounted for 93% of PM_{10} concentrations. By the end of 2009, the central valley (Region VI) is expected to be decreed a PM_{10}-saturation zone and authorities will begin drafting a decontamination plan.

A review of pollution measurements in Chilean cities found that, excluding Santiago, Coyhaique (Region XI) has the highest level of local air pollution, followed by Rancagua (Region VI), Osorno (Region X) and Temuco (Region IX). In Coyhaique, PM_{10} emissions were, on average, 80µg/cm in 2008 and 2009. Rancagua and Osorno also exceeded the permitted maximum, recording annual averages of 69 µg/cm and 68 µg/cm, respectively.

Critique

Although biomass is an abundant and renewable energy resource, wood use for energy has not always been managed in a sustainable manner in Chile. The *Native Forest Law* and other impending legislation are a step in the right direction and their implementation should be strictly enforced. The wood sector needs effective political and legislative support. The deficient regulatory framework and lack of resources make it difficult to monitor wood use. CONAF should be given more resources to police illegal logging.

The use of wood is the main contributing factor to the high levels of local air pollution in many cities in south-central Chile, and there is evidence that wood use has led to deforestation around urban centres throughout the country.

The Chilean government appears to be taking a supply-side approach to wood energy use, by focusing on certification of wood supply and imposing penalties on illegal felling as contemplated in the proposed law currently under public review. Efforts on the demand side, however, need further development. Most of the affordable stoves and other wood-burning appliances are both inefficient and polluting.[86] There is an urgent need for an increased focus on technological development – and cost reduction – of more efficient stoves. In the interim, a certification mechanism for more efficient stoves should be introduced without delay. In addition, the Chilean government should consider targeted incentives to promote their purchase by low-income households.

The Chilean government should be commended for its inclusion of biomass in the 2008 *Energy Policy: New Guidelines*, which is an important first step in addressing biomass issues. The creation of a National Biomass Policy has been discussed, but no decision has been taken yet. For the time being, efforts are dispersed across various public institutions: the SEC, CONAMA, CONAF, the Ministry of Health, etc., including the CNE. Within the CNE, different departments should co-ordinate their work on biomass, biofuels, and rural energisation. There is a clear need to co-ordinate all actors to develop a comprehensive approach to sustainable biomass, both on the demand and on the supply sides. The government's preference appears to be for a National Biofuels Policy, despite the fact that wood use at the

86. "Strategic Analysis of the Potential of Fuelwood in the Chilean Energy Matrix", "*Chile Ambiente*" *(commissioned by the National Energy Commission).*

household level is leading to local deforestation and is producing local air pollution, and needs urgent governmental oversight. The government does, however, recognise the need to regulate the informal wood sector as well as the economic potential of the sector.

On the demand side, studies commissioned by the CNE and currently under review by the government show that, with minimal investment in improved stoves, great gains could be achieved in health benefits and savings in emissions. These studies should be carefully considered by the Chilean government to develop specific goals with clear targets and incentives. These will form part of the government's long-term view to enhance the sustainability of the wood energy market.

Efficiency is greatly enhanced when wood is converted to pellets, chips or briquettes before combustion. Small industries, schools and other public buildings should be encouraged to use these wood products. Pellet production initially designed for export could be diverted to local markets. Pellet stoves and boilers, however, are expensive and would not penetrate the residential market without strong government incentives.

As with all energy sources, the government's actions regarding wood use for energy involve a trade-off between environmental impact and economic development. Wood is an inexpensive energy source, being sold in the market at less than one-sixth of the price of LPG for cooking, but its market value does not reflect the negative impacts its use has on health and on the environment.

Wood is the cheapest fuel for household use in Chile. It is likely that the price of wood will rise as the wood market is formalised and prices may approach those of pellets, kerosene, LPG and gas. While certification mandating the use of dry wood will reduce emissions, switching to cleaner fuels is one long-term solution for reducing the negative impacts of traditional wood use on health and local air pollution. The government should encourage cleaner fuels and/or more efficient technologies for cooking and heating through public information campaigns as well as targeted incentives, including subsidies for more efficient wood-burning appliances in poor households given the positive social benefits at stake.

Recommendations

The government of Chile should:

- Set a clear mandate to improve the sustainable use of wood for energy, on the basis of CNE biomass studies and backed by effective, comprehensive regulation, and more funding and staff.
- Formulate and actively pursue policies to improve the efficiency of domestic wood-burning stoves to reduce local air pollution and adverse health impacts.
- Consider the establishment of: i) a labelling scheme and; ii) a subsidy targeting low-income households to encourage the purchase of more efficient appliances.
- Set up an inter-ministerial task force, including the Ministries of Energy and Health, CONAF and CONAMA, to create a National Wood Energy (Biomass) Strategy, which clearly reflects all aspects of wood energy use and supply. Such a strategy should be enforced and implemented at the regional and local level and be incorporated into the long-term National Energy Policy.

9. ACCESS TO ENERGY IN RURAL AREAS

Background

Since 1990, high economic growth and active social investment policies have reduced poverty in Chile. In 1990, 39% of Chileans lived below the poverty line; by 2006 the share had fallen to less than 14%, according to data from the most recent National Socioeconomic Survey (CASEN) conducted by the Ministry of Planning (MIDEPLAN).[87] This survey also showed that for the first time, in 2006, rural poverty (12.3%), was lower than urban poverty (13.9%). Extreme poverty was also down by 70% compared with 1990, which makes Chile the first Latin American country to achieve the extreme poverty reduction target set in the Millennium Development Goals.[88]

Despite lower poverty levels, progress in reducing the extreme inequality of income distribution has been less marked. According to the 2006 CASEN survey, the share of the richest tenth of the population in national income is almost 40%, while that of the poorest tenth is barely 1%. The United Nations Development Programme (UNDP) reports that income inequality is also reflected in income-related differences in average life expectancy, infant mortality and educational attainment.[89]

Based on data from the 2002 National Census from the National Statistics Institute, some 13.4% of Chileans lived in rural areas. This amounted to approximately 2 million people and represented 20% to 25% of the population outside of the Santiago Metropolitan Region.[90] A recent study from the UNDP on Chile's rural population suggests that the official definition may underestimate total rural population.[91]

The CNE reports that current electricity access nationwide is 98.5%, with an estimated 94.5% of rural households having access to electricity and 99% of urban households connected to the grid (see Figure 9.1). According to the CNE, there are still around 40 000 families without access to electricity and 5 000 with deficiencies in terms of availability and quality of service (without

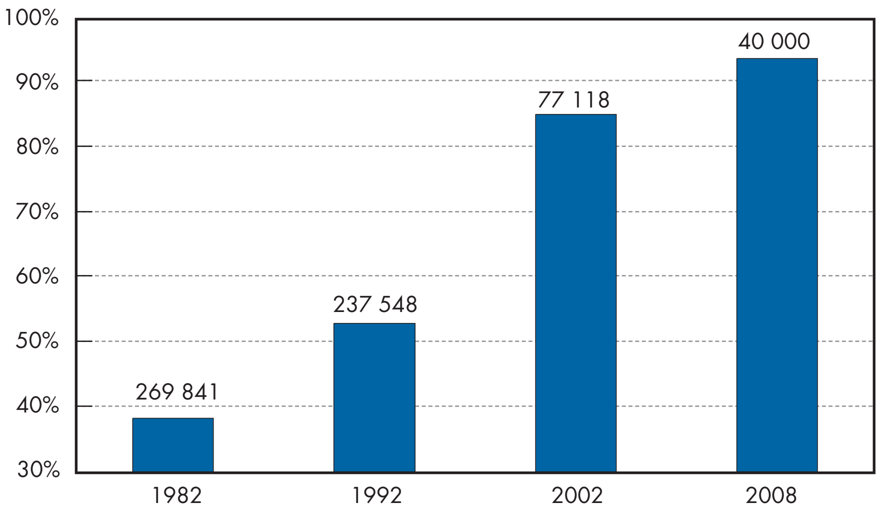
87. www.mideplan.cl/final/categoria.php?secid=25&catid=124
88. www.un.org/millenniumgoals/bkgd.shtml
89. hdrstats.undp.org/countries/country_fact_sheets/cty_fs_CHL.html
90. Rural, as defined by the National Statistics Institute (INE), consists of those areas having a) 1000 inhabitants or less; or b) 1001 - 2000 inhabitants with less than 50% of their population economically active, dedicated to secondary or tertiary activities.
91. www.desarrollohumano.cl/otraspub/pub11/informe%20rural.pdf

considering projects currently in progress or planned for implementation in 2009). Access of the rural population to modern energy services is an explicit aim of the Chilean government. Originally, the government focused on rural access to electrificity only. The national Rural Electrification Programme has extended coverage to approximately 150 000 households since 1995.

Recognising that rural economic development involves more than just household electrification, in early 2009 the CNE started a new programme to meet other energy needs such as cooking and heating, refrigeration and access to electricity for local development with the launch of the Rural and Social Energisation Programme (PERyS).

Figure 9.1

Rate of Rural Electrification and Number of Households without Access to Electricity, 1982–2008



Source: CNE.

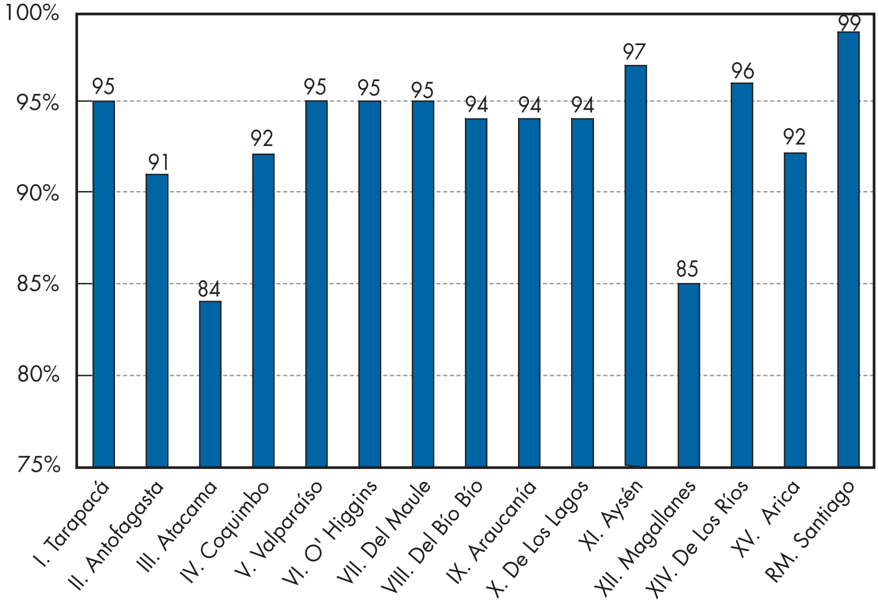
Rural Electrification Programme

Overview

Within the framework of the power sector reforms initiated in the 1980s, the Chilean government developed one of the most successful demand-driven rural electrification programmes with clear coverage targets, innovative co-financing mechanisms and efficient subsidy allocation.

Figure 9.2

Rate of Rural Electrification in Chile's 15 Regions, 2008



Source: CNE.

The Rural Electrification Programme (PER) is a decentralised programme, which was created in November 1994 as part of the government strategy to fight poverty, raise the quality of life in rural areas, and incorporate rural households into the country's economic and social development. At the beginning of the PER, rural electricity coverage was 59%. The aim of the programme was to reach 75% coverage by the end of President Frei's government in 2000. When this goal was reached one year early with 76% coverage, it was estimated that approximately 137 000 rural homes still lacked access to electricity. A more ambitious goal was established under President Lagos' government, aiming for 90% coverage for each one of the country's regions by the end of 2006.

The government of President Michelle Bachelet is committed to reaching 96% electricity coverage of rural households by end-2010, and to improving quality of supply in isolated communities by promoting the use of non-conventional renewable energy (NCRE).

Current rural electrification rates in Chile's 15 regions as of 2008 are shown in Figure 9.2 (also see Map 2). According to CNE data, the majority of the rural dwellings still lacking access are in the following regions: Tarapacá, Atacama, Coquimbo, Araucanía, Los Lagos and Arica. Based on the 2002 national census, the Araucanía and Los Lagos regions are Chile's most rural, have the highest number of non-electrified rural households and include a large indigenous population. In the Atacama and Coquimbo regions, the coverage deficit is made up of isolated and scattered rural residences.[92] As a result, the 2003 IADB Rural Electrification Programme targeted the Coquimbo, Araucanía and Los Lagos regions.

Rural areas are not always profitable markets for power companies. The distances between houses are often large and connected loads are usually low. The government largely finances the capital costs of rural electrification.[93]

There are currently two categories of rural electrification projects in Chile: grid extension projects and off-grid projects. Grid extension projects are operated and maintained by local distributors. Supply quality, which is supervised by the Superintendence for Electricity and Fuels (SEC), must meet specific quality of service standards. Rural customers connected to the grid pay the same tariffs as other households connected to the grid in a particular concession area, as stipulated in the *General Law of Electric Services*, which defines tariffs (see Chapter 6: Electricity).

Tariffs for customers in off-grid networks are based on operating, administration and maintenance costs, and on the number of customers. They are set through formal agreements between the mayor and the legal representative of the local electricity provider. In most cases, they are much higher than in regulated areas connected to the grid. Since the beginning of 2009, the government started subsidising the operation of the system, so that off-grid customers ultimately pay the same tariffs as those connected to the grid.

Financing

Because rural electrification projects are not, in general, financially attractive to distribution companies or co-operatives, the state provides incentives for these projects through subsidies. In the case of projects to expand the distribution network, a subsidy is available through a subset of the National Fund for Regional Development dedicated to rural electrification (FNDR-ER). The subsidy covers between 70% and 90% of the investment outlay.

92. See Rural Infrastructure in Chile, *Policy Briefing, The World Bank, 2004*

93. A detailed description of the government's objectives and policies, along with the institutions, financing and methodologies, for rural electrification, is available at www.cne.cl

The beneficiaries must pay the cost of the installations required within their homes (approximately 10% of the total investment) and the distribution company or co-operative finances the remainder.

In the context of enhanced decentralisation, regional governments are responsible for decisions regarding planning, priorities and implementation. Investment proposals are initiated by a request from the communities themselves, for example through community councils. The local municipality is then responsible for preparing the project and the proposed budget. They can obtain external technical support if needed.

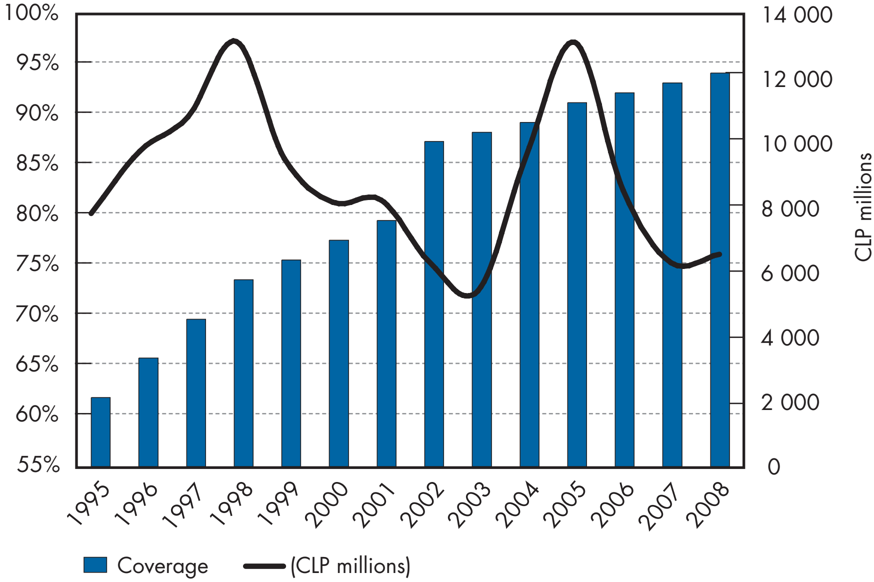
In accordance with the project evaluation methodology established by the MIDEPLAN and the CNE, eligible projects must demonstrate that they will have a positive social and negative private net present value. They must also establish the users' willingness to pay for the service, meet the country's social and environmental standards, and correspond to local government priorities in the regional planning process. The prepared projects are incorporated into the National Investment System administered by MIDEPLAN and are then sent to the Regional Planning and Co-ordination Secretariat (SERPLAC). SERPLAC verifies that projects comply with the necessary requirements and gives its approval, which allows application for financing. The projects are subject to prioritisation by vote in regional councils depending on regions' funding.

Projects are mainly financed by government funds from the FNDR-ER and from the FNDR, which are administered by the Sub-secretariat of Regional and Administrative Development (SUBDERE). Every year, the CNE proposes the allocation of a certain share of FNDR-ER funds to the SUBDERE based on the quantity of project proposals.

From 1995 to 2008, the government's cumulative contribution to rural electrification reached CLP 122 700 million, equivalent to approximately USD 230 million (see Figure 9.3). From 2003 to 2007, the Inter-American Development Bank (IADB), in collaboration with the Chilean government, carried out a Rural Electrification Programme. The programme's total cost was USD 57.2 million. The IADB financed USD 40 million loan and the government of Chile the remaining USD 17.2 million. The bulk of these funds, USD 45.2 million, went toward covering the cost of the state subsidies to private investment for rural electrification. More than half (56%) of the project loan went to create incentives to invest in grid extension projects and 27% for incentives to invest in off-grid generation projects. Since the end of the project in 2008, rural electrification subsidies have come only

Figure 9.3

Government Subsidies for Rural Electrification (FNDR-ER) and Rural Access Rate, 1995-2008



Source: CNE.

from national funds. This will remain the case unless a new credit from the IADB is approved during 2009 to finance new projects.

The Chilean rural electrification scheme requires both the users and the distribution company to contribute to the financing. Users must pay the costs of wiring within the house. These costs can be initially financed by the operators and repaid by the user over time as a supplement to the tariff. The scheme uses a competitive mechanism for the allocation of grants. Companies prepare submissions specifying the areas to be electrified and the number of consumers to be connected. These submissions compete for grants, but there is no direct competition between companies to electrify a given area.

This demand-driven approach to choose projects helps to ensure that those selected have local support and that there is sufficient willingness-to-pay for electricity. It also improves the probability that the forecast demand for new connections and electricity will materialise, thus helping to ensure projects' financial viability. Finally, it increases the chances that the allocation of capital costs and subsidies is targeted toward maximising the desired goal, which is the delivery of electricity services.

Service Delivery Models

Distribution companies typically manage the operation, maintenance and administration of grid-based projects. Distribution companies or electricity co-operatives usually construct these projects. Once operational, they become part of the assets of the company or co-operative. By law, distribution companies that have won a concession for a specific area are obliged to provide electric power to all customers within the boundaries of the concession area.

For off-grid systems, the management model depends mainly on the existence of an entity that can operate the electrical system, such as a local power company, a co-operative or the municipality itself. Co-operatives are usually organised specifically to tackle a local energy requirement and must have at least ten members. Co-operatives must comply with the *Basic Cooperative Law* (Decree-Law 05 of the Ministry of Economy, Promotion and Reconstruction). In general, the municipality is in charge of administration and basic maintenance tasks.

The quality of service of off-grid projects does not fall under SEC supervision. However, they are required to meet all the relevant Chilean standards. Several case studies have demonstrated that the lack of local capacity for operation and maintenance limits the sustainability of those systems, and that availability and quality of service is usually lower than for grid-based systems.[94] If a skilled worker in the community can be trained, then higher-level maintenance and emergencies can be resolved locally. Experience has shown that, to reduce the technical vulnerability inherent in off-grid projects, negotiating a maintenance and operation contract with an organisation belonging to the sector, and including the costs of its service in the tariff to be paid, tends to work best.

The Role of Non-Conventional Renewable Energy Sources

Although some projects based on renewables energies such as solar photovoltaics, wind and mini-hydro, have been implemented in Chile, gasoline and diesel generators remain predominant in isolated areas because of relatively easier operation and maintenance. NCRE projects have lower operational costs than gasoline or diesel generators, but capital investment is higher.

94. The World Bank, 2004

At present, private companies are less interested in off-grid projects in Chile because of higher technical complexity and limited experience. The government therefore plays a more active role in the pre-investment, design and implementation of these projects. In the case of self-generation and renewable energy projects, the municipality or the local government

Table 9.1

Current and Planned NCRE Projects under the PER

Period covered	Households served	Region(s)	Technology
1995-2000	100	Araucania	Micro-hydro plant
	61	Maule	Individual photovoltaic systems
	36	Los Lagos	Biomass gasification system for lighting and other energy services
	70	Magallanes	Micro-hydro plant
2001-2009	171	Bío Bío	Natural gas
	3 300	Chloe Province, Los Lagos	Diesel-fired generation and submarine cables
	1 000	Antofagasta	First electricity co-operative administered by indigenous people
	110	Antofagasta	Micro-hydro plant
	89	Los Lagos	Hybrid wind-diesel system
	15	Bío Bío	Micro-hydro plant
	3 064	Coquimbo	Photovoltaic systems
	150	Valparaíso	Improvements in electricity distribution and generation
	42	Arica, Parinacota	Photovoltaic systems
	62	Atacama	PV-electricity generation
	35	Atacama	PV-electricity generation
	75	Valparaíso	PV-electricity generation
	42	Maule	PV-electricity generation
	154	Aysen	Micro-hydro plant
Projects under development (CNE, CNE-GEF study)	3 720	Arica and Parinacota, Antofagasta, Atacama, Coquimbo, Maule, Aysen	Photovoltaics

Source: Achievements of the Rural Electrification Programme, CNE, 2008.

relies on the CNE to prepare a technical evaluation in line with the National Investment System of the Ministry of Planning methodology, which includes technical design, socioeconomic evaluation, and legal and administrative aspects. The methodology also includes tariff calculation to make projects economically sustainable.

The government of Chile, through the CNE, is implementing the project Removal of Barriers for Rural Electrification from Non-Conventional Renewable Energy Sources. This project was initiated in September 2001 and will end in December 2009. It is administered through the UNDP and was financed by the Global Environmental Facility (GEF) with a budget of USD 6 million. The Chilean government provided co-financing of USD 17.3 million while Chilean households and the private sector contributed an additional USD 9 million.

The UNDP-GEF project has developed a portfolio of 90 NCRE projects to supply approximately 10 500 households. In the process, the project has developed technical norms, certification procedures, capacity building and pilot schemes for NCRE projects. It has also conducted an assessment of wind and solar resources. The project aimed to reduce GHG emissions from diesel generators and improve the living conditions of rural communities. In co-operation with the National Normalisation Institute, a total of 43 technical standards for rural electrification projects using NCRE were published in 2006-07. More recently, the CNE, together with the GEF, has undertaken a number of studies on potential projects using NCRE. The scale being considered will require substantial funding (see Table 9.1).

Next Steps for the PER

The Chilean government is now focusing on maintaining the coverage reached in rural areas while improving the quality of service through the hybridisation of diesel-based systems, as well as developing productive activities with self-generation projects using NRCE sources.

To meet these new goals, the government has requested a technical assistance grant from the IADB (of approximately USD 500 000) to prepare a potential new loan. The grant will be used to carry out three main activities:

1. Carry out an *ex-post* evaluation of the PER, and assess the experience and knowledge gained to use it for future operations.

2. Conduct studies and other supporting activities for the preparation of a new loan.

3. Develop and implement a number of pilot projects to contribute to the conceptualisation, preparation and estimation of the budget for a new loan. This will be executed jointly by the SUBDERE and the CNE.

Rural and Social Energisation Programme

The Rural and Social Energisation Programme (PERyS) was launched by the CNE in early 2009 to promote economic development in rural areas. The goal of PERyS is to expand the provision of energy for public services (health clinics and schools) and develop pilots systems that can be replicated for productive activities, principally in isolated areas. Priority is given to NCRE sources, mainly solar energy in the north and centre of the country and small hydro and wind in the central-south regions.

The programme is co-ordinated with other agencies, including the Agricultural Development Institute (INDAP) and the Solidarity and Social Investment Fund (FOSIS), to finance renewable energy systems installation and training. Demonstration systems are being set up to increase the penetration of NCRE technologies for pumping water, heating, cooking and refrigeration, among other uses.

The CNE is also conducting an assessment of various NCRE technologies to promote their use. Solar collectors are being installed for hot water heating in social housing projects, boarding schools and other institutions to test the technology and its social adaptability in different regions. The Chilean Congress recently passed a bill providing tax incentives for the installation of solar water heaters (see Chapter 7: Renewables).

In the Coquimbo Region, four demonstration systems for solar water pumps have been installed. Given the success of these pilot schemes, INDAP is considering financing a similar programme at the regional level. In parallel, the CNE, through the GEF project, has completed a registry to determine the number of potential beneficiaries and has provided the technical design for the programme to the local government.

On completion of the UNDP-GEF project, the CNE pursued the promotion of NCRE for rural development by transferring limited CNE funding to local institutions to set up pilot schemes. In doing so, the CNE has closely co-ordinated projects with other institutions, mainly local government and municipalities, to leverage financing. A total of approximately USD 3.5 million has been allocated so far. Work is also in progress to generate an evaluation methodology for NCRE projects to make them eligible for financing from the National Investment System.

In 2004, the Ministry of Finance requested World Bank support in preparing and financing a multi-sectoral infrastructure programme targeted to the poorer communities. The World Bank Infrastructure for Territorial Development Project (USD 90 million) was approved in November 2004 and will be implemented until end-2010. At the national level, the project will be implemented through SUBDERE. The project's objective is to increase the effective and productive use of sustainable infrastructure services by poor rural communities in selected territories of the regions of Coquimbo, Maule, Bío Bío, Araucanía and Los Lagos. The Chilean government contributed USD 40 million in addition to the World Bank loan of USD 50 million. The project includes approximately USD 8 million for rural electrification.[95]

Even though the CNE was identified as a key technical partner in the Project Appraisal Document,[96] to date, the PERyS efforts to co-ordinate projects with this multi-sectoral programme have met with limited success.

Critique

The government of Chile should be commended for achieving such rapid success in providing electricity to rural households, reaching nearly universal access in less than 20 years. Between 1992 and 2008 rural access to electricity rose from 53% to 94.5%. Chile's rural electrification scheme has been recognised as international best practice and has been replicated in several other countries across Latin America. Rural energy investments achieve greater development benefits when they are not solely driven by targets, but are integrated into more detailed, cross-sectoral local development plans. The Chilean government recognised this by establishing the PERyS and should be praised for fine-tuning its approach to rural energisation

The establishment of the PERyS is an important first step in the formulation of a multi-sectoral approach to address the challenge of rural economic development, as opposed to single-sector, target-driven service delivery mechanisms. Several international projects conducted by the IADB, WB and UNDP have shown that cross-sectoral territorial approaches can improve co-ordination and complementarity of investments, and build linkages with productive activities, thereby creating a virtuous circle of higher capacity-to-pay and economic viability.

95. Project appraisal document for an infrastructure for territorial development project in Chile, November 19, 2004, Report No: 30463-CL, The World Bank, available at http://web.worldbank.org/external/projects/main?pagePK=51351038&piPK=51351152&theSitePK=40941&projid=P076807
96. Ibid.

This approach, however, requires a shift in the manner in wich the investments are identified and evaluated. Studies show that when several infrastructure services are made available simultaneously in the same rural area, the impact is greater than the sum of the individual effects when the services are provided separately. Poor rural Chilean farmers typically rely upon traditional, low-profit agricultural goods. Upgrading the level of electricity service to three-phase and providing farmers with access to external market information can create opportunities for adding value to local production through agro-processing and improved marketing. Modern energy services promote economic development by enhancing the productivity of labour and capital, while also contributing to higher living standards. More efficient technologies provide higher quality energy services at lower costs and free up household time for more productive or social purposes.

There are important development benefits to be gained from expanding access to modern energy services in combination with other infrastructure services and productive uses. The Chilean government should be commended for taking the first step by establishing the PERyS, which is implementing tangible solutions in improving quality of service as well as encouraging productive uses. The government of Chile should step up its current efforts by establishing an inter-sectoral planning approach to achieve synergy in rural development across different technical agencies covering health, education, agriculture, water, roads, telecommunications and environment. Considerably more human, technical and financial resources are needed if rural development objectives are to be achieved.

Furthermore, while the CNE is actively involved in government efforts to create a multi-sectoral rural infrastructure programme, weak co-ordination has limited the effectiveness of government investments in rural infrastructure. The government should further improve co-ordination, particularly information sharing, through strategic collaborative meetings among government agencies at the national, regional and local level, and, importantly, with the communities themselves. A specific task force should be set up to evaluate progress in meeting rural energisation objectives.

Implementing the PERyS also implies methodological complexity. Supporting productive activities in rural areas is more complicated than simply electrifying households. It requires the full integration of energy policies with those for other social and economic infrastructure sectors (*e.g.* agriculture, forestry, education, roads, water and telecommunications). In this regard, completing the needed steps to create a methodology for project evaluation by the Ministry of Planning in collaboration with the CNE is essential. The quality and reliability of electricity supply are also key elements to ensure the sustainable development of productive activities. For example, incorrect electricity demand assessments in some communities have failed to capture the willingness-to-pay for a higher level of service and thus have failed to identify and develop income-generating activities such as fisheries.

While the Chilean government has designed the PERyS to ensure ownership by the rural end-users, evidence has shown that service delivery models are key to ensure the technical and financial sustainability of energy investments. Off-grid solutions, particularly those utilising NCRE sources, require technical expertise for installation and maintenance that are usually best performed by small or micro private entreprises and technicians. In contrast, community electricity committees usually handle more easily the operation and maintenance of traditional diesel generator systems.

Therefore, special attention should be paid to capacity building of new entities acting as service providers in the PERyS, such as electricity co-operatives or small and micro enterprises known as Rural Energy Service Companies (RESCOs). Chile has already developed successful community-managed approaches to rural water supplies, which could be expanded for off-grid electricity projects. Energy efficiency measures should also be considered in the design and implementation of rural energy systems to enhance sustainability.

The group working on rural energisation in the CNE is understaffed. There are currently three professionals working on implementing the PERyS, and three professionals working in the PER, which has no regional offices. The CNE should consider hiring additional staff to facilitate project preparation and implementation at the local level. Technical assistance throughout the whole project cycle is key to correct information asymmetry between electricity companies and local authorities. While municipalities and regional planning agencies may exert some pressure on the distribution companies at the planning stage to keep costs low, their lack of information limits their effectiveness: municipalities have little understanding of electricity distribution; and regional planning agencies have little knowledge of geographic constraints to electrification in particular areas.

In this regard, as contemplated in the proposed bill to establish a Ministry of Energy, the creation of Regional Ministerial Secretaries of Energy (SEREMIs) should be an important step forward in providing energy-specific technical assistance at the local level, thereby improving the sustainability of investments. In addition, co-ordination should be developed across work on the sustainable management and use of biomass and the PERyS, as well as across relevant government agencies including the CNE, CONAMA, SEC, and the Ministry of Health, among others (see Chapter 8: Biomass).

The lack of resources to finance demand and engineering studies can be a serious limit to the PERyS, especially given the complexity involved in designing integrated projects and in evaluating their social and environmental benefits. The PERyS also lacks adequate funding for financing new rural energy projects. The government of Chile should therefore provide additional funding to support the implementing agency of the PERyS, and to finance rural energy projects to cover the last "mile to development".

Recommendations

The government of Chile should:

- Establish an inter-sectoral planning approach to achieve synergy in rural development both vertically (across relevant technical agencies covering health, education, agriculture, water, roads, telecommunications and environment) and horizontally (across the national, regional and local level levels of government). A specific task force should be set up to evaluate progress in meeting rural energisation objectives.
- Enhance the sustainability of the rural energisation programme by ensuring that local service providers are adequately trained in the operation and maintenance of renewable energy technologies, and embed energy efficiency measures in the implementation of rural energy systems.
- Ensure that the implementing agency of the PERyS has sufficient funding and trained staff to achieve the Programme's objectives.
- Provide new lines of funding for rural energy projects, making sure that they are closely integrated with other rural development services.

10. TRANSPORT

Overview

In Chile, as in many other developing countries, transport is one of the most rapidly growing end-use energy sectors. Between 1990 and 2007, final energy consumption in the transport sector grew at an average annual rate of 5.2%, compared with 4.6% for the economy as a whole. The sector depends almost exclusively on oil derivatives for its energy use and accounts for more than 60% of the country's total final oil consumption. According to available estimates, transport emits about one-third of Chile's energy-related GHG emissions (see Table 10.1).

Within Chile's transport sector, road-based modes predominate, accounting for nearly 70% of the sector's final energy consumption. Urban transport accounts for 45% of the country's transport energy use and inter-urban for 55%. Passenger movements account for 65% of total transport energy.[97] Unofficial forecasts suggest that transport will be the most rapidly growing energy-consuming sector over the next 20 years or so, accounting for more than 50% of total final energy consumption (TFC) by 2030, compared with 33% in 2007.[98]

Four factors determine transport energy use and emissions: the number of trips made and the distances covered; the modes used to undertake these trips; the fuel intensity of the vehicles; and the type of fuel used.

Income plays a major role in driving transport energy use. The number of trips made and the distances travelled tend to increase with income. Higher incomes are also reflected in increased vehicle ownership, more private car use, lower occupancy levels and higher energy intensity for a given level of activity. Higher incomes also increase the opportunity cost of time: wealthier individuals and firms are more willing and able to pay for speed, which tends to be more energy intensive. Thus, the basic energy challenge for transport is how to decouple transport growth and transport energy use from a country's economic growth.

Chile is no exception to these global trends and challenges. Sustained economic growth has led to rapid motorisation, growth in trip rates, shifts toward private motor vehicle travel and increased transport by air. Over the

97. O'Ryan and Díaz, 2008.
98. Ibid.

Table 10.1

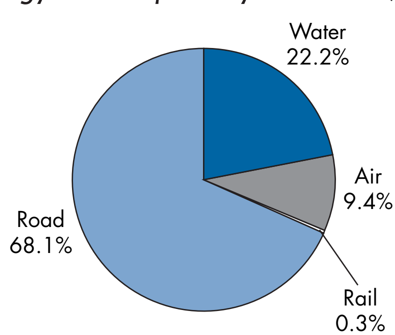
Transport Contribution to Total Final Energy Consumption and Greenhouse Gas Emissions

	2007	AAGR (1990-2007)
Total final energy consumption (TCal)	240 938	4.6%
- Transport (TCal)	86 924	5.2%
- Transport share of total final	36%	
Total final petroleum consumption (TCal)	138 869	4.9%
- Transport (TCal)	86 319	n.a.
- Transport share of total final	62%	
Total CO_2 Emissions (Gg)	63 279 - 80 057	4.9% - 5.9%
- Transport CO_2 (Gg)	22 094 - 23 347	6.0% - 6.3%
- Transport share of total	29% - 35%	

Notes: Total final energy consumption adheres to the IEA definition of the sum of consumption by the different end-use sectors, excluding energy consumed, or losses incurred, in the conversion, transformation and distribution of the various energy carriers. Greenhouse gas emissions estimated including energy transformation processes. The ranges come from two unofficial sources, one includes only CO_2 the other includes CO_2-e.

Figure 10.1

Transport Final Energy Consumption by Sub-sector, 2007



Source: CNE, 2008b.

past decade, the private vehicle fleet (autos, pickups, motorcycles, etc.) has grown at an average annual rate of about 4.2%.[99] Assuming similar growth trends, by 2020 the number of private vehicles per capita will increase by more than 50%, from about 150 vehicles per 1000 persons in 2007 to 230. Over the period 1991 to 2006, the trip rate (trips per person) in the country's capital, Santiago, increased by an average 2.6% per year and the share of trips by private motor vehicle increased by an average 4.2% per year (see Table 10.2). Freight transport is already dominated almost entirely by road-based, truck transport, although the truck fleet in recent years has been growing at only about one-half the rate of growth of light-duty vehicles. Increasing trip rates and growing distances travelled will continue to drive transport energy demand increases in the country.

Institutional Framework

There are several ministries within the Chilean government with direct relevance to the transport sector.

The Ministry of Transport and Telecommunications (MTT) is primarily responsible for sector operations, including relevant policies and regulations. The Ministry of Public Works (MOP) is responsible for the construction and maintenance of transport infrastructure of national and regional importance. Through its Planning Directorate, MOP carries out relevant infrastructure planning activities (including modelling); MOP also runs the country's important infrastructure concessions programme, through its Public Works Concessions Co-ordinator. The Ministry of Housing and Urban Development (MINVU) has responsibility for urban planning and is in charge of developing regional land-use plans and regulations, and making large urban transport infrastructure investments.

An inter-Ministerial Secretariat for Transport Planning (SECTRA), under the Ministry of Planning (MIDEPLAN), guides transport planning activities in the country. SECTRA develops and operates transport planning models and methods for urban, inter-urban and international transport. SECTRA has developed urban transport models for 26 Chilean cities and has also developed a mobile source emissions model (MODEM) in 17 of them. SECTRA has also developed an inter-urban, multi-modal (air, road, rail and water) transport planning model for the southern Chile, with plans underway to extend it to the rest of the country. In transport infrastructure planning, however, considerable overlap exists with unclear delineation of

99. INE, 2003 and 2008b.

responsibility between SECTRA and MOP. In principle, investment projects must comply with approved methodologies (regarding project economic evaluation criteria) of MIDEPLAN and receive budgetary approval from the Ministry of Finance.

At the regional level, the national ministries operate through Regional Secretariats. At the local level, municipal governments have somewhat limited authority in the transport sector, primarily with responsibility for building and maintaining local infrastructures, typically with support from higher levels of government. For the large metropolitan areas that include more than one municipality (Greater Santiago, Greater Concepción and Greater Valparaíso-Viña del Mar), formal metropolitan authorities do not exist. In Greater Santiago, a special agency, the General Co-ordinator for Transportation in Santiago (CGTS), was created to implement the Transantiago Plan (Box 10.1). Technically an inter-Ministerial Commission directly linked to the Ministry of the Presidency, CGTS depends on MTT for its budget and, in fact, exists with unclear legal status. A bill currently in Congress seeks to legally enable metropolitan transport authorities.

The transport sector in Chile largely reflects the country's free-market philosophy. Most services across the sector operate without explicit government subsidies; the primary exceptions are a number of water (maritime, lake and river), land and air services to isolated communities and ongoing operating subsidies to inter-urban passenger rail services. Urban public transport operates without an explicit subsidy – even Santiago's urban heavy rail, Metro, covers its operating costs through revenues. This situation is likely changing in the wake of Transantiago (see Box 10.1). In terms of transport infrastructure in the country, no explicit public finance system exists. Most taxes (*e.g.* on fuel) and fees (*e.g.* vehicle ownership charges) are under the direct control of the Ministry of Finance; earmarking of revenues (such as the establishment of a roadway trust fund from fuel taxes) is not permitted under Chilean law. As such, the degree of implicit transportation infrastructure subsidies in the country is not easily uncovered; for example, funding for Metro infrastructure in Santiago comes entirely from national public coffers. The infrastructure concessions programme has, however, introduced some degree of explicit financing by charging via fees (*e.g.* highway tolls) for relevant infrastructure use (*e.g.* of ports, airports and highways). Some implicit subsidies in the concessions programmes may exist, in the form of revenue guarantees, land provision, and the like. Value capture mechanisms (whereby increased land value due to infrastructure development is recovered through fees/taxes) have not been widely deployed in the sector.

Table 10.2

Evolution of Basic Socioeconomic and Travel Characteristics in Santiago Metropolitan Region

Category	Item	1977	1991	2001	AAGR (91-01) %
Socioeconomics	Avg. HH Income (USD 2001)	n.a.	USD 4 700	USD 9 000	6.50
Demographics & motorisation	Households	649 820	1 162 845	1 484 903	2.40
	Persons	3 483 084	4 502 099	5 325 193	1.70
	Auto fleet	208 263	414 798	748 007	5.90
	Vehicles per 1000 persons	59.90	93.60	140	4.20
	Vehicles per household	0.32	0.36	0.50	3.50
Trip making	Trips per person	1.04	1.69	2.39	3.50
	Work share all trips	n.a.	39%	27%	-3.70
	School share all trips	n.a.	28%	19%	-3.50
	"Other" share all trips	n.a.	1.30%	22%	28.00
Aggregate mode share	Private transport mode share	11.60%	19.70%	39%	6.80
	Public transport mode share	83.40%	70.50%	51.80%	-3.10
	Other	5.00	9.80	9.30	-0.50

Notes: Only data for the jurisdictions common to the surveys are used. Travel information is for comparable observations (i.e. trips over 200 m, by individuals over five years old) for the normal work week. AAGR = average annual growth rate; n.a = not available. For average household income the average annual growth rate is through 2001 since comparable figures for 2006 were unavailable.

Sources: Household travel surveys carried out for SECTRA-MIDEPLAN in 1991, 2001 and 2006 (1977 data from 1991 summary report).

Box 10.1: Public Transport Dynamism in Santiago

Driven by rapid economic growth, Santiago's transport system is under rapid transformation (see Table 10.2). The motorisation rate (vehicles per 1000 persons) increased nearly 3% per year over the period 1991-2006 (although in 2006 it still stood at only 20% of the United States level and just 30% of Western European levels), while private motorised travel demand increased even more rapidly.

The overall trip rate increased at almost 3% per year, with a large growth in non-work, non-school trips as a share of total travel. The government has embarked on major interventions in the sector over the past decade, including: aggressive expansion of roadway infrastructure, including through Chile's highway concessions programme; urban heavy rail (Metro) expansion; and important reforms to Santiago's bus-based public transport. Public transport reform has been implemented under the umbrella "Transantiago" plan, encompassing a re-organisation of bus services, bus priority infrastructure, and service and fare integration among bus services and the Metro, among other initiatives.

Before implementation of Transantiago, the city was served by 8 000 buses on 380 routes. Despite important service improvements induced by government regulations since 1990, the system remained loosely regulated, marked by atomised ownership structure, competition in the streets for passengers (drivers were compensated according to passengers carried), fairly unsafe operations, congestion and air pollution, and a significant degree of collusion among the companies. Fares on the system were not integrated, neither between buses nor between buses and the Metro, making transfers expensive.

In response to these conditions, authorities devised the Transantiago plan, which intended to drastically modernise the city's public transportation system, maintain the public transport mode share, and improve transportation energy use and air pollutant emissions. To achieve these ambitions, authorities designed a network of five trunk corridors and ten feeder areas, with the Metro serving as a backbone. This design would reduce total bus fleet size and bus travel distances, and imply an increase in the number of transfers that users would have to make relative to the existing system. Other important elements of system design included: keeping bus services unsubsidised; eliminating the direct link between drivers salaries and passengers carried; integrating services and fares (including with Metro); introducing modern buses; eliminating cash from the system via smart cards; implementing a GPS-based monitoring and fleet management system to provide information to bus companies, users and authorities; and constructing several segregated bus corridors and well-designed bus stops. As originally designed, Transantiago represented nothing short of a revolution in the city's public transport system.

Unfortunately, the final design and implementation of the originally envisioned Transantiago plan was hampered by political, institutional, financial, and technical problems. At the broadest strategic level, evidence suggests that considerable institutional and planning capital in the years leading up to Transantiago's implementation went towards large-scale infrastructure development in the city – particularly urban highways and Metro expansion – at the expense of efforts to smoothly and effectively develop the physical and institutional infrastructure necessary for efficient bus operations. More concrete shortcomings included:

- Political changes at the highest levels, especially the change in the responsible minister one year prior to scheduled implementation.
- Changes in important system elements including bus ownership requirements, and the scope of the GPS-based monitoring and information system.
- Failure to construct needed infrastructure (dedicated busways and adequate bus stops).
- The requirement that the bus system be responsible for partially funding the expansion of the Metro infrastructure.
- Insufficient provision of capacity in the Metro system.
- Delays implementing the requisite smart card technologies.
- Low service coverage in certain areas of the city.
- The lack of adequate information for users.

These shortcomings, among others, led to abysmal system performance when Transantiago debuted in early 2007. Waiting times proved to be high and extremely variable; the Metro suffered from intense over-crowding; the transfer conditions (bus-bus and metro-bus) were poor; and users experienced worsened travel times and – in many parts of the city – increased walking distances to access the system. Transantiago quickly became a serious political liability for the government and further deteriorated the image of public transport in the city. Anecdotally, automobile and motorcycle sales in Santiago increased in Transantiago's wake.

Authorities have since put considerable effort into improving the system, such as: renegotiations with operating companies (including incentives to increase operating fleet size); changes in operational programmes aimed at increasing the total fleet size and improving frequencies; reductions in fare evasion; increased service flexibility; implementation of the service control system; and improved Metro efficiency (including introduction of express services). As a result, commercial speeds and coverage have increased, and waiting times have gone down.

The most important improvements remaining for Transantiago have to do with infrastructure, both the construction of exclusive lanes on several important corridors and the development of pre-pay bus stops and improved transfer stations. A key pending issue relates to long-term public transportation financing in the city, as Transantiago now requires public subsidies for operations that were previously unsubsidised. A full review of transportation system finance will likely be required. Towards this end, the government recently introduced legislation which is currently being discussed in a special Senate commission. The city's experience with public transport reform certainly holds lessons for improvement attempts in other Chilean cities.

Sources: de Cea and Fernandez, 2009; Muñoz and Gschwender, 2008.

Inter-urban Transport

At the inter-urban level, Chile's geography and low density (long distances between population centres) produce great travel distances nationally, with road transport modes dominating both passenger and freight movements. While reliable and comparable time-series data are unavailable for inter-urban passenger travel, auto transport has apparently increased most rapidly from 1990 to 2006, at an average annual growth rate of 17%, followed by air transport at 9%, rail at 4.5%, and bus at 1.4%.[100] Cars likely dominate total inter-urban travel in terms of passengers transported, although again reliable data are not available. Of the public transport modes, bus dominates, carrying just under 90% of interurban trips, followed by air with nearly 6% and rail with approximately 5% in 2006.[101] In terms of freight transport, road

100. These numbers should be viewed with some caution. Auto traffic is based on vehicle counts at tolls (not passengers) and the number of toll booths have certainly increased over the period 1990-2006. Also, the rail estimate may be somewhat anomalous as the 2006 figure (18.6 million passengers) represents a 7 million passenger increase over the previous year – this could be due to the addition of suburban rail services operated by EFE O'Ryan et al., 2002; INE, 2007; INE, 2008a)

101. The rail figure is re-adjusted from that reported in INE (2007) to account for the fact that 85% of EFE's reported passengers are for suburban rail services in Valparaíso (MERVAL, Puerto-Limache) and Santiago (Metrotrén, Santiago-San Fernando) (EFE, 2007).

transport is far and away the dominant mode, accounting for an estimated 96% of tonnes transported, with air, maritime and rail comprising nearly equal shares of the remainder.[102] Transport final energy consumption by sub-sector reflects rather different shares (see Figure 10.1).

The Chilean inter-urban trucking industry has grown considerably with the country's economy and today includes specialised services oriented around export goods. While a large number of companies (over 30 000), exists, trucking activity is concentrated among medium- and large-scale operators – just 7% of the trucking companies account for almost 60% of the industry's sales and fewer than 50% account for 95% of all sales.[103] There are seven rail freight companies, primarily operating in the north, with several operating directly for the mining industry. Two of these companies operate on rails owned by the state railroad company (EFE), the rest run on privately owned tracks. Rail freight transport has increased modestly, at an average rate of almost 3% per year, over the past decade. Domestic air freight transport has been steady.

Inter-urban bus service operates in a deregulated market, with a wide range of services. Again, a small number of companies dominate. Of the 116 inter-urban operators, 20% account for 80% of the vehicles, 75% of the passengers carried, and 83% of the passenger-kilometres carried (indicating that the larger companies likely have a larger presence in the longer distance markets).[104] For inter-urban passenger rail service, the state (EFE) is the sole operator of suburban, medium- and long-distance services – 85% of EFE passengers are in the suburban rail markets of Valparaíso and Santiago. EFE had operating losses of USD 68 million in 2007.[105, 106] Recently, in an attempt to improve this situation and introduce more transparency in the system, EFE has separated passenger operations to form associated operating enterprises, with EFE maintaining responsibility for infrastructure management. The aim is to operate in a similar way as for freight rail services, with private operators offering the services and paying fees to EFE for infrastructure use.

While the inter-urban railway infrastructure remains largely in the hands of the state, the inter-urban highway infrastructure has gradually been transferred to and expanded by the private sector, via the MOP infrastructure concessions programme, initiated in the early 1990s. Over 2 000 km of

102. For domestic freight only. Tonnes of rail, maritime, air transported come from INE (2007); truck tonnes from INE (2008a).
103. INE, 2008a.
104. Ibid.
105. These include income and costs of operations for passenger and freight since these are not separated out in the accounting.
106. EFE, 2007.

inter-urban highway infrastructure have been developed via 20 separate concessions since 1993, signifying an investment of approximately USD 3.4 billion; the average concession period for these projects is 25 years. An additional 450 km of inter-urban highway concessions are currently under construction, implying another nearly USD 1 billion in private sector investments. By 2010, almost 1 800 km of Route 5 (the Pan-American Highway), Chile's main North-South highway, will be operated under the concessions programme. Efforts to upgrade the inter-urban railway infrastructure via concessions have proven, to date, unsuccessful.

In terms of air transport, the country has 16 commercial airports, seven for international travel. The airport terminals, for both passenger and freight, also operate under the Chilean infrastructure concessions programme. The country has three carriers: LAN Chile, which operates a fleet of 60 to 80 planes for international and domestic travel; Sky, which operates approximately 10 planes for domestic travel; and Principal Airlines, which operates a fleet of two planes for domestic travel. Although accounting for a relatively small share of inter-urban travel, domestic air travel has been increasing rapidly, at almost 9% per year since 1990.

Urban Transport

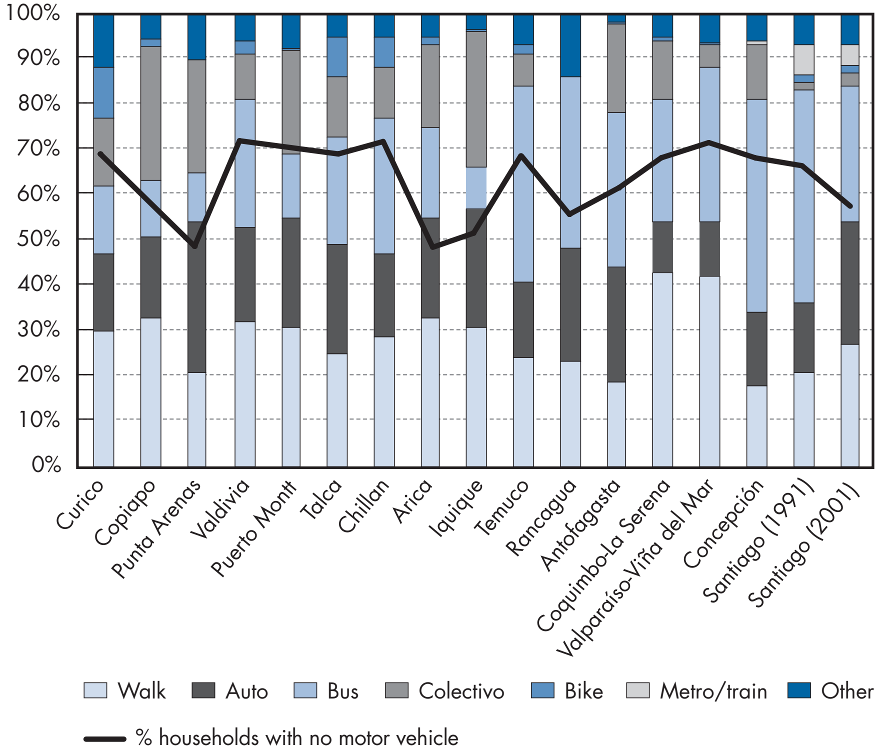
Chile is highly urbanised, with 87% of the country living in urban areas,[107] and roughly two-thirds of the country's population living in cities larger than 100 000. Half the country's population resides in the three largest metropolitan areas, Santiago, Valparaíso-Viña del Mar and Concepción. In fact, the country remains demographically heavily centralised in the Santiago Metropolitan Region, which accounts for roughly 40% of the country's population, 43% of GDP and 43% of the country's motor vehicles.

Recent travel surveys carried out under the auspices of SECTRA in the 16 principal Chilean cities, which account for 65% of the country's population, provide a glimpse at the similarities and differences in terms of basic travel characteristics (see Table 10.3 and Figure 10.2). A general trip rate of two trips per person per day is fairly consistent across the cities; the primary exceptions are Valparaíso, Concepción, Temuco and Chillán, each of which had unemployment rates of 10% or higher at the time of their surveys. Punta Arenas also exhibits a lower trip rate, despite low unemployment; but Punta

107. According to INE's definition, an urban entity is a group of concentrated housing with more than 2 000 residents, or between 1 001 and 2 000 residents with 50% of more of the economically active population dedicated to secondary or tertiary activities (INE, 2004).

Figure 10.2

Mode Share (Work Day) and Share of Households with No Motor Vehicle in Primary Chilean Cities



Notes: The relevant year for each city can also be found in Table 10.2. In Valdivia, Bicycle includes Motorcycle; for Rancagua, Public Transport mode was not disaggregated. The cities are listed in ascending order, based on population size, from left to right. Household auto ownership information was not available for Copiapo or Puerto Montt. The 2001 data for Santiago have been made comparable with these surveys by only including trips >200 meters by persons > 5 years old.

Sources: Derived from household travel surveys carried out for SECTRA-MIDEPLAN; see Zegras, 2005.

Arenas also has the highest concentration of retirees (10%) among the cities for which that information was available. Against these cities, Santiago's trip rate stands out as the highest (at 2.4 trips per person per day). Most likely the wealthiest city in the group, Antofagasta (home to large mining operations), does not have a remarkably high trip rate.

Turning to mode share and auto ownership across the cities, evidence shows a heavy dependence on walking as the basic mode of transport, accounting for 20% to 40% of daily weekday trips (see Figure 10.2). No apparent pattern relating walking to city size clearly emerges. Shared fixed-route taxis

Table 10.3

Chile's Principal Cities, Demographics and Socioeconomics

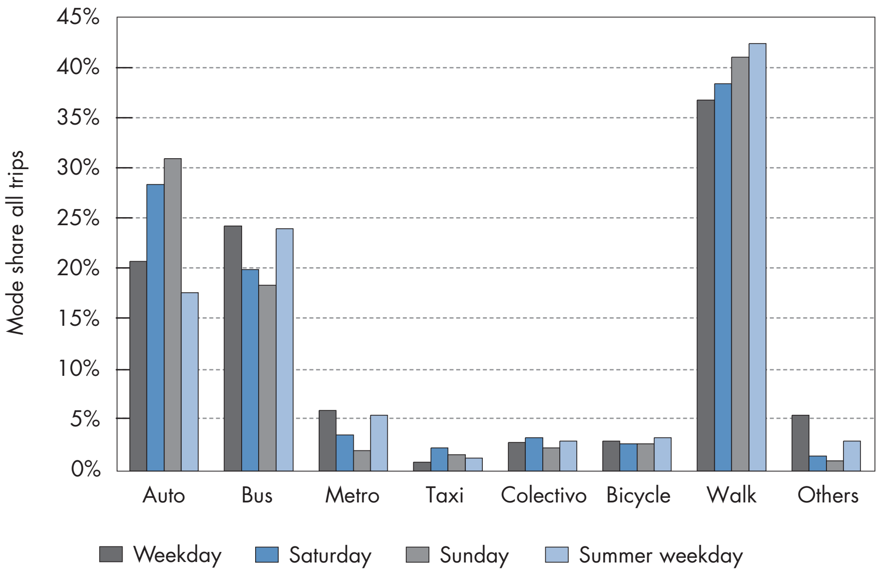
City	Year	Trip rate	Demographics (thousands) Pop.	HHs	Pers/HH	Percent poor (region)	Unemployed (%)	Percent HHs in income category Low (%)	High (%)	Education level (%) Univ.	High school
Curico	1996	2.06	65.6	17.9	3.67	20	3.0	65	4	6	40
Copiapo	1998	2.10	111.6	27.9	4.00	20	n.a.	n.a.	n.a.	n.a.	n.a.
Punta Arenas	1998-9	1.84	112.5	31.9	3.53	8	3.0	39	7	9	33
Valdivia	1996	2.15	122.1	29.6	4.13	18	11.0	53	10	13	38
Puerto Montt	1998	1.94	125.5	32.2	3.89	18	4.0	45	10	9	31
Talca	1996	2.15	153.8	41.2	3.73	20	4.0	63	6	10	38
Chillan	1996	1.50	168.2	38.7	4.35	23	12.0	65	5	9	40
Arica	1998	2.12	171.0	42.4	4.00	15	4.4	48	5	9	34
Iquique	1998	2.17	185.4	45.9	3.90	15	3.5	31	9	9	36
Temuco	1996	1.85	231.0	57.6	4.01	24	11.0	34	6	13	43
Rancagua	2000	2.05	243.5	61.0	4.00	15	4.2	37	14	11	33
Antofagasta	1998	2.09	248.7	60.3	4.10	9	3.0	26	18	12	33
Coquimbo-La Serena	1999	2.05	259.9	63.8	4.10	18	5.9	49	3	8	36
Concepcion	1999	1.86	834.0	200.7	4.16	23	13.0	52	7	8	39
Valparaiso-Viña del Mar	1999	1.47	858.5	224.4	3.83	16	10.0	31	9	12	38
Santiago	1991	1.69	4 502.1	1 162.8	3.87	n.a.	3.0	49	9	9	34
Santiago	2001	2.39	5 772.6	1 473.7	3.92	11		40	6	13	35

Notes: HH = household. In Curico, Talca and Chillan, secondary education is combined with Technical/Professional Degree. The ranges of household incomes encompassing the two income categories reported here (middle income is not included for parsimony) are not entirely consistent across each city. The range is (in USD 2001 per year): 0-USD4 000 per year, low; USD 4 000-15 000, medium; over USD 15 000, high. Both high school and university may include individuals still studying. The 2001 data for Santiago have been made comparable with these surveys by only including trips >200 meters by persons > 5 years old.

Source: Zegras. 2005. Sustainable Urban Mobility: Exploring the Role of the Built Environment. PhD Dissertation submitted to the Department of Urban Studies and Planning. Massachusetts Institute of Technology. Cambridge. MA. September.

Figure 10.3

Mode Share for All Trips in Santiago. Variation by Season and Weekday/Weekend, 2004-2006



Source: SECTRA-MIDEPLAN, 2006.

(*colectivos*) play an important role as well, especially but not exclusively in the smaller cities. A general trend appears in which bus transport mode share increases with city size. As expected, an apparent relationship between auto ownership and auto mode share exists.[108] Notably, the cities with duty-free trade zones (Iquique, Punta Arenas and Arica)[109] have the lowest share of auto-less households in the country; households apparently have taken advantage of the free importation of used vehicles allowed in these places. Punta Arenas has the highest auto mode share, followed by Santiago and Iquique. Finally, the data indicate some predilection for bike travel, not only in Curicò (Chile's most bicycle-friendly city), but in other cities further south (notorious for rainy winters) such as Talca and Chillán – in these cities, bicycle mode share ranges from 7% to 11% of weekday trips.

Similar to inter-urban services, urban bus transport remains exclusively in the hands of the private sector, operating without explicit subsidy from the

108. As measured by percentage of households with no motor vehicle in the home, the only relevant data point that was universally available across the surveys.

109. The duty-free zone exists at the Port of Iquique. However the zone benefits extend to the city of Arica and other areas of Chile's northern Region I.

public sector (although this situation may change in the case of Santiago, see Box 10.1). In the three largest cities, bus operations are regulated via service concessions to operators; these operator concession schemes have recently been extended to the cities of Antofagasta, Iquique and Rancagua, and are under development in four other cities. Absent these concessionary schemes, the services operate under loose regulation. The only significant rail-based public transport services operate in Santiago and Valparaíso-Viña del Mar. In Santiago, these include Metro (an urban heavy rail system, operated by a state-owned enterprise over a network of approximately 80 km), and a suburban rail service run by EFE. In 2006, the last year for which travel survey data are available, Metro carried less than 6% of all trips in Santiago, while buses and autos accounted for roughly 25% each (Figure 10.3). Metro's mode share has likely increased since that time, due to the near doubling of the Metro network length since 2001 and to implementation of Transantiago, which funnelled a large number of public transportation users onto the urban heavy rail system.

The country's infrastructure concessions programme has also produced a large share of new and upgraded highway infrastructure in the capital. Since 2001, approximately 180 km of new highways have been added to Santiago via private sector concessions, signifying an investment of approximately USD 1.7 billion. Users pay for travel on these highways via per-distance charges collected automatically with in-vehicle transponders; the fees vary by time of day.

Transport Sector Contribution to Urban Air Pollution

Santiago suffers from among the worst air pollution in Latin America, due to high concentrations of total suspended particulates (TSP), respirable particulates (PM_{10}), ozone (O_3) and carbon monoxide (CO). As of 2005, the transport sector accounted for 37% of PM_{10}, 32% of $PM_{2.5}$, and 70% of nitrogen oxides (NO_x) emissions, a precursor to ozone (transport is responsible for 19% of volatile organic compounds (VOCs), the other ozone precursor)[110] . Santiago has employed, since the late 1980s, a vehicle restriction programme (*la restricción vehicular*), which during most of the year (1 March to 31 December) restricts vehicles without catalytic converters from operating on one day per week, based on the license plate number. This restriction programme has accelerated vehicle turnover and the purchase of cleaner vehicles in the city. Nonetheless, the increase in vehicles not subject

110. CONAMA, 2007.

to control under the restriction has reduced its overall effectiveness in terms of congestion reduction, although since 2007 vehicles with catalytic converters are subject to *la restricción vehicular* during episodes of high air pollution – typically, once or twice per year.

In the past decade, authorities have focused on reducing Santiago's transport air pollutant emissions primarily by improving fuel quality and strengthening vehicle emission standards, but also through the use of several system management measures put into place during periods of severe pollution risk. In combination with interventions targeting fixed sources, the efforts have produced important improvements in pollutant concentrations as exhibited by declines in severe pollution days. For example, over the first six years of implementation of the pollution control plan of 1997, the city experienced an 18% to 34% drop in average winter time PM_{10} concentrations measured at seven monitoring sites across the city (the city suffers from a thermal inversion in the winter months).[111] Ozone concentrations have proven to be more tenacious, with the number of days exceeding the norm staying relatively constant (40 to 46 per year) over the same period.[112] While early air quality management plans[113] explicitly mentioned rationalising private auto use and reducing motorised trip demand as pollution control measures, such policies do not appear in more recent plan monitoring and updates.[114] The original concept of Transantiago aimed at providing an attractive public transportation option to potential auto users (as well as improving emissions and energy use). However, the design and implementation to date has had the opposite effect (Box 10.1).

Santiago has a history of initiatives aimed at improving driving conditions, beyond the bus system concessioning scheme which evolved into Transantiago (Box 10.1). Other initiatives include a computerised traffic signal synchronisation programme, a programme of reversible one-way streets on crucial commute corridors during peak travel periods, *la restricción vehicular*, as well as a number of additional emergency measures implemented during high pollution incidents. The emphasis on these "soft" control measures has declined over time, as authorities have put more faith on hard infrastructure expansion in recent years. *La restricción vehicular* and pollution problems in Santiago have stimulated fleet turnover, both for the public and private fleets, although as the purpose was for local pollutant emission control, the direct effects on fuel consumption were to the degree that newer vehicles

111. Authorities are currently developing an air quality standard for highly respirable particulate matter, PM2.5.
112. CONAMA, 2003.
113. CONAMA, 1998.
114. MINSEGEP, 2006.

replaced less fuel efficient older vehicles. Efforts to rationalise the public transport fleet size, in Santiago and other cities, also produce improvements in the fuel intensity of the system, as long as such fleet size reductions do not come at the expense of service quality which might push users into private motorised transport modes. Santiago's Metro has implemented a number of important energy-saving measures in recent years, including vehicles with regenerative braking, traffic control systems with energy saving capabilities, and express train services, among others.

Currently, under Chilean environmental law, at least three other Chilean cities are required to develop either pollution control or prevention plans: Temuco, Concepción, and Tocopilla. While data are not yet available, transport likely does not play a major role in these cities' air pollution due to the strong role of other emission sources. Complete emissions inventories for most Chilean cities do not exist; roughly ten cities currently have inventories, at varying degrees of detail.

Vehicles and Fuels

A range of technological factors play a role in fuel intensity – that is, the consumption of fuel per passengers and freight moved – including engine type, technology and vehicle age. Driving conditions also affect fuel intensity (*e.g.* stop-and-start travel conditions worsen fuel consumption per distance travelled), as do vehicle load factors (occupancy levels).

Chile has no significant domestic motor vehicle production industry (beyond some bus assembly), and thus imports virtually all vehicles used in the country (buses, autos, trains, etc.). In the road transport sector, vehicle emission standards have been gradually increased over time, particularly in Santiago as a result of air pollution control plans. The country generally uses emission standards established in the United States by the Environmental Protection Agency (EPA) and in the European Union (EU). In the Santiago Metropolitan Region, new trucks and buses must comply with Euro III or EPA 98 standards, with plans to introduce Euro IV or EPA 2007/Tier 2 standards by 2012. Gasoline- and diesel-powered automobiles and light-duty vehicles must comply with Euro IV standards as of 2008.

In the rest of the country, the same emissions standards will eventually apply, with some delay relative to Santiago primarily due to challenges in ensuring adequate nation-wide supply of the higher quality fuels required. The country has a national vehicle inspection and maintenance programme. In addition, MTT operates a vehicle certification plant (3CV), which serves primarily to ensure that all new models entering the domestic market meet established emissions standards. The 3CV facilities include capabilities to test light- and heavy-duty gasoline and diesel vehicles, and can also test fuel quality; 3CV has tested several biofuel blends for the local market (*e.g.* biodiesel and gasoline-ethanol blend). It has also certified two hybrid automobiles, two conversion kits (for LPG and CNG), and one dedicated CNG vehicle.

Of the 2.8 million motor vehicles running in the country in 2007, private vehicles accounted for almost 87%, public transport for 6% and freight vehicles for 7%. Gasoline-powered vehicles still dominate the motor vehicle fleet, particularly in the case of private passenger vehicles. Nonetheless, among the total motor vehicle fleet, diesel vehicles have experienced an important increase in recent years, growing from 13% of the vehicle fleet in 2002 to 19% in 2007. A minor portion of vehicles uses natural gas, while electric vehicles are virtually non-existent.[115] Nationally, over 70% of vehicles are equipped with catalytic converters. Data from Santiago's 2001 household survey suggest that one in three private vehicles is less than five years old, with an average vehicle age of eight years; data from 2008 vehicle inspections reveal a similar average age for private motor vehicles. In the trucking industry, the larger companies have the newest fleets; the 7% of the companies accounting for 60% of freight sales have 60% of their vehicles under six years old (the comparable figure for the remaining 80% of the operators is 42%).[116]

As already mentioned, Chile's transport sector relies almost entirely on petroleum-based fuels. Gasoline dominates, although diesel has been increasing in recent years, likely in part due to diesel's more favourable treatment under fuel excise tax policy. As in some other countries, the relatively favourable tax treatment of diesel originates in the desire to increase equity (lower cost fuels for public transport buses) and increase economic development (reducing road freight costs). However, it appears that the fuel cost differential may be increasing ownership of light-duty diesel vehicles. Alternative fuels, including biofuel mixes for transport, receive a slight fuel tax advantage.

Nonetheless, the estimated number of alternative-fuelled road vehicles in the country is small (5 000 natural gas vehicles and less than 100 electric vehicles). In the early 2000s, Santiago's Metro explored the possibility of sourcing its energy exclusively from hydroelectric sources, but the contract

115. *INE, 2008b.*
116. *INE, 2008a.*

proved unfavourable and the Metro continues to draw its electricity from the SIC. Several efforts to implement alternative-fuelled buses in Santiago have resulted only in pilot programmes (*e.g.* for natural gas buses), but no widespread implementation of alternatives to diesel combustion. This may be partly due to limited natural gas supplies in Chile (see Chapter 5: Fossil Fuels). Tests of emissions and performance characteristics of several local biofuel blends (including a rapeseed-based diesel blend and ethanol-gasoline blends) have been carried out in 3CV, and biofuel blends (5%) have been authorised for gasoline and diesel, with fuel tax incentives (see Chapter 7: Renewables). As mentioned, the inter-urban rail system uses both electricity and diesel powered locomotives. Any major shift from petroleum as the primary energy source for the transport sector in the medium term seems unlikely.

Spurred in large part by the need to address Santiago's air pollution problems, the country has embarked on aggressive transportation fuel quality improvements in recent years. Unleaded gasoline was first introduced to Santiago in 1991 (to accommodate the influx of cars with catalytic converters), and since April 2001 the sale of leaded gasoline has been discontinued, nation-wide. For diesel, in Santiago, the maximum sulphur content is already 50 parts per million (ppm); this norm will become nation-wide in 2010, while in Santiago the diesel sulphur norm will be lowered to 15 ppm in September 2011. In addition to directly reducing sulphur emissions, these norms will allow increasingly sophisticated diesel emission control technology on relevant vehicles.

In the rail sector, 90% of the 210 freight locomotives run on diesel; the remaining 10% on electricity. The passenger rail services are split nearly 50-50 between electric and diesel locomotives. Santiago's Metro draws its electric power from the SIC.

Critique

Chile benefits from considerable technical expertise in the transport sector, as evidenced in: relatively sophisticated urban transport modelling capabilities; good data and data-gathering practices for urban passenger mobility; well-managed infrastructure delivery, maintenance and operations; and strong project evaluation procedures. From a transport energy use perspective, the sector has a number of advantages, including a high share of urban trips still made by relatively energy-efficient modes (*e.g.* public transport and non-motorised transport) and a relatively new and efficient automotive fleet, influenced, in part, by incentives to promote vehicle turnover (at least in the capital city, Santiago). Furthermore, in the absence of any domestic vehicle manufacturing industry, initiatives aimed at influencing the vehicle fleet (such as standards) may, theoretically, be subject to less opposition lobbying. Santiago's air pollution problems have spurred the development of strong relevant analytical capabilities (*e.g.* emissions and air quality modelling) and technical capacity for vehicle testing and enforcement. They have also accelerated adoption of cleaner vehicles and prompted innovations in transport system management in response to high pollution episodes.

Nonetheless, transport certainly represents the country's most vulnerable sector with respect to oil security. Transport uses the major share of the country's oil and the sector itself is nearly entirely oil-dependent. In the face of sustained supply disruptions, the country's transport system would effectively be crippled. Recent trends seem to be only further exacerbating this situation. The sector may be entrenching itself in a road-based, infrastructural path dependence similar to many IEA member countries, which will be difficult to change. Rail plays a minor role for both passenger and freight inter-urban travel, and does not seem to figure prominently within future plans; the inter-urban rail mode does not have as high profile an institutional/political advocate as does the highway sector in Chile. Potential demand levels and infrastructure improvement costs may preclude serious passenger and/or freight rail transport in the future. In addition, inter-urban infrastructure operations (dominance of private highway concessions) and planning (Ministry of Public Works' focus on road demand forecasts) also pose a barrier to serious consideration of rail.

The most prominent reform in recent years has been Transantiago (see Box 10.1). Despite its troubled initiation, Transantiago includes important achievements (*e.g.* public transport fare and service integration) and ongoing improvements should shore up public transport service in the capital. Whether the system will ultimately serve to halt, or at least slow, the ongoing shift to private motorised transport use in the city remains to be seen, but this seems unlikely without serious efforts to manage automobile use. Efforts towards that end, particularly via the introduction of some form of congestion pricing in the city, have not been aggressively pursued despite years of consideration by analysts (congestion pricing legislation has been languishing in the Chilean Congress for nearly two decades). The segregated bus corridors under development in Santiago and the extensions of the Metro infrastructure should help increase the attractiveness of public transport operations, as should Metro's plans to work with municipalities to integrate local land-use plans with Metro infrastructure.

Other public transport concessions in the cities of Gran Concepción, Valparaíso-Viña del Mar, Antofagasta, Iquique and Rancagua should also have positive energy efficiency impacts by improving system management. Hopefully, authorities will learn from the mistakes of Transantiago implementation in working to improve public transport services in these other cities. The recent efforts to promote bicycle use via dedicated infrastructure has, apparently, produced some increases in bicycle use, and plans to develop a large-scale bicycle network and related facilities (such as secure parking) may increase bicycle mode share in Santiago and other cities.

At the inter-urban level, absent a major change in policy and investment strategies, road-based transport of both passengers and freight will only increase in dominance.

Chile does not have direct vehicle fuel economy standards, but authorities are working to develop a fuel economy labelling scheme to inform consumers. Several other relevant programmes are under development or in pilot stage, including the development of a fleet procurement manual, which will explicitly include life-cycle considerations, allowing for the more expensive up-front purchase price of efficient vehicles to be amortised over the lower lifetime operating costs. Additional initiatives under development and implementation by authorities include: truck fleet renewal incentives (subsidies and soft credits); truck driver training programmes; a technical assistance centre; and incentives to purchase hybrid light-duty passenger vehicles. The latter come in the form of discounted annual vehicle registration fees (*permiso de circulación*). For hybrid vehicles with a purchase price under approximately USD 25 000 (CLP 14 million), the discount exempts owners from paying registration fees for the first four years; for vehicles worth more than USD 25 000, registration fee exemption lasts for the first two years. In the former case, the savings amount to approximately 7% of the vehicle purchase price.[117]

More generally, vehicle registration fees vary inversely based on vehicle age, with the perverse effect of rewarding older vehicle ownership. The primary

117. The registration fee is based on the assessed vehicle value, which changes annually based on an estimated depreciation rate. According to SII (2009) a 2008 Honda Civic Hybrid had an assessed value of CLP 10 490 000 (~USD 16 500 at January 2009 exchange rates), incurring a registration fee of CLP 257/860 (~USD 400). Assuming a 5% annual depreciation, a marginally declining fee rate (from 2.5% in Y1 to 2.2% in Y4), and a 10% discount rate, this translates into a present value savings of CLP 730 800, or roughly 7% of the Y1 original assessed value.

challenge to changing this structure is equity-based, as poorer people tend to own older cars. The vehicle sales tax system does not reflect vehicle efficiency. In theory, a vehicle "feebate" scheme – in which vehicle purchase taxes are higher on less efficient vehicles to provide purchase rebates for more efficient vehicles – is possible but has not yet been explored for the country.

Finally, fuel choice influences the energy diversity of the sector and can also influence local and global emissions based on a fuel's chemical composition and the related vehicle technological characteristics. In the case of electricity-powered transport, the effects depend on the original fuel source(s), the combustion technologies, and any transmission and distribution losses. Renewable fuels offer some promise for energy independence and reduction of local and global pollutants, but the impacts depend critically on the feedstock used, production processes, etc.

Institutionally, the transport sector faces a number of challenges, despite its relatively sophisticated planning capabilities. Most notable is the lack of clear lines of authority and accountability, and the isolated process of sectoral plan development, manifest in competition and contradiction in plans and programmes. For example, some of MINVU actions ostensibly seek to densify the urban areas (*e.g.* via urban revitalisation subsidies) while MOP highway development plans and road concession programmes clearly encourage urban expansion. Competing schools of thought among different public institutions cannot be eliminated; nonetheless, a unified policy, built through participation with the many stakeholder groups (both public and private), can help establish a framework for coherently pursuing plans and projects. Such a transport policy does not yet exist at the urban or inter-urban levels.

The effects are also represented in the lack of integrated land use-transport planning, despite important analytical capabilities, which can be seen in the significant low-density, highway-oriented urban expansion (in Santiago and likely elsewhere). Strategic incorporation of energy and environmental effects into transport is still lacking. An initiative aiming to develop strategic energy and environmental planning capabilities for the sector (the AARTE Programme of SECTRA) was abandoned in 2003. Despite – or now, perhaps, due to – the roadway concessions programme and automatic tolling that goes with it, road transport pricing does not include full costs (*e.g.* congestion pricing, pollution pricing). Congestion pricing legislation has languished in Congress since 1991.

Most recent formal plans specifically targeting improved transport energy use and environmental conditions, seen in Santiago's pollution plan, the PPEE, and the National Climate Change Action Plan, remain heavily technology-focused (that is, focused on fuel type and technological efficiency) although the PPEE and the National Action Plan do aim to promote bicycle use. More broadly, while behaviourally oriented measures – including road pricing, plans to modify land development patterns, etc. – have been included over the years in relevant transportation plans, implementation has remained elusive. The longer-term behavioural impacts (*i.e.* structural shifts in trip-making activities and mode shares) of Transantiago remain to be seen. Overall, to adequately confront the energy challenges the country faces, a full suite of measures, covering trip-making, mode choices, fuel intensity and fuel choice, will need to be implemented.

Looking to the future, Chile should expand its transport energy efficiency policy portfolio. As a first step, Chile should take a comprehensive and systematic approach to integrating energy efficiency policies into transport and environmental policy at a strategic level. To this end, practical measures should address, in priority:

- Improvements in transport fleet energy efficiency through fuel economy standards for vehicles and regulations addressing non-motor components that affect vehicle energy efficiency (*e.g.* tyre rolling resistance and tyre pressure).
- Increased support for more energy efficient transport modes, including public transport, rail, shipping, non-motorised energy modes and integrated transport/land-use management.
- More aggressive development and adoption of renewable and emerging transport fuels and technologies.

The application of prices reflecting the full costs of transport fuels, roads and modes (including the progressive introduction of the cost of externalities such as environmental and health impacts) is also important to facilitate the transition to a more sustainable energy system. As mentioned earlier, a differential vehicle taxation regime favouring efficient light-duty vehicles could usefully be extended to provide even stronger support for transport energy efficiency.

Recommendations

The government of Chile should:

- Adopt strong and increasingly stringent vehicle fuel economy standards or GHG standards, and introduce a vehicle purchase or registration fee structure that incentivises the purchase of fuel efficient vehicles.
- Develop and pursue more ambitious transport demand-side management measures, including strengthened efforts to promote non-motorised transport. This should integrate analysis and debate regarding energy efficient urban structures, and the mechanisms and institutionality necessary for implementation.
- Accelerate and strengthen efforts to develop full multi-modal (air, road, rail and water) inter-urban transport planning capability (passenger/freight) to enable better forecasts and option analysis, seeking in particular to induce shifts to less energy-intensive modes.
- Fully empower an independent planning authority (*e.g.* SECTRA) with the capability and responsibility for planning and monitoring that integrates transport, land use, energy and environmental concerns, independent of construction, management and operations.

11. ENERGY RESEARCH & DEVELOPMENT

Overview

Chile is endowed with abundant clean energy resources, including hydropower, geothermal, ocean, wind and solar energy. At the same time, the country is highly dependent on fossil fuels. As a result, there is a need to focus on energy diversification and sustainable energy, utilising indigenous resources. This requires a strategic focus, anchored in policy goals and implemented throughout the energy R&D chain from basic and applied research to demonstration, deployment and commercialisation. The Chilean government recognises the need for a more comprehensive approach to energy R&D, and is working to develop a long-term strategy for energy R&D that will take advantage of Chile's strong innovation network.

Energy R&D Strategic Goals and Policy

Currently, no coherent strategy or system for prioritisation of activities exists to guarantee continued research, development and deployment of new and improved energy technologies. In its *Energy Policy: New Guidelines*, the CNE recognises the importance of developing a long-term vision for the energy sector, as it is seen as playing an important role in the country's long-term development. To address this gap, the CNE is currently in the process of developing a new national energy policy. Given the challenges it faces, the Chilean government is considering investing strategically in a few technologies consistent with the country's resource potential and national capabilities.

Chile faces the challenge of adapting its existing R&D structure to a more strategic approach, which addresses the specific needs of a market-driven energy policy. The country has a high potential for energy production from renewable sources, namely geothermal, wave, ocean, wind, and solar, though the extent to which it can realise this potential has not been quantified. In terms of fossil fuels utilisation for power generation, the private sector currently plans to build a significant amount of new coal-fired capacity. This calls for an understanding of the technologies that are widely available to ensure adoption of the cleanest combustion and clean-up technologies.

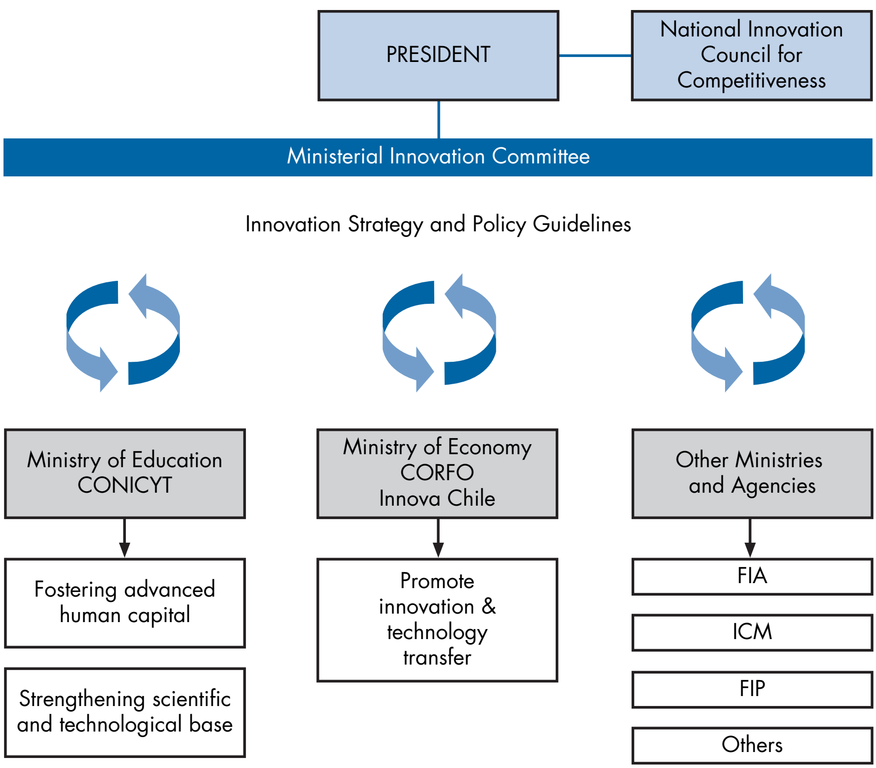
Sector Organisation

A number of institutions are involved in various aspects of energy R&D policy and funding, including the National Innovation Council for Competitiveness (CNIC), the National Commission for Scientific and Technological Research (CONICYT) and the Chilean Economic Development Agency (CORFO). In 2008, public investment in innovation for competitiveness amounted to USD 600 million, more than double the amount allocated in 2005.

The National Innovation System in Chile comprises a group of public policy and funding entities, universities, research centres and private companies. As of 2007, public funding is the major contributor to R&D expenditure (53%). The private sector accounts for 37% of this total and 10% comes

Figure 11.1

Chile's National Innovation System



Notes: CORFO: Chilean Economic Development Agency; CONICYT: National Commission for Scientific and Technological Research; ICM: Millennium Scientific Initiative (Ministry of Planning); FIA: Agrarian Innovation Foundation (Ministry of Agriculture); FIP: Fishing Research Fund (Ministry of Economy).

Source: CONICYT.

from other sources.[118] The National Innovation Council, created in 2005 as a counselling body of the Presidency of Republic, plays a key role in defining policies. To ensure co-ordination through different ministries, a committee (the Ministerial Innovation Committee) is now officially responsible for the co-ordination of public innovation policies (see Figure 11.1).

CONICYT and CORFO are essential entities in this system, and are responsible for the implementation of this action plan. Each institution covers different stages of the R&D process, from individual basic research grants (CONICYT) to industrial innovation and applied R&D (CORFO). Figure 11.1 shows the organisation of Chile's science, technology and innovation system.

CONICYT aims to promote advanced human capital training and to strengthen, develop and disseminate scientific and technological research, in coherence with the National Innovation Strategy. In this way, CONICYT contributes to the economic, social and cultural development of the country. It also seeks to promote innovation as a tool to add value and ensure the effective use of natural resources.

The National Scientific and Technological Development Fund, FONDECYT, funds individual basic research activity, with proposals funded according to merit. The Fund for the Promotion of Scientific and Technological Development (FONDEF) is a co-financing scheme that requires complementary private funding. Apart from these, there are specific programmes for regional development applied centres and an Associative Research Program (PIA) that supports groups of researchers and different Centres of Excellence.

In addition, CONICYT is in charge of supporting and strengthening the training of advanced human capital (in the country and abroad), attracting international researchers of excellence and promoting labour insertion in all areas, through the Advanced Human Capital Programme.

The Competitiveness Innovation Fund (FIC) is a specific programme for regional development. The Innovation Committee decides the allocation of 75% of the Funds and the Regional authorities determine the programme's focus and the types of projects to be supported with the remaining 25%.

CORFO, through the Innovation Promotion Agency created by InnovaChile in 2005, is actively engaged in helping Chilean firms improve their international competitiveness. Priorities for funding include technology transfer and dissemination as well as pre-competitive research and innovation. Since

118. The energy sector in Chile – Research capabilities and science and technology development areas, CONICYT, 2007).

2005, InnovaChile has supported 68 innovation projects related to energy, with a public funding contribution of USD 13 million. Among the main beneficiaries are R&D university research centres involved in private sector projects and energy related small- and medium-size companies.

Public research centres play an important role in energy R&D in Chile. There are 34 university research centres that have some focus on energy. More than half are developing small-scale non-conventional renewable energy (NCRE) projects. Of the rest, 11 focus on electricity-based R&D, seven on general and cross-cutting issues, and one concentrates on nuclear research, the Chilean Nuclear Energy Commission (CCHEN).

Two new entities are in the process of being established: the Chilean Energy Efficiency Agency (ACHEE) and the Centre for Renewable Energy (CER). ACHEE is an execution agency charged with the implementation of energy efficiency programmes. The clear articulation between policy formulation and implementation as envisaged in the proposed energy bill is advantageous, since practical experience can inform the design of new programmes. Collaboration with academia and researchers aimed at the promotion of new ideas and concepts should also be considered in the portfolio of new projects.

The Centre for Renewable Energy is expected to have a lead role in promoting renewable energy technologies in the market and to function as a clearinghouse connecting research entities and private companies to the international network of renewable technologies. The Centre will also monitor the effectiveness of policy instruments and identify barriers.

However, there appears to be little co-ordination among these actors, and activities are often implemented in isolation. The CNE and the Minister of Energy currently do not participate in the Ministerial Innovation Committee, nor in the National Innovation Council for Competitiveness. There is a disconnect between energy institutions and the national innovation system. Co-ordination mostly happens on a personal basis for specific projects.

R&D Budget and Funding

Energy projects represent a small part of Chile's total expenditure on R&D, and are mainly dedicated to basic research. The country has various public funds and allocation usually depends upon criteria based on excellence. Financing is obtained through public resources and programmes funded by credits from international organisations such as the World Bank, the Inter-American Development Bank and the European Union, or by charitable foundations.

In 2006-07, the CNIC developed a National Innovation Strategy for Competitiveness, based on the development of clusters. In this strategy, energy is not considered as a cluster but as a transversal technological platform required for all the productive clusters. This is an important step forward. However, adding energy as a specific cluster of focus would be advantageous for the Chilean economy as it would contribute to reinforcing and creating technological capabilities and pushing new technologies into the market. Within Chile's Innovation Strategy, an action plan was drawn up for the period 2008-2010, which establishes a set of business and technology platforms with the aim of promoting productivity and economical development in Chile.

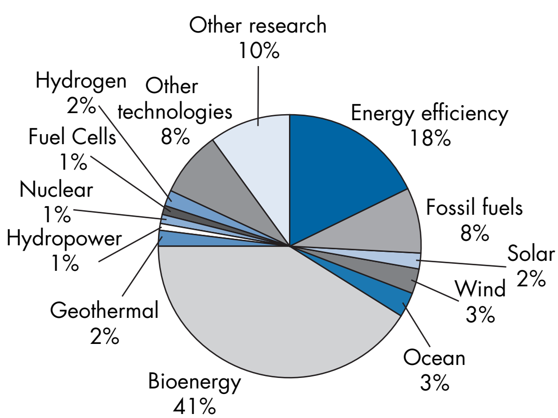
There is insufficient information on training and human capacity spending for energy R&D in Chile; however, there appears to be a challenge with a low level of researchers (less than 200) in this field.

R&D Activities

Table 11.1 and Figure 11.2 are based on the database of energy-related R&D projects in Chile currently being developed by the CNE and integrating information for CONICYT and CORFO. The list of energy R&D projects shows the allocated funding provided by all Chilean R&D funding institutions of different energy sub-sectors. While Chile has a number of activities underway, the funding is largest for two areas: energy efficiency and bioenergy.

Figure 11.2

Energy R&D Funding by Project Type, 1998-2008



Source: CNE, 2009.

Even though InnovaChile funds are demand-driven, the agency has developed national consortia contests to encourage the development of second-generation biofuels projects. Between 2005 and 2008, biofuels received the largest share of InnovaChile funds, amounting to over 75% of total funds. Overall, since 2005, InnovaChile has supported 68 innovation projects in the energy area (34 during 2008). This represents a total contribution of CLP 6 900 million (USD 13 million) by the government to the sector. One-third of these 68 projects are related to biofuels.

Whilst research on electrical energy has been carried out for many years, renewable energy projects have been implemented only recently. Electrical energy research is focused on improving energy generation, transmission and distribution. The aim is to improve efficiency, reduce costs and increase yield so as to meet the country's growing energy demands.

Table 11.1

List of Energy R&D Projects by Sub-sector and Funding, 2008

Area of activity	Number of Projects	Share (%)	Funding (billion CLP)	Share (%)
Energy efficiency	**91**	**60.3**	**6.40**	**23.0**
Industry	42	27.8	2.81	10.1
Residential and commercial	22	14.6	1.29	4.6
Transport	16	10.6	1.27	4.6
Other	11	7.3	1.02	3.7
Fossil fuels	25	16.6	2.72	9.8
Oil and gas	11	7.3	1.24	4.5
Coal	9	6.0	0.57	2.1
Carbon capture and storage	5	3.3	0.90	3.2
Renewable energy	**90**	**59.6**	**18.46**	**66.1**
Solar	12	7.9	0.75	2.7
Wind	11	7.3	1.06	3.8
Ocean	9	6.0	1.107	4.0
Bioenergy	48	31.8	14.61	52.3
Geothermal	5	3.3	0.73	2.6
Hydropower	5	3.3	0.19	0.7
Nuclear	**8**	**5.3**	**0.53**	**1.9**
Nuclear Fission	6	4.0	0.45	1.6

Table 11.1

List of Energy R&D Projects by Sub-sector and Funding, 2008 (continued)

Area of activity	Number of Projects	Share (%)	Funding (billion CLP)	Share (%)
Nuclear Fusion	2	1.3	0.08	0.3
Fuel cells	**8**	**5.3**	**0.36**	**1.3**
Hydrogen	**6**	**4.0**	**0.87**	**3.1**
Other technologies	**21**	**13.8**	**2.72**	**9.7**
Electricity transformation	7	4.6	0.82	2.9
Transmission and distribution	7	4.6	0.80	2.9
Electricty storage	7	4.6	1.09	3.9
Other research	**52**	**34.5**	**3.72**	**13.4**
Energy systems analysis	30	19.9	2.28	8.2
Other	22	14.6	1.44	5.2
Total	**155**		**29.42**	

Notes:

Total projects were 155 at the end of 2008 for a total amount of CLP 29 billion, equivalent to USD 52 million.

One or more projects can be classified in more than one energy sub-sector. The sum of projects by sub-sector may therefore equal to more than the total indicated.

Source: CNE database under construction, with input from CONICYT, CORFO, FONDECYT, FONDEF.

In the case of FONDEF, a total of USD 6.4 million was allocated to finance energy projects between 1991 and 2006, by which time biomass projects accounted for USD 2 million of the total. Other projects included NCRE, energy efficiency, gas and coal.

Pre-investment and Deployment Activities

Since 2005, the Chilean Economic Development Agency, with technical support from the CNE, has been providing subsidies for pre-investment stages of NCRE projects through co-funding of pre-feasibility studies for such projects.[119] The maximum subsidy is USD 60 000, with a limit of 50% of the study cost and 2% of the estimated investment. At the end of 2008, some 130 projects based on wind power, biomass, biogas, geothermal energy and small-scale hydroelectric plants received support from CORFO. Some of these projects have already been implemented; others are currently under construction or in the process of obtaining permits.

119. This includes, among others, conceptual engineering, prospection and environmental impact assessment studies.

CORFO also provides grants for pre-investment studies under advanced stage of development. This incentive finances part of the costs of advanced engineering studies such as basic and detailed engineering, studies of electrical connections, and environmental impact studies. These grants can provide up to 50% of the total cost of the study, with a maximum of 5% of the estimated investment and not surpassing USD 160 000 per project submission. This instrument does not apply to studies measuring the availability of resources or to pre-feasibility studies.

Moreover, CORFO also offers support for foreign products and service providers for renewable energy projects through the High Technology Investment Programme. The programme delivers grants for the pre-investment phase and for fixed assets, as well as incentives for the start-up of a company, settlement and human resources. The programme applies to ancillary services and products for renewable energy generation such as: wind power logistics, maintenance, off-shoring of engineering, manufacturing of turbines, laboratories, etc.

It is likely that the number of projects and the amount of funding for energy efficiency and renewable energies will increase, as a result of the consolidation of the framework set up by the CNE's *Energy Policy: New Guidelines*. Efficient co-ordination and the involvement of the Chilean Energy Efficiency Agency and the recently launched Centre for Renewable Energies are crucial for the success of this development.

In the case of nuclear energy, although there is no activity related to power production, there is know-how and expertise related to the use of these technologies. The Chilean Commission of Nuclear Energy is a public agency that advises the government and develops research within the scope of nuclear applications in the areas of agriculture, food, industry, environment, medicine and mining.

Training

In 2009, CONICYT and CNE launched an Energy Programme. This programme aims to generate scientific and technological capabilities in the energy sector, through short-term training courses of energy issues, scholarships for internships abroad and long-term initiatives.

In 2008, the CNE organised a series of workshops with all R&D stakeholders to identify priority technologies and potential projects. In October 2008, the CNE also organised an international conference entitled: *Thinking today about tomorrow's energy*. The conference aimed to gain international insight into promising energy technologies that might fit Chile's conditions. Outcomes from these workshops should provide valuable input into a national energy R&D strategy for the use of diversified, efficient and clean energy technologies. Building human resource capacity is also recognised to be an important element of Chile's energy policy guidelines.

International Activities

The importance of international co-operation in the R&D field is generally acknowledged. The Chilean government has promoted the participation of foreign experts in peer reviews and workshops discussing technological options. CONICYT has also developed bilateral technology co-operation agreements with the United States, Canada, the European Union, France, Germany and Finland, among others, to develop specific research projects, in particular on NCRE.

There are also promising opportunities for greater international co-operation on energy technology R&D. There are a number of multilateral partnerships, such as the International Partnership on Energy Efficiency (IPEEC) and many others, that offer platforms for information exchange, human capacity building and networking should Chile choose to join. In addition, the IEA technology network offers a wide range of Implementing Agreements that could be useful to contribute to energy security and economic and environmental goals, namely on clean coal and renewable energy technologies. Such collaborative opportunities should be considered in the context of the Chilean government's energy policy goals.

Critique

Chile currently imports nearly all of its fossil fuels; as such, the country is vulnerable to market changes. The country is endowed with strong hydroelectric and non-conventional renewable energy resources, particularly solar, wave, ocean, wind and geothermal. The government has established a successful approach that utilises an innovation network to foster advances in energy R&D. For example, CORFO funding and support for innovation in key energy areas (such as second-generation biofuels) are positive examples.

Despite this progress, due to the lack of a national policy on energy R&D, Chile does not have a comprehensive energy strategy linked to R&D priorities. The merit and excellence of individual projects is the only basis used for the approval of basic research funding. The result is a dispersion of activities, lack of formal collaboration between institutions, and research that is project-driven rather than set by or geared to the country's needs. The level of funding on research in innovation for competitiveness is significant, reaching of USD 600 million in 2008. But energy-related projects account for only a fraction of the total expenditure.

Box 11.1: Technology Transfer Needs for a Climate Change Policy

The economic development agency of Chile (CORFO) is currently co-ordinating a consultancy that aims to define a technology transfer (TT) strategy, based on products and techniques for GHG emissions mitigation and adaptation to climate change, to support Chile's National Climate Change Policy. The counterpart team includes several professionals from Chilean public institutions such as CORFO, InnovaChile Committee, Clean Production Committee, CONAMA and the National Energy Efficiency Programme.

This study should be available at the end of 2009, and will serve as an input for Chile's Second National Communication on Climate Change. The outcome of the study will help assess Chile's technological needs as an input for the international climate change negotiation process.

Under the UNFCCC Bali Action Plan, Parties agreed on the need for nationally appropriate mitigation actions by developing country Parties – supported and enabled by technology, financing and capacity building in a measurable, reportable and verifiable manner. The success of the current international negotiation process will depend on long- term co-operative action within Parties, incorporating TT for climate change mitigation and adaptation.

Technology development is guided by product orientation, where industrial participation is promoted by forming consortia addressing specific areas in which the country considers having competitive advantage. An Innovation Strategy was formulated based on cluster development and the importance of human capacity development. These two elements are expected to introduce new technologies into the market. However, this might not be the case for energy, as it is not considered to be a cluster for developing Chilean competitiveness, but rather as a platform for the development of other clusters. Therefore, the majority of R&D public funds support innovation projects with short-term economic benefits. The government of Chile should be praised for identifying focus areas for technology and human capital development needs in energy, particularly second-generation biofuels (including microalgae fixation), solar, geothermal and wave energy. The definition of roadmaps could be a useful tool to identify niche research areas in wich Chile already has or might develop a competitive advantage.

However, competitiveness may too narrow a goal for energy R&D. According to the *IEA Shared Goals*, economy is only one of the three key principles of a sound energy policy. Environment and energy security must not be overlooked by any approach. The finalisation of Chile's long-term energy policy with clear priorities and objectives will be a key element, as it will also allow the prioritisation of R&D activities that could contribute to energy security and environmental sustainability. In this regard, the recent consultancy co-ordinated by CORFO regarding technology transfer for climate change should be praised as it precisely seeks to integrate Chile's energy policy and its National Action Plan on Climate Change (see Box 11.1).

The government is aware of the GHG implications of the projected substantial increase in Chile's dependence on coal. Large coal-fired plants should at least be built with sufficient space for the later retrofit of CO_2 capture equipment and with some confidence that underground storage sites for the captured CO_2 exist within a viable transport distance. Because Chile does not appear to have suitable storage sites, at least on initial inspection, more work is needed to assess CO_2 storage potential in Chile, perhaps drawing on work in Japan, which faces similar problems.

Chile has long-term potential in emerging renewable energy technologies, including solar, deep-drilling geothermal and wave energy. The government has introduced commendable specific, risk-sharing measures for geothermal and funding for solar demonstration plants, which could be replicated for other NCRE projects with a high potential. However, experience in other countries has shown that an appropriate combination of technology development and market deployment is key to attracting large private investments, triggering innovation and driving down costs. Taking early action would have the advantage of preparing for future market integration of these technologies and of reducing the costs of their adaptation to the Chilean framework. It would also contribute to creating jobs in the relevant supply chains, triggering innovation and economic development.

An important step towards the provision of comprehensive information to investors and other stakeholders, as well as the co-ordination of R&D and promotion activities, will be the establishment of the Renewable Energy Centre. The Centre has the purpose of acting as an antenna for renewable energy development, identifying technological advances and best practices around the world to organise and make available information within Chile. In addition, the Centre will review experience with various types of incentives for alternative energy projects, generate systematic reviews of available natural resources, provide capacity building, orient potential investors, administer direct financing instruments, and create networks with other specialised centres of R&D and incentives in renewable energies.

The Centre should also facilitate co-ordination between the Ministerial Innovation Committee, in charge of formulating Chile's innovation policies (led by the Minister of Economy), and the Ministry of Energy by providing a feedback mechanism for energy R&D project implementation and formulation of policy advice. The Minister of Energy should be formally integrated into the Ministerial Innovation Committee to articulate energy R&D policy with Chile's national economic development strategy.

The National Scientific System includes research centres and universities that have R&D projects in the energy field. The perception is that these activities are dispersed among various centres and have few researchers. Moreover, the energy utilities do not use the available domestic research potential to help meet energy efficiency objectives or to identify new technology potential. The Chilean government should be aware of the potential of Chile's research centres and universities, especially the public institutes working in the energy field, and should create conditions to improve their visibility and profile and to increase industry's confidence in using their services and knowledge. This would reinforce the policy goals relating to energy efficiency and the environment.

Finally, while there are isolated examples of Chilean participation in international energy R&D activities and networks, there is much to be gained from a more strategic, pro-active approach. Chile can benefit from participating in multilateral energy networks and partnerships, as well as through the IEA's Implementing Agreements. This would allow a relatively isolated country to learn from and adapt best practices from leading institutions around the world.

Recommendations

The government of Chile should:

- Define a long-term science and technology policy and action plan aligned with energy policy priorities, incorporating R&D in a more co-ordinated manner across public institutions.

- Concentrate competencies and teams in the energy area as an alternative to researchers being distributed among various research centres. Such an infrastructure should support the government in the development of a long-term vision, as well as in the implementation of multi-annual energy R&D programmes.
- Conduct roadmapping exercises to identify niche research areas in which Chile already has or might develop competitive strengths.
- Assess the many carbon abatement options available, including carbon capture and storage, on an objective basis to determine how they might be applied in Chile.
- Continue promoting the formation of multi-disciplinary consortia for technological development projects. Ensure their monitoring and and follow-up as well as adequate funding for demonstration projects of new technologies.
- Strengthen coordination between involved agencies through the Centre for Renewable Energy currently under development.
- Integrate the Energy Minister in the Ministerial Innovation Committee to articulate energy R&D policy with Chile's national economic development strategy.
- Continue promoting international collaboration and consider joining the IEA technology network by participating in the Implementing Agreements of most interest to Chile.

ANNEX I

ENERGY BALANCES AND KEY STATISTICAL DATA

Unit: Mtoe

SUPPLY		1973	1990	2000	2004	2005	2006	2007
TOTAL PRODUCTION		**5.08**	**7.43**	**8.20**	**8.07**	**8.86**	**9.14**	**8.46**
Coal		0.96	1.45	0.24	0.13	0.27	0.26	0.10
Peat		-	-	-	-	-	-	-
Oil		1.79	1.13	0.43	0.38	0.34	0.33	0.55
Gas		0.53	1.41	1.60	1.37	1.61	1.55	1.08
Comb. Renewables & Waste[1]		1.33	2.68	4.26	4.30	4.37	4.49	4.73
Nuclear		-	-	-	-	-	-	-
Hydro		0.48	0.77	1.67	1.89	2.28	2.51	1.99
Wind		-	-	-	0.00	0.00	0.00	0.00
Geothermal		-	-	-	-	-	-	-
Solar/Other[2]		-	-	-	-	-	-	-
TOTAL NET IMPORTS[3]		**3.39**	**6.99**	**18.27**	**21.29**	**21.04**	**22.17**	**24.13**
Coal	Exports	0.00	-	0.03	0.03	0.03	0.01	0.03
	Imports	0.20	1.13	2.94	2.61	2.44	3.01	4.04
	Net Imports	0.20	1.13	2.92	2.58	2.42	3.00	4.01
Oil	Exports	0.06	0.21	0.86	1.46	1.72	2.00	1.22
	Imports	3.55	6.07	12.45	14.29	14.89	16.15	18.86
	Int'l Marine and Aviation Bunkers	0.31	-	-	0.00	0.00	0.00	-
	Net Imports	3.19	5.86	11.59	12.82	13.16	14.14	17.64
Gas	Exports	-	-	-	-	-	-	-
	Imports	-	-	3.67	5.72	5.27	4.82	2.34
	Net Imports	-	-	3.67	5.72	5.27	4.82	2.34
Electricity	Exports	-	-	-	-	-	-	-
	Imports	-	-	0.10	0.16	0.19	0.20	0.14
	Net Imports	-	-	0.10	0.16	0.19	0.20	0.14
TOTAL STOCK CHANGES		**0.03**	**-0.60**	**-0.26**	**-0.46**	**-0.29**	**-0.85**	**-1.79**
TOTAL SUPPLY (TPES)[4]		**8.50**	**13.82**	**26.21**	**28.90**	**29.61**	**30.46**	**30.79**
Coal		1.20	2.47	3.02	2.70	2.70	3.29	3.32
Peat		-	-	-	-	-	-	-
Oil		4.97	6.77	11.96	12.86	13.31	13.72	17.26
Gas		0.53	1.14	5.21	6.99	6.78	6.26	3.35
Comb. Renewables & Waste[1]		1.33	2.68	4.26	4.30	4.37	4.49	4.73
Nuclear		-	-	-	-	-	-	-
Hydro		0.48	0.77	1.67	1.89	2.28	2.51	1.99
Solar/Wind/Geothermal/Other[2]		-	-	-	-	-	-	-
Electricity Trade[5]		-	-	0.10	0.16	0.19	0.20	0.14
Shares (%)								
Coal		*14.1*	*17.9*	*11.5*	*9.3*	*9.1*	*10.8*	*10.8*
Oil		*58.5*	*49.0*	*45.6*	*44.5*	*44.9*	*45.0*	*56.1*
Gas		*6.2*	*8.3*	*19.9*	*24.2*	*22.9*	*20.5*	*10.9*
Comb. Renewables & Waste		*15.6*	*19.4*	*16.2*	*14.9*	*14.7*	*14.7*	*15.4*
Hydro		*5.7*	*5.5*	*6.4*	*6.5*	*7.7*	*8.2*	*6.5*
Solar/Wind/Geothermal/Other[2]		-	-	-	-	-	-	-
Electricity Trade		-	-	*0.4*	*0.6*	*0.6*	*0.6*	*0.5*

0 is negligible, – is nil, .. is not available

Unit: Mtoe

DEMAND

FINAL CONSUMPTION BY SECTOR

	1973	1990	2000	2004	2005	2006	2007
TFC	**6.52**	**11.43**	**21.36**	**22.95**	**23.24**	**24.56**	**24.55**
Coal	0.65	0.73	0.80	0.77	0.80	0.98	0.65
Peat	-	-	-	-	-	-	-
Oil	3.84	5.86	10.15	10.61	10.94	11.41	12.77
Gas	0.10	0.95	3.33	3.63	3.53	3.79	2.32
Comb. Renewables & Waste[1]	1.31	2.56	3.92	3.89	3.82	4.01	4.24
Solar/ Geothermal/Other	-	-	-	-	-	-	-
Electricity	0.63	1.33	3.16	4.05	4.16	4.37	4.56
Heat	-	-	-	-	-	-	-
Shares (%)							
Coal	*10.0*	*6.4*	*3.8*	*3.4*	*3.4*	*4.0*	*2.7*
Peat	-	-	-	-	-	-	-
Oil	*58.9*	*51.2*	*47.5*	*46.2*	*47.1*	*46.5*	*52.0*
Gas	*1.5*	*8.3*	*15.6*	*15.8*	*15.2*	*15.4*	*9.5*
Comb. Renewables & Waste	*20.0*	*22.4*	*18.4*	*17.0*	*16.5*	*16.3*	*17.3*
Solar/ Geothermal/Other	-	-	-	-	-	-	-
Electricity	*9.6*	*11.7*	*14.8*	*17.6*	*17.9*	*17.8*	*18.6*
Heat	-	-	-	-	-	-	-
TOTAL INDUSTRY[6]	**2.32**	**4.47**	**9.24**	**10.01**	**9.93**	**11.01**	**10.24**
Coal	0.46	0.67	0.79	0.74	0.78	0.96	0.64
Peat	-	-	-	-	-	-	-
Oil	1.21	1.51	2.13	2.37	2.24	2.61	3.31
Gas	0.00	0.75	2.98	3.14	3.04	3.26	1.76
Comb. Renewables & Waste[1]	0.24	0.67	1.13	1.00	1.06	1.24	1.45
Solar/ Geothermal/Other	-	-	-	-	-	-	-
Electricity	0.41	0.87	2.21	2.77	2.80	2.95	3.08
Heat	-	-	-	-	-	-	-
Shares (%)							
Coal	*20.0*	*15.0*	*8.6*	*7.4*	*7.9*	*8.7*	*6.2*
Peat	-	-	-	-	-	-	-
Oil	*52.2*	*33.8*	*23.1*	*23.6*	*22.6*	*23.7*	*32.3*
Gas	*0.1*	*16.7*	*32.3*	*31.4*	*30.6*	*29.6*	*17.2*
Comb. Renewables & Waste	*10.2*	*15.0*	*12.2*	*9.9*	*10.7*	*11.2*	*14.2*
Solar/ Geothermal/Other	-	-	-	-	-	-	-
Electricity	*17.6*	*19.5*	*23.9*	*27.6*	*28.2*	*26.8*	*30.1*
Heat	-	-	-	-	-	-	-
TRANSPORT[4]	**1.84**	**3.42**	**6.63**	**6.95**	**7.55**	**7.70**	**8.22**
TOTAL OTHER SECTORS[7]	**2.36**	**3.54**	**5.49**	**5.99**	**5.77**	**5.84**	**6.08**
Coal	0.06	0.06	0.01	0.03	0.02	0.02	0.01
Peat	-	-	-	-	-	-	-
Oil	0.94	0.95	1.42	1.34	1.20	1.16	1.30
Gas	0.09	0.20	0.34	0.46	0.46	0.50	0.54
Comb. Renewables & Waste[1]	1.07	1.89	2.79	2.90	2.76	2.77	2.79
Solar/ Geothermal/Other	-	-	-	-	-	-	-
Electricity	0.20	0.44	0.93	1.26	1.33	1.39	1.45
Heat	-	-	-	-	-	-	-
Shares (%)							
Coal	*2.5*	*1.6*	*0.2*	*0.5*	*0.3*	*0.3*	*0.2*
Peat	-	-	-	-	-	-	-
Oil	*39.7*	*26.9*	*25.8*	*22.4*	*20.8*	*19.9*	*21.3*
Gas	*3.9*	*5.6*	*6.2*	*7.7*	*8.0*	*8.6*	*8.9*
Comb. Renewables & Waste	*45.4*	*53.4*	*50.8*	*48.4*	*47.8*	*47.5*	*45.8*
Solar/ Geothermal/Other	-	-	-	-	-	-	-
Electricity	*8.5*	*12.4*	*17.0*	*21.1*	*23.1*	*23.8*	*23.8*
Heat	-	-	-	-	-	-	-

Unit: Mtoe

DEMAND

ENERGY TRANSFORMATION AND LOSSES

	1973	1990	2000	2004	2005	2006	2007
ELECTRICITY GENERATION[8]							
INPUT (Mtoe)	**1.44**	**3.05**	**6.17**	**7.70**	**8.23**	**8.14**	**9.15**
OUTPUT (Mtoe)	**0.75**	**1.58**	**3.45**	**4.40**	**4.51**	**4.76**	**5.03**
(TWh gross)	8.77	18.37	40.08	51.21	52.48	55.32	58.51
Output Shares (%)							
Coal	*14.0*	*38.3*	*22.5*	*15.1*	*13.7*	*19.2*	*22.7*
Peat	-	-	-	-	-	-	-
Oil	*20.5*	*9.2*	*2.3*	*4.7*	*6.4*	*4.6*	*24.6*
Gas	*1.1*	*2.1*	*22.7*	*33.1*	*25.9*	*20.7*	*7.9*
Comb. Renewables & Waste	*0.6*	*1.9*	*4.0*	*4.2*	*3.5*	*2.9*	*5.3*
Nuclear	-	-	-	-	-	-	-
Hydro	*63.8*	*48.5*	*48.5*	*42.9*	*50.5*	*52.7*	*39.5*
Wind	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-
Solar/Other	-	-	-	-	-	-	-
TOTAL LOSSES	**1.98**	**2.38**	**4.86**	**5.97**	**6.33**	**6.03**	**6.30**
of which:							
Electricity and Heat Generation[9]	0.69	1.47	2.72	3.29	3.72	3.39	4.11
Other Transformation	0.30	-0.11	0.84	0.75	0.63	0.64	0.59
Own Use and Losses	1.00	1.02	1.30	1.93	1.97	2.00	1.60
Statistical Differences	-	0.02	-0.01	-0.02	0.05	-0.13	-0.06

INDICATORS

	1973	1990	2000	2004	2005	2006	2007
GDP (billion 2000 USD)	21.83	40.76	75.78	88.21	93.11	97.15	102.10
Population (millions)	10.09	13.18	15.41	16.12	16.30	16.43	16.60
TPES/GDP[10]	0.39	0.34	0.35	0.33	0.32	0.31	0.30
Energy Production/TPES	0.60	0.54	0.31	0.28	0.30	0.30	0.28
Per Capita TPES[11]	0.84	1.05	1.70	1.79	1.82	1.85	1.86
Oil Supply/GDP[10]	0.23	0.17	0.16	0.15	0.14	0.14	0.17
TFC/GDP[10]	0.30	0.28	0.28	0.26	0.25	0.25	0.24
Per Capita TFC[11]	0.65	0.87	1.39	1.42	1.43	1.49	1.48
Energy-related CO_2 Emissions (Mt CO_2)[12]	19.8	32.7	56.0	62.6	63.6	66.2	71.0
CO_2 Emissions from Bunkers (Mt CO_2)	1.0	-	-	0.0	0.0	0.0	-
GROWTH RATES (% per year)	**73-79**	**79-90**	**90-00**	**00-04**	**04-05**	**05-06**	**06-07**
TPES	1.3	3.8	6.6	2.5	2.5	2.9	1.1
Coal	-1.5	7.7	2.0	-2.8	0.2	21.9	0.8
Peat	-	-	-	-	-	-	-
Oil	0.2	2.8	5.8	1.8	3.5	3.1	25.8
Gas	5.1	4.4	16.4	7.6	-3.0	-7.7	-46.5
Comb. Renewables & Waste	4.4	4.1	4.7	0.3	1.4	2.9	5.4
Nuclear	-	-	-	-	-	-	-
Hydro	4.9	1.6	8.1	3.1	20.5	10.0	-20.6
Wind	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-
Solar/Other	-	-	-	-	-	-	-
TFC	1.2	4.5	6.5	1.8	1.3	5.7	-0.1
Electricity Consumption	4.2	4.7	9.0	6.4	2.7	5.2	4.4
Energy Production	-0.2	3.6	1.0	-0.4	9.8	3.2	-7.5
Net Oil Imports	5.5	2.7	7.1	2.6	2.7	7.4	24.7
GDP	3.0	4.2	6.4	3.9	5.6	4.3	5.1
Growth in the TPES/GDP Ratio	-1.7	-0.3	0.2	-1.3	-3.0	-1.3	-3.8
Growth in the TFC/GDP Ratio	-1.7	0.4	0.0	-2.0	-3.8	1.2	-5.1

Please note: Rounding may cause totals to differ from the sum of the elements.

Notes to Energy Balances and Key Statistical Data

1 *Combustible renewables and waste comprises solid biomass and biogas. Data are often based on partial surveys and may not be comparable between countries.*

2 *Other may include tide, wave and ambient heat used in heat pumps.*

3 *Total net imports include coal, oil, gas and electricity.*

4 *Excludes international marine bunkers and international aviation bunkers.*

5 *Total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.*

6 *Industry includes non-energy use.*

7 *Other Sectors includes residential, commercial, public services, agriculture, forestry, fishing and other non-specified sectors.*

8 *Inputs to electricity generation include inputs to electricity and CHP plants. Output refers only to electricity generation.*

9 *Losses arising in the production of electricity and heat at main activity producer utilities and auto-producers. For non-fossil-fuel electricity generation, theoretical losses are shown based on plant efficiencies of 100% for hydro and wind.*

10 *Toe per thousand US dollars at 2000 prices and exchange rates.*

11 *Toe per person.*

12 *Energy-related CO_2 emissions have been estimated using the IPCC Tier I Sectoral Approach from the Revised 1996 IPCC Guidelines. In accordance with the IPCC methodology, emissions from international marine and aviation bunkers are not included in national totals.*

ANNEX II

INTERNATIONAL ENERGY AGENCY "SHARED GOALS"

The Member countries of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants.

In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

1. **Diversity, efficiency and flexibility within the energy sector** are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. **The environmentally sustainable provision and use of energy** are central to the achievement of these shared goals. Decision-makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the Polluter Pays Principle where practicable.

4. **More environmentally acceptable energy sources** need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve

the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. **Improved energy efficiency** can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-Member countries, should be encouraged.

7. **Undistorted energy prices** enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. **Free and open trade** and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. **Co-operation among all energy market participants** helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The "Shared Goals" were adopted by IEA Ministers at their 4 June 1993 meeting in Paris.)

ANNEX III

ABBREVIATIONS AND UNITS

Abbreviations (Organisations)

ACHEE	*Agencía Chilena de Eficiencia Energética* (Chilean Energy Efficiency Agency)
APEC	Asia-Pacific Economic Co-operation; www.apec.org
ARIAE	*Asociación Iberoamericana de Entidades Reguladoras de la Energía* (Ibero-American Association of Energy Regulators); www.ariae.org
CCHEN	*Comisión Chilena de Energía Nuclear* (Chilean Nuclear Energy Commission)
CDEC	*Centro de Despacho Económico de Carga* (Economic Load Dispatch Centres)
CER	*Centro de Energías Renovables* (Chilean Centre for Renewable Energy)
CGTS	*Coordinación General de Transporte de Santiago* (General Co-ordinator for Transportation in Santiago)
CIER	*Comisión de Integración Electrica Regional* (Regional Electricity Commission)
CNE	*Comisión Nacional de Energía* (National Energy Commission); www.cne.cl
COCHILCO	*Comisión Chilena del Cobre* (Chilean Copper Commission); www.cochilco.cl
CODELCO	*Corporación Nacional del Cobre* (National Copper Corporation); www.codelco.cl
CONAF	*Corporación Nacional Forestal* (National Forestry Corporation)
CONAMA	*Comisión Nacional del Medio Ambiente* (National Commission for the Environment)
CONICYT	*Comisión Nacional de Investigación Científica y Tecnológica* (National Commission for Scientific and Technological Research)

COREMA	*Comisión Regional del Medio Ambiente* (Regional Environment Commission)
CORFO	*Corporación de Fomento de la Producción* (National Economic Development Agency)
DOJ	United States Department of Justice
ECLAC	Economic Commission for Latin America and the Carribean of the United Nations
EFE	*Empresa de los Ferrocarriles del Estado de Chile* (State Railroad Company)
ENAP	*Empresa Nacional de Petróleo* (National Petroleum Company)
EPA	Environmental Protection Agency of the United States
FAO	Food and Agriculture Organization of the United Nations; www.fao.org
FNDR-ER	*Fondo Nacional de Desarrollo Regional – Electrificación Rural* (National Fund for Regional Development dedicated to rural electrification)
FNE	*Fiscalía Nacional Económica* (National Economic Prosecutor's Office)
IAEA	International Atomic Energy Agency; www.iaea.org
IADB	Inter-American Development Bank; www.iadb.org
IEA	International Energy Agency; www.iea.org
INDAP	*Organismo dependiente del Ministerio de Agricultura* (Agricultural Development Institute)
INE	*Instituto Nacional de Estadisticas de Chile* (National Statistics Institute); www.ine.cl
IMF	International Monetary Fund; www.imf.org
IPCC	Intergovernmental Panel on Climate Change; www.ipcc.org
IRENA	International Renewable Energy Agency; www.irena.org
MIDEPLAN	*Ministerio de Planificación* (Ministry of Planning); www.mideplan.cl
MINSEGEP	*Ministerio Secretaría General de la Presidencia de la República* (Ministry of the Presidency)
MINVU	*Ministerio de Vivienda y Urbanismo* (Ministry of Housing and Urban Development)

MOP	*Ministerio de Obras Públicas* (Ministry of Public Works)
MTT	*Ministerio de Transportes y Telecomunicaciones* (Ministry of Transport and Telecommunications)
OECD	Organisation for Economic Co-operation and Development; www.oecd.org
OFGEM	Office of Gas and Electricity Markets in the United Kingdom
OLADE	*Organización Latinoamericana de Energía* (Latin American Energy Organization); www.olade.org.ec
SEC	*Superintendencia de Electricidad y Combustibles* (Superintendence for Electricity and Fuels)
SECTRA	*Comisión de Planificación de Inversiones en Infraestructura de Transporte* (Inter-Ministerial Secretariat for Transport Planning)
SEREMI	*Secretaría Regional Ministerial* (Regional Ministerial Secretariats)
SERNAC	*Servicio Nacional del Consumidor* (National Consumers' Association)
SERPLAC	*Secretaría Regional de Planificación y Cooperación* (Regional Planning and Co-ordination Secretariat)
SII	*Servicio de Impuestos Internos* (Chilean Tax Administration)
SIC	*Sistema Interconectado Central* (Central Interconnected Electricity System)
SING	*Sistema Interconectado del Norte Grande* (Northern Chile Interconnected Electricity System)
SUBDERE	*Subsecretaría de Desarrollo Regional y Administrativo* (Sub-secretariat of Regional and Administrative Development)
TDLC	*Tribunal de Defensa de la Libre Competencia* (Competition Tribunal)
UNASUR	*Unión de Naciones Suramericanas* (Union of South American Nations)
UNDP	United Nations Development Programme; www.undp.org
UNFCCC	United Nations Framework Convention on Climate Change; www.unfccc.int
WB	World Bank; www.worldbank.org
WHO	World Health Organization; www.who.org

Abbreviations

3CV	Vehicle certification plant
AAGR	Average annual growth rate
BRICS	Brazil, Russia, India, China and South Africa
CASEN	*Caracterización Socio-Económica Nacional* (National Characterization Socio-economic Survey); www.mideplan.cl/casen
CCGT	Gas-fired combined-cycle gas turbine
CDM	Clean Development Mechanism
CHP	Combined heat and power
CEOP	Exploration and exploitation contracts
CIF	Cost, Insurance and Freight
CLP	Chilean peso
CNG	Compressed natural gas
CSP	Concentrated solar power plant
EIA	Environmental impact assessment
EUR	Euro
FEPP	Oil Price Stabilisation Fund
FEPC	Fuel Price Stabilisation Fund
FOSIS	*Fondo de Solidaridad e Inversión Social* (Solidarity and Social Investment Fund)
GBP	British pound
GDP	Gross domestic product
GEF	Global environmental facility
GHG	Greenhouse gas
GPS	Global positioning system
HHI	Herfindahl-Hirschman Index

LHV	Lower heating value
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MAED	Model for analysis of energy demand
MEPS	Minimum energy performance standards
MESSAGE	Model of Energy Supply Systems and their General Environmental Impacts
MODEM	Mobile source emissions model
NCRE	Non-conventional renewable energy sources
NGO	Non-governmental organisations
PAL	Principal airlines
PANCC	National Action Plan on Climate Change
PDC	*Partido Demócrata Cristiano* (Christian Democrat Party)
PER	*Programa de Electrificación Rural* (Rural Electrification Programme)
PERyS	*Programa de Energización Rural y Social* (Rural and Social Energisation Programme)
PS	*Partido Socialista* (Socialist Party)
PPD	*Partido por la Democracia* (Democratic Party)
PPEE	*Programa País Eficiencia Energética* (National Energy Efficiency Programme)
PPP	Purchasing power parity
PRSD	*Partido Radical Social Demócrata* (Radical Social Democrat Party)
PV	Solar photovoltaics
R&D	Research and development
RESCO	Rural Energy Service Companies
RM	*Región Metropolitana* (Metropolitan region)
SEIA	*Sistema de Evaluación de Impacto Ambiental* (Environmental Impact Assessment System)
SNCL	National Firewood Certification System

TFC	Total final consumption
TPES	Total primary energy supply
TSP	Total suspended particles
UF	*Unidad de Fomento* (Unit of account)
UK	United Kingdom
US	United States
USD	United States dollars
UTM	*Unidad Tributaria Mensual* (Monthly tax unit)
VAD	*Valor Agregado de Distribución* (Distribution margin)
VAT	Value-added tax
VOC	Volatile organic compounds

Units

This book uses the following codes for complex unit signs:

k	kilo or 10^3
M	mega or 10^6
G	giga or 10^9
T	tera or 10^{12}
P	peta or 10^{15}

µg	microgramme
b	barrel; equivalent to 159 litres (l)
bcm	billion cubic metres
b/d	barrel per day
cal	calorie, equivalent to 4.1868 joules (J)
cm	cubic metre
Gcal	gigacalorie
Gg	gigagramme (= 1 000 tonnes)

GW	gigawatt
GWh	gigawatt-hour
ha	hectare
J	joule; equivalent to 0.2388 calories (cal)
km_2	square kilometres
kV	kilovolt
kWh	kilowatt-hour
l	litre
m^3	cubic metres
Mb	million barrels
Mb/d	million barrels per day
Mcm	million cubic metres
MPa	megapascal
Mt	million tonnes
Mtoe	million tonnes of oil equivalent; equivalent to 1.4285 million of tonnes of coal equivalent (Mtce);
MW	megawatt
MWh	megawatt-hour
Pa	pascal
p.a.	per annum
t	tonne
Tcal	teracalorie
tCO_2	tonne of carbon dioxide
TJ	terajoule
toe	tonne of oil equivalent
TW	terawatt
TWh	terawatt-hour

V	volt
W	watt
WTI	West Texas Intermediate

ANNEX IV

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