ENERGY POLICIES BEYOND IEA COUNTRIES

Chile

2018

International Energy Agency
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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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Foreword

The International Energy Agency (IEA) has been conducting in-depth country reviews since 1976. It is a core activity and the process of review by peers not only supports member countries' energy policy development and mutual learning, but it also encourages the exchange of international best practice and experience. In short, by seeing what has worked – or not – in the "real world," these reviews help to identify policies that achieve objectives and bring results.

In 2016, the IEA decided to modernise the reviews by shifting their focus to key energy security challenges in fast-changing global energy markets, and to the transition to a clean energy system.

Occasionally, and upon request, the IEA also conducts these peer reviews for Partner countries. This second in-depth review of Chile's energy policies takes stock of the progress in Chile's energy policy since the 2009 IEA review. Chile's energy policy has evolved dynamically in recent years. In response to changes in the domestic and international environment, significant institutional and policy reforms as well as major infrastructure projects have been carried out. The National Energy Policy 2050 was adopted in 2015, and the electricity sector, in particular, has developed quickly. Chile has also emerged as a world-class destination for investment in solar and wind energy.

As the new administration prepares to take over the helm of energy policy in March 2018, it is my hope that this review and its policy recommendations will prove useful as a reference point for policymakers and stakeholders alike. The IEA will be delighted to continue this policy dialogue which started with the first in-depth review in 2009 and to continue supporting Chile in its quest for a secure, affordable and environmentally sustainable transformation of its energy sector and economy.

Dr. Fatih Birol

Executive Director

International Energy Agency

ENERGY INSIGHTS

ENERGY SECURITY

ENERGY SYSTEM TRANSFORMATION

ANNEXES

LIST OF FIGURES, TABLES AND BOXES

Figures

Tables

Boxes

Executive summary

This second in-depth review of Chile's energy policies by the International Energy Agency (IEA) takes stock of the progress in Chile's energy policy since the 2009 IEA review. Chile's energy policy has evolved dynamically over the past decade. In response to changes in the domestic and international environment, significant institutional and policy reforms as well as major infrastructure projects have been carried out. The reforms were implemented in the aftermath of the protracted reduction of the gas supply from Argentina (from 2004) and the 2010 earthquake, which disrupted energy supplies and electricity transmission.

Chile's energy challenges and opportunities are shaped by the country's extraordinary geography and resource endowment. Continental Chile is 4 300 km long and only 177 km wide on average, which entails unique challenges for the energy infrastructure. However, the Atacama Desert has the world's best solar resources. Chile also has the world's longest national mountain ridge and shoreline, running in parallel, which provides a high potential for wind and hydropower, as well as geothermal and, in the future, ocean energy.

Chile has emerged as a world-class destination for investment in variable renewable energy (VRE) – solar and wind power. This has been led by considerable declines in technology costs, but also by enabling policies, such as technology-neutral tenders for electricity supply. Chile's prospects for exploiting its vast potential for solar and wind energy are bright, but to better integrate these variable energy sources successfully will require investments in grids, storage and flexible capacity, as well as a smart-system design.

Launching new institutions and a new long-term energy policy

A major development in the institutional set-up of the Chilean energy sector is the creation of the Ministry of Energy (2010). Other new entities created recently include the Chilean Energy Efficiency Agency and the single National Electricity Co-ordinator (ISO).

A major achievement of the government has been to develop a long-term energy policy to 2050. The Ministry of Energy was put in charge of the planning process. The process involved a nationwide public consultation and culminated with the adoption of the National Energy Policy 2050. The Chilean public was consulted on a broad basis for the first time and the exercise has become an internationally outstanding example for public consultations on energy policy.

The resulting strategy document, which was launched by President Bachelet in December 2015, defines four key pillars of energy policy: 1) the quality and security of supply, 2) energy as a driving force for development, 3) environmentally-friendly energy, and 4) energy efficiency and energy education. It sets targets for both 2035 and 2050.

To support implementing the 2050 energy policy, the IEA encourages the government to continue to spell out concrete and immediate actions and to consider expanding its ambition on sustainability and energy security. For this purpose, the government is also encouraged to enhance interministerial co-ordination across the sectors of environment, transport, housing and buildings, spatial planning, hydropower and irrigation, agriculture and forestry, and finance and taxation.

High quality energy data should be pursued to support policy making, monitoring of achievements and market transparency. Therefore, the government should define the legal and regulatory basis for energy data collection.

In recent years, the Chilean state has assumed a stronger role in energy policy, which has helped to inject a new dynamism in the development of energy projects, in particular for power generation. The efforts to allay nimbyism ("not in my back yard") and reduce the number of projects blocked in the courts are commendable. Further action is suggested for transposing voluntary permitting guidelines into legislation.

Building a low-carbon national electricity system

Electricity demand is set to continue to grow fast. Generation capacity has already more than tripled over the past 20 years (from around 6 500 megawatts [MW] in 1997 to around 23 000 MW by the end of 2017), and the government's business-as-usual (BAU) scenario sees electricity demand more than double by 2050. Therefore, significant investment in grids and generating capacity are needed.

Chile has a vast untapped potential for renewable electricity, which can help limit carbon dioxide (CO_2) emissions and air pollution, and reduce import dependency. The government has set a target for a 60% share of renewable power by 2035 and 70% by 2050. The share is currently around 40%.

To attain a 60% share of renewable power by 2035 at the least cost, the share of solar photovoltaics (PV) and wind power must increase considerably. This is possible, because the costs of these technologies have decreased substantially and will decline further, while the potential is very high for solar and high for wind power. However, to integrate a large share of variable renewable energy (VRE), the flexibility of the power sector must be increased. More transmission infrastructure, storage and demand-side response needs to be developed. Natural gas could be used more as a backup fuel for solar and wind power and for that purpose, a liquid wholesale market for gas would be beneficial.

New legislation has been adopted to encourage investment in new capacity across the electricity sector. In particular, the 2016 Transmission Law not only created a single ISO, but also enhanced the role of the state in energy planning and expansion of the transmission system. A major achievement is the interconnection, in November 2017, of the two main electricity systems – the Central Interconnected System (SIC) and the Greater Northern Interconnected System (SING). As a result, the National Electricity System was created.

Electricity supply has traditionally been dominated by three or four large generators and the prices spiked following Argentina's decision in the previous decade to restrict its natural gas supply. The government therefore took measures to increase the competition in electricity generation to reduce the generating costs and, eventually, end-user prices.

Wholesale competition in Chile occurs in the 'contract market', in which generators sell electricity freely to large (non-regulated) customers, and through tenders to distributors that supply small (regulated) customers. Around half of the electricity demand in Chile is supplied under these tenders.

Encouragingly, the distribution tenders are both driving investment in green, affordable electricity and increasing competition, as many new companies have won contracts. The most recent tenders in 2016 and 2017 were clear successes. Both the record-low prices and the increasing share of renewable energy sources are very good news. As a result, renewable electricity capacity will be built without subsidies, which is highly positive and can set an example to many other countries that still subsidise renewable energy.

At the same time, however, the tenders lock distribution companies into long-term contracts. This can be justified from the security of supply perspective, but it deters competition for a long period, excludes consumer choice and hinders the competition for additional services by retailers. A more general challenge with a concession-based monopoly retail sector, such as that in Chile, is that it typically requires regulation to foster innovation in electricity supply and demand response. This is a highly topical issue, as technological change through digitalisation is blurring the distinction between generators and consumers. The government should consider ways to reform the distribution sector and gradually to liberalise retail electricity supply. One way to do this would be to gradually reduce the threshold of regulated customers and to look for mechanisms to deal with demand risk for distributors.

The IEA urges the government to continue and enhance its efforts to strengthen the research, development and innovation (RDI) on renewable energy. The IEA welcomes the Solar Energy Programme 2016-25, which aims to develop an export-oriented national solar-power industry, and encourages the government to increase public funding for energy-related RDI.

Limiting energy-related CO_2 emissions

In many respects, Chilean energy policy has traditionally been characterised by a strong focus on the power sector. Although this is understandable in view of the significant challenges the country has faced, but to ensure a holistic coverage energy policy should focus on the transport and heat sectors as well. This is particularly critical for the mitigation of energy-related CO_2 emissions.

Linked to the fast economic growth and the increase in energy use, greenhouse gas (GHG) emissions have more than doubled since 1990. This trend is obviously unsustainable in the long run, but, fortunately, Chile has significant potential to reduce GHGs in all sectors. As energy-related GHG emissions account for around 77% of the total emissions, the energy sector is key in mitigation efforts, but the potential outside the energy sector should not be neglected either.

Chile ratified the Paris Agreement in January 2017. Its Nationally Determined Contribution (NDC) has two energy-related targets: an unconditional target to reduce the GHG-emissions intensity of the economy by 30% below the 2007 level by 2030, and a conditional target of a 35-45% reduction in GHG emissions intensity subject to international financial support. The Ministry of Energy is developing policies and measures to meet the NDC under the “Mitigation Plan for the Energy Sector”. The plan was adopted in December 2017 and it foresees that the target can be met in a way that will actually save money in the medium and long term, because efficiency measures will limit energy demand, and low-cost renewable electricity will replace imported fuels. Energy efficiency in mining, transport and heavy industry is projected to be particularly profitable.

Power generation is the largest GHG emitter and, so far, the only direct measure used to limit its emissions is a carbon tax. Chile is the first country in South America to introduce carbon taxation, and the IEA applauds this. The carbon tax is applied from 2017 and paid from 2018 onwards, but it is, at least initially, set at a relatively low level of 5 USD (United States dollars) per tonne of CO_2. Modest carbon prices can lead to some fuel switching, make near-to-market low-carbon technologies cost-effective and promote other low-carbon support policies. However, they cannot drive all the necessary low-carbon investments, force the early retirement of high-carbon assets or give strong signals for the electrification of heat and transport. It is critical to monitor the functioning of the carbon tax and adjust the tax level, if needed. For power generation, the government should consider introducing higher CO_2 taxes or CO_2-intensity limits or more cost-effective carbon-pricing instruments. The scope of the carbon tax could also be broadened to sectors beyond power generation.

Transport is the second-largest emitting sector, after power generation. As the economy continues to grow and Chileans become wealthier, the number of cars may also increase significantly. For example, if private car ownership in Chile increased to today’s average European Union level, the country’s car fleet would double to nine million. To avoid a lock-in to inefficient and energy-intensive urban structures dominated by private cars, energy and climate aspects should be an integral part of the long-term policies for transport and urban development.

More immediately, the government should consider further measures to limit the growing CO_2 emissions from transport. The IEA encourages the government to introduce mandatory emission standards for vehicles, a standard measure in many countries. To facilitate a modal shift will address these issues, and to promote electric mobility is also worth considering. In this context, the IEA welcomes Chile’s recent electric mobility strategy.

Realising the energy efficiency potential

Energy efficiency is yet to be seen as a credible resource (on par with renewable energy) that can help meet national energy and climate change goals as well as contribute to social and economic development. Chile has an Energy Efficiency Roadmap that aims to reduce its final energy demand by 20% below BAU by 2025, but arguably more could be achieved by adopting a suitable legal framework to realise Chile's energy efficiency potential.

Chile is a global leader on energy efficiency labelling for appliances, with mandatory labelling for close to 30 products, and this policy has helped move the market to appliances of higher efficiency. In addition to labelling, Chile should make more use of mandatory minimum energy performance standards (MEPS) for products and equipment. Research shows that MEPS are by far the most cost-effective energy efficiency policy worldwide.

Energy codes and standards for buildings in Chile are essential to improve their energy performance and comfort. Energy efficiency standards exist for social housing (around 80% of the residential new build today) and private residential buildings (about 20% of the new build today). The challenge is that the Ministry of Housing cannot afford social housing of higher efficiency without reducing the number of houses being built per year. The long-term benefits for consumers in energy-cost savings and health benefits are clear, and, therefore, the government should identify financing mechanisms for efficient social housing. The government also needs to introduce energy efficiency standards for non-residential buildings or dedicated energy efficiency programmes for commercial buildings.

Also, the government should ensure that private residential buildings comply with the efficiency regulations. Presently, these buildings are required to be in compliance only at the design phase, but there is no verification during and after construction. In many IEA countries, compliance is verified by public sector building inspectors, and the government should consider this approach.

In industry, all the existing energy efficiency measures are voluntary. Related to this, the industrial energy intensity has remained relatively unchanged since 2005. An independent study should be carried out to determine and validate the potential energy savings in industry and assess the costs and benefits of energy efficiency measures to realise that potential.

Ensuring efficient and clean use of firewood

Firewood is an important energy source in Chile, especially in the south, where nearly 80% of households use it to heat and/or cook. The inefficient burning of moist low-quality firewood is the largest cause of air pollution in the country. The external costs of burning low-quality firewood are extremely high, but can be avoided. The government has developed several approaches to reduce the negative impacts of firewood use. In this context, the IEA welcomes the 2015 Policy for Use of Wood and Its Derivatives for Heating. Although the IEA recognises that it is not easy to find policies to tackle the informal firewood market, it strongly urges the government to adopt more ambitious policies and measures to stimulate the efficient and clean use of firewood. The use of sustainable dry wood and alternative heating technologies can be supported through policies, regulation and financial incentives.

Improving oil security

Oil remains the largest primary energy source in Chile, and almost all oil is imported. Oil-importing companies have a stockholding obligation equivalent to 25 days of their domestic average sales in the previous six months. In practice, some companies do not know if this obligation applies to them or not, and the government institutions seem to lack the legal powers to control or enforce this obligation. The government should closely work with the National Petroleum Company (ENAP) and other stakeholders to complete the establishment of a comprehensive set of security measures and capacity to identify and respond to critical risks in crude-oil and oil-product supply. It should also clarify the oil-stockholding obligation for all oil companies, and enforce this obligation where necessary.

Key recommendations

The government of Chile should:

- ☐ Ensure progress towards the medium-term goals of the National Energy Policy 2050 by spelling out concrete and immediate actions; consider increasing the strategy's ambition on sustainability and energy security.
- ☐ Strengthen the proactive role of the government, including enhanced planning and consultation faculties for energy policy and energy investments, and broadening the sectoral coverage and interministerial co-ordination.
- ☐ Ensure the electricity market design and infrastructure is developed to facilitate the value-maximising integration of VRE into the electricity system.
- ☐ Work ambitiously to limit energy-related GHG emissions and use its significant potential for energy efficiency and renewable energy to this end.

1. General energy policy

Key data

(2016 provisional)

TPES: 37.5 Mtoe (oil 41.1%, biofuel and waste 21.2%, coal 20.3%, natural gas 11.7%, hydro 4.5%, wind 0.5%, solar 0.7%) +27% since 2006

TPES per capita: 2.1 toe (IEA average, 4.4 toe)

TPES per unit of GDP: 98 toe/USD million PPP (IEA average, 109 toe/USD million PPP)

Energy production: 13.0 Mtoe (biofuels and waste 60.9%, coal 12.9%, hydro 12.9%, natural gas 7.9%, oil 2.0%, wind 1.5%, solar 1.9%) +35% since 2006

Country overview

Chile is a country in South America that occupies a long and narrow coastal strip tucked between the Andean Mountains on the east and the Pacific Ocean on the west (Figure 1.1). It borders 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). Chile also has several overseas territories, which include Easter Island in Polynesia. Chile's population in 2016 is estimated at 18 million. The country's gross domestic product (GDP) in 2016 was USD 247 billion (United States dollars, USD 429 billion using purchasing power parities [PPPs]), which ranks Chile the forty-second-richest country globally. Chile's GDP (PPP) per capita, at USD 23 478, is the highest in South America, ahead of Uruguay, Argentina and Brazil.

Chile is 4 300 km long and, on average, 175 km wide, and has a total surface area of 757 000 square kilometres (km^2), Its length and diverse topography provide for a varied climate, which ranges from the world's driest desert – the Atacama Desert – in the north, to 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, in which the capital, Santiago, is located, dominates the country in terms of population and agricultural resources.

Chile is divided into 16 administrative regions, each of which is headed by an administrator (*intendente*) appointed by the president of Chile. Each region is further divided into provinces, with provincial adminstrators also appointed by the president. Around 87% of the country's population live in urban areas, with 40% in the Santiago Metropolitan Region. Two-fifths of the population, or around 7 million, live in the Santiago Metropolitan Region. Other populous regions are Biobio (around 2 million) and Valparaíso (1.8 million). Chile's official language is Spanish, but around 5% of the population also speak native indigenous languages, such as Mapudungun, Quechua and Rapa Nui.

Figure 1.1 Map of Chile

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Chile has a four-year presidential term, with presidential and congressional elections that coincide. Consecutive presidential terms are barred under the Constitution. In 2015, Chile completed a landmark electoral reform in which it moved away from the previous binomial system to a proportional representation system. With the parliamentary elections in 2017, the Chamber of Deputies (lower house) increased its size from 120 to 155 deputies, and the Senate is now composed of 50 members instead of 38. This reform gives more representation to large and population-dense districts, as well as sets a quota that limits the gender disparity in candidates for Congress to a ratio of 60% to 40%.

Economic overview

Chile's economy has grown impressively in the past two decades. From 2003 to 2013, real growth averaged 4.65% per year, despite a 1.7% fall during the 2009 global financial crisis. Its real GDP (USD 2010) per capita in 2016 was 115% higher than that in 1996. Nonetheless, Chile's average growth rate has been below 2% for the past three years and the OECD expects it to strengthen gradually to 2.9% and the unemployment rate to stabilise at 6.5%. The impressive performance of the economy owes much to a sound institutional framework, countercyclical fiscal policy, tight monetary policy and integration into the global economy (OECD, 2017).[1]

In 2016, services accounted for 63.6% of GDP, industry for 32.5% and agriculture, forestry and fishery for 3.9%, according to Chile's Central Bank. Chile's economy is export driven and its main export goods are commodities. In particular, the country is the largest copper exporter in the world and changes in global copper prices have a strong impact on the national economy. Copper prices slumped from 2012 to 2016, falling 40% from 2011, and the contribution of copper mining declined from 14.7% of GDP in 2010 to a still high 7.3% of GDP in 2016. Services have driven Chile's economic growth in recent years (Banco Central de Chile, 2017).

Energy supply and demand

Chile largely depends on imports for domestic energy supply as its domestic energy production is only about one-third (34.7% in 2016) of its total primary energy supply (TPES)[2] of 37.5 million tonnes of oil equivalent (Mtoe) in 2016.[3] Given the small domestic production of fossil fuels, the majority is imported. Oil is the largest primary energy source, followed by biofuels (mainly firewood) and coal.

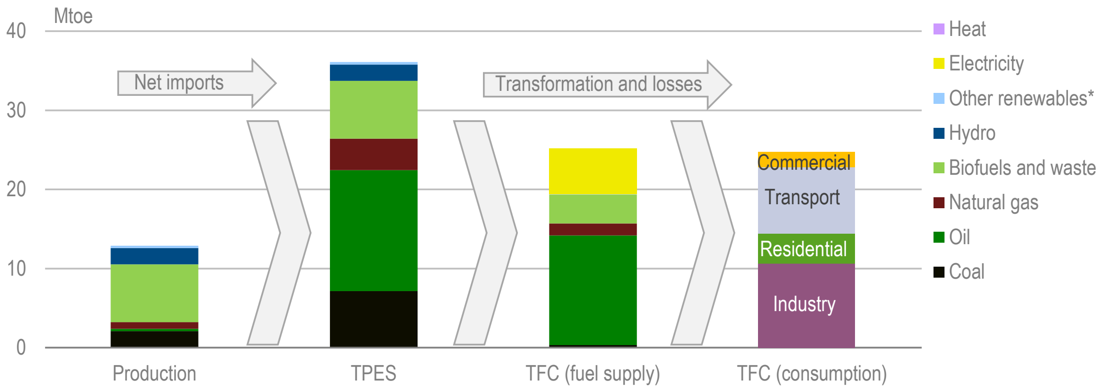
[1] Chile has the strongest sovereign bond rating in Latin America, with a yield of 2.68% for the one-year bond (compared with Mexico's 6.94%, and Brazil's 8.70%). In 2016, exports accounted for 28.5% of GDP and imports for 27.6%. Since 2007, the government has accumulated revenue surpluses in a sovereign wealth fund which allows it to maintain expenditure levels stable during periods of low copper prices and growth. The market value of the Economic and Social Stabilization Fund was USD 14.4 billion at the end of May 2017.

[2] TPES is made up of production + imports – exports – international marine and aviation bunkers ± stock changes. This equals the total supply of energy that is consumed domestically, either in transformation (e.g. power generation and refining) or in final use.

[3] The average TPES in 2015 for the IEA member countries was 168.46 Mtoe. The median was 45.45 Mtoe.

Industry and transport account for more than three-quarters of TFC (Figure 1.2 and Figure 1.7). Oil is the most-important energy source for both sectors, although the dominance of oil in the industry sector is not as prominent as it is in the transport sector (Figure 1.8).

Figure 1.2 Overview of energy production, TPES and TFC, 2015



**Other renewables* includes solar and wind.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Supply

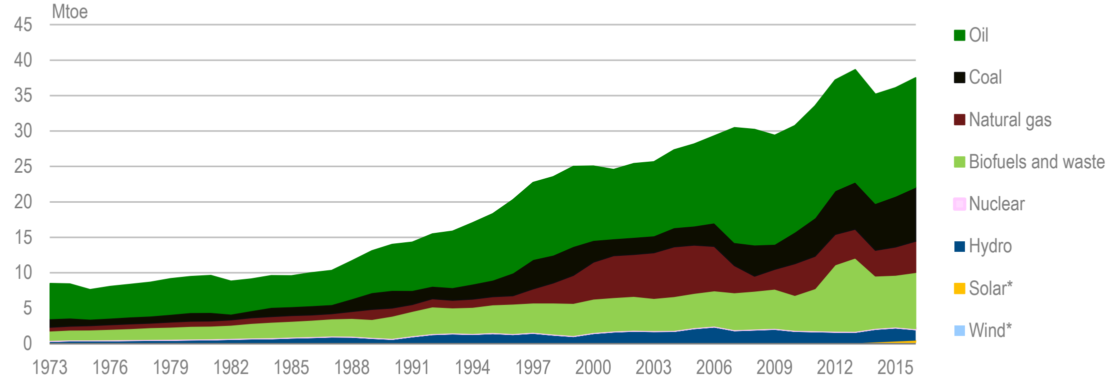
Fossil fuels accounted for 73.2% of the TPES in 2016 (Figure 1.3), and consisted of oil (41.1%), coal (20.3%) and natural gas (11.7%). For the period 2006-16, the share of fossil fuels in total supply practically remained unchanged (74.0% in 2006), although coal overtook natural gas as the second-most-important fossil fuel. During this period, coal use grew 130%, which offset the decline in natural gas production and imports (supply fell 30%).

Renewable energy has been an important energy source for many decades, at 25-30% of the TPES. In 2016, it accounted for 26.8% of the TPES. This category comprises biofuels and waste (21.2%), hydropower (4.5%), wind (0.5%) and solar energy (0.7%). Traditional use of firewood for heating and cooking in the residential sector represents the main share of biofuels and waste consumption (see the note for Figure 1.4).

From 2006 to 2016, the renewable energy supply in the TPES grew by 35%, or 2.6 Mtoe. This growth mainly resulted from a nearly 50% increase in biofuels supply. Wind and solar energy have begun to increase in recent years, but from a very low level. Hydropower supply varies significantly year-on-year, depending on the hydrological conditions.

Chile's TPES was the 18th highest compared to the 29 International Energy Agency (IEA) member countries. The share of fossil fuels in the TPES in 2016 was just below average in this comparison (Figure 1.4), whereas the share of biofuels and waste was the fourth highest after Finland, Denmark and Sweden.

Figure 1.3 TPES by source, 1973-2016

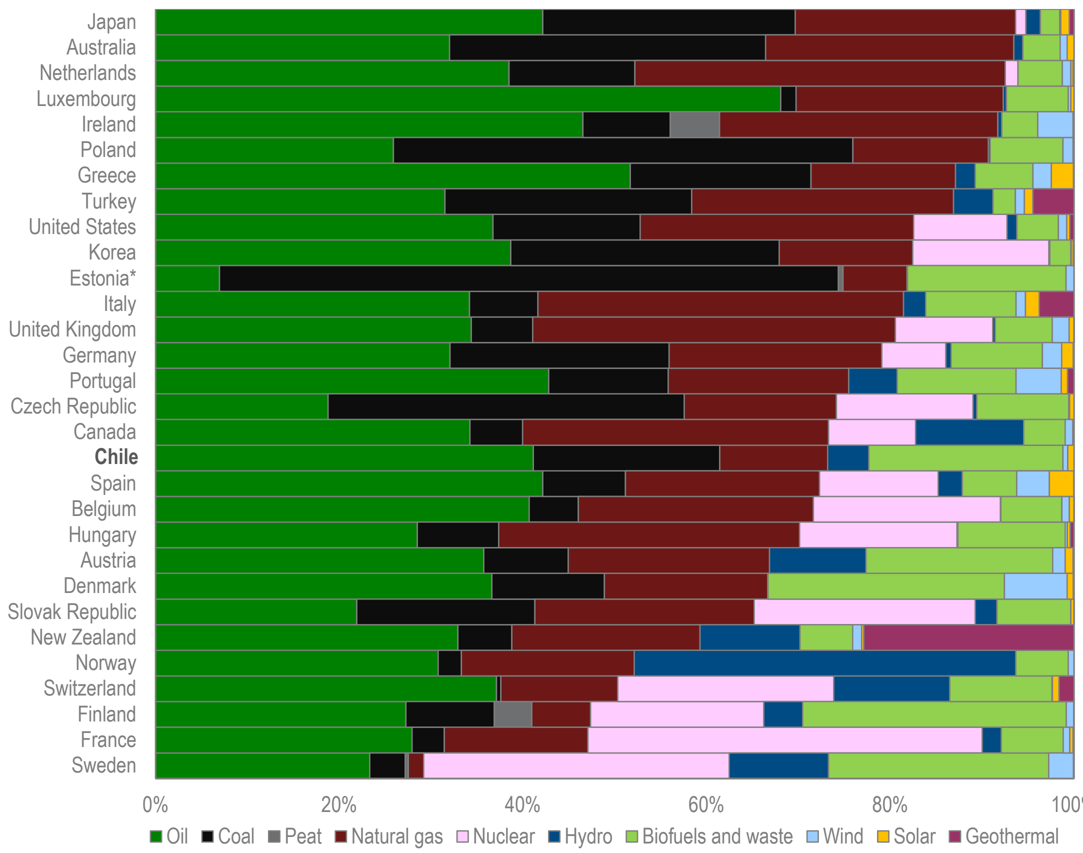


*Negligible.

Notes: Biofuels and waste increased rapidly in 2012 and dropped again in 2014 as a result of strongly fluctuating numbers in the statistics of firewood consumed in the residential sector. Data are estimated for 2016.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Figure 1.4 Breakdown of TPES in Chile and IEA member countries, 2016



*Estonia's coal is oil shale.

Note: Data are provisional.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Production and imports

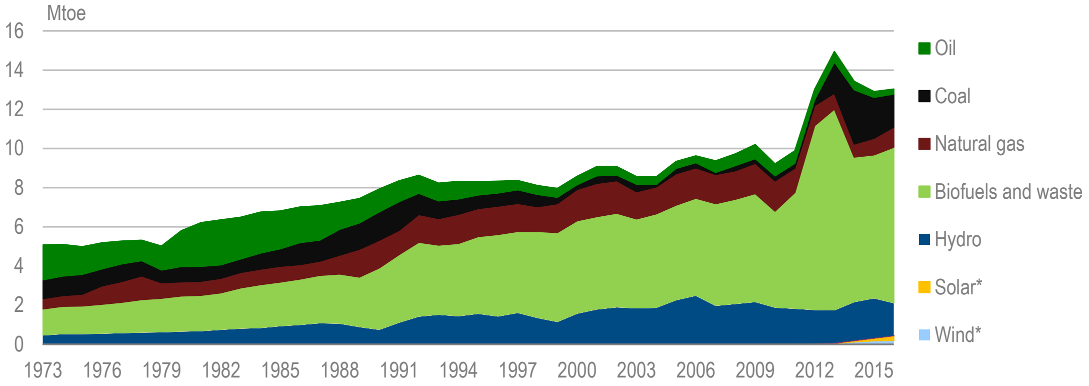
Chile's energy production increased steadily in the decade to 2016, when it totalled 13.0 Mtoe (Figure 1.5). Self-sufficiency[4] increased to 34.7% from 32.6% in 2006, but was below the peak of 38.7% in 2013. Biofuels and waste is the main locally produced energy source, at 60.9% of total production in 2016, with a 60% growth in volume from 2006.

Coal represented 12.9% of total production in 2016, up from 2.3% only four years earlier in 2012. Coal production increased significantly in 2013-14 thanks to the opening of the large Mina Invierno mine in Magallanes. Since the peak at 2.8 Mtoe in 2014, however, production has declined by 39% to 1.7 Mtoe in 2016.

Solar and wind power production have grown from insignificant levels in 2006. In 2016, solar power production was 0.25 Mtoe (1.9% of the total) and wind power was 0.19 Mtoe (1.5%).[5]

In contrast, natural gas production declined by 33% to 1.0 Mtoe between 2006 and 2016, and oil production declined by 25% to 0.3 Mtoe over the same period. Hydropower generation varies significantly year-on-year, according to the hydrological conditions.

Figure 1.5 Energy production by source, 1973-2016



*Negligible.

Notes: Biofuels and waste increased rapidly in 2012 and dropped again in 2014 as a result of strongly fluctuating numbers in the statistics of solid biofuel consumed in the residential sector. Data are provisional for 2016.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Chile largely depends on imports for domestic energy supply, with net imports accounting for roughly two-thirds of the TPES in 2016 (Figure 1.6). Imports accounted for all oil and 77% of natural gas supply in the TPES.

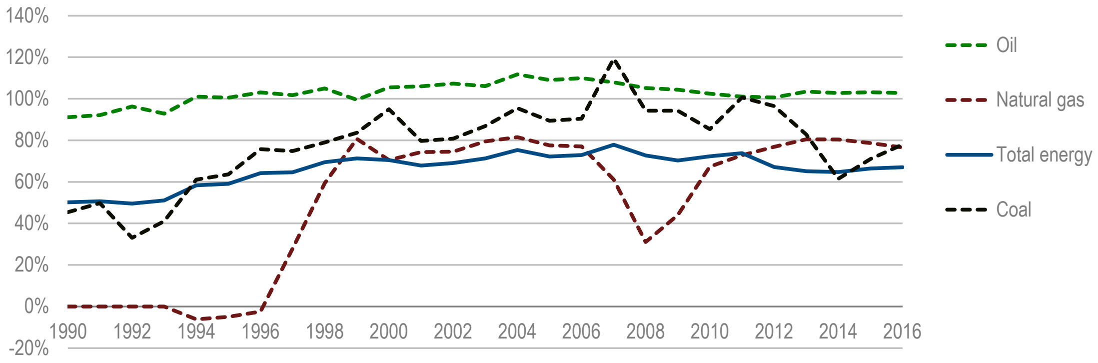
Although the share of imported oil in total oil supply has remained at a similar level over the past decades, natural gas has experienced large fluctuations. Between 2006 and 2008, gas imports fell by 88% as a result of a curtailment of gas supply from Argentina. This made domestic production cover a larger share of total supply, and

[4] Self-sufficiency is defined as production as a share of total primary energy supply.

[5] Solar PV and wind production have continued to grow at a high pace; output in May 2017 was 214 gigawatt hours (GWh) and 279 GWh, respectively, 111% and 58% higher than the 2015 monthly average (101 GWh for solar and 176 GWh for wind).

import-dependency numbers dropped. For coal, the import dependency has fluctuated, but overall it decreased from 90% in 2006 to 78% in 2016 as domestic coal production increased.

Figure 1.6 Import dependency by fuel, 1990-2016



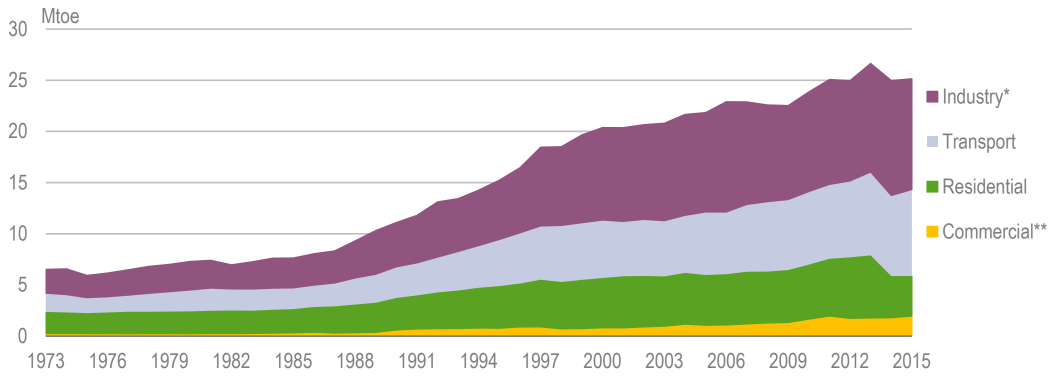
Notes: Net import as share of the TPES. Data are estimated for 2016.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Demand

In 2015, Chile's total final consumption (TFC) was 25.1 Mtoe, an increase by 15% from 2005. The growth in TFC was mainly a result of significant growth in oil consumption, from 9.6 Mtoe in 2005 to 13.9 Mtoe in 2015, because of increased oil demand in transport and industry. The industry sector used oil to cover for the drop in natural gas supply after 2006, which led to a decline of natural gas in the TFC by 57% from 2005 to 2015. Coal consumption also declined by 46% over the same period.

Figure 1.7 TFC by sector, 1973-2015



**Industry* includes non-energy use.

***Commercial* includes commercial and public services, agriculture, fishing and forestry.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Industry, which is the largest sector, accounted for 43.0% of TFC in 2015 (10.8 Mtoe). Industry demand increased by 11% from 2005 to 2015, slower than the overall TFC, and its share in TFC declined slightly from 44.5% to 43.0%.

Transport is the second-largest consuming sector and accounted for 33.6% of TFC (8.4 Mtoe) in 2015, up from 28.2% in 2005. It is the fastest growing sector in Chile in absolute terms, with a 37% increase in TFC between 2005 and 2015. Oil products account for 98.7% of total transport energy consumption, although the demand for electricity has grown at an average rate of 14% per year in the past decade.

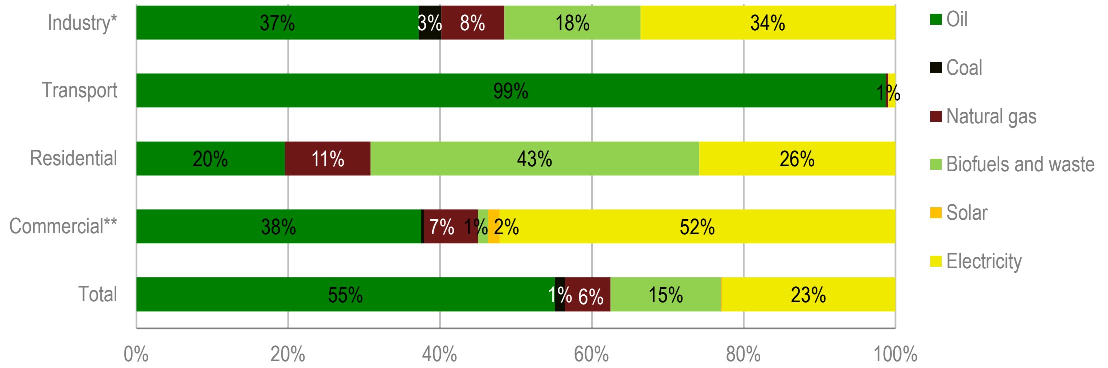
The residential and commercial sectors account for the remaining share of TFC. Solid biomass is the most-consumed energy sources in the residential sector, whereas electricity covers over half of TFC in the commercial sector (Figure 1.8).

The residential sector accounts for 15.6% of energy demand (3.9 Mtoe). Its TFC fell by 20% from 2005, and its share in TFC from 22.5% in 2005 to 15.6% in 2015. In particular, firewood consumption declined by half from 2005. This decline, however, is mainly statistical, because in 2014 the Chilean Administration introduced a change in the methodology used to collect data on primary solid biofuels (see Chapters 7 and 8) (CNE, 2016).[6]

Although the commercial-sector demand is the smallest in Chile, it has also been the one with the highest growth rate. It accounts for 7.8% (2 Mtoe) of TFC, up from 4.9% in 2005 (1.1 Mtoe).

Historically, oil is the largest energy source in TFC, and its share in TFC increased from 44% in 2005 to 55% in 2015. The transport sector accounted for 60% of oil consumption in TFC. Electricity is the second-largest source and accounted for 23% of TFC in 2015. The share of biofuel and waste in Chile's TFC is the fourth-highest compared with IEA countries, mainly because firewood is a dominant heat source in southern Chile.

Figure 1.8 Fuel share of TFC by sector, 2015



**Industry* includes non-energy use.

***Commercial* includes commercial and public services, agriculture, fishing and forestry.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Institutions

Energy policy institutions

The Ministry of Energy has the responsibility to elaborate, co-ordinate and implement national energy policy. The Ministry was established in 2010 and has led the work to enhance the legal framework, strategies and action plans to structure Chile's energy

[6] Information on the consumption of biomass in the residential sector is difficult to obtain; a change in the methodology to improve the data resulted in the decrease in biomass in the past two years.

sector. Until 2010, the responsibility to formulate and implement energy policy had been fragmented across several ministries and entities, which included the Ministry of Mining and the Ministry of Economy.

In 2014, the Division of Participation and Social Dialogue was created. Its objective is to promote inclusive, timely and transparent participation in the development of energy policies, plans, programmes and projects, and also incorporate the indigenous relevance into these developments.

The Ministry's Energy Infrastructure Division oversees the development of the energy infrastructure, including power generation projects, transmission lines and gas infrastructure. The division has two operating units: The Project Management Unit and the Transmission Siting Unit.

The Ministry of Energy oversees and co-ordinates the work of several other organisations in the energy sector. They are described below and in Figure 1.9. The Ministry also sets the tariffs for regulated clients and grants electricity concessions.

The National Energy Commission (CNE – *Comisión Nacional de Energía*) is a technical organisation with the responsibity to analyse prices, tariffs and technical norms with which energy production, generation, transport and distribution companies must comply. The main objective of the CNE is to ensure that energy supply is sufficient, safe and compatible with the most-economic operation. Some of its principal responsibilities are to:

- Provide a technical analysis of the structure and level of the prices and tariffs of energy goods and services.
- Establish technical and quality norms for the functioning and operation of energy installations.
- Monitor and model the current and anticipated functioning of the energy sector and advisory to the Ministry of Energy on legal and regulatory norms.

In addition, an independent co-ordinating entity, the National Electricity Co-ordinator, replaces the economic load dispatch centres (CDEC – *Centro de Despacho Económico de Carga*). This "co-ordinator" is in direct contrast to the CDEC, which was composed of members who were chosen by key players in the electrical system. It is responsible for the co-ordination of the short-term operation of the National Power System,[7] with all the owners of interconnected facilities subject to its instructions. Some of its principal functions are to:

- Ensure the safety of the service provided by the electrical system, co-ordinate and guarantee the most cost-effective operation and open access to every transmission system.

[7] The National Power System will connect Chile's grid along its territory. It will be composed by all the interconnected power generators, transmission lines, substations and distribution lines with an installed capacity of at least 200 of power. It will cover a distance of 3 100 km with an installed capacity of 24 000 MW. It is expected to start functioning in 2018.

- Track and monitor competition, payment chain and economic competition conditions of the energy market.[8]

- Establish the data-submission requirements for the operating companies, and ensure information transparency regarding the technical and economic situation of the operating companies.

- Ensure the compliance with norms and standards by the operating companies, which include operating and maintenance procedures.

- Research, develop and innovate energy related matters to improve the operation and co-ordination of the electrical system.

- Set the rules and manage tenders of new transmission contracts.

The Superintendent of Electricity and Fuels (SEC) monitors energy markets to verify the quality of the services provided to users. Its main tasks are to supervise compliance with the laws, rules and technical norms of the generation, production, storage, transport and distribution of fuels, gas and electricity. SEC also provides temporal concessions and informs the Ministry about the definitive concessions in electricity distribution and transmission. Previously, SEC was overseen by the Ministry of Economics.

The National Petroleum Company (ENAP – *Empresa Nacional del Petróleo*) is the state-owned oil company in charge of operations in the exploration, production, refining and retail sales of hydrocarbons and derivatives. A recent law change also authorised ENAP to enter the electricity market. ENAP has two subsidiaries: ENAP Sipetrol, for the exploration and production of hydrocarbons, and ENAP Refinery, for the refining, transportation, storage and commercialisation of hydrocarbons.

The National Commission of Nuclear Energy (CCHEN – *Comisión Chilena de Energía Nuclear*) is the organisation that advises on the research, development and usage of nuclear energy in all its aspects. It promotes, realises or investigates the exploration, exploitation and benefit of atomic materials. The CCHEN also collaborates with the Ministry of Health to control the production, acquisition, transport, imports and exports, use and handling of radioactive materials.

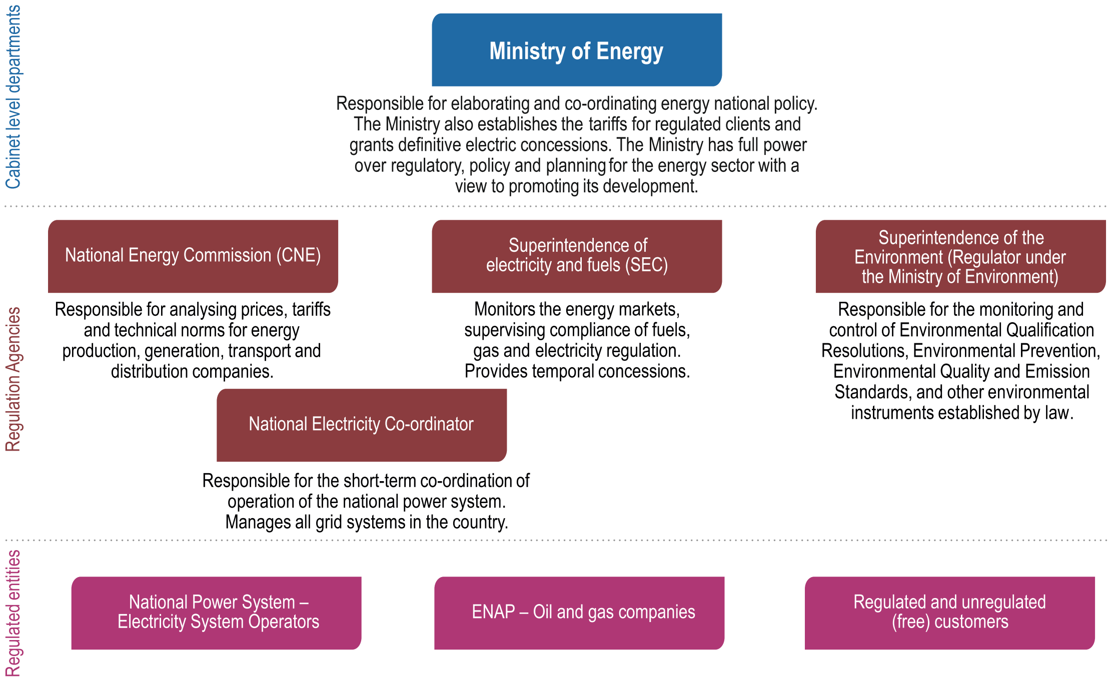
The Chilean Agency for Energy Efficiency (AChEE – *Agencia Chilena de Eficiencia Energética*) is a non-profit public–private foundation with the mission to promote and strengthen the efficient use of energy through programmes and specific projects in industry and mining, transport, and residential and commercial sectors, as well as in education and dissemination programmes.

The Panel of Experts is an autonomous collegiate body created in 2004 with the function to rule on discrepancies and conflicts with the electricity legislation, specifically, to resolve conflicts between the agents of the sector or between companies and the authorities in

[8] It should also inform anomalies to the National Economic Prosecutor.

cases of tariff discrepancies and in regard to matters specifically delimited in the General Law of Electrical Services. The Panel's decisions are final and cannot be appealed.[9]

Figure 1.9 Structure of energy institutions in Chile



Source: IEA (2017b), *IDR Chile Questionnaire, Overview and Description of Recent Developments in Energy Policy.*

A key feature of the 2010 institutional reform is the direct involvement of the central government (Ministry of Energy and Ministry of Environment) in energy-sector planning and regulation, which is in turn implemented by the CNE. In addition, the creation of an independent system operator (ISO) – the National Electricity Co-ordinator – which replaced the CDEC, increased the impartiality in the decision making and the representation of the interests of all the users.[10]

Other relevant institutions

Several other institutions are closely related to the tasks of the Ministry of Energy, although they do not work directly in energy policy. These institutions were involved in the Energy 2050 process and are still relevant for the implementation of the National Energy Policy 2050.

[9] 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.

[10] Chile has four main separate electricity networks: the Central Interconnected System (SIC – *Sistema Interconectado Central*), which serves the central part of the country; the Greater Northern Interconnected System (SING – *Sistema Interconectado del Norte Grande*), which serves the desert mining regions in the north, and the Aysén and Magallanes systems, which serve small areas of the extreme southern part of the country. The SING covers an area equivalent to 25% of Chile's continental territory, in which about 6% of the population of Chile lives. The SIC coverage reaches about 92% of the population, with more than 70% of the customers under a regulated tariff. Before the creation of the ISO, SIC and the SING had their own CDECs, which were originally controlled by the largest generators and the transmission companies in each system. After 2005, the boards of both system operators were required to include a representative of large industrial companies.

The Ministry of Environment has the responsibility to design and apply policies, programmes and plans in environmental matters, to protect and conserve biological diversity and natural resources, and to promote sustainable development. The Ministry replaced the National Commission of Environment and started operations on October 2010.

The SMA has the responsibility to execute, organize and co-ordinate the monitoring and control of Environmental Qualification Resolutions, the measures contained in Environmental Prevention and/or Decontamination Plans, the content of the Environmental Quality Standards and Emission Standards, and Management Plans, when applicable, and all other environmental instruments established by law.

The Environmental Assessment Service (SEA – *Servicio de Evaluación Ambiental*) is a dependent body of the Ministry of Environment, which manages the Environmental Impact Assessment System (SEIA – *Sistema de Evaluación de Impacto Ambiental*). SEIA is an instrument with the aim to prevent environmental damage in relation to investment projects in the country.[11]

Environmental Courts are special, autonomous and independent jurisdictional bodies whose function is to resolve environmental disputes. There are three environmental courts, one each in the north, centre and south of the country, all created in 2012.

The Ministry of the Presidency 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 government's relations with Congress, the development of the legislative agenda and to keep track of bills and other legislative activity in Congress as they pertain to the government.

The Ministry of Mining is responsible for the development of mining policies with the aim to increase the contribution of mining activity to national development, diversify the activity to take advantage of the resources available in sustainable conditions and to create value for the citizens. The Ministry of Mining works closely together with the Ministry of Energy, especially regarding energy efficiency issues.

The Ministry of Housing and Urban Development (MINVU – *Ministerio de Vivienda y Urbanismo*) has the mission to enable access to quality housing solutions and contribute to the development of equitable, integrated and sustainable neighbourhoods and cities, all under decentralisation, participation and development criteria. MINVU and the Ministry of Energy work closely together in many areas, such as energy efficiency and sustainable construction.

The Ministry of Transport and Telecommunications (MTT) proposes national policies in the field of transport and telecommunications and exercises the direction and control of their implementation; it also supervises the public and private companies that operate the means of transport and communication in the country. The MTT and Ministry of Energy work closely together in energy efficiency issues related to transportation.

[11] SEIA is responsible for environmentally evaluating the projects, and encouraging and facilitating citizen participation in the evaluation of the projects. This service fulfils the function to standardise the criteria, requirements, certificates, formalities, and environmental procedures established by the competent ministries and other agencies of the state through the establishment of guidelines.

The Ministry of National Assets is a strategical partner of the Ministry of Energy, especially with regard to geothermal concessions. Its responsibility is to administer fiscal property, regularise small private real estate and co-ordinate with other entities of the state in territorial matters.

The Tribunal for the Defence of Free Competition is a judicial entity that is also referred to as the Antimonopoly Commission. It monitors the implementation of antimonopoly legislation and limits the concentration of economic power, including in the electricity sector. It has the power to investigate possible cases of collusion or anticompetition practices, it can impose penalties that range from simple fines to the obligation to dissolve a company and it can also prohibit mergers.

The National Economic Prosecutor’s Office is a decentralised public service, a separate legal entity with its own financial resources. Its head is appointed by the president of the republic, but it has statutory independence from any authority. Its mission is to prosecute and investigate anticompetitive conduct, merger policy, abuse of dominance and collusion, and it acts on behalf of the general interest. The Prosecutor’s Office can present cases to the Competition Tribunal.

The National Economic Development Agency (CORFO – *Corporación de Fomento a la Producción*) is an agency of 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 the 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 Committee for the Development of the Solar Energy Industry (Solar Committee) was created by CORFO with the aim to develop the solar industry in Chile. Its main objective is to promote the development of a national solar-energy industry through the design and implementation of projects that increase the competitiveness, productivity, technological capabilities and markets of the companies in the sector.

The National Commission for Scientific and Technological Research aims to promote and strengthen scientific and technological research, and to develop specialised human resources and new areas of knowledge and productive innovation, including those in renewable energy.

The National Forestry Corporation (CONAF – *Corporación Nacional Forestal*) is a private legal entity under the Ministry of Agriculture, whose main task is to manage the forestry policy of Chile and promote the development of the sector. CONAF and the Ministry of Energy work closely together in many areas, such as biomass use and atmospheric decontamination.

The National Service of Mining and Geology (SERNAGEOMIN – *Servicio Nacional de Geología y Minería*) is a public service dependent on the Ministry of Mining, and reports data to the ministry for the products obtained by mine extraction, the annual coal production and its reserves and the consumption of energy by different types of mines.

The National Customs Service records all imports and exports of all types of products, information that is updated monthly. From this service, the Ministry of Energy obtains information about the international trade from different fuels, such as oil, natural gas, coal and their derivatives.

The regional ministerial secretariats (*seremis*) are devolved organisms representing each of the key central ministries at the regional level. Each seremi is controlled by a regional ministerial secretary who, notwithstanding 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.

The Council of Ministers for Sustainability is chaired by the minister of environment and composed of the ministers of agriculture; finance; health; economy, development and reconstruction; energy; public works; housing and urban development; transport and telecommunications; and mining and social development. The Council has the responsibility to provide assistance to the president in the areas of environmental protection; sustainable development and sustainable use and management of natural renewable resources; protection of natural resources, including marine parks and reserves; strategic environmental assessment of sectorial policies; and any bill or administrative act that contains environmental standards.

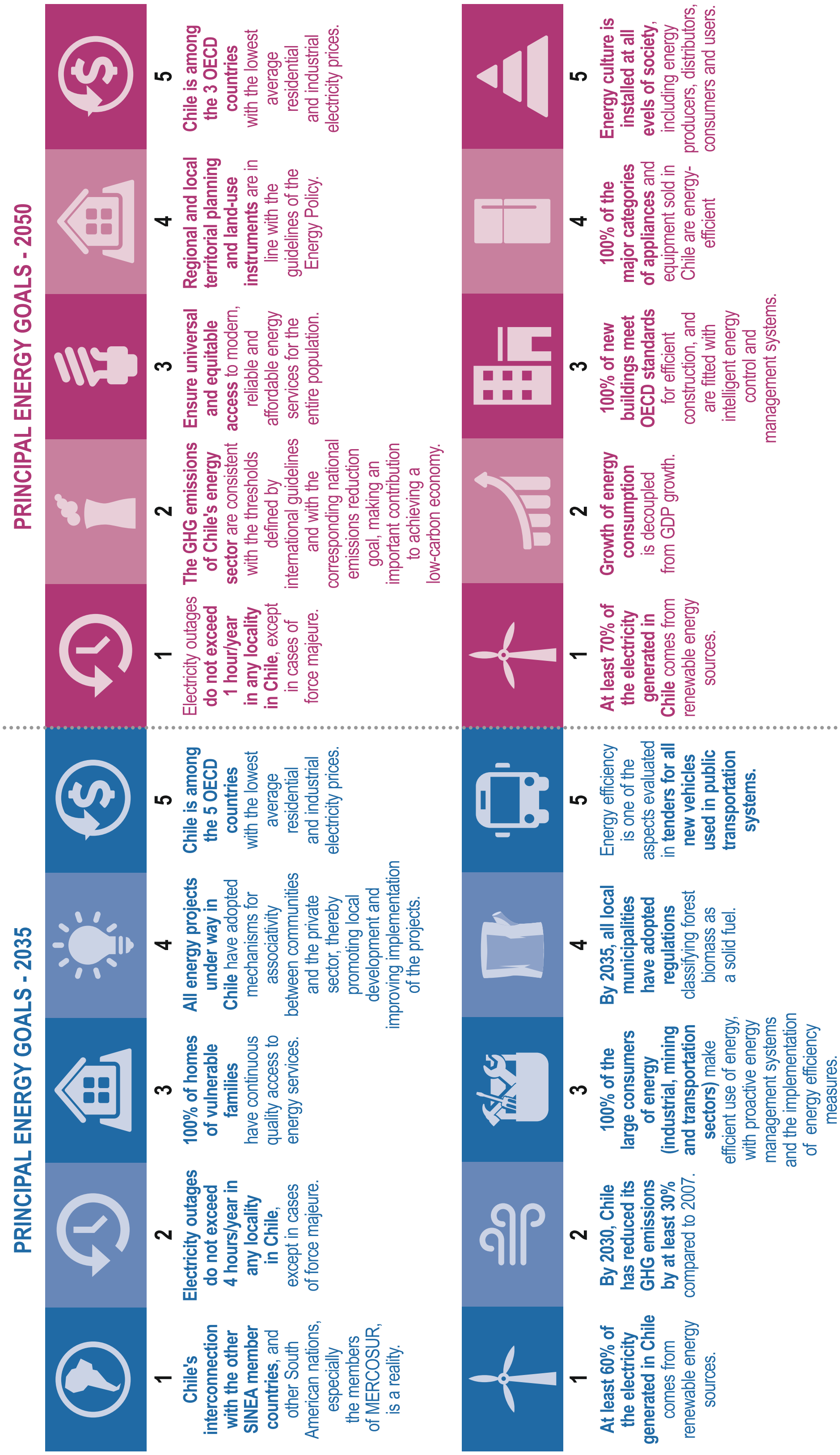
Energy policy objectives

In May 2014, the Ministry of Energy presented the Energy Agenda 2014-18, which contains the priority measures for the sector with emphasis in the short and medium term:

- a new role for the state in energy development
- reduction of energy prices with more competition, efficiency, and diversification of the energy market
- development of self-owned energy resources
- connectivity for energy development
- an efficient sector that manages consumption
- boost for energy investment for the development of Chile’s energy infrastructure
- citizen participation and territorial organisation.

After that, the government established the National Energy Policy 2050, which lays out a long-term vision with objectives and measures. Both documents, the Energy Agenda 2014-18 and the National Energy Policy 2050, were created under a consultative approach and participative process (Box 1.1), which resulted in the creation of a consultative committee formed of public, private and civic representatives, as well as of thematic roundtables led by the ministry and a wide participation of the society through digital media, deliberative polls and workshops across the country. As a result of these efforts, the government established a total of 20 principal energy goals, ten by 2035 and ten by 2050 (Figure 1.10).

Figure 1.10 Goals in the National Energy Policy 2050



Note: SINEA, Andean Electrical Interconnection System (*Sistema de Interconexión Eléctrica Andina*).

Source: Ministry of Energy (2016), *National Energy Policy 2050 Principal Energy Goals*, www.energia2050.cl/wp-content/uploads/2016/08/PRINCIPAL-GOALS.pdf.

Box 1.1 Energy 2050 – a comprehensive public consultation process

Energy 2050 was conceived as a participatory process to build energy policy. Energy 2050 considered four stages of development (thematic panels, roadmap, energy policy and promotion) and three segments of participation:

- in political and strategic levels with an Advisory Committee
- in technical, expert and sectors involved in thematic working groups level
- at a level that includes all the population, with citizen platform, deliberative workshops and public consultation.

During this two-year initiative, Chile built its national long-term energy-planning instrument: the National Energy Policy 2050. This strategy is the result of an integrated and inclusive exercise, and followed a sequential planning process in which a broad spectrum of public participation was considered.

Energy 2050 was divided into thematic panels, and its development considered two horizons:

- in the short term, to work in terms of standards, policies and regulations to ensure technical feasibility and sustainability
- in the medium and long term to discuss strategic and technological aspects.

The dynamic of the thematic panels delivered valuable inputs into ongoing policy making, which include an energy efficiency law project. All the results from the panels worked as an input for the establishment of an Advisory Committee. The principal output expected from the Committee was the "Roadmap to 2050".

Roadmap to 2050 was developed in two phases. In Phase 1 a multivariable participative process with expert groups was developed according to key energy subsectors, to formulate the subsector visions to 2050. From this process, six strategic axes with targets to 2035 and 2050 were defined in Phase 2: sustainable energy, land management, communities and energy poverty, energy efficiency and culture, innovation and productive development, and an additional cross-sectorial axis of institutionalism. Building on these phases, the Ministry of Energy elaborated the National Energy Policy.

For each stage, the three segments of participation were always represented and involved different stakeholders according to the themes and regions implied. Also, some panels and conferences took place in different cities for a more-diverse participation and ease of access. In addition, online surveys allowed for direct input to the process by citizens.

Note: All the documentation of these processes can be found at www.energia2050.cl/programa.

Source: IEA (2017b), *IDR Chile Questionnaire, Overview and Description of Recent Developments in Energy Policy.*

The National Energy Policy 2050 aims to set the requirements to put Chile on a path to be an innovative, sustainable energy leader in the region and around the globe. This energy reform aims to set the role of the state in the quest for the transition from a low-security energy environment, highly dependent on oil and coal imports, into a self-sufficient energy sector that supplies modern, reliable and affordable energy services to the entire population, and decouples energy consumption from GDP growth.

To attain the vision of the energy sector, the National Energy Policy 2050 proposes the following pillars:

- Quality and security of supply.
- Energy as a driving force for development.
- Environmentally-friendly energy.
- Energy efficiency and energy education.

Each pillar sets specific goals for horizons in the years 2035 and 2050 (Figure 1.10), and action plans that contribute to achieving the main objectives of the policy.

Pillar 1: Quality and security of supply

This pillar refers to the reliability of the Chilean energy system, and the need for quality access to energy to attain an inclusive development. It also acknowledges that a secure energy system is a prerequisite for competitive prices, which in turn are an essential condition for sustainable development. Finally, the promotion of responsible use and the efficient production of energy is necessary for a lower environmental impact. The goals of this pillar are to:

- Attain security and flexibility at the level of centralised production.
- Develop decentralised production and active management of demand.
- Set up risk and energy emergency management plans that ensure resilience and reliability of the energy system.
- Integrate with South American neighbours and interconnect with other countries by 2035.
- Create a bidirectional energy system that allows the top-down and bottom-up production, and management of resources.
- Improve the quality of energy supply and reduce power outages in all regions to an average of less than one hour per year by 2050.

Pillar 2: Energy as a driving force for development

With this pillar, Chile looks for inclusive development and economic competitiveness, and acknowledges that energy development is crucial for the development of infrastructure. Therefore, the country needs to have a reliable energy sector, with an energy matrix that reduces the environmental and social impact. Furthermore, an adequate territorial management and efficient use of energy needs a strategy for research and innovation in energy efficiency that fosters an environmentally sustainable energy sector. The goals of this pillar include to:

- Promote growth by offering inclusive energy with equitable access, territorial co-ordination and prices that promote competition.
- Deliver equitable access to energy services and quality of life through the development of a strategy to foster cross-links between energy projects and the communities in their vicinity.
- Ensure territorial inclusiveness through regional energy plans.
- Bring competitiveness to the energy sector by encouraging energy-supply competition that, in the long term helps, to position Chile among the three OECD members with the lowest average residential and industrial electricity prices.

Pillar 3: Environmentally friendly energy

As regards environmental sustainability, Chilean energy policy stresses the co-benefits of a flexible and diversified energy matrix that draws on renewable energy sources for the security of the system. Furthermore, to achieve social inclusiveness that brings real improvements to people's quality of life, environmental impacts must be reduced at both local and global levels. The goals of this pillar are to:

- Provide 60% of electricity generated from renewable energy sources by 2035, and at least 70% by 2050.
- Internalise negative local externalities to ensure environmental standards for energy projects are consistent with international guidelines and the needs of society.
- Encourage adequate use of biomass through the regulation of forest wood as a solid fuel and the replacement of heaters.
- Ensure greenhouse gas (GHG) emissions by the energy sector are consistent with global limits and with the corresponding national reduction goals, while promoting cost-effective mitigation measures.[12]

Pillar 4: Energy efficiency and energy education

This pillar aims to make use of the multiple benefits of energy efficiency to support the other pillars of the long-term vision. Additionally, the strategy acknowledges the role of education in fostering awareness of each citizen’s role in implementing the vision of a reliable, inclusive, competitive and sustainable energy system. The goals of this pillar are to:

- Decouple energy consumption from GDP growth.

[12] Chile has announced its national contribution to the new climate change treaty, The Paris Agreement, and has undertaken to reduce GHG emissions intensity by 30% compared with 2007 levels by 2030.

- Ensure residential, public and commercial sector attain the highest international standards of energy efficiency.

- Embed energy efficiency and energy culture in all formal education plans.

Key legislation

Two pivotal laws among Chile's energy legislation are the ones that created the Ministry of Energy ("Energy Ministry Law", Law 20.402 of 2010) and the Ministry of the Environment ("Environment Ministry Law", Law 20.417 of 2010). The Energy Ministry Law defines not only the regulatory, policy and planning roles for the ministry itself, but also moves the oversight of the SEC, the CNE and the CCHEN under the purview of the Ministry of Energy. This ended an institutional framework that grouped mining and energy activities under the Ministry of Mining. The Environment Ministry Law centralises the environmental competencies in dedicated bodies: the Ministry of Environment is responsible for policy making, SEA is in charge of SEIA and SEC is responsible for oversight.

The framework for the electricity sector is set by the General Law of Electric Services (*Decreto con Fuerza de Ley 4*, 1982), which created an unbundled and privately owned sector, modelled on the United Kingdom example. 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 the former system operators that co-ordinated the operations of competitive generators.

The Transmission Law (Law 20.936 of 2016) established the new National Transmission System (to replace the Trunk Transmission System) and created the National Electricity Co-ordinator, a unified ISO[13] that supports the grid expansion and the interconnections between the transmission grids, and modifies the transmission toll payments to foster renewables.[14] The most-important amendments introduced by this Law are the ensurance of open access to transmission facilities, the introduction of single-access charges and the transfer of transmission systems costs to the final customers.

The hydrocarbons legal framework is not enshrined in a unified legislation. The Constitution stipulates that "the State has absolute, exclusive, inalienable and imprescriptible domain over hydrocarbon deposits". Relevant hydrocarbons legislation includes the law that created ENAP (Law 9.618 of 1986), the decree law that contains the rules for special oil operation contracts for the exploration and exploitation of hydrocarbons (Law Decree 1.089), the Gas Service Law that regulates the gas market and allows the concessioned companies to set their tariffs freely according to a maximum profitability limit (Law No. 20999) and technical regulations regarding the import, transportation, storage and marketing of liquid hydrocarbon issued in the form of decrees by the Ministry of Economy and the Ministry of Mining. The ENAP Law was

[13] On 1January 2017 the National Electricity Co-ordinator started its operation with the integration of both CDECs (SING and SIC).
[14] The creation of the Generation Development Hub was also established by this law, which aims at the deployment of renewable energies in areas with a high potential for power generation that will be included in future transmission-grid expansion plans.

revised in 2016 to allow it to enter the electricity generation market and develop power-generation projects (Law 20.897 of 2016).

Other relevant laws for the energy sector are:

- The Non-Conventional Renewable Energy Law ("NCRE" Law 20.257), enacted in 2008 and amended in 2013, aims to fulfil future energy requirements by developing non-conventional renewable sources for electricity generation, such as geothermal, wind, solar, tidal, biomass and small hydroelectric plants (IEA, 2015).[15]
- The so-called "20/25 Law" (Law 20.698) targets to generate 20% of Chile's electricity from renewable sources by 2025, excluding hydropower plants over 20 megawatts (MW).[16] This law also introduces a new public auction system for years when it is anticipated that the renewable electricity quota will not be fulfilled.
- The so-called "Short Law II" (Law 20.018, *Ley Corta II*), last modified in 2015, improves competition conditions in generation activities, as distribution agents are required to buy energy through public auctions instead of using the price regulated by the CNE (OECD, 2014).[17]
- The net billing law (Law 20.517 of 2014) basically grants users the right to sell their surplus directly to the grid (electricity distributor) at a regulated price. The Equity in Tariffs Law (Law 20.928 of 2016) established mechanisms of equity in the tariffs of electricity services.
- The General Environmental Law (Law 20.417) established the Environmental Assessment System, sets emission and quality standards, and creates prevention and decontamination plans.
- In October 2014, Chile enacted the first climate pollution tax in South America (Law 20.780, Article [Art.] 8). This green-taxes reform imposes an annual tax on emissions from boilers and turbines with a thermal input of at least 50 MW, and entered into force in 2017.[18]

Legal competences for land use

State ownership and management of land has been crucial for the development of renewable energy; over 65% of all solar projects and 20% of all wind-energy projects in Chile are located on state-owned land. However, geothermal and hydropower projects are typically more likely to attract opposition from environmental and indigenous groups.

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[15] For capacity projects that are below 20 MW. However, for a plant that produces between 20 MW and 40 MW, a portion of the energy can be considered non-conventional based on a decreasing function, with the non-conventional energy content of a 40 MW plant equal to zero. The 2013 amendment mandates that electric utilities with more than 200 MW operational capacity should generate 20% of electricity from renewable sources by 2025; and for companies that can produce energy on their own or by contracting from third parties, it establishes an increasing obligation of 0.5% annually, to reach 10% in 2024.

[16] Law 20.698 was enacted in 2013.

[17] The aim of this law was to boost the long-term economic signals for energy prices to reflect the expectations of the cost of generation of the generators themselves.

[18] The tax reform introduced a gradually increased tax rate, and a gradually increased tax base. The GHGs taxed are CO_2, PM, NO_x and SO_2. The initial carbon tax is USD 5 per tonne of CO_2.

In 2013, the government decided to include formal consultations with indigenous groups into the new regulation of SEIA. The new regulation requires SEA to consult indigenous communities in the context of carrying out an environmental impact assessment (EIA). The consultation process increases the duration of the EIA, but provides more guarantees to investors.

Under Chilean law, mining-land property is treated differently to surface property. A person can obtain mining concessions, regardless of who owns the land. Therefore, a landowner and a mining-concession owner can coexist, but this makes them more susceptible to conflict if they are different entities. As mining law stipulates that landownership is subject to the obligations and limitations established by law to facilitate mining activities, some energy-infrastructure developers have to complement their land property rights with mining rights.[19] Historically, mining concessionaires have used injunctions, such as “New Works Claims”, against project developers to halt work and negotiate a higher compensation for the mining rights. However, by Law 20.701 (2013) and Law 20.897 (2016), electric concessionaires and non-conventional renewable energy developers are protected from this provisional suspension that otherwise could jeopardise the financial feasibility of a project.[20]

Data collection

Chile’s national energy balance is prepared by the Ministry of Energy on the basis of annual surveys sent to the main companies in the energy sector, which includes producers, importers, exporters, distributors and large consumers in Chile, with special interest in energy-intensive firms from the transport and mining industries. Currently, the directory of surveyed companies includes about 800 companies that cover the whole energy-supply chain in Chile.[21]

The fundamental legal power to request information is scattered across several laws and regulations. However, none of these regulations specifies either the type of information or the basis for compliance. Currently, information is required on an ad hoc basis to relevant entities. The Ministry of Energy and the CNE have the legal authority to request information from other ministries, public institutions or entities in which the state has participation or representation. This entitlement can be extended to entities and companies with activities in the energy sector.[22]

SEC has the formal authority to collect technical information about the use of resources by the electric, gas and liquid-fuel companies, based on the guidelines produced by the CNE.[23] The National Electricity Co-ordinator has the formal authority to ask its

[19] Statistics provided by the National Geology and Mining Service show that, as at 2012, mining concessions had been granted in relation to 42% of Chilean territory.

[20] NCRE and electric concessionaries now have the faculty to employ the consignment of an adequate surety to suspend the effects of the injunction. An adequate surety should cover the costs of the eventual demolition of the work, or compensate the damages it may cause. NCRE developers using indigenous lands with ancestral use are excluded from this protection.

[21] The responsibility of collecting the information for the energy balance belongs to the Unit of Statistical and Economic Analysis that is part of the Division of Prospective and Energy Policy of the Ministry of Energy.

[22] Law 20.402, Art. 12.

[23] Law 19.613, Art. 1, No. 1g.

co-ordinated entities for information about economic transactions between them, about contracts between suppliers and clients, and about land use.[24]

The CNE has put great effort into the verification and compilation of energy data produced by the Ministry of Energy, SEC, CNE, CCHEN and AChEE. The CNE compilation effort evolved into a new open energy-data platform (*Energía Abierta*) focused on reducing information asymmetries and increasing transparency. This platform facilitates access to the statistics, indicators, maps, legal standards, studies, glossary and web applications related to the energy sector.

In practice, to prepare the energy balance, the Ministry of Energy complements its own survey with information requests to the following agencies:

- The CNE collects diverse data, such as electricity generation (reported by private organisations), installed capacity, energy prices and production and consumption of oil and gas.
- SEC collects information by monitoring energy suppliers and their relation with customers, and on this basis it provides the number of electricity customers and the production and consumption of oil products reported by ENAP.
- The National Electricity Co-ordinator has the mandate to collect information about technical and economic characteristics of the electric system under its operation, which includes generation, transmission, distribution and clients. It also has the authority to audit the co-ordinated entities and report anomalies to the SEC.
- The SERNAGEOMIN reports data such as the products obtained by mine extraction, the annual coal production and its reserves, and the consumption of energy by different types of mines.
- The Santiago Chamber of Commerce reports data collected by the National Customs Service on international trade for different fuels, such as oil, natural gas and coal, and their derivatives.
- The National Statistics Institute provides additional details about electricity generation by self-producers. Information on biomass consumption is obtained partly from the estimates of annual electricity generation and gas production reported by the companies, and partly from estimates of residential consumption using time-series data.

Assessment

The government of Chile is to be commended for the numerous reforms it has undertaken since the previous IEA in-depth review (IDR) in 2009. The following reforms deserve to be highlighted, as they are in line with the 2009 IDR recommendations. On the institutional front, the creation of a dedicated Ministry of Energy and the subsequent long-term energy planning process that started with the Energy Agenda 2014-18 and culminated with the National Energy Policy 2050 in 2015. Further, the creation of AChEE

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[24] Law 20.936, Art. 72, No. 2.

in 2010 and the creation of a single National Electricity Co-ordinator (ISO). On the legislative front, the Law on Non-Conventional Renewable Energies was amended in 2013 and the Tax Reform Law of 2014 introduced green taxes on carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particulate matter (PM) emissions.[25]

On a wider energy-policy front, the government has enhanced energy-supply security by attracting significant private investment in liquefied natural gas import terminals, electricity production – including the connection between the Central Interconnected System (SIC – *Sistema Interconectado Central*) and the Greater Northern Interconnected System (SING – *Sistema Interconectado del Norte Grande*) grids, another IDR 2009 recommendation – and transmission, as well as oil and gas exploration. Energy supply has diversified as Chile has emerged as a world-class destination for investment into renewables.

Furthermore, the government has continuously adjusted its electricity- and gas-market designs. The 2016 Transmission Law not only created a single ISO, but also it enhances the role of the state in energy planning and expansion of the transmission system, supports grid expansion, as well as national and international interconnections between transmission grids, and defines an ancillary services market. Based on this law, the government has organised several successful tenders for generation capacity and has (almost) completed an interconnector between the country's two main power systems. Wholesale electricity prices have decreased to levels close to those prior to the energy crisis of 2008, when Argentina stopped gas deliveries. The Energy Efficiency Roadmap was adopted with the aim to reduce final energy demand by 20% below business as usual until 2025.

In spite of these important achievements, this IDR identifies key areas for further reform and ambition as regards permitting, implementation measures for the National Energy Policy 2050 guidelines, independence of market oversight, grid integration of variable renewables, emissions mitigation in the transport and heat sectors, and electricity-sector market design, as well as the data-collection set-up, as discussed in the following sections.

Permitting

In recent years, the government accentuated the role of the state in energy policy. Notwithstanding commendable efforts to allay nimbyism ("not in my back yard") and reduce the number of projects blocked in courts (judicialización), the government should take further action in transposing voluntary permitting guidelines (*Compromiso de Diálogo* [Standards of Participation]) into streamlined and unambiguous permitting regulation, which should also address land planning and local economic development. In this context, new challenges arose after the recent adherence (under the International Labour Organization) to Convention C169 – Indigenous and Tribal Peoples Convention – regarding aboriginal communities' prior and informed consent to the development of energy projects in their territory. Formalisation of processes in this area would enhance transparency, provide clearer guidance to all stakeholders involved in permitting procedures and lift investor confidence.

[25] Law 20.257 (NCRE Law), and Law 20.780, Art. 8 (green taxes law).

Implementation measures for the National Energy Poiicy 2050 guidelines

The government has demonstrated its commitment to sustainable-energy goals by formulating targets for a 60% share of renewable energies in electricity by 2035 and submitting its National Determined Contribution (NDC) under the Paris Agreement, i.e. a 30% decrease in GHG emission intensity measured against GDP compared with the 2007 figure. As emissions from the energy sector account for 77% of GHG emissions, the lion's share of the NDC will have to be delivered by that sector.

The National Energy Policy 2050 comprises 38 detailed guidelines. However, the government appears to be too prudent with respect to the implementation timeline and quantification of many of these measures. As recent experiences with renewable quotas have shown, market and technology developments can outpace the government's agenda. That is why the government should raise its ambition by accelerating the implementation of many of the guidelines contained in the National Energy Policy 2050. Implementation of measures requires continuity and sometimes a solid legal foundation, such as the Energy Efficiency Law. If promulgation of such laws risks being too protracted, the government should consider implementing some policies and regulations in advance of a comprehensive legislation.[26]

Grid integration of variable renewables

The flourishing photovoltaic (PV) sector and the lack of transmission infrastructure has led to the oversupply of energy in the SIC grid, which hampers the revenues and expansion-financing options of power-plant operators.[27] The growing penetration of renewable-energy sources has increased the importance of energy-storage technologies as a complement to variable renewable energy (VRE) generation and a requirement for the stability and security of the power grid.

Several factors create operational challenges to the ISO regarding power-system flexibility and stability of the system. These include the larger share of solar and wind in the north of the SIC along with the technical capabilities of existing thermal generation, and the abrupt load changes in the Greater Northern Interconnected System (SING – *Sistema Interconectado del Norte Grande*) and lack of hydropower. Currently, no major demand-side management (DSM) programmes are in place in Chile, even though DSM can address concerns over the security of electricity supply and be a cost-effective complement for VRE generation.

Mitigation in the transport and heat sectors

With the National Energy Policy 2050 and the Energy Mitigation Plan, the government has taken steps to shape the country's future energy mix. Although an initial focus on

[26] Under the current legal framework, the Ministry of Energy and AChEE have limited power to mandate energy efficiency measures in specific sectors, particularly the high energy-consuming sectors, such as industry and transport.

[27] In the northern SIC, spot market prices have dropped to 0 Chilean pesos per megawatt hour during daytime hours. This situation might limit the availability of financing for developers, and potentially result in higher capital costs and decrease the bankability of new projects. In the future, this will be relieved because the interconnection of the SIC and the SING is in process, and a major expansion of the 500 kilovolt transmission system in the north of the country is underway.

electricity is understandable in light of the country's emergency situation after the 2008 crisis, the government should broaden its energy planning by giving as much attention to the heat and transport sectors as it does to electricity and by pursuing an integrated multisector approach. This will also enable the government to assess whether it is on track with its NDC.

If the 60% renewable share is to be met by 2035, fossil-based power generation must hardly increase above the present levels under the medium-growth power-demand projections. It is unlikely that market forces alone will deliver this target, given that additional coal capacities are underway, and the output variability of solar and wind energy imposes stability constraints to the system. It cannot be taken for granted that the very low prices achieved at the first renewable-energy auctions held in Chile will be replicated in the future. Chile should therefore consider putting in place policy instruments to flank the existing auction mechanism, to ensure future progress on the deployment of low-carbon energy technologies.

Equally, the NDC emissions target may be out of reach if transport emissions are not resolutely tackled, e.g. by imposing fuel economy standards. As it stands, energy policy has focused its attention mostly on the electricity sector, which leaves the potential to improve the second largest consumer of energy, the transport sector. Although half of the 2035-50 energy goals focus on the electricity sector, transport and heat are targeted only by three out of 20 principal energy goals. Current measures to increase energy efficiency in the transport sector, such as energy efficiency labels for light and medium-sized vehicles, subsidies for the replacement of taxis and efficient driving techniques, could benefit from fuel-economy standards for vehicles, as could energy efficiency labels for heavy-duty vehicles and better data to identify the impact of these policies.

Sustainable use of firewood

Firewood accounts for over 20% of the TPES and is the dominant heat source in southern Chile. As the wood is overwhelmingly burned undried in inefficient furnaces, it causes very serious local air pollution. The government is aware of the challenge and is running programmes to dry the wood and deploy modern furnaces. However, the scope of these programmes is far too modest to remedy the problem in the medium term. Although the Ministry of Environment is implementing environment decontamination plans to reduce the pollution in some cities of the country, the challenge is more akin to modernising a whole informal industry, which may demand a broader government effort. Meanwhile, gas companies are partly displacing firewood with natural gas. Although natural gas has the merit of easing local air pollution, Chile should spare no effort to transform carbon-neutral firewood into a sustainable resource.

Electricity market design

Despite the successes in the electricity market, further challenges are looming. Electricity demand is set to grow fast. Significant investment in grids and generating capacity will be needed. The main vehicles for investment in new generating capacity are the tenders for long-term supply to regulated customers. Around half of electricity demand in Chile is supplied under them and they are driving investment in green, affordable electricity and increasing competition in wholesale markets.

At the same time, the tenders lock distribution companies in long-term contracts. This can be justified from security of supply perspective, but it deters competition for a long time, excludes consumer choice and hinders competition on additional services by retailers. A more general challenge with a concession-based monopoly retail sector, such as the one in Chile, is that it typically requires regulation to foster innovation in electricity supply and demand response. This is a highly topical issue, as technological change through digitalisation is blurring the distinction between generators and consumers. The IEA sees that more Incentives are needed for innovation.

Additional challenges are related to the integration of renewables, particularly variable ones. The government should tackle reforms aimed to introduce additional flexibility into the power market and to better evaluate the advantages of individual technologies for the system.[28] The marginal-cost model of the spot market needs adjustments and greater transparency. The independence of the ISO and the CNE are to be enhanced. Network responsibilities need to be unbundled from generation and retail to foster distributed power generation and DSM. Policy and regulatory action should be reinforced to prevent possible abuse of market power. Discussion on this issue is ongoing in the context of a new electricity distribution law. Operation of the interconnections with Argentina should be optimised. Advancement of the additional interconnectors with neighboring countries should be accelerated.

Interministerial co-ordination

More interministerial co-ordination is required in the sectors of the environment, transport, housing and buildings, hydropower and irrigation, agriculture and forestry, and finance and taxation. The Ministry of Energy's dialogues with civil society are laudable and understandable given the large number of contested projects; however, permitting and land use are issues of national importance and should be under the remit of a non-sectoral ministry.

Data collection

The legal and regulatory basis for data collection is only defined in a minimal way, and for much information the Ministry of Energy has to rely on ad hoc requests, which depend on the goodwill of participating agencies and companies. Additional clarity on data requirements, the flow of information and compliance mechanisms would help to ensure a steady and high-quality supply of energy data for policy making and market transparency alike. In addition, sufficient resources should be dedicated to the compilation of information at the Ministry of Energy, to ensure continuity and quality of energy data.

[28] Regulation for ancillary services is currently under revision to establish payments for flexibility in the system (e.g. reserve, frequency control, etc.).

Recommendations

The government of Chile should:

- ☐ Take a more proactive role in energy policy and regulation, particularly for permitting energy projects.
- ☐ Plan the development of the energy sector in a more integrated way by dedicating as much attention to the heat and transport sectors as to electricity, and by improving co-operation with other ministries in cross-cutting domains, such as transport, land use, water and forestry.
- ☐ Develop an integral engagement approach among communities and energy projects, which includes local participation and development standards, and also address indigenous communities' concerns.
- ☐ Continue to improve the electricity-market design to better reflect the system value of individual technologies and foster flexibility. Reform the power distribution sector, and consider including a gradual liberalisation of retail electricity supply.
- ☐ Ensure continuity of the energy policy by providing a legal basis for comprehensive energy planning and by sheltering energy-market oversight from political influence.
- ☐ As far as possible, clarify and strengthen the legal authority of relevant institutions to request energy information from market participants and specify data-submission requirements in explicit regulations.

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2. Oil

Key data
(2016 provisional)

Crude oil production: 0.25 Mt, –22% since 2006

Net imports of crude oil: 8.56 Mt (8.56 Mt imported, 0 Mt exported)

Oil products production: 9.65 Mt, –17% since 2006

Net imports of oil products: 6.85 Mt (7.29 Mt imported, 0.44 Mt exported)

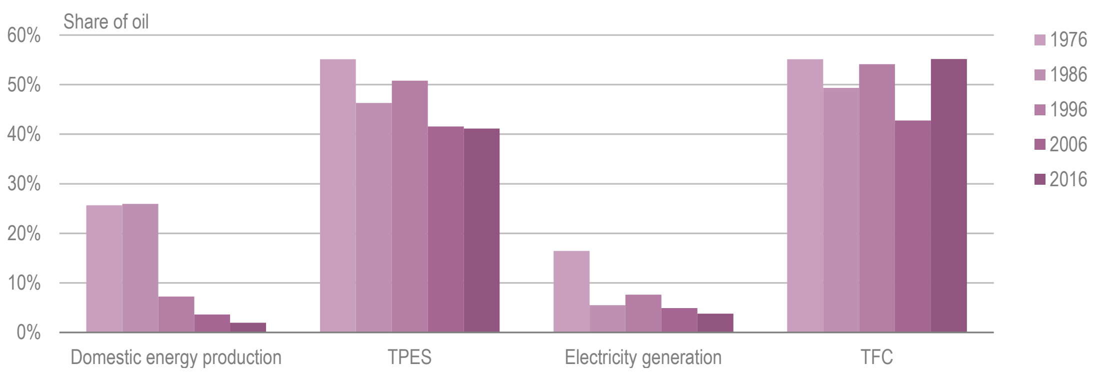
Share of oil: 41.1% of TPES and 55.2% of TFC (2015)

Consumption by sector (2015): 15.29 Mtoe (transport 54.4%, industry 26.3%, power generation 5.0%, residential 5.0%, commercial 4.8%, other energy 4.5%)

Overview

Oil is the most-dominant fuel in Chile, accounting for over 40% of total primary energy supply (TPES) and more than half of total final consumption (TFC) (Figure 2.1). Domestic oil production is small and Chile heavily relies on imports to satisfy its oil demand. Brazil is the largest source of crude oil and the United States the largest supplier of oil products.

Figure 2.1 Oil's share in Chile's energy sector, 1976-2016



Notes: Latest consumption data are for 2015. Data are provisional for 2016.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

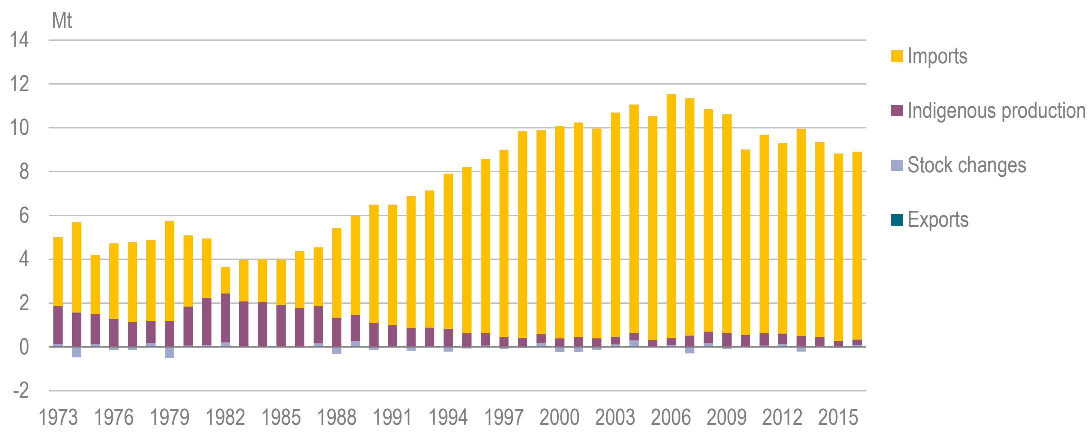
Oil consumption has increased over the past decade. The increase was initially driven by the need to compensate for the decline in Argentinean natural gas. After the diversification of import sources for natural gas, oil use for power generation declined again, but the overall increase in oil consumption was sustained because of the growth in other sectors. Transport is the largest oil consumer in Chile, followed by industry.

Supply and demand

Production, imports and exports

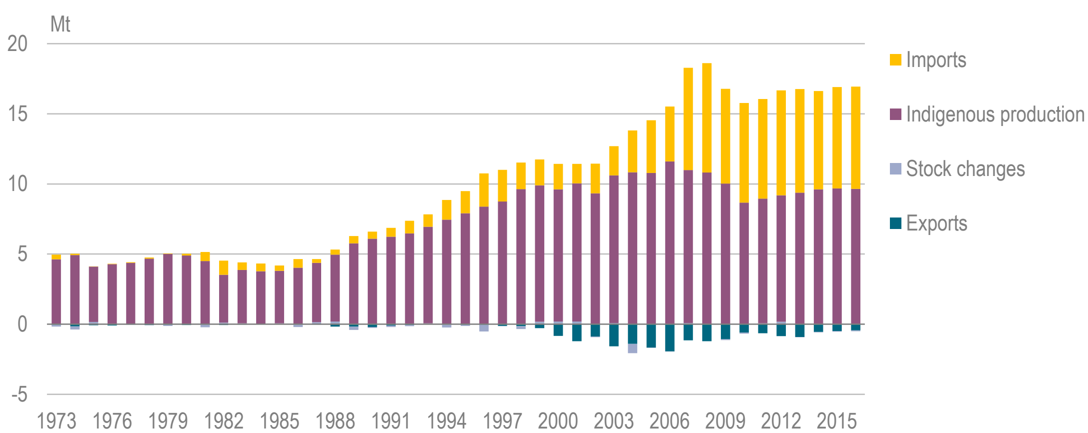
Oil production in Chile is small, accounting for only 3% of the country's total crude oil supply in 2016 (Figure 2.2). Self-sufficiency, measured as domestic production divided by oil in TPES, has declined significantly over the past decades because of a strong increase in oil demand and the depletion of the oil fields in the Magallanes. Accordingly, Chile relies largely on oil imports to meet the domestic demand. In 2016, Chile imported 8.56 Mt of crude oil and 7.29 Mt of oil products. Although imports of crude oil decreased by 23% from 2006 to 2016, imports of oil products increased by 86% (Figure 2.3), and drove up the total oil imports.

Figure 2.2 Crude oil supply, 1973-2016



Source: IEA (2017b), *Oil Information 2017* (database), www.iea.org/statistics/relateddatabases/oilinformation/.

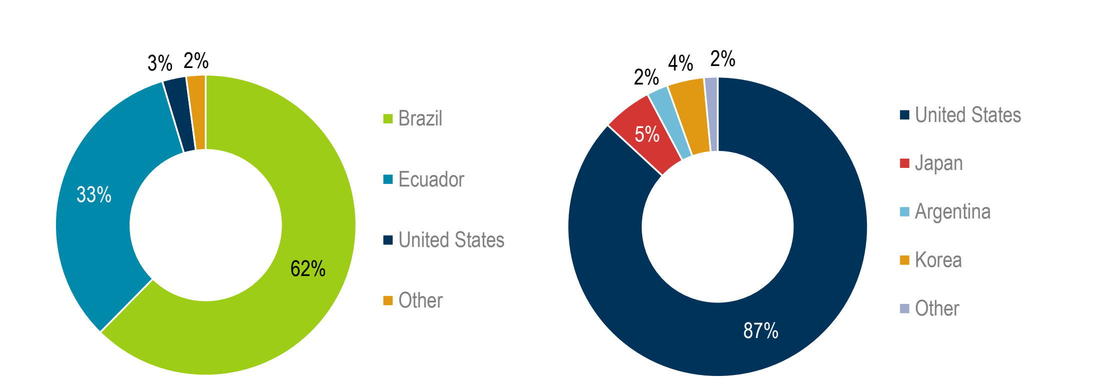
Figure 2.3 Oil products supply, 1973-2016



Source: IEA (2017b), *Oil Information 2017* (database), www.iea.org/statistics/relateddatabases/oilinformation/.

Brazil is the single-largest exporter of crude oil to Chile, providing 62% of the total in 2016, followed by Ecuador at 33%. The total share of South American countries in crude oil imports has grown from 65% in 2006 to 97% in 2016, because of lower transportation costs and a tariff agreement, and made possible by adapting the National Petroleum Company (ENAP – *Empresa Nacional del Petróleo*) refineries to process heavy crude oil from Brazil or Ecuador. In terms of oil products, the United States is the largest exporter to Chile, accounting for 87% of the total imports in 2016 (Figure 2.4).

Figure 2.4 Crude oil and oil products imports by country, 2016



Note: Data are estimates.

Source: IEA (2017b), *Oil Information 2017* (database), www.iea.org/statistics/relateddatabases/oilinformation/.

Consumption

In 2015, Chile consumed 15.3 million tonnes of oil equivalent (Mtoe) of oil, up 32% from 2005. Oil consumption rose abruptly in 2007, as it was used for power generation when natural gas imports were curtailed. Oil use at power plants quadrupled, but since then has returned to pre-2007 levels as natural gas import sources were diversified. However, this has not led to an overall decline in oil consumption, as demand in other sectors has increased (Figure 2.5).

The transport sector is the largest oil consumer, accounting for over half of the total oil consumption in 2015. Transport oil consumption increased by 34% from 2005 to 2015, but the sector's share remained unchanged. Road transport consumes 49% of the total oil products.

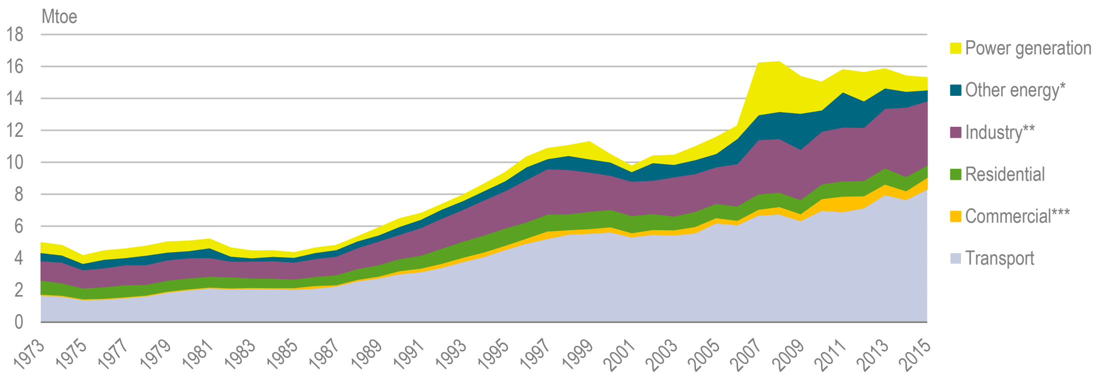
Industry is the second-largest oil consumer, representing over one-fifth of the total oil consumption in 2015, and its consumption increased by 76% over the past decade. Mining and quarrying is the largest oil-consuming industry sector. The industry sector includes the consumption of oil products for non-energy purposes, but this accounts for less than 1% in Chile.

The remaining oil consumption is made up of the power generation, residential, commercial and other energy sectors, accounting for roughly 5% of the total consumption each. Notably, the share of oil in power generation surged to 27% in 2007-08, but has since declined to its previous level of around 4% of the total electricity generation.

By product, diesel is the most-dominant oil product, accounting for over half of the total consumption, followed by motor gasoline at 22% (Figure 2.6). Whereas almost all gasoline is consumed in road transport, diesel products are shared between the transport sector and the industry sector. Other important fuels are jet fuel and liquefied petroleum gases, of which more than half is consumed bottled in the residential sector for heating and cooking.

In recent years, diesel consumption has increased sharply. This is consistent with a 76% increase in the number of diesel cars from 2010 to 2016 to 1.2 million (INE, 2011, 2017), replacement of fuel oil-using machinery by diesel-using ones in mining and the sharp decrease of the use of diesel in power generation.

Figure 2.5 Oil consumption by sector, 1973-2015



* *Other energy* includes petroleum refineries and energy own-use.

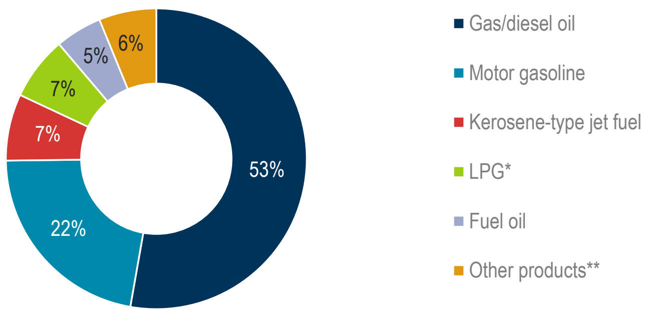
** *Industry* includes non-energy use.

*** *Commercial* includes commercial and public services, agriculture, forestry and fishing.

Note: TPES of oil by consuming sector.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Figure 2.6 Oil supply by product (volumes), 2016



* Liquefied petroleum gases.

** *Other products* include petroleum coke, other kerosene and other unspecified oil products.

Source: IEA (2017b), *Oil Information 2017* (database), www.iea.org/statistics/relateddatabases/oilinformation/.

Infrastructure

Refineries

From a regulatory standpoint, Chile's refining sector is open and competitive as there are no legal impediments to private participation. However, in practice, ENAP holds a monopoly in the sector, as it owns all three of the country's refineries and therefore 100% of refining capacity.

Chile has three refineries. Aconcagua (104 kilobarrels per day [kb/d]), in the Valparaiso Region, and Bio Bio (116 kb/d), in the Biobio Region (Figure 2.7), are both complex refineries. They account for around 90% of Chile's total refining capacity and serve the country's main consumption centres. They produce primarily liquid fuels and liquefied gas for domestic consumption, along with some other industrial products.

The third refinery, Gregorio, is located in Magallanes in the southern tip of the country and serves the southern rural regions. With a capacity of around 16 kb/d, the facility has one topping unit and produces primarily diesel and kerosene. Owing to its low complexity and location near oil-producing regions, Gregorio is used primarily by ENAP to upgrade crude prior to sending it to the Aconcagua and Bio Bio refineries.

Utilisation rates at Chile's refineries have hovered near 70% since the strong 2010 earthquake. ENAP's total refinery output was 197 kb/d in 2015, up 1% from 2014. This figure remains well below ENAP's peak production levels of the late 2000s, during which it topped 220 kb/d. Refinery yields have remained relatively consistent over time, with gasoline and gasoil accounting for 60% of the total production.

Chile's refining sector is relatively sophisticated by regional standards. Over the past decade, ENAP has invested in several new conversion units at its refineries. As a result, they are now capable of processing a wider slate of crude oils, which has reduced the reliance on light crudes.

Ports and pipelines

Chile's heavy reliance on imported crude and oil products makes its maritime terminals an integral component of the country's infrastructure. Chile has 17 operational seaports capable of handling imports and/or exports of crude oil and refined products. These ports have a combined uploading capacity of around 1.25 million cubic metres per day (mcm/d) (7.9 million barrels per day [mb/d]).

Terminal ownership in Chile is diversified, with both fuel distributors and ENAP having access to import/export facilities.

Chile's pipeline system is used to transport crude oil, liquid fuel and LPG between storage plants. In the central part of the country, crude oil is transported by pipeline from the marine terminal in Quintero to the Aconcagua refinery (Figure 2.7), both of which are located in the Valparaiso Region. In the south-central area, there is a system of pipelines for transporting liquid fuels from the Quintero terminal to marine terminals and the Bio Bio refinery. With a few exceptions (indicated below), the pipelines operate in one direction.

Two companies dominate Chile's pipeline logistics: ENAP and Sonacol. Sonacol operates a 465 km product pipeline network, primarily serving the central regions. Copec owns the largest share of the company (40.8%), followed by Petrobras (22.2%), ENEX (14.9%), Abastible (12%) and ENAP (10.1%). ENAP operates a pipeline network in the central and southern regions, and it is also the network's sole user.

The key components of Chile's pipeline network are:

- Quintero to Concon: The pipeline system that carries liquid fuels, including LPG, from the marine terminals and fuel-storage plants in Quintero to ENAP's Aconcagua refinery. ENAP and Sonacol both own different portions of this section, and certain sections of ENAP's pipelines are bidirectional.

- Concon to Quillota: The pipeline that supplies diesel to the Nehuenco and San Isidro power plants located near Quillota. The pipelines are owned by Electrogas.

- Concon to Maipu: Two pipelines that transport LPG and liquid fuels from the Aconcagua refinery to storage facilities in Maipu, near Santiago in the Metropolitan Region. It is owned by Sonacol.

- Maipu to Santiago Airport: Transports liquid fuels that are used at the airport. It is owned by Sonacol.

- Maipu to San Fernando: Supplies fuel (but not LPG) to storage facilities, and is bidirectional. This section is owned by Sonacol.

- Linares to San Fernando: Carries fuels (but not LPG) to ENAP storage facilities. The pipeline is also owned by ENAP.

- Biobio to Linares: Connects marine terminals and fuel storage plants near Bio Bio with the storage plants located in the city of Linares. It carries liquid fuels, which include LPG. This segment of the pipeline is owned by ENAP.

Chile also has two international crude pipelines: Sica-Sica, owned by Bolivia's Yacimientos Petrolíferos Fiscales Bolivianos YPFB, and Estensoro-Pedrals, owned by Argentina's YPF. The Estensoro to Pedrals crude pipeline, which was designed to supply the Concepción refinery with Argentine crude, no longer operates, as the refinery now processes crude sourced from other countries.

Storage

Chile holds around 3.3 mcm (20.8 mb) of storage capacity for total crude oil and oil products. Crude-oil storage, which accounts for around 35% of total storage, is concentrated around ENAP's refineries. Liquid fuel and LPG storage is less concentrated, with storage facilities located at refineries, marine terminals and other areas throughout the country. The bulk of the total capacity is concentrated around the Valparaíso and Bio Bio regions, close to the country's two largest refineries and demand centres.

Figure 2.7 Oil supply infrastructure, 2016

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Private participation in logistics ownership is extensive and supported by Chile's open regulatory framework. ENAP controls around 73% of the storage capacity. The remainder is split between major distribution companies, electricity generators and the mining sector. Individual companies may choose to own and operate storage facilities on their own or enter into partnerships with other companies. Wholesale and retail companies, such as Petrobras and ENEX, hold maritime terminals and Copec, Chile's leading marketing operator, is currently constructing an oil product facility at its import terminal in Quintero that will increase capacity by 40 000 m^3 (252 000 barrels). There is no obligation to provide open access to storage to third parties, so access is determined by the specific policies of each company. For example, ENAP offers storage-capacity rental to distributers.

Industry structure/retail sector

Liquid fuels

Chile's oil production is small and ENAP produces around 66% of it. The remainder comes from several smaller producers that operate under special oil-operation contracts (CEOPs – *Contrato Especial de Operación Petrolera*).Over the past decade, Chile's retail fuels market has become one of the most consolidated in Latin America after the exit of multiple international oil companies. The main distributors of liquid fuels to industrial and retail customers are Copec S.A., Esmax S.A. and Enex S.A. After ENEX's acquisition of Shell's Chilean downstream assets in 2011 and Terpel's in 2013, ENEX controlled over 93% of the country's retail fuel market. The companies are vertically integrated, with assets throughout the chain of distribution. Additionally, retailers such as Combustibles Hn and JLC Combustibles are also active in the sector.

Franchising is common in the retail market, whereby large companies franchise their brands to third parties who are then required to buy that brand's fuel.

Currently, Esmax operates the Petrobras brand. Petrobras, Chile's third-largest fuel retailer, sold its downstream assets to the Argentine private equity firm Southern Cross Group in May 2016 for USD 490 million (United States dollars). At the end of 2015, Petrobras accounted for 17.5% of Chile's service stations and 15% of its retail motor-fuel sales. The sale included 279 service stations and eight fuel-distribution plants, among other assets. The Southern Cross Group has yet to announce its plans for its new acquisitions; however, the group is likely to shed some underperforming assets. This should provide Chile's smaller retail players with a chance to expand their position, albeit marginally.

ENAP does not operate in the wholesale or retail distribution markets, although there is no legal barrier to doing so.

Liquefied petroleum gas

LPG is widely used in Chile for domestic purposes, which include water heating, cooking and heating. It is used in the vast majority of the country, except for the Magallanes region where natural gas is available. LPG is stored in plants before typically being packaged and sold to customers either in bulk or bottled.

In Chile, the main LPG distribution companies are Abastible S.A., Gasco S.A. and Lipigas S.A., which control approximately 37%, 37% and 26% of the market, respectively. LPG is imported either by sea, at terminals located in Quintero and San Vicente, or by land.

Prices and taxes

As a general rule, Chile does not regulate retail fuel prices. Prices are freely set at all stages of the distribution system (i.e. refiners, distributers, retailers, etc.). A specific excise tax (IEC – *impuesto específico a los combustibles*]) is levied on transport fuels, although the rates vary by fuel type. Gasoline is taxed at a fixed rate of monthly tax unit (UTM – *unidad tributaria mensual*)[1] of 6 UTM per m^3 (UTM/m^3) diesel at 1.50 UTM/m^3, automotive LPG at 1.40 UTM/m^3 and automotive compressed natural gas (CNG) at 1.93 UTM/1 000 m^3. All fuels are subject to the normal value-added tax rate of 19%.

Owing to its high levels of imports, Chile is exposed to the volatility in international crude oil and product markets. To compensate, it has a history of using price-stabilisation mechanisms to mitigate the impact of this volatility on end consumers. After the Gulf War, the government established the oil-price-stabilization fund (FEPP – *El Fondo de Estabilización de Precios del Petróleo*) as a way to shield domestic prices for some fuels from potential spikes in international oil prices. The FEPP still exists today, although it currently only applies to kerosene for heating in domestic use. In 2011, as the FEPP had been depleted several times, Chile switched to a system based on excise tax, known as the Consumer Protection System for Fuel Excise Taxes (SIPCO – *Sistema de Protección al Contribuyente*). It was then replaced with the current Fuel Price Stabilization Mechanism (MEPCO – *Mecanismo de Estabilización de Precios de los Combustibles*), in August 2014.

MEPCO works by applying weekly changes to the variable component of the IEC to limit weekly variations in prices to 0.12 UTM/m^3. The IEC consists of both a base component (which remains constant) and a variable component (i.e. total IEC = base IEC + variable IEC). Today, this amounts to CLP$5.6/litre [L], which is up from CLP$5/L when the system was implemented.

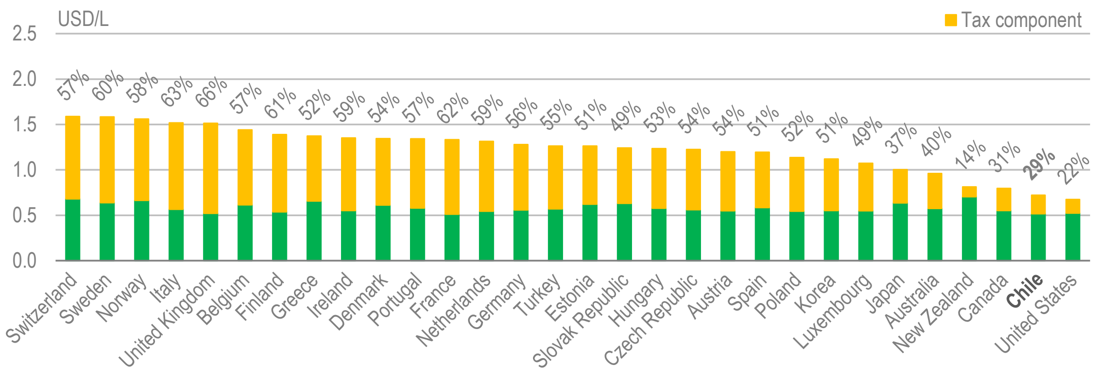
The National Energy Commission (*Comisión Nacional de Energía*) calculates the prices required for MEPCO, taking into consideration both current and future prices of Brent crude oil, free-on-board fuel price and refining margin. MEPCO operates through a 5% price band, and If global petroleum prices fall outside of this band, the variable component of the IEC is adjusted to compensate. The prices are calculated in Chilean pesos. ON contrast, for SIPCO, the price was calculated in USD and the price band was 10%. Fuels included in MEPCO are 93 and 97 research octane number (RON) unleaded motor gasoline, diesel fuel, automotive LPG and CNG. For CNG, the law stipulates that the variable component of its IEC will be equal to 1.5195 times the variable component of automotive LPG.

[1] The UTM is an inflation-tracking currency unit used by the Chilean government. As of March 2017, 1 UTM = CLP 46 368.

Consumer prices for most transport fuels are low in Chile compared with International Energy Agency (IEA) member countries because of the relatively low taxes (Figure 2.8). In the second quarter of 2017, the diesel price in Chile was the second lowest after only the United States, and the gasoline price was the fourth lowest after the United States, Canada and Australia.

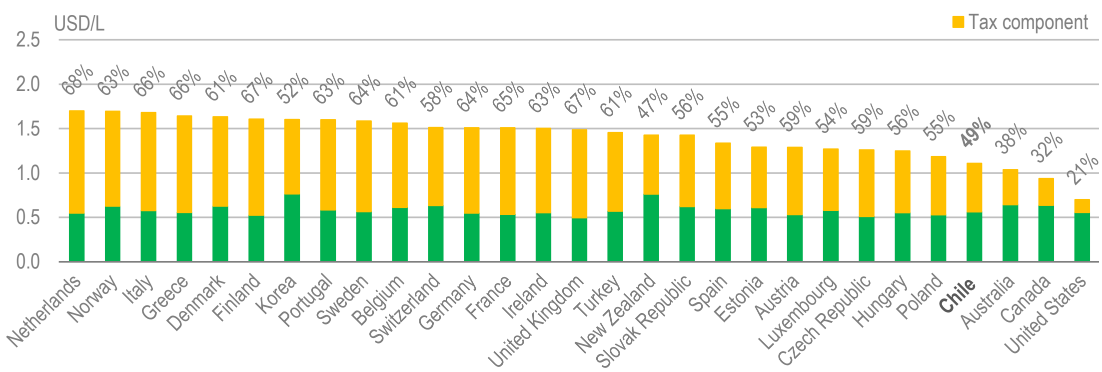
Figure 2.8 Transport fuel prices in Chile and IEA countries, second quarter 2017

Automotive diesel



Note: USD/L = USD per litre.

Premium unleaded gasoline (95 RON)



Note: Data not available for Japan.

Source: IEA (2017c), *Energy Prices and Taxes, 2017*, http://dx.doi.org/10.1787/energy_tax-v2017-2-en.

Emergency response policy

Security of supply

Domestic oil production in Chile is very low, between 2 kb/d and 3 kb/d for the past decade. Chile relies heavily on imports to meet its demand (around 97%). As the sole operator of the refineries in Chile, ENAP is also the sole importer of oil. Although sources (and shares) may vary from year to year, imports arrive primarily from South America as the geographical proximity and existence of tariff agreements help to minimise costs. In 2015, 60% of imports came from Brazil, followed by 38% from Ecuador and almost 2% from Angola.

Over the past decade, ENAP has invested in several new conversion units at its refineries. As a result, they are now capable of processing a wider slate of crude oils, which has resulted in a lower overall reliance on light crudes. In 2015, only 5% of refinery inputs were light, compared with 54% in 2004. Overall, Chilean refineries have a well-balanced slate, with heavy crude accounting for the largest share (35%), followed by medium (49%), feedstocks (19%) and light (5%).

With respect to products, Chile's general policy regarding fuels and derivatives is to promote free enterprise, while complying with safety and quality regulations, as well as others applicable to the sector. Both ENAP and other private operators supplement their local supply of liquid fuels with imports, which improves diversification and minimises the supply risk.

Decision-making structure

In May 2011, the government issued a directive for the establishment and operation of the National Emergency Operations Committee (COE – Centro de Operaciones de Emergencia Nacional). In 2014, the Sectoral Energy Operations Committee (COSE – Comité Sectorial de Operaciones Energética) was established. The COSE is responsible for assisting the Ministry of Energy in the event of a national emergency that affects the energy supply. Its staff includes authorities and professionals from the Ministry of Energy, Superintendent of Electricity and Fuels, and regional representatives of the ministry (Seremis). The COSE remains on standby during normal day-to-day operations, but could be mobilised upon request by the National Emergency Bureau to the COE Nacional, generally in response to a significant disruption to energy supplies.

At the international level, Chile's structure for disaster risk reduction is part of the Sendai Framework, which was signed in March 2015 in Japan. This treaty defines the key pillars of disaster risk management that must be included in public policies of the participating countries, including Chile. Since 2016, in addition to establishing the Risk Management Unit, the Ministry of Energy has adopted a strategy for risk management that goes beyond emergency responses. The ministry is currently preparing a National Plan for Risk Management for the Energy Sector to cover all sector stakeholders and all stages of the risk cycle. This work is scheduled to be completed by mid-2018.

Emergency stockholding

Chile imposes a mandatory minimum-inventory requirement on producers and importers (if the imports are for their own consumption) of petroleum-derived liquid fuels. They must hold inventory levels that equal 25 days of average sales (or average imports) of the previous six months.

The government has acknowledged the need to expand the 25-day stockholding obligation and increase overall stock levels. The government's stated goal is to have sufficient emergency stocks by 2035. To this end, it reviewed the legislation and identified the following issues:

- The regulation should determine how such stocks are quantified, administered or managed during emergency situations.
- The regulation should include a clear methodology on how to quantify the existing stocks; a mechanism or procedure for using these stocks in the case of an emergency; and

enforcement of compliance with this obligation (no penalties have ever been levied for non-compliance).

- The regulation should apply also to LPG and crude oil, in addition to liquid fuels.

The government's efforts to update the emergency stockholding obligation are ongoing. The cost of establishing new storage facilities has been estimated under various pricing scenarios, and geographical risks are being analysed. However, any plans to increase the levels of emergency stocks remain preliminary. Between now and 2030, the government plans to focus on increasing investments to support the various aspects of the fuel chain to reduce the vulnerability of fuel supplies.

Assessment

Oil is the largest energy source in Chile, at 40% of TPES in 2015. The transport sector consumes at least half of all oil, followed by industry and mining at around one-quarter of the total. Imports cover 97% of crude-oil demand and the rest is extracted in the Magallanes Region. Almost all crude-oil imports come from South American countries because of the low transportation costs and existing tariff agreements. Oil products are mostly sourced from the United States. Chile's refineries produce enough gasoline to cover domestic demand, whereas around two-thirds of diesel has to be imported.

Given that the Chilean state is the owner of the country's hydrocarbon resources, the state company ENAP has been in charge of oil exploration and production. In the 1960s, oil production in Magallanes accounted for more than half of the total supply of crude oil, but through the years this percentage declined to less than 5% today. This decline is because of the strong increase in demand for liquid fuels as well as the depletion of the fields in the Magallanes.

Oil refining is liberalised in Chile, so any company, state-owned or private, can build or acquire a refinery, provided it meets all the environmental requirements and other regulations. In practice, however, the state-owned ENAP is the only company that owns refineries (three in total). ENAP also imports refined fuels, owns crude oil and liquid-fuels pipelines, fuels-unloading maritime terminals and storage plants. There are no obligations to provide open access to third parties on any of these assets. Therefore, access depends on the specific policies of each company.

The government approves all ENAP's investments, whether upstream or downstream. The government can also direct ENAP to invest, as it did for the LNG terminal in Quintero, and more recently the government instructed ENAP to invest in power generation, which is a competitive market. In a positive development, in July 2017 the National Congress adopted a law to modernise ENAP´s corporate governance and insulate the company from the political cycle by adopting the Organisation for Economic Co-operation and Development corporate governance practices and standards. ENAP's CEO is appointed by its board.

Oil-importing companies have a stockholding obligation equivalent to 25 days of their domestic average sales in the previous six months. In practice, some companies require clarification regarding the applicability of this obligation, and the government institutions seem to lack the legal powers to control or enforce this obligation. In practice, only ENAP holds emergency stocks, even though there are more oil-importing companies. Regardless, the administration has acknowledged that the 25-day stockholding obligation may not be sufficient and that the law needs to be updated to better address the country's needs regarding energy security.

Chile has a price-stabilisation system to manage weekly price volatility for final consumers of transport fuels, called MEPCO, which entered into force in 2014. It is applicable to 93 and 97 octane gasoline, diesel fuel, automotive LPG and natural gas for transport. The Ministry of Finance adjusts the IEC tax to attenuate volatility if the price deferential to the previous week exceeds UTM 0.12/m^3. However, fuel retailers are not obliged to adjust their prices following a tax change by the Ministry of Finance, but in practice they adjust them. The MEPCO mechanism thus transfers price signals to fuel buyers, but in a moderated way. The government considers that the system manages to stabilise the variation of vehicle fuel prices in a fiscally neutral way. The citizens believe that the mechanism has kept the weekly variations bounded (the price signals are still transferred to them, but in a smoother trajectory).

The following policy objectives for oil products are contained in the 2015 National Energy Policy: *i*) increase the security of the logistic fuel chain by raising the investment in cost-efficient infrastructure and new supply routes; *ii*) increase the security and quality of oil supply, specifically by promoting exploration and exploitation of hydrocarbon resources in Magallanes and in the rest of the country; and *iii*) improve energy efficiency in vehicles and their operation by means of establishing energy efficiency standards for light, medium and heavy vehicles. These are welcome objectives.

Recommendations

The government of Chile should:

- Closely work with ENAP and other stakeholders to complete the establishment of a comprehensive set of security measures and capacity to identify and respond to critical risks in crude-oil and oil-product supply.
- Clarify the oil-stockholding obligation for all oil companies, and enforce this obligation where necessary.
- Consider the administrative and other costs, and the public benefits, of the MEPCO price-stabilisation mechanism and whether continuing it would still deliver the intended results.

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3. Natural gas

Key data
(2016 provisional)

Natural gas production: 1.2 bcm, –33% since 2006

Net imports: 4.0 bcm, –30% since 2006

Share of natural gas: 12% of TPES and 16% of electricity generation

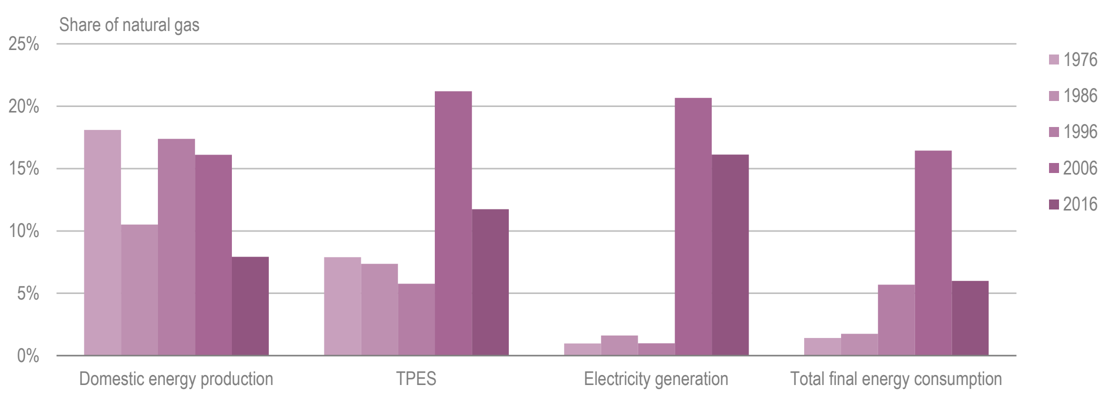
Consumption by sector* (2015): 4.0 Mtoe (power and heat generation 52.6%, industry 24.4%, residential 11.9%, other energy 6.6%, commercial 3.8%, transport 0.7%)

* Consumption by sector only available for 2015. In 2016, domestic consumption was 4.4 Mtoe or 5.0 bcm (the difference between production plus net imports and consumption is because of a statistical difference).

Overview

The importance of natural gas in Chile's energy supply has significantly declined in the past decade; its share in total primary energy supply (TPES) fell from 21% in 2006 to 12% in 2016 (Figure 3.1). As Argentina cut and eventually almost completely stopped gas exports to Chile, power generators switched first to diesel, then to coal and recently to renewable energy, whereas industry switched to oil.

Figure 3.1 Natural gas shares in different energy supplies in Chile, 1976-2016



Notes: Latest consumption data are for 2015. Data are provisional for 2016.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

As a countermeasure, two onshore liquefied natural gas (LNG) regasification terminals were developed in a public–private partnership and since 2010 has Chile depended on imported LNG for its gas supply. Domestically, gas is produced in small volumes in the Magallanes region in the south of the country where it is also used, mainly to meet local demand for electricity and heating. Chilean gas consumption is split into three local markets (North, Central [both depending on LNG] and South) without interconnections.

Supply and demand

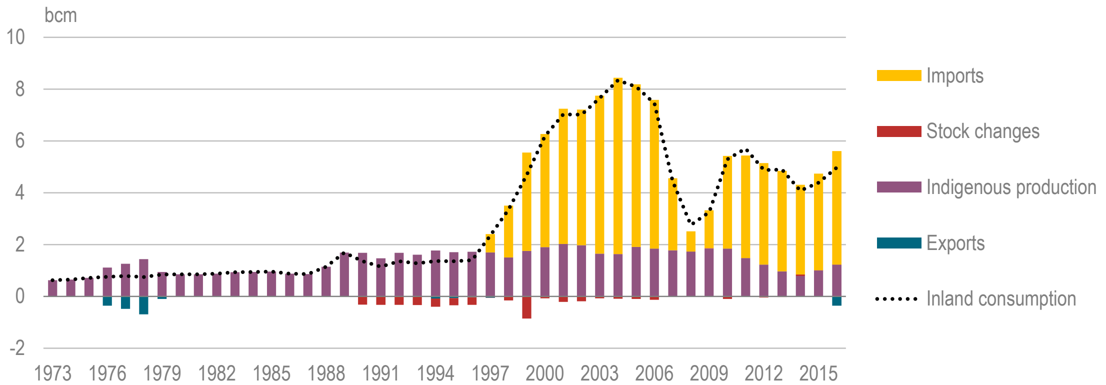
Supply

In 2016, 5.2 billion cubic metres (bcm) (4.4 million tonnes of oil equivalent [Mtoe]) of natural gas were supplied in Chile, accounting for 12.0% of TPES. Domestic production accounted for less than one-quarter of the supply (1.2 bcm) and the rest was imported (Figure 3.2).

Exclusive imports of natural gas from Argentina began in 1997 (Figure 3.3). Gas imports increased significantly until a peak in 2004, when Chile's total natural gas supply was 8.3 bcm, and then fell to a low of 2.5 bcm in 2008, after Argentina's faltering domestic production led to its cutting exports to neighbouring Chile.

Domestic gas production supplies an isolated network in the Magallanes Region in the far south. In the past decade, production has declined sharply from around 1.75 bcm per year registered from the 1990s to 2010 to the low of 0.8 bcm in 2014. Since then, it increased to 1.2 bcm in 2016. Consequently, energy policy focuses on increasing production in the region through concessions for the exploration and exploitation zones. Natural gas reserves are sufficient to cover residential consumption in the Magallanes Region for at least 20 years, and could also supply industrial clients.

Figure 3.2 Gas supply by source, 1973-2016



Note: Data are provisional for 2016.

Source: IEA (2017b), *Natural Gas Information* (database), www.iea.org/statistics/relateddatabases/naturalgasinformation/.

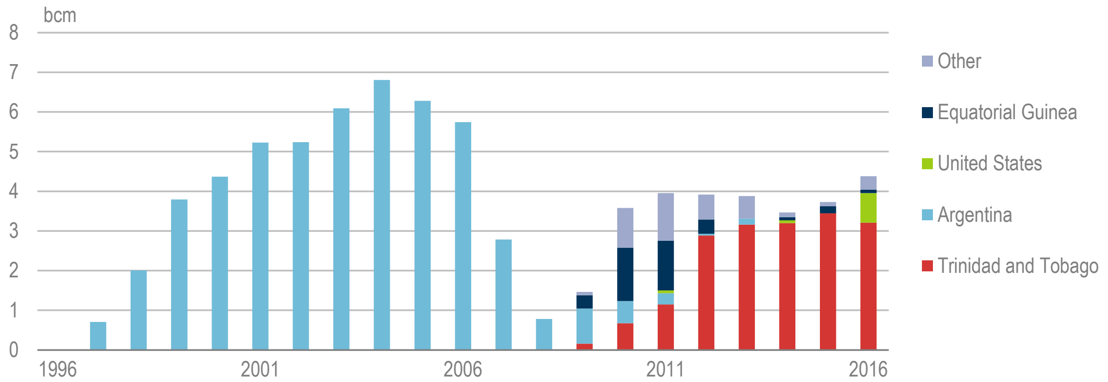
Imports and exports

After the 2004 energy crisis in Argentina, gas exports from that country to Chile were rapidly reduced. As a consequence, gas demand shrunk by two-thirds from 2004 to 2008. In response to this, two LNG terminals – with a public/private ownership – were built at short notice. The Quintero LNG plant in the central region was commissioned in 2009 and the Mejillones LNG plant in the far north in 2010.

LNG has mostly been imported from Trinidad and Tobago (92% of total imported natural gas in 2014-15). However, thanks to the expansion of the Panama Canal, the transit time from the Atlantic is shorter and import sources became more diversified in 2016: next to Trinidad and Tobago (72%) are also the United States (East Coast) (17%), France reloads (4%), Norway (3%), Qatar (2%) and Equatorial Guinea (2%). Since 2015, no gas has been imported from Argentina, according to Enargas, Argentina's gas regulator.

Since 2016, Chile has also exported (imported) natural gas to Argentina. Argentina's gas production became insufficient in the past few years, and the country has had to resort to LNG imports and pipeline imports to complement its supply and to replace diesel for part of the electricity generation. Chile's and Argentina's state-owned production companies National Petroleum Company (ENAP – *Empresa Nacional del Petróleo*) and ENARSA (*Energía Argentina Sociedad Anónima*) have agreed to supply natural gas on the basis of winter-season contracts, and swap exchanges between Chile and Argentina have already started. In practice, ENAP sources supply from LNG imports from the two LNG terminals and uses reverse flow in both cross-border pipelines to ship these to Argentina. The initial contract was set to cover one winter season, with the possibility of repeats in the future depending on the needs of Argentina, which is supposed to develop its own domestic shale-gas potential.

Figure 3.3 Natural gas net imports by country, 1996-2016



Note: Data are provisional for 2016.

Source: IEA (2017b), *Natural Gas Information* (database), www.iea.org/statistics/relateddatabases/naturalgasinformation/.

Consumption

Natural gas consumption fluctuated widely over the past decade. Consumption peaked at 6.0 Mtoe in 2004 and plummeted to just 2.1 Mtoe in 2008 (Figure 3.4). Consumption has partly recovered with the diversification of import sources, but remains below the levels before Argentina's energy crisis. In 2015, Chile's natural gas consumption was 4.0 Mtoe, 41% less than in 2005.

Power generation accounted for over half of the total natural gas consumption, up from 40% in 2005. Gas demand for power generation decreased over this period (–6%), but at a lower rate than total gas consumption.

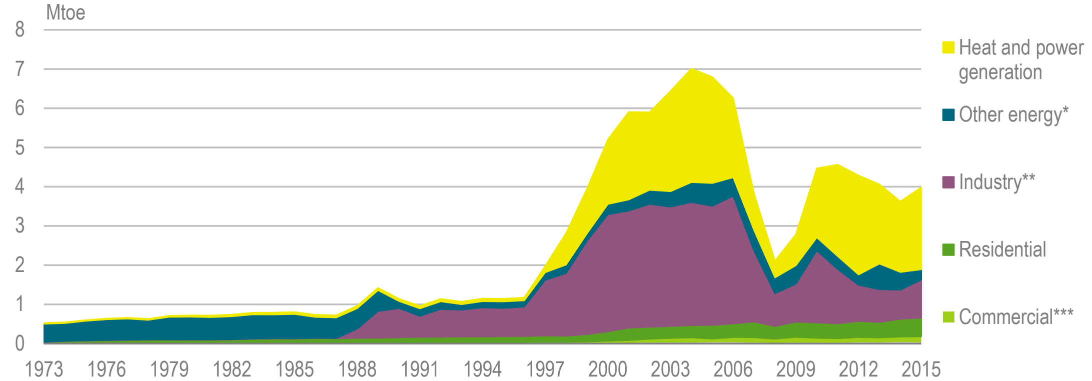
Industry was the second-largest consumer in 2015, at 24.4% of total gas demand (1 Mtoe), down from 44.7% (3.0 Mtoe) in 2005. The only sectors in which gas consumption increased in absolute terms were residential (up by 38%) and commercial (up by 63%). Both sectors more than doubled their share in total gas consumption.

Consumption patterns vary across regions. In the far north, natural gas is mainly used for power generation and is supplied via the Mejillones LNG terminal. In the central and southern regions, natural gas is consumed by both industry and households and supplied via the Quintero LNG terminal. Lastly, the far south region (Magallanes) relies on limited domestic production for power generation, residential heating and the methanol-production industry.

The total final consumption is concentrated in Santiago's Region Metropolitana, which accounted for 63% of the gas final demand in 2015. The Magallanes region represented 23% and the Valparaiso region 11% (SEC, 2017).

Gas demand peaks both in the autumn (March–May in the southern hemisphere), when hydro reservoirs are low and combined-cycle gas turbines (CCGTs) are used to fill the gap, and in winter (June–August) because of heating demands.

Figure 3.4 Natural gas consumption by sector, 1973-2015



* *Other* energy includes petroleum refineries and energy own-use.

** *Industry* includes non-energy use.

*** *Commercial* includes commercial and public services, agriculture/fishing and forestry.

Note: TPES of natural gas by consuming sector.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Institutions

The Ministry of Energy is responsible for creating and co-ordinating plans, policies and regulations for the operation and development of the energy sector, including the natural gas activities. It also grants concessions for the distribution and transport of natural gas. The ministry is also in charge of upstream contracts (CEOPs – *Contrato Especial de Operación Petrolera*), see below), but the National Energy Commission (CNE –*Comisión Nacional de Energía*), the Ministry of Finance and the Central Bank also participate regarding issues such as energy, taxes and foreign exchange, respectively. The Ministry's Energy Infrastructure Division oversees the development of energy Infrastructure, including gas infrastructure (see Chapter 5 for more details).

CNE is a technical entity in charge of analysing prices, tariffs and technical regulations for the companies that deal with energy production, power generation, transportation and distribution. Specifically, it checks the annual profitability of each gas-distribution concessionaire and is responsible for the pricing process for those gas companies whose prices are set (the relevant decree is then issued by the president). It also calculates the value of the natural gas facilities and the cost of capital rate (CCR) applicable to distributors, and reports the asset valuation for each company that participates in the natural gas market.

The Superintendent of Electricity and Fuels (SEC – *Superintendencia de Electricidad y Combustibles*) sets standards and oversees compliance with all regulation related to the production, storage, transportation and distribution of gas from the concessionary companies and distributors in general. In case of non-compliance, SEC may set fines and take over the administration of deficient services at the expense of the concessionaire. It must also prepare and publish relevant information on the energy sector.

Regulatory framework

Natural gas complements renewable energy to help the energy system perform in an efficient and clean manner, a goal included in the National Energy Policy 2050. The main policies related to natural gas include the concession of natural gas exploration and exploitation zones in the Magallanes region, a stronger role for ENAP in the upstream segment and to modify the Gas Services Law to expand the distribution networks for natural gas throughout the country.

Upstream

According to the Constitution, hydrocarbons belong to the Chilean state. By law, gas exploration and extraction can only be carried out by ENAP or by the private sector through prior administrative concessions or CEOPs[1] with the state. However, there is no specific regulation for selecting participants in exploration and production.

Mid- and downstream

The legal base for mid- and downstream gas-market regulation is provided by the Gas Services Law. The law was broadly amended in 2017 to clarify the legal framework for the distribution of gas through networks and thus encourage the expansion of natural gas at the distribution level.

ENAP and private companies may import, store, transport, distribute and market gas. These activities are subject to specific technical standards on safety and quality.

The government expects that natural gas networks will continue to be expanded throughout the country. In particular, in the centre-south region (from the Region of O'Higgins to the Region of Aysén) most large cities are struggling with air pollution from the intensive use of low-quality firewood. A switch to natural gas in heating and industrial processes is expected to help reduce the emissions of particulate matter and thus improve air quality.

[1] In practice, only CEOPs have been used to permit private-sector hydrocarbon exploration and exploitation. A CEOP is a binding agreement between the state and a private entity that allows for the exploration and exploitation of hydrocarbon deposits at the contractor's risk.

For gas supply to the regions that do not have it, satellite regasification plants (SRPs) are to be installed in large cities, as is already the case in all regions from Coquimbo to Los Lagos. These plants would be supplied with LNG from the Quintero terminal by tanker trucks, and a third LNG project is expected in Biobio by end 2019 (floating regasification). In the future, tanker trucks could also load at the Mejillones terminal.

The law allows the gas-distribution companies (concessionaries) to set their prices freely, provided that a maximum profitability limit is observed. The maximum profitability limit is the CCR plus 3%. The current level of the CCR, set by law, is 6% and therefore the profitability limit is 9%. The CNE monitors and enforces this limit through an annual profitability check.[2] The new Gas Law establishes a Panel of Experts to resolve any discrepancies related to the calculation of the CCR and the profitability check. The CCR is calculated every four years with an annual revision.[3] A temporary exception to the free setting of prices is the Magallanes Region, where prices were frozen in early 2017 and will be to around mid-2019.

Concessionaries that exceed the profitability limit are automatically transferred to a fixed-fare regime, and their consumers will be compensated. The fixed-fare contains two elements: the prices of buying and transporting the gas down to the distribution network, plus the aggregated value or the direct costs of the distribution, such as land-use rights, connection of new clients to the system and maintenance and operation of the system, all corrected by efficiency requirements.

Customer-switching procedures were introduced in 2017, under the Gas Services Act. Before 2017, such procedure did not exist, which drew complaints from customers in non-concession LPG networks (private networks), because, for example, there was no way to ensure that suppliers would comply with the LPG refilling process in a timely manner. However, customer switching in the retail market is virtually non-existent, although official figures are not available.

In September 2016, CNE issued a technical norm that requires power generators to notify the National Electricity Co-ordinator (CEN – Co-ordinador Eléctrico Nacional), the system operator, whether they have contracted LNG supply contracts, and whether these are subject to take or pay commitment, and thus considered as not flexible. Generators have to disclose all the relevant information related to both the technical and commercial conditions of their supply contracts. The norm also sets planning and cost recovery formulae and conditions. The norm was set to be introduced gradually over the first quarter of 2017 (CNE, 2016).

Industry and market structure

Upstream

The main stakeholder of the upstream industry in Chile is the state-owned ENAP, which is responsible for the exploration and exploitation of hydrocarbons, directly or through

[2] The profitability rate is calculated annually as the three-year average annual rate of profit.
[3] Before these amendments, the allowed profitability spread was five percentage points, setting the maximum profitability limit at 11%.

special contracts with private players (CEOPs). From 2007 to 2016, ENAP produced 11.8 bcm of gas, whereas CEOPs produced 3.1 bcm.

In the past decade, ENAP has explored for oil and gas in the Magallanes Region, both on its own and through CEOPs. Thanks to recent discoveries, it plans to increase its investment in unconventional hydrocarbons (tight gas). Eleven CEOPs with exploration or exploitation activities are currently operating in the Magallanes Basin, while three are abandoning or closing operations.

According to a 2016 study by the US Geological Survey, the Magallanes Basin has 8.3 trillion cubic feet of tight-gas potential.[4] In 2016, ENAP and ConocoPhillips signed a CEOP to explore the Coiron block, and are preparing for the first horizontal drilling for unconventional natural gas.

Mid- and downstream

Downstream natural gas companies can sell natural gas to large customers without a distribution concession and, as there is no wholesale market for natural gas in Chile that offers a benchmark, prices are agreed bilaterally. Three companies sell natural gas directly to large customers without a distribution concession. In addition, gas distributors Metrogas and GasValpo also deliver gas directly to large customers within the companies' networks located within their concessions.

In contrast, the transmission and distribution of natural gas requires a concession, and transmission networks must be operated under an open-access principle. Six companies provide this service in different geographic areas (Table 3.1). Service-area concessions are not exclusive, but only some cities in the Biobio and Los Lagos Regions have more than one distribution company.

Table 3.1 Natural gas distribution companies, 2016

Company	Ownership	Operation regions	Clients (Nov. 2016)
Lipigas	Consortium of local private investors (74.42%)	Antofagasta (Calama)	3 276
Metrogas	Gas Natural Chile S.A. (~52%), Copec (40%), CGE-GN (~8%)	Metropolitan (Santiago), O´Higgins (Rancagua)	443 465
GasValpo/ Energas	Australian Gas and Light Company (100%)	Coquimbo (Coquimbo, La Serena), Valparaíso (Los Andes, Valparaíso y Viña del Mar), Maule (Talca)	83 550
Gas Sur	Gas Natural Chile S.A. (100%)	Biobío (Los Ángeles, Concepción)	26 214
Intergas	Garfin Group Holding	Biobío (Chillán, Los Ángeles) and Araucanía (Temuco)	14 938
Gasco Magallanes	Gasco S.A. (100%)	Magallanes (Puerto Natales, Punta Arenas y Porvenir)	55 115

Note: CGE-CN = Compañía General de Electricidad – Gas Natural.

Source: Information provide by the Ministry of Energy.

[4] As a reference, the accumulated gas production in the basin over the past 70 years is 4.2 trillion cubic feet.

In the Magallanes Region, most gas is sold by Gasco Magallanes, which buys the gas from ENAP and then transports and distributes it to its residential, commercial and industrial customers in its own network. Likewise, ENAP distributes natural gas to rural customers using its own pipelines.

In the rest of the country, gas supply is based on LNG imports at the two LNG terminals, Mejillones and Quintero.

LNG from the Mejillones terminal is injected into the regional pipeline network and delivered to power plants in the Antofagasta Region (Figure 3.5). Additionally, some large mining customers import their own LNG through Mejillones or buy it in the secondary market from electricity or trading companies. Heating needs are generally low in the Antofagasta Region and gas is little used for that purpose. The only gas-distribution network is in the medium-sized town of Calama.

The Quintero LNG terminal serves the regions in central-south Chile, including the Metropolitan and O'Higgins Regions, which account for 71% of the residential and commercial clients in the country and 50% of the sales (in gas volume).

The Biobio Region was originally supplied from Argentina through the Gas Pacífico international pipeline, but now has a SRP in Pemuco that receives LNG from the Quintero LNG terminal delivered by trucks and it injects natural gas into the system. Under this virtual gas pipeline business model, LNG trucks also supply some industrial clients directly. Coquimbo, Talca and Temuco also benefit from this trend to expand the natural gas distribution network to areas not connected to pipelines.

The largest gas distributors in the central part of the country have supply contracts for at least ten years. GasValpo in the regions of Valparaiso and O'Higgins, and Metrogas in the Metropolitan and O'Higgins regions represented 11% and 63%, respectively, of the country's distributed gas consumption in 2015. ENAP in Magallanes accounted for another 23%. GasValpo has contracts with ENAP, and Metrogas with its affiliates. Other gas distributors must resort to importers.

As gas supply for residential customers and other customers is firm, and there are compensations for customers if the supply is interrupted, gas concessionaires benefit from incentives to sign long-term supply contracts.

Distribution networks are expanding. As of June 2017, 14 new concessions were under study. Metrogas and Lipigas are expanding gas-distribution operations to cities in the south of the country. In addition, natural gas use through SRPs is growing, both in households and in industry.

Infrastructure

Pipelines

In the early 1990s, Chile’s economic growth led to a rapid growth in electricity generation, but the decline of its coal deposits and the higher extraction costs halted plans to expand coal-fuelled technologies, which made the abundant and affordable Argentinian gas an attractive alternative for power generation and the industry sector. The signing of the gas-integration protocol with Argentina in 1995 triggered a series of international pipelines and initiated the Chilean dependence on imported natural gas. Significant investments in distribution systems, along with the acquisition of conversion machinery and equipment, were also necessary to increase the use of natural gas.

Chile's gas system is regionally disconnected. The central and northern regions are supplied through LNG imports via two LNG maritime terminals, whereas the southern region (Magallanes) relies on local production.

Gas transportation networks are owned by several entities, such as transportation companies, natural gas producers and/or distributors (see Table 3.2).

Table 3.2 National and international natural gas pipelines, 2017

Zone	Gas pipeline	Owner*	Region	Activity start	Capacity** (mcm/d)	Length (km)
North	GasAtacama (international)	Gasoducto Atacama Chile Ltda.	Antofagasta	1999	8.5	410
	Norandino (international)	Gasoducto Norandino SpA	Antofagasta	1999	7.8	1 056***
	Taltal (national)	Gasoducto Atacama Chile Ltda.	Antofagasta	2000	2.0	226
Central -south	GasAndes (international)	GasAndes S.A.	Metropolitana–Libertador Bernardo O'Higgins	1997	10.8	541***
	Electrogas (national)	Electrogas S.A.	Metropolitana–Valparaíso	1998	20.0	165
	Gas Pacífico (international)	Gas Pacífico S.A.	Biobío	1999	6.0	674.1***
	Red Innergy (national)	Innergy Holdings	Biobío	2000	9.5	114
Austral	Cóndor-Posesión (international) 2	ENAP	Magallanes	1999	2.5	9***
	Posesión - Cabo Negro (national)	ENAP	Magallanes	1987	6.3	177 (not operating)
	Posesión - Cabo Negro 2 (national)	ENAP	Magallanes	1999	7.0	177
	Dungeness – Daniel Este****	ENAP	Magallanes	1999	2.8	10.8
	Cóndor-Posesión (international)	ENAP	Magallanes	1999	2.0	9***

* In the case of international gas pipelines, the owner of the Chilean section is shown.
** Corresponds to the section of greater capacity.
*** Refers to total length, including sides and stretch abroad.
**** Gas pipeline that transports gas and does not deliver to final customers.
Notes: mcm/d = million cubic meters per day; km = kilometres.
Source: Information provided by the Ministry of Energy.

The Gas Atacama and Taltal pipelines are controlled by Enel Generacion Chile S.A. (formerly Endesa), a company involved in the electricity generation market and, until recently, partial owner of GNL Quintero (20%, now sold) and Electrogas (42.5%, now sold). It also sells LNG in the local market.

Norandino's parent company (Engie Energia Chile S.A., 100%) takes part in the electricity-generation market. In turn, its parent company (Engie Chile S.A., 53%) is the controller of the GNL Mejillones terminal (63%).

The Electrogas pipeline is partially owned by Colbun S.A. (42.5%), which participates in the electricity-generation and transmission markets. ENAP also participates (15%), which is a fuel refiner, importer and LNG distributor. It also operates in the electricity-generation market. Until recently, it also was part of Enel Generacion Chile S.A. (42.5%, now sold).

The Gas Andes pipeline is partially owned by CGE-GN S.A. (47%). It operates in the electricity-generation, transmission and distribution markets, natural gas distribution (it controls Metrogas and GasSur) and transportation (Pacifico and Innergy pipelines).

Pacifico and Innergy pipelines are controlled by CGE-GN S.A., as explained above.

In the Magallanes Region, natural gas is carried through a pipeline network of over 1400 km primarily owned by ENAP, although some minor gas pipelines that transport gas to the largest collectors are owned by the CEOPs.

LNG terminals

In 2004, Chile suffered the so-called "gas crisis". Argentina began restricting the supply of natural gas to the country, including Methanex, because of its higher domestic demand during winter. Additionally, the gas that did arrive to the country was subject to significant export taxes (compared with the price of fuel). Between 2005 and 2007, the supply to Chile was reduced to a minimum, which created a major problem both for Chilean gas-fired power plants that had scheduled their production based on Argentinian gas, and for the residential, commercial and industrial segments. To improve the co-ordination between energy-sector companies, SEC issued Order No. 754 from 2004, which created two committees in charge of prioritizing natural gas domestic supply in the case of rationing; it is no longer in operation.

After this crisis, a group of public and private Chilean companies worked together to build LNG terminals to avoid dependence on Argentina. GNL Quintero was built in the Valparaiso Region and GNL Mejillones in the Antofagasta Region (Table 7.3). Plans exist to expand both terminals.

Capacity allocation in the LNG regasification terminals is not set by law. Each terminal sets its own methodology.

The Mejillones terminal operates under an open system in which any interested party can contract regasification capacity, declaring with due notice the timeframe they will need to use the terminal. In this way, the company can prepare its Annual Delivery Programme. Before the onshore storage tank was installed, the terminal used the BW GDF SUEZ BRUSSELS as a floating storage unit. At that time, a closed or semi-closed model was used, in which only four companies had access to the terminal. The truck yard is contracted separately.

The Quintero terminal has a contract (terminal-use agreement) with GNL Chile S.A. for 100% of its current and future unloading, storage and regasification capacity, at least up to 20 mcm/day. The shareholders of GNL Chile are ENAP, Aprovisionadora Global de Energia S.A. and Enel Generacion Chile S.A. (one-third each). Initially, each of these three companies owned 20% of GNL Quintero S.A.[5] Metrogas and Aprovisionadora Global de Energia have the same shareholders – Gas Natural Chile (51.84%), Empresas Copec (29.83%) and Gas Natural Fenosa (8.33%). Gas Natural Chile is controlled by Gas Natural Fenosa.

To assign the terminal's capacity, GNL Chile signs natural gas delivery contracts (gas-sale agreements) with non-partner third parties through open-season processes. Any third party interested in contracting natural gas supply must be awarded the capacity in open-season processes or purchase natural gas from those who have contracts.

Table 3.3 LNG terminals in Chile, 2017

Name	Region	Owners	Dock	Storage	Regasification	Truck loading
GNL Mejillones	Antofa-gasta	Engie Chile S.A. (63%), Codelco S.A. (37%)	Unloading 10 000 m^3 LNG/h	175 000 m^3 LNG (1 × 175 000 m^3)	Up to 5.5 mcm/day LNG (2 × 2.75 mcm) Backup 2.75 mcm/d	Four daily trucks: 88 tonne LNG/d (around 200 m^3 LNG/d)
GNL Quintero	Valpa-raíso	Terminal de Valparaíso (Enagás, 40%; OMERS, 29.6%; ENAP, 20%) Terminal Bahía de Quintero (10.4%)	Unloading 12 000 m^3 LNG/h Ships of up to 265 000 m^3 LNG	334 000 m^3 LNG (2 × 160 000 × m^3 +1 × 14 000 m^3)	Up to 15 mcm/d LNG (3 × 5 mcm/d) . Backup 5 mcm/d	2 500 m^3/d (50 trucks × 50 m^3/d)

Note: Terminal Bahía de Quintero is owned by Enagás (51.9%) and OMERS (48.1%).

Source: Ministry of Energy, gnlquintero.cl.

There are two projects for floating storage regasification units (FSRU) LNG terminals in the Biobio region under development, and a significant number of requests for distribution concessions in major cities, while the appearance of SRP has allowed the creation of trading companies that buy LNG from third parties and then sell it to their own customers. One of the FSRUs, Penco-Lirquén LNG Terminal, is currently under environmental assessment. The second FRSU project, Talcahuano LNG Terminal, obtained its environmental approval in 2017.

[5] Initially, GNL Quintero S.A. was owned by BG Group (40%), Metrogas S.A. (20%), Endesa Chile S.A. (part of Enel) (20%) and ENAP S.A. (20%). Metrogas and Endesa Chile sold their shares to Enagas, and the BG Group sold its share to Terminal of Valparaiso S.A. Thus, GNL Chile partners are the three original owners of GNL Quintero S.A. with operations in Chile (BG Group also sold the fuel).

Figure 3.5 Natural gas infrastructure, 2017

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Storage

Chile does not have specific natural gas storage facilities, partly because stand-alone gas-storage facilities could face safety risks because of the country's geology and seismicity. Therefore, the two LNG terminals (Mejillones and Quintero) are the only storage sites, with 509 000 m^3 of LNG storage capacity.

There is no obligation to provide open access to storage to third parties. Total LPG storage capacity in the country is almost 350 000 m^3, including all sizes of storage tanks. Of that capacity, 135 000 m^3 is located in large tanks in maritime LPG terminals, and in some cases is destined, through contracts, as backup for natural gas companies in case of disruptions to the natural gas supply chain.

Prices

In 2016, the average price of natural gas for households in Chile was 83.89 United States dollars (USD) per megawatt hour (MWh), the sixth highest in comparison with International Energy Agency (IEA) member countries, and 16% of the price was tax. Prices have historically varied significantly (Figure 3.6). They were generally lower before 2004, when Chile imported Argentinean pipeline gas, and peaked in 2008 when the supply from Argentina had practically ceased. A second peak came in 2011 at 137.87 USD/MWh when both national gas demand and global oil and gas prices were increasing. Since then, the price has been decreasing as global oil and gas prices have fallen.

Prices in Chile also differ from the prices in other countries that use only or mostly LNG, such as Japan and Korea (Figure 3.7), as LNG pricing varies across countries and companies. For example, in Japan oil-indexed long-term contracts are dominant, whereas Chile relies more on the spot market and uses the Henry Hub and Brent crude prices as the benchmarks, depending on the contract.

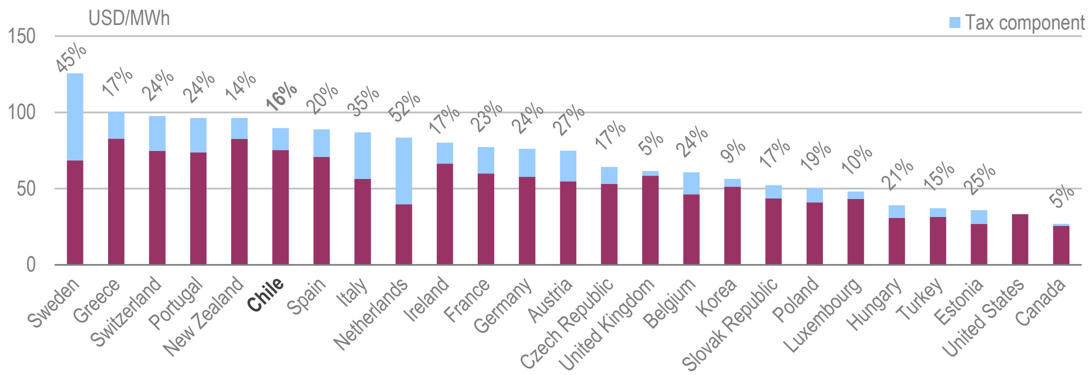
In more detail, at GNL Quintero, Metrogas and ENAP have long-term contracts, which include minimum fixed amounts to be hired (take or pay) and the possibility of taking additional vessels, if needed. In contrast, GNL Mejillones sources supply mostly from the spot markets, because the firm demand is low in the region. The main LNG claimants (Engie and ENEL) have the flexibility to contract supply with their parent/related companies or divert vessels from the contract supplied by GNL Quintero.

Gas production is not subsidised in Chile. For heating, in certain regions, some lower-income households are granted technology-neutral lump-sum payments (heating bonuses) for any type of heating in autumn and winter.

In the Magallanes Region, however, prices for all households are subsidised. This is the result of a decision not to raise household prices as the region has become reliant on more-expensive unconventional gas for the supply. The price the gas-distribution concessionaire pays to the gas producer ENAP covers, on average, 25% of the production cost.[6] The Ministry of Energy pays ENAP the difference between the production costs and the sales price from the state budget.

In 2017, the compensation, i.e. subsidy cost, amounted to CLP 66.7 billion, or around USD 107 million (at the rate of 19 October 2017), around USD 1945 per customer (households, industry, commercial and power generation). In addition, around 3000 low-income households received additional direct subsidies of CLP 108 000 (USD 172) per household per year from the Ministry of the Interior. Around 10 200 low- and medium-income families that do not receive this subsidy have, since 2011, received another direct subsidy of CLP 751/month (CLP 9012 or USD 14.4 per year), which represents 3% of their bills, according to the government.

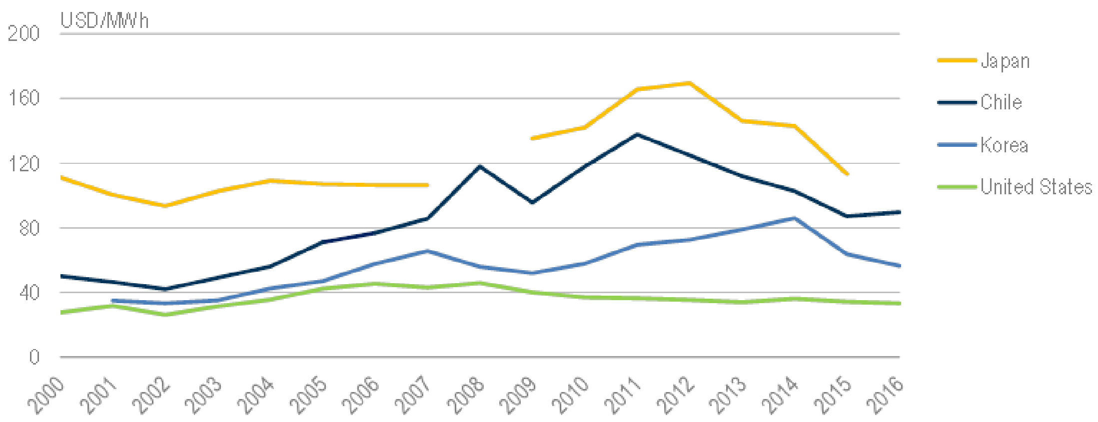
Figure 3.6 Natural gas prices for households in Chile and IEA member countries, 2016



Note: Data are estimated. Data are not available for Australia, Denmark, Finland, Japan and Norway. Tax data not available for the United States.

Source: IEA (2017c), *Energy Prices and Taxes 2017*, http://dx.doi.org/10.1787/energy_tax-v2017-2-en.

Figure 3.7 Natural gas prices for households in Chile and selected IEA member countries, 2000-16



Note: Data are estimated for 2016. Data are not available for Japan in 2008 and 2016.

Source: IEA (2017c), *Energy Prices and Taxes 2017*, http://dx.doi.org/10.1787/energy_tax-v2017-2-en.

[6] The average price in January 2017 was CLP 50.7/m^3 and the estimated cost CLP 204.2/m^3.

Security of supply

Chile does not have an explicit policy to diversify LNG supply, neither in terms of routes nor supplying countries. However, the expansion of the Panama Canal has reduced the transit time from the Gulf Coast in the United States and Trinidad and Tobago. Each company is responsible for its own supply and diversification policies.

Regarding upstream, Magallanes has winter programmes for access to the facilities, given the extreme weather conditions, which include the preparation of roads and rescheduling activities. In addition, efforts have been devoted to increasing exploration and reservoirs, initially by ENAP on its own and later by ENAP through CEOPs, and the focus is now on unconventional natural gas.

Natural gas distributors distinguish between interruptible and firm (uninterruptible) contracts. The uninterruptible category includes residential and commercial customers, as well as hospitals and other strategic customers. In contrast, for industry and power generators, some level of interruptibility is implicit or explicit in the contracts.

The Gas Services Law and its regulations stipulate that, by default, distributors must provide to their customers an uninterruptible gas supply, unless the gas distributor company and a large customer (with monthly consumption greater than 100 gigajoules) agree an interruptible supply service. In case of force majeure, the distributor must start by cutting the service to the large interruptible customers, then to the large non-interruptible customers and finally to the rest of the non-interruptible customers.

As a market consequence of the Argentinian gas crisis, it is common for the gas distributors to include contract clauses with the large industrial customers that allow them to interrupt the delivery of natural gas in case of a lack of supply. This includes the power generators that are supplied from the gas concessionaires of the distribution network.

During the gas crisis with Argentina in 2004, SEC mandated the gas industry to inform the government and work together to manage the shortage situation. Today, this request is not in force, as the emergency was overcome by installing LNG regasification terminals.

The Argentine gas crisis also triggered distributors in Chile to install diluted propane backup plants. Propane's combustion characteristics are similar to those of natural gas and it can be injected into the natural gas pipelines under certain technical and safety conditions.

Also, by law, natural gas exports may be prohibited, limited or suspended to ensure domestic supply.

Assessment

For the past five years, the share of natural gas in TPES (12% in 2016), net imports (4.0 bcm), final consumption (1.6 Mtoe) and the share in electricity generation have remained relatively constant. The new Gas Services Law and ENAP's enhanced role in the sector appear to be good efforts to boost the relevance of natural gas in energy supply and its role in the integration of variable renewable energy (VRE).

Energy crisis

The cut in the gas supplies and the drought that affected the hydropower generation in the second half of the 2000s had a significant impact on electricity prices and energy costs in general, because Chile had to use "air LPG" as a substitute for natural gas in the residential and commercial sectors and to build many diesel plants rapidly to replace gas-fired generation within one year. LNG terminals were built quickly in Quintero and Mejillones, which enabled the diversification of natural gas imports, provided for gas storage and improved the security of supply.

Indigenous gas

Domestic gas production is concentrated in the south of the country, in the Magallanes Region. The region is far from the major consumption centre of central Chile, and domestic gas is consumed locally.[7] Around 55 000 gas customers are connected to the regional grid. Production costs in Magallanes have increased, but end-user prices have not been raised correspondingly. The gas producer ENAP is paid at a level of around 25% of the costs (production costs or cost of buying from third parties).[8] ENAP receives an annual government subsidy of around USD 100 million as compensation. In 2017, this is roughly USD 1950 per customer, which appears very high. In addition, smaller subsidies are granted to low-income families. This money from the government budget would be better spent on the energy efficiency of buildings and possibly on other clean heating technologies.

Infrastructure

The pipeline infrastructure was designed to import gas from Argentina (from east to west) by dedicated private pipeline companies. As gas exports from Argentina are no longer available and gas is imported through LNG terminals in the west, the same pipelines are now used to transport gas in the opposite direction, with some exports to Argentina through two pipelines in 2016 (361 mcm) and continued through one pipeline in 2017. The gas-pipeline network does not reach all the regions in Chile and, as a consequence, some regions are now supplied by LNG trucks and SRPs. However, to create new pipelines and connections, and thereby develop new markets for gas use, is hindered by permitting procedures and negotiations with local authorities that prevent or delay the construction of new pipeline infrastructure.

Natural gas market conditions

The use of natural gas in residential heating could open a new market for natural gas, and help to reduce the massive use of low-quality firewood in seriously polluted cities. Some low-income households in certain regions are granted a lump-sum subsidy for heating, which is often used for firewood; such subsidies could be used to encourage the use of cleaner fuels, better cooking and heating equipment, and better insulation.

The development of new applications for gas is hindered by the absence of infrastructure and a lack of a liquid-gas wholesale market. The gas market is dominated by four

[7] The distance between Punta Arenas and Santiago de Chile is more than 3000 km and all the major roads and pipelines pass through Argentina.
[8] The average price in January 2017 was CLP$50.7/$m^3$ and the estimated cost was CLP$204.2/$m^3$.

suppliers that have access to the LNG terminals, and their gas is mostly sold via long-term (10 to 20 years) bilateral contracts with industry or distribution companies, which, in several cases, are vertically integrated. In contrast, gas contracts with power plants tend to be of short duration (1 or 2 years) and are usually based on the expected hydrology conditions that affect the availability of hydropower.

The lack of a liquid-gas market also hinders the development of gas trade with Argentina that could well use Argentinian gas in the Biobio region in exchange for Chilean gas in the central and northern regions. The government should assess the potential benefits of a closer gas market integration with Argentina. In a welcome development, swap exchanges between Chile and Argentina have already started.

In addition, under the current market design, the integration of VRE needs flexible generation technologies that depend on short-term fuel contracts that are expensive and hard to obtain. So far, VRE is mainly present in the Central Interconnected System (SIC – *Sistema Interconectado Central*) electricity system, where hydro has a major share, and coal, fuel oil and gas provide some flexibility. The SIC–SING (*Sistema Interconectado del Norte Grande*) interconnection would enable a connection with additional thermal capacity from the north.

Price and regulation

Gas distribution is not separated from gas supply, and six gas-distribution companies in Chile own a distribution grid and supply the commodity. In theory, more than one distribution company can have a distribution network in a city, which could result in direct competition. In practice, this rarely happens, as it is inefficient to duplicate networks.

Gas prices for consumers are indirectly regulated through capping the return on assets of the distribution companies to 9% (capital cost rate + three percentage points of margin). The retail gas price contains the distribution tariff and the price for the commodity. The costs of making a connection to a residential dwelling are considered an operational expenditure of the distribution companies and can be amortised as part of the asset base of the distribution company for ten years. The government should monitor whether this rule reduces the appetite for investment in new connections. At the moment, several new concessions have been solicited and recently approved, and companies are also investing in new grids, for example, in the south of the country.

Recommendations

The government of Chile should:

- ☐ Examine options for a liquid wholesale spot market for natural gas, and facilitate its creation.
- ☐ Facilitate the development of transport capacity in the central regions through effective permitting processes, to support the role of gas as a backup fuel for VRE and facilitate its role in replacing unsustainable firewood in urban residential heating.

- Work to restructure and eventually phase out indirect subsidies for gas use in the Magallanes region; in particular, consider ways to promote more–efficient energy use for heating.
- Assess the potential benefits of a closer gas-market integration with Argentina.

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4. Coal

Key data

(2016 provisional)

Coal production: 2.53 Mt (hard coal)

Coal imports and exports: 11.43 Mt imported, 0.87 Mt exported (hard coal)

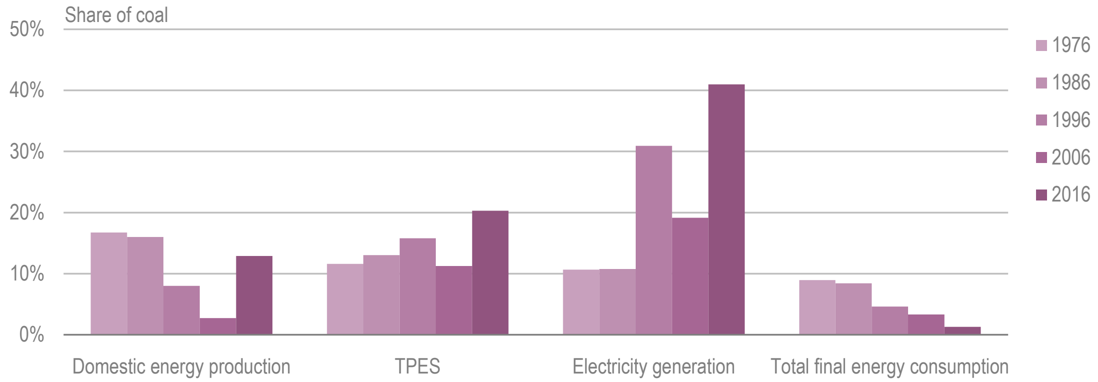
Share of coal: 20% of TPES and 41% of electricity generation

Consumption by sector (2015): 7.17 Mtoe (power and heat generation 91.7%, industry 4.5%, other energy 3.7%, commercial 0.1%)[1]

Overview

Coal has been an important energy source in Chile for decades. The share of coal in total primary energy supply (TPES) increased from 11% in 2006 to 20% in 2016. Despite a rapid growth in indigenous coal production with the operation of a new coal mine in the Magallanes region, imported coal still accounts for roughly four-fifths of total coal supply. Most of the coal supply is hard coal (anthracite and bituminous coal).

Figure 4.1 Coal's share in different energy supplies in Chile, 1976-2016



Notes: Latest consumption data are for 2015. Data are provisional for 2016.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

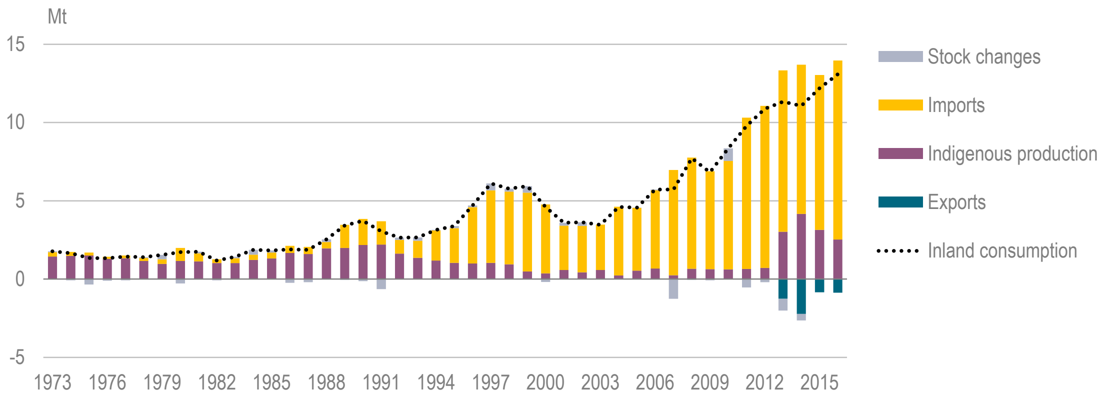
[1] *Other energy* covers the use of energy by transformation industries and the energy losses in converting primary energy into a form that can be used in the final consuming sectors. It includes losses by gas works, petroleum refineries, coal and gas transformation and liquefaction. It also includes energy used in coal mines, in oil and gas extraction and in electricity and heat.

Coal has long been a major source of energy in Chile's electricity generation and, since 2012, is now the largest one. Over 90% of coal is used in power generation; the rest is mainly consumed in iron and steel production. In contrast to coal power generation, coal consumption in other sectors has been declining since 2000.

Supply

In 2016, Chile produced 2.5 Mt of hard coal, accounting for 19% of its total coal supply (Figure 4.2). The opening of the Mina Invierno mine in the Magallanes region in 2013 increased domestic coal production more than fourfold. However, coal demand continues to be met mostly through imports (11.4 Mt). Chilean coal is typically sub-bituminous and mixed with imported coal of higher calorific value.[2]

Figure 4.2 Coal supply by source, 1973-2016



Note: Data are provisional for 2016.
Source: IEA (2017b), *Coal Information 2017* (database), www.iea.org/statistics/relateddatabases/coalinformation/.

Chile has around 1.2 billion tonnes (bt) of coal reserves, mostly in the south, and around 4.1 bt of coal resources (BGR, 2016). The largest reserves are on the island of Isla Riesco which also hosts the Mina Invierno. Several mines are being planned on the island.

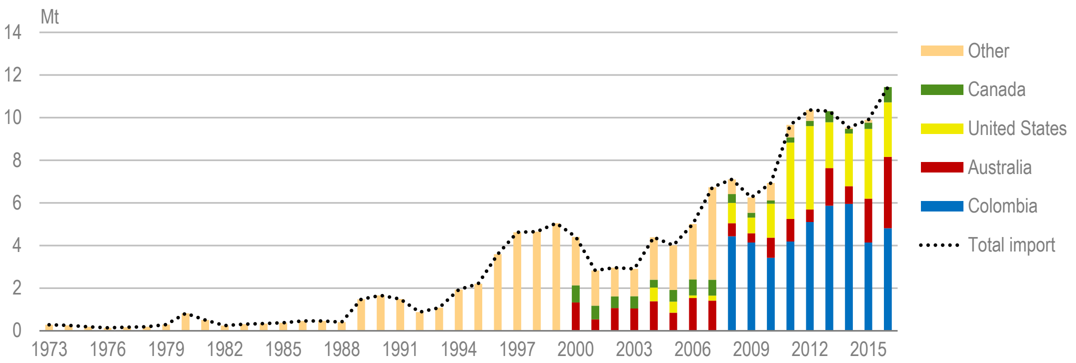
In 2016, net imports of hard coal totalled 10.6 Mt, or more than twice the 2006 level. Colombia was the largest source of imports (42% of the total), followed by Australia (29%) and the United States (22%) (Figure 4.3). Imports are delivered directly to ports close to the power plants.

In total, Chile's coal supply increased by 129% in a decade, from 5.7 Mt in 2006 to 13.1 Mt in 2016. Accordingly, coal's share in TPES nearly doubled from 11% in 2006 to 20% in 2016. This growth is related to the sharp reduction in gas imports, which heavily increased Chile's reliance on other fossil fuels to meet the electricity demand.

[2] Chilean sub-bituminous coal has a net calorific value of around 4 000 kilocalories per kilogram (kcal/kg), and a sulphur content of 0.4%. In contrast, imported bituminous coal from Colombia contains more energy (5 750 kcal/kg to 6 000 kcal/kg), but also more sulphur.

As coal production grew at a faster rate than coal imports, Chile's self-sufficiency in coal supply, measured as the ratio between domestic production and total supply (TPES), improved from 11.8% in 2006 to 19.3% in 2016. In addition, Chile began exporting coal for the first time in 2013, mostly to India.

Figure 4.3 Coal imports by country, 1973-2016



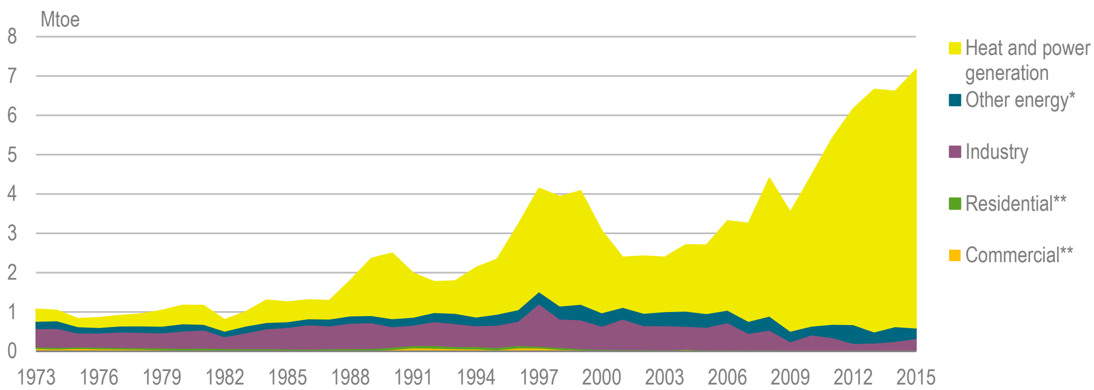
Note: Data are provisional for 2016.

Source: IEA (2017b), *Coal Information 2017* (database), www.iea.org/statistics/relateddatabases/coalinformation/.

Demand

In 2015, Chile consumed 7.2 Mtoe of coal, 165% more than the 2.7 Mtoe consumed in 2005 (Figure 4.4). Electricity generation was the largest consuming sector, at 91.7% of the total. Coal consumption in power generation increased almost fourfold from 1.7 Mtoe in 2005 to 6.6 Mtoe in 2015. Coal's importance in electricity generation grew as it became an affordable substitute for oil and helped to substitute natural gas after Argentina's curtailment of gas exports from 2004 on.

Figure 4.4 Coal consumption by sector, 1982-2015



* *Other* energy includes coke ovens.

** Negligible.

Note: TPES of coal by consuming sector.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

As a result, coal became the largest source for power generation in 2012, matching the growth in electricity demand from the second half of the 2000s.[3] Consequently, its share in power generation increased from 13.7% in 2005 to 37.1% in 2015 and further to 41% in 2016.

Coal was also consumed in industry (4.5% of the total), coke ovens (3.7%) and the commercial sector (0.1%). Coal consumption declined in these three sectors over the past decade, which reinforces the power sector's dominance in coal demand.

Coal-fired power generation

The first large coal-fired power plant in Chile, the 120 megawatt (MW) Ventanas plant in Valparaíso, started in 1964 (a much smaller Laguna Verde plant had been commissioned in 1939). By 1977, three power plants with a combined capacity of 470 MW were generating 10.8% of the total power output. For the next two decades, Chile's electricity production relied on hydropower, and it was only in 1995, when new coal-fired power capacity (four plants, 629 MW in total) was installed.

In 2016, coal-fired power plants accounted for 44% of the 74 terawatt hour (TWh) generated in the two main interconnected systems (the Central Interconnected System SIC – *Sistema Interconectado Central*] and the Greater Northern Interconnected System (SING – *Sistema Interconectado del Norte Grande*). Specifically, coal provided 32% of the electricity in the SIC and 79% in SING. Regarding generation capacity, coal-fired power plants accounted for 14% of the 16.8 gigawatts (GW) in the SIC and 48% of the 5 GW in the SING system.

Chile's coal power plants are relatively new, 35% (1 676 MW) of the installed capacity is at most five years old, and 10% (470 MW) are between 40 and 53 years old.

Chile has 28 coal-fired units, located mainly along the coast, that provide baseload power to the country. They are fitted with subcritical technology with a relatively low average thermal efficiency of less than 36%. The exception is Colbún's Santa María (2012), a 350 MW pulverised coal combustion plant with a maximum thermal efficiency of 41%.

From 2008 to 2012, coal had the highest annual capacity factor for electricity generation in Chile (> 65%). This is important because flexibility in the dispatchable generation is essential to the integration of variable renewable technologies and the coal fleet is the least flexible in the Chilean power sector.[4] Coal plants have the highest warm start-up times, the lowest upward ramp rate, the highest minimum stable output and the highest start-up cost (see Box 4.1).

[3] From 2005 to 2015, electricity demand grew by 18.6 TWh, while coal-fired electricity output grew by 20.8 TWh.
[4] Flexibility depends on three main factors: adjustability (minimum stable output), ramping and start-up time.

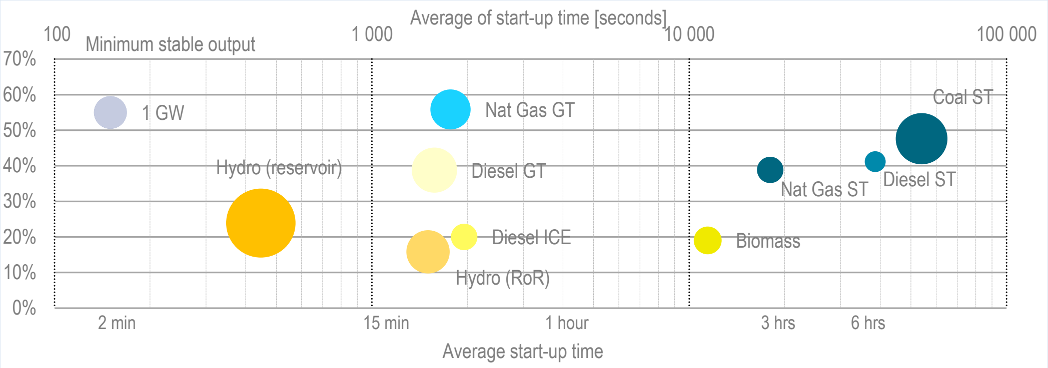
Box 4.1 Power system flexibility in Chile's main power grids, SIC and SING

Most power generation in Chile is dispatchable, i.e. from power plants that can adjust their output and provide system-support services at the request of system operators.

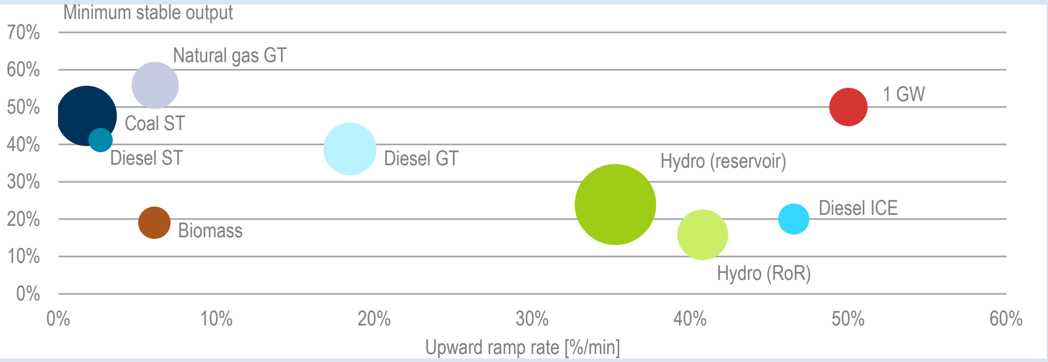
In the SIC system, coal plants represent 17% of the dispatchable capacity and have an average capacity factor of 75%, a minimum stable output below 50%, a 15 hours (hr) average warm start-up time[5] and an upward ramp rate[6] of around 2% per minute. The dispatchable generation fleet of the SING system is by far dominated by coal power plants (69%) with an average start-up time of around 13 hr, a minimum stable output closer to 60% and an upward ramp rate similar to SIC's. The relatively inflexible generation from coal (Figure 4.5) is a challenge to introducing variable resources in the SING system.

Figure 4.5 Minimum stable output as percentage of capacity in SIC, 2015

Minimum stable output as a percentage of the nameplate capacity, warm start-up times and capacity for selected technologies, 2015



Minimum stable output as a percentage of the nameplate capacity, upward ramp rate as a percentage of rated capacity per minute and capacity for selected technologies, 2015



Notes: ST = steam turbine, GT = gas turbine, ICE = internal combustion engine, RoR = run of river, Nat = natural.

[5] Start-up time can be defined based on the time interval of the previous stop/stand-by condition. There are generally three start-up conditions: cold (when the power plant is reactivated after a long period of stop, over 48 hr for a coal plant), warm (8 hr to 48 hr in stand-by conditions) and hot (less than 8 hr in stand-by conditions).

[6] Ramping is defined as the speed at which output levels can be changed.

> When the interconnection of the SIC and SING becomes available, this will likely be a challenge for the whole interconnected system. However, recent Chilean studies (e.g. *Mesa ERNC* (Ministry of Energy/GIZ, 2015) indicate that the interconnected SIC–SING electricity system will be able to hold, without an increase in overall system cost, up to 30% variable renewable generation (photovoltaics and wind).
>
> *Source: IEA (2017c), The Prospects of Large-Scale Integration of Variable Renewable Energy in Chile.*

Assessment

In 2016, coal provided one-fifth of primary energy supply in Chile, roughly the same as biomass. Power generation consumes around 92% of all coal, and it also accounts for around one-third of the country's carbon dioxide (CO_2) emissions. Around four-fifths of the coal is imported. The use and production of coal are private-sector activities and not subsidised. As several plans exist for new coal mines, the government should ensure that safety, environmental and post-closure issues are adequately considered.

Power generation

Coal is a key component in Chile's energy security strategy. In particular, after the natural gas shortage of the mid-2000s, the increasing coal use for power generation helped to maintain the security of electricity supply and limit the use of expensive diesel as an emergency fuel. Furthermore, coal remains essential for the long-term energy policy. Unabated coal-fired power plants are still being added, namely, two plants (Cochrane I and II, 532 MW in total) started to operate in 2016, and the 375 MW Mejillones II plant is expected to be operational by 2018. However, no plans for new coal plants beyond these exist.

Chile does not regulate the lifetime of its coal power plants, but significant changes are needed to meet the National Energy Policy 2050 goals. Almost half of the coal-fired power plants (37% by installed capacity) will be at least 30 years old by 2020. As thermal power plants approach their decommissioning date, plant owners may face the decision to retrofit or retire the plant.

The planned presence of larger shares of variable generation will force those plants designed for baseload generation into a cycling mid-merit and peaking application (IEA, 2017c).[7] Efforts should be made to increase the flexibility of coal-fired power plants to make them more compatible with the renewable-energy-deployment goals.

Also, generation from subcritical coal-fired power plants should be gradually limited and ultimately phased out and replaced with the best-available technology. To the extent possible, new coal-fired power units, when built, should be encouraged to add flexibility to the power grid to balance electricity supply and demand, and support the integration of variable renewable energy (VRE) into the system.

[7] SING's demand is very flat; therefore, the majority of its power plants are dispatched for more than 75% of the year.

Emissions targets

Despite the security of supply and affordability benefits of coal, increasing its use may not be consistent with the government climate policy objective to reduce the CO_2 intensity of GDP by 30% from the 2007 levels unconditionally by 2030 (the National Determined Contribution [NDC]) and the National Energy Policy targets to meet 60% of national electricity generation with renewable energy by 2035 and 70% by 2050.

However, there seems to be no direct effective policies and measures to limit the increasing coal-fired power generation capacity. This can be understood from the security-of-supply perspective and Chile's experience with a gas crisis and drought in the previous decade. The LNG terminals have, however, improved the gas security. Yet, there are the Non-Conventional Renewable Energy Law targets (20% to 2025) and the emissions taxes (for local pollutants and for CO_2). Also, Chile does not have any specific programmes to promote clean coal technologies in electricity generation, with the exception of the national emission standards for thermoelectric power plants.

To ensure that coal use is compatible with the renewable energy and climate targets, the government should consider introducing higher CO_2 taxes or CO_2-intensity limits for power generation. A first step in that direction was the September 2014 green-tax regulation to limit emissions of CO_2, sulphur dioxide, nitrogen oxides and particulate matter from thermal power generation (from 2017 on).

Recommendations

The government of Chile should:

- Ensure that coal mining addresses safety, environmental and post-closure issues.
- Ensure coal use is consistent with Chile's NDC and renewable electricity targets.
- Ensure coal-fired power generation adds security and flexibility to the power grid, to support the integration of VRE sources.

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5. Electricity

Key data
(2016 Provisional)

Total electricity generation: 78 TWh, 42% since 2006

Electricity generation mix: coal 41.0%, hydro 25.0%, natural gas 16.1%, biofuels and waste 7.9%, oil 3.8%, wind 2.9%, solar 3.3%

Installed capacity (2017)*: 23.5 GW

Electricity consumption (2015): Industry 62.6%, commercial 17.6%, residential 17.4%, transport 1.4%, other energy 1.0%

** Source: National Energy Commission, November 2017.*

Overview

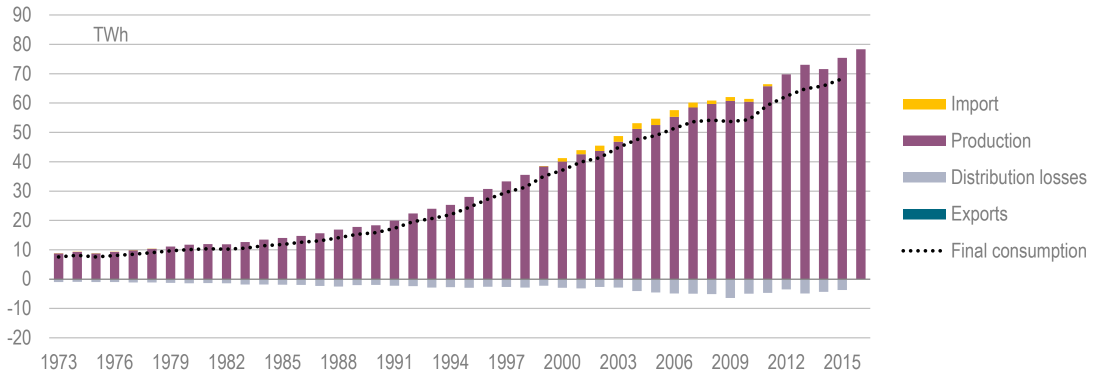
Electricity demand is increasing fast, along with economic growth, and is expected to keep growing rapidly. Under the business-as-usual (BAU) scenario, demand would more than double by 2050. At the same time, Chile aims to meet a growing share of electricity from renewable sources. The country has vast resources of solar energy and also abundant untapped potential for wind, hydro and geothermal (Chapter 9).

The rapidly declining technology costs and improvements in Chile's energy auction system are strongly increasing the competitiveness of renewable energy, and the government does not have to directly subsidise it. During the past decade, Chile's electricity regulation has been reformed to increase the flexibility and diversity of energy supply. Recently, the government has introduced several laws and policies to encourage much-needed investment, mostly in transmission infrastructure, but also in generating capacity.

Supply and demand

Chile remains an electricity island, with only one cross-border connection. Practically all of its electricity has to be generated in the country. Electricity demand has grown rapidly with the strong economic growth. From 2006 to 2016, electricity generation increased on average by 3.3% per year to reach a record of 78 terawatt hours (TWh) (Figure 5.1).

Figure 5.1 Electricity gross generation and final consumption, 1973-2016



Notes: The latest available consumption data are from 2015. Data are estimated for 2016.
Source: IEA (2017a), *Electricity Information 2017*, http://dx.doi.org/10.1787/electricity-2017-en.

Generation

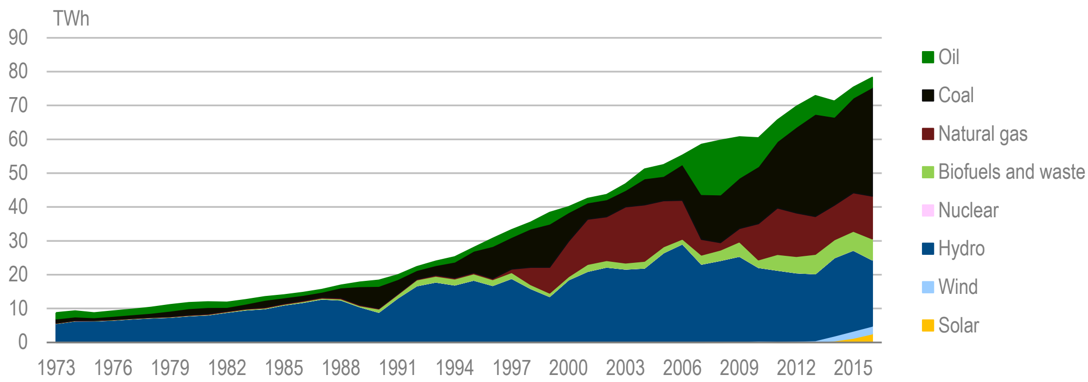
Over the past decade, the energy mix of Chile's power generation has changed remarkably (Figure 5.2). In 2004-07, Argentina, the sole natural gas supplier to Chile then, faced an energy crisis and restricted its gas exports. Consequently, the natural gas supply in Chile decreased significantly in 2007 and its share in electricity generation dropped by 60%. To make things worse, Chile had a drought in 2007-08 in the central-south region, which reduced hydropower supply by 20%, or 6 TWh.

As a short-term remedy, oil was largely used to fill the gap left by gas. Oil-fired generation increased more than fivefold from 2006 to 2007. Later, oil was replaced by a combination of coal-fired generation and, after the commissioning of the two liquefied natural gas regasification plants, natural gas from other countries. CO_2 emissions from power generation increased by 77% from 2003 to 2008.

These acute scarcity episodes shaped the performance of and investments in Chile's electricity sector in the subsequent years. For instance, the share of coal in power generation rose from 10% in 2003 to 24% in 2008/09. Coal has continued to grow quickly. In 2016, it was the largest source of power generation, accounting for 41.0% of the total of 78 TWh, followed by hydro (25.0%) and natural gas (16.1%). Biofuels and waste accounted for 7.9% of the total and oil for 3.8%. Wind and solar power will grow rapidly, but in 2016 their shares in total power generation were still rather low, 2.9% for wind and 3.3% for solar.

In comparison with International Energy Agency (IEA) member countries, Chile's share of fossil fuels in electricity generation (61%) was the twelfth highest in 2016, just above the mean (58%), between Italy and the Czech Republic, with the fifth-highest share of oil and seventh-highest share of coal and hydro (Figure 5.3).

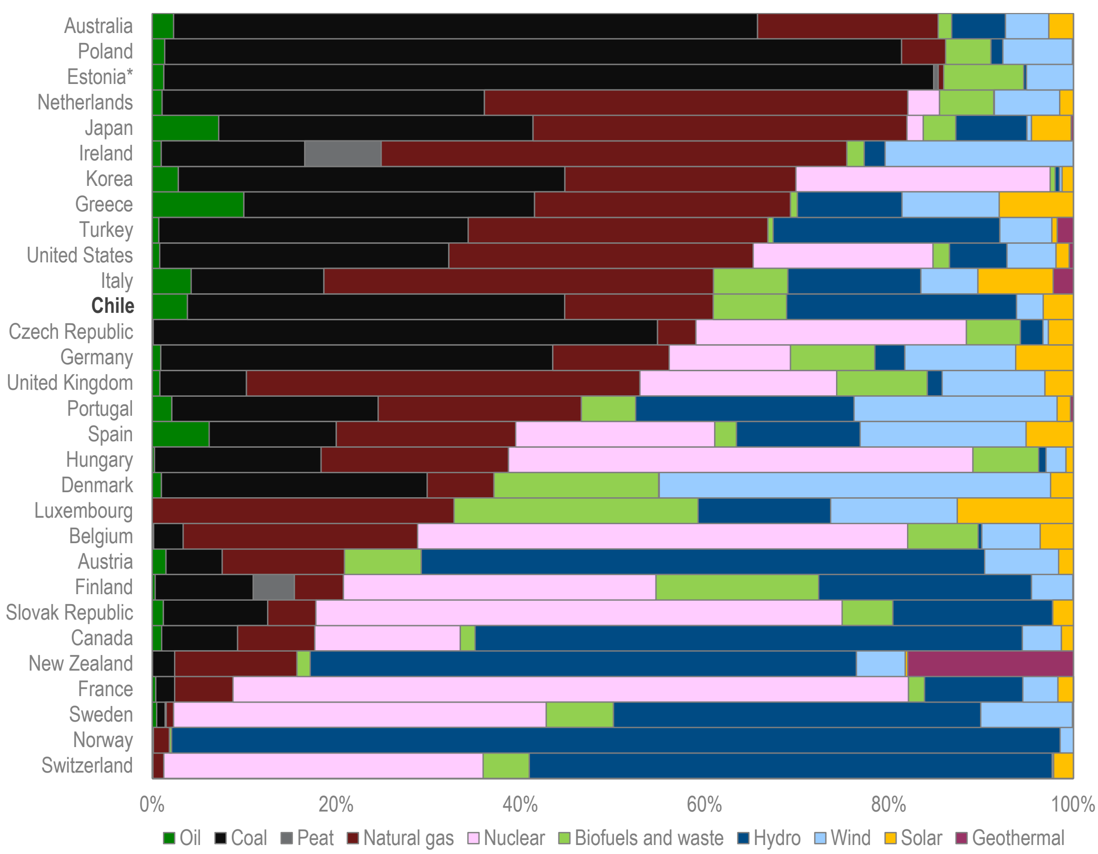
Figure 5.2 Electricity generation by source, 1973-2016



Note: Data are estimated for 2016.

Source: IEA (2017b), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Figure 5.3 Breakdown of electricity generation by source in Chile and IEA member countries, 2016



* Estonia's coal represents oil shale.

Note: Data are estimated for 2016.

Source: IEA (2017b), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Generating capacity

At the end of 2015, Chile had an installed generating capacity of around 21 600 megawatts (MW), up by 85% from 2005 (Table 5.1). At the end of 2016, the total had increased to around 22 500 MW. The National Energy Commission (CNE –

Comisión Nacional de Energía), the regulator, expects this to increase to around 24 000 MW by 2018 and peak demand to rise to 11 000 MW.

Combustible fuels accounted for 62.9% of the installed capacity, an increase of eight percentage points from 2005. In contrast, hydro has lost ground and its share shrank from 41.5% in 2005 to 30% in 2015.

Over the past few years, wind and, especially, solar have emerged as market-competitive technologies and their share in electricity supply is significantly higher than what is required under the renewable electricity quota obligation system (Chapter 8). Their increase is set to continue, thanks to huge resources, better grid connections, more efficient technology and successful public policies. As of December 2017, environmental impact assessments had been approved for more than 29 GW of non-conventional renewable energy (NCRE)[1] capacity, most of which is solar, and were being evaluated for another 4.3 GW.

Generating capacity by system area is discussed in the Industry and infrastructure section below.

Table 5.1 Electricity capacity in Chile, 1990-2018 (MW)

Energy source	1990	2000	2005	2010	2015	2018*
Coal and coal products	481	629	629	871	2 264	4 859
Natural gas	24	72	480	619	740	3 733
Liquid fuels, including refinery gas	416	561	706	2 840	3 353	3 762
Other combustible fuels	0	22	36	526	826	
Liquid/gas	0	2 369	3 194	4 061	4 208	
Solid/liquid	411	1 300	1 378	1 659	2 225	
Total combustible fuels**	2 421	5 464	7 360	10 576	13 616	12 354
Hydro	2 678	4430	5 224	5 467	6 498	7 097
Wind	0	0	2	163	908	1 333
Solar PV	0	0	0	0	617	2 789
Other sources	0	0	0	25	0	516
Total capacity	**5 099**	**9 894**	**12 586**	**16 231**	**21 639**	**24 089**

* Estimated by the NCE.

** Total combustible fuels is not equal to the sum of the electricity capacity by combustible fuels because of limited data availability.

Source: IEA (2016a), *Electricity Information 2016*, http://dx.doi.org/10.1787/electricity-2016-en.

Imports and exports

Cross-border trade in electricity is low in volume. It is carried out through the Andes-Salta line that connects the Antofagasta Region and the Interconnection System of Argentina (SADI). In 2016, exports from Chile amounted to 102.3 GWh and imports to 1.6 GWh.

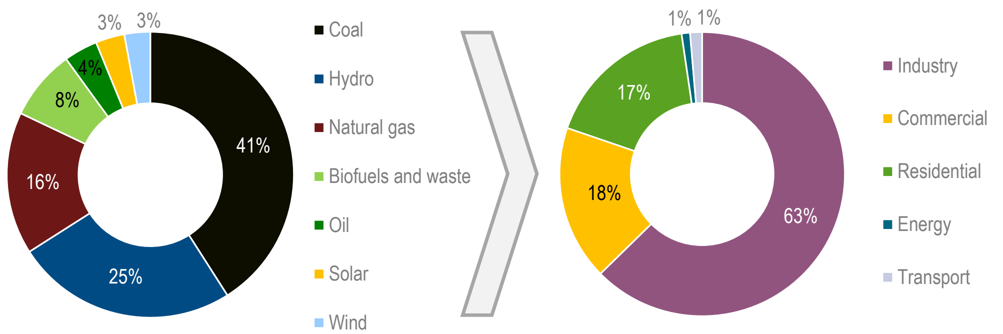
[1] Solar, wind, geothermal, biomass and marine energy, plus hydropower lower than 20 MW of capacity.

Consumption

In 2015, electricity consumption in Chile amounted to 67.5 TWh, 38% more than in 2005. Industry consumed the most electricity, 62.6% of the total (Figure 5.4). This is the second-highest share among the Organisation for Economic Development and Co-operation (OECD) countries. Specifically, the mining industry accounted for 37.1% of total consumption, the highest share in the OECD. Residential and commercial sectors combined accounted for 35% of the total. The remaining sectors (i.e. transport and other energy sectors) consumed 2.4% of the total.

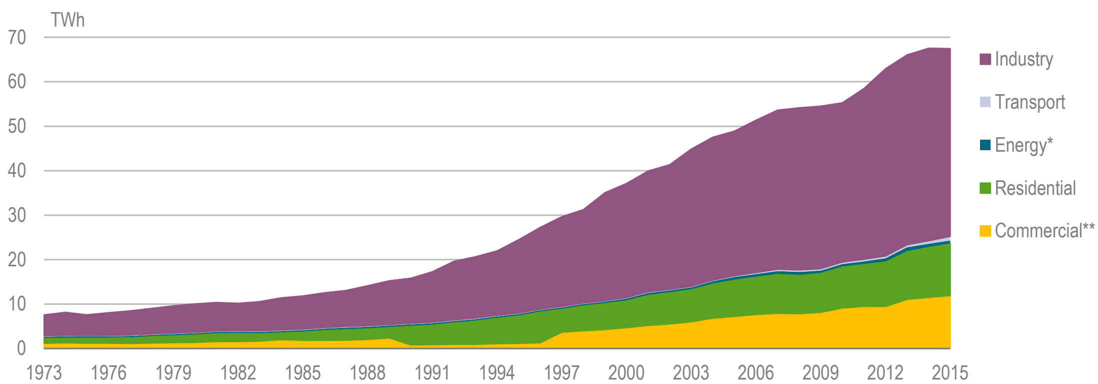
From 2006 to 2016, electricity demand increased by 42%, in tandem with gross domestic product (GDP), which grew by 40%. From 2005 to 2015, electricity demand increased quickly in all sectors: by 37% in the residential, 60% in the commercial and 33% in industry (Figure 5.5). Transport had the highest annual rate of growth, at 10%, but its absolute consumption remains small.

Figure 5.4 Electricity generation by source and consumption by sector, 2016



Notes: Consumption data are from 2015. Data are estimated for 2016.
Source: IEA (2017b), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Figure 5.5 Electricity consumption by sector, 1973-2015



* *Energy* includes energy own-use and the transformation sector.
** *Commercial* includes commercial and public services, agriculture, fishing and forestry.
Source: IEA (2017a), *Electricity Information 2017*, http://dx.doi.org/10.1787/electricity-2017-en.

Despite the strong growth, electricity demand per head remains low in Chile. In 2016, it was 4.1 megawatt hours (MWh) per head, less than half the IEA average of 8.7 MWh, However, under the Ministry of Energy's BAU scenario, electricity demand will more than double by 2050, growing significantly faster than the population.

Institutions

Three government entities are primarily responsible for designing, regulating, implementing and enforcing the electricity sector legislation and policies: the Ministry of Energy, the CNE and the Office of the Superintendent of Electricity and Fuels (SEC – *Superintendencia de Electricidad y Combustibles*).

The Ministry of Energy was established in 2010 and is responsible for elaborating and co-ordinating national energy policy. It oversees and co-ordinates the work of several other organisations in the energy sector. The Ministry also sets the tariffs for regulated customers and grants electricity concessions. The Ministry's Energy Infrastructure Division oversees the development of energy Infrastructure, including power generation projects and transmission lines. The division has two operating units: The Project Management Unit (UGP in Spanish) and the Transmission Siting Unit (UFT in Spanish). The UGP's objective is to understand energy projects, their status and the growth strategy of the companies to help private investment. To this end, the unit actively co-ordinates with other government agencies, regional authorities and company executives. The UFT, in turn, determines which new transmission lines, from those listed by the CNE, are required to have a Corridor Study in order to determine a preliminary corridor for them.

The CNE is a technical organisation responsible for analysing prices, tariffs and technical norms with which electricity generation, transmission and distribution companies must comply. The main objective of the CNE is to ensure that energy supply is sufficient, safe and efficient. Some of its principal responsibilities are the technical analysis of prices and tariffs of electricity, technical and quality norms for the functioning and operation of electricity infrastructure, and monitoring and modelling of the current and anticipated functioning of the energy sector.

The SEC monitors energy markets to verify the safety and quality of the services provided to users. Its main tasks are to supervise compliance with the laws, rules and technical norms of electricity generation, storage, transmission and distribution. The SEC also provides temporal concessions and informs to the Ministry about the definitive concessions in electricity distribution and transmission and hydropower generation.

In addition, since January 2017, a unified independent system operator, the National Electricity Co-ordinator (CEN [*Co-ordinador Eléctrico Nacional*], former CDEC SIC and CDEC SING), operates the National Electricity System. The CEN replaced the economic load dispatch centres. It is in charge of ensuring the safety of the power services and the access to the transmission grid. It also oversees competition in the electricity market and supervises the compliance of the operating companies and organises calls for tenders of new transmission contracts.

Regulatory framework

The legal base for the electricity sector is set mainly by the General Law of Electric Services (LGSE – Ley General de Servicios Eléctricos). The law was originally enacted in 1982 to privatise the electricity industry, introduce competition into the generation sector and separate the industry's generation, transmission and distribution segments.

Chile was the first country in the world to liberalise the electricity sector in this way. Privatisation of the state-owned utilities began in 1986 and was completed by 1998.

Since 1982, the LGSE has been amended several times. It, together with the related regulations, sets requirements for generators, transportation systems and facilities that provide complementary services, energy storage systems, distribution facilities and facilities interconnected with the system. It requires free access to transmission and distribution networks.

Transmission

Transmission-system development is a critical part of Chile's efforts to develop a national electricity system based on the use of the country's vast potential for renewable energy. A major reform to this end is the adoption of Law 20.936 on the transmission system (Transmission Law) in 2016. The law enhances the role of the state in the energy planning and the expansion of the transmission system – the state now assumes certain functions that were previously in the hands of the private sector.

The law introduces several new features for Chile's electricity sector. It creates the CEN, a unified independent system operator.[2] It supports grid expansion and cross-border connections. It also modifies the transmission toll payments to increase competition in generation.

The procedure to permit transmission projects was simplified and shortened in 2013. The procedure now also allows requests for transmission concessions to be divided into segments. It also proves a clearer process for valuing land and solving conflicts between concessionaries.

Grid expansion and interconnections

The Ministry of Energy is in charge of developing long-term energy planning processes for time spans of at least 30 years. One result of this process are the generation expansion planning scenarios which are used by CNE for transmission planning. The CNE analyses which transmission lines are necessary and the CEN issues tenders for companies to build and operate these lines. Currently, eight companies own national transmission networks in Chile.

The law establishes the National Electricity System through the interconnection of the Greater Northern Interconnected System (SING – *Sistema Interconectado del Norte Grande* and the Central Interconnected System (SIC – *Sistema Interconectado Central*) (see the "Industry and infrastructure" section below for details on the transmission network). The interconnection of the two major systems aims to diversify sources of generation and increase competition in the market. It also encourages the construction of backup transmission lines to enhance the security of supply and optimise the dispatch of power plants.[3]

[2] The specific regulation of the CEN regarding its duties and faculties will come into force on 1 July 2018.

[3] For example, during rainy seasons, the interconnection could increase hydropower generation and provide cheaper generation from SIC to SING. In dry periods, it could help switch from costly diesel generation to the more-efficient thermal power generation.

The law also separates the transmission network into six types of systems, depending on the purpose and use of the transmission assets:

- The national system, which includes the highest voltage and longest lines.
- The zonal system, which includes the lines established mainly for the supply of distribution customers.
- The dedicated lines, owned by single large customers, such as industrial and mining companies, and generation plants.
- The development hubs, for groups of generation plants (see below).
- The public service cross-border lines.
- The private service cross-border lines.

Development hubs

An explicit objective of the 2016 Transmission Law is to encourage renewable electricity generation. For that purpose, the Ministry of Energy is tasked to identify areas for so-called development hubs, i.e. areas of high economic potential for power generation from renewable sources that offer public utility. These areas are identified in the long-term energy planning process and will be included in future transmission-grid expansion plans. This will enable renewable generation at these hubs to reach demand, which opens the market for several renewable energy projects in the same area and optimises the costs of connecting to the grid.

Transmission tolls

The law guarantees non-discriminatory open access to the transmission grid. It also changes the way the access charges (transmission tolls) are paid. Under the 2016 law, the tolls are borne completely by the consumers. Previously, they were paid 80% by the generators and 20% by the consumers in the In the former Area of Common Influence. Removing the costs of the transmission grid from the generators enables variable renewable energy (VRE) developers to choose more-distant and resource-rich areas for generation.

The tolls are set by the CNE based on a value of annual transmission that includes investment, operation and maintenance costs of the transmission asset. Small NCRE generators have a low impact on transmission grids and have exemptions from the toll.[4]

Increasing competition

The 2016 Transmission Law also limits cross-ownership in the electricity sector as follows:

- A transmission company may not have any interest in any generation or distribution company.

[4] There are two scales for the toll: one for plants that generate up to 9 MW and another one for those that generate between 9 MW and 20 MW.

- A generation or distribution company may not hold more than 8% of the total investment in the National Transmission System (NTS).
- The sum of the shares of all generating companies, distributors and free customers in the NTS may not exceed 40% of the total investment in the NTS.

These limits also apply to groups or companies that are part of the transmission companies or that have joint action agreements with transmission, generation and distribution companies.

Distribution

Electricity distribution is organised through concessions. In total, there are 32 distribution companies. The distribution companies must have a permanent supply of energy to enable them to meet the total consumption of their regulated customers in their concession area. Regulated tariffs apply to customers with a connection less than 5 MW (previously 2 MW). However, customers with a connection between 0.5 MW and 5 MW can choose to be in the free market, but they will have to stay in the free market for at least four years and inform the distributor at least a year in advance. In 2016, regulated customers accounted for 55% of electricity purchases and unregulated for 45%.

Electricity supply for regulated customers is based on maximum 20-year power purchase agreements (PPAs) which result from open tenders to generators (see below). The end-user prices are the sum of the distribution tender prices (energy charge), transmission charges and distribution charges (added value of distribution [VAD, *valor agregado de la distribución*]). Each of these components are determined as a result of processes regulated by the law.

The energy charge is calculated as the weighted average energy price of the current energy contracts (from tenders, see section below) in each distribution zone. Mid- and low-voltage losses are added to the charge. The resulting price is known as the average nodal price. An equalisation mechanism is used to ensure that energy prices in individual distribution zones do not exceed the average price of the entire system by more than 5%. Finally, a compensation mechanism is also applied in municipalities with generation facilities, so that end-users may be offered lower prices.

Distribution charges are calculated by comparison with a model company (benchmarking), so that distributors receive a return of all of their efficient costs: capital, operation, maintenance and administration. The CNE calculates the VAD every four years to ensure a 10% real return on assets before taxes for the model company. Similar to energy prices, distribution charges are also subject to an equalisation mechanism to ensure similar distribution charges across Chile.

The government is studying a new regulatory framework for the distribution sector. The CNE is working on a proposal for a new distribution law that would ensure the modernisation of the distribution sector. The objective is to encourage the development of a more efficient and more intelligent distribution grid, to introduce new technologies and new commpanies, and to expand business opportunities in the sector.

Tenders for long-term electricity supply

For final consumers in Chile, electricity had traditionally been relatively costly. The introduction of the new tenders law (Law 20.805) in 2015 aims to reduce electricity tariffs and encourage market competition.

In the tenders, generation companies can offer their bids based on existing or new capacity. The tenders are designed, co-ordinated and directed by CNE and conducted by distribution companies. They are organised at least five years before the start of the supply contract (prior to 2015, this was three years).

Before launching a tender, CNE has to prepare an adequacy report that outlines future electricity supply and demand. As input to the report, CNE uses projections from individual distribution companies. CNE also has to decide about the volume of the tender, the length of the tender contract (maximum 20 years). The distribution companies are consulted on the initial tender design. CNE will also define a price cap for the offers.

Several supply blocks are offered (whole year 24/7, quarterly, daylight and night time). New projects may postpone or cancel their supply in the case that the projects are delayed by processes that their developers cannot control. Similarly, prices may be revised, if taxes or laws change. If the supply and/or demand projections prove inaccurate, CNE may launch short-term tenders.

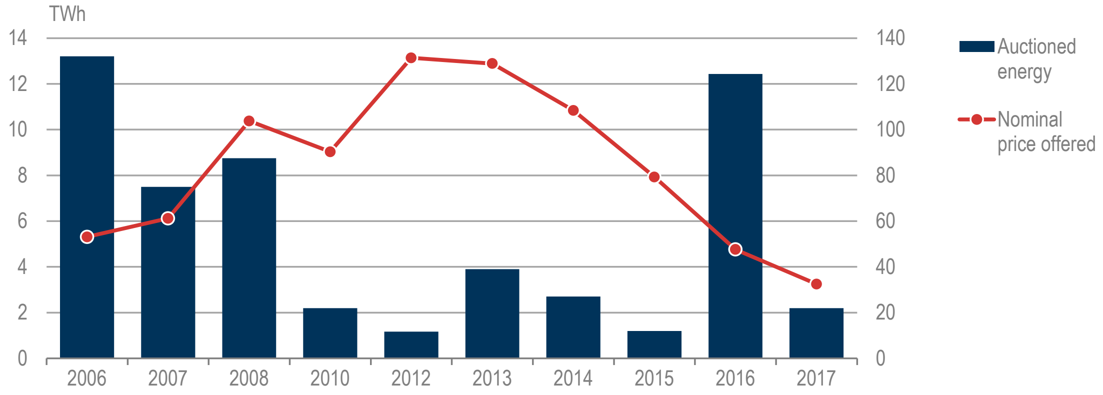
In January 2017, the CNE also announced new rules for the auctions, which include higher penalties for project cancellations to reduce unrealistic bids and to ensure project delivery.

Tender results

In recent tenders, prices have decreased and the number of participants increased dramatically. In the 2012 tender, there was just one participant and the price peaked at United States dollars (USD) 131.4 per MWh (/MWh). In 2013, two generators participated, again supplying at high prices. Since then, many new generators have entered the tenders: in 2014, the number of offers rose to 18, in 2015 to 38 and in 2016 it jumped to 84. In 2017, there were 24 offers.

At the same time, prices have declined by 75% from 2012 to 2017 (Figure 5.6). Solar and wind have emerged as market-competitive technologies – unlike in many other countries, they do not receive direct subsidies in Chile.

Figure 5.6 Volume and price (USD/MWh) of electricity-supply tenders, 2006-17



Source: CNE, 2017.

In the 2016 auction, 84 offers from domestic and foreign generators competed for contracts to deliver a total of 12.4 TWh per year of electricity for 20 years from 2021. The volume is expected to cover 23% of the projected electricity demand for regulated customers in the coming decade. The average price was then a record low, USD 47.6/MWh. The supply will come from new wind capacity (45.5%), new solar capacity (6.8%) and from a mix of conventional capacity (47.6%).

In the 2017 auction, 2.2 TWh per year from 2024 to 2044 were contracted at the record-low average price of USD 32.5/MWh. 46% of the supply will be from new renewable electricity projects (25% solar/wind, 16% solar and 5% wind) (Ministry of Energy, 2017).

In the power-supply auctions, the contracts are denominated in USD and adjusted periodically in line with the United States' Consumer Price Index. This protects developers and investors from both interest-rate risks and inflation risks in Chile. However, the long-term PPAs awarded in the energy auctions in 2015 and 2016 do not fully guarantee price stability over the contract period. Developers have to account for the price-difference risk between the generation and distribution nodes. This may lead to project delays or cancellations.

Distributed generation and self-consumption

Relevant to the distribution sector, small generators, many of which use NCRE technologies, may participate in the spot market and are guaranteed a connection to the country's power grids.

The National Energy Policy 2050 promotes self-consumption, with a special focus on developing solar photovoltaics (PV) systems to reduce energy costs and carbon dioxide (CO_2) emissions and thus to foster commercial and industrial competitiveness.

There are two main models for distributed generation, i.e. generation units connected to power networks at the distribution level (up to 23 kilovolts [kV]): net billing and small distributed generation systems (PMGD – *Pequeños Medios de Generación Distribuidos*), discussed below.

Net billing

Net billing was introduced in 2012 by Law 20.571 and it is operative since October 2014. It applies to small-scale end users supplied at the regulated rate and having their own NCRE or efficient cogeneration facilities with a maximum installed capacity of 100 kW. End users under the net billing scheme benefit from very simple connection procedures and a simplified billing system. They are allowed to inject their power surplus into the grid without having to form an electricity company or to register with the CEN. They sell this energy directly to the distribution company, so they do not need to participate in the wholesale energy market.

The electricity injected into the grid is measured and valued separately from the electricity purchased from the grid. The compensation price, equal to the regulated energy price plus the avoided distribution losses, is deducted from the monthly electricity bill. This energy price corresponds to avoided energy cost for each distribution company, so energy consumed and injected into the grid are valued at the same price for all distribution customer but residential ones. In this last case, the energy is valued at the retail tariff including both energy costs and charges for distribution services and for power purchases, so energy consumed has a higher price than energy injected.

Under this price scheme, the distribution company is neutral between buying energy from generators that participate in the energy auctions or from small-scale distributed generators. In 2016-17, net billing offered around USD 80-110 per MWh, while the short range average nodal price, calculated by CNE, was around USD 60 per MWh. As of end of December 2017, net billing had resulted in over 12 MW of mostly solar PV being installed, corresponding to 2 000 distributed generators, mostly residential systems.

Small distributed generation systems

PMGD applies to distributed generation facilities with a capacity of up to 9 MW, using any type of generation technology connected to a distribution network. These generators can inject their power surplus into the network and sell it at the marginal hourly cost or at a stabilised energy price. Today, this stabilised energy price is equal to the short range average nodal energy price as calculated by CNE (a four-year projection of the marginal costs of the system is calculated by CNE every six months). PMGD generation units with a capacity below 1.5 MW classify as low impact for the grid and can be connected to the grid through a fast-track procedure.

Unlike the systems under net billing, PMGDs are registered and co-ordinated by the CEN. This means that they must be created as electricity companies, issue invoices and report their operations to the CEN. This model is suitable for both commercial generation projects (that inject their total production into the system) and self-consumption projects (that meet a local demand and inject their surplus into the network).

By November 2017, 152 systems with a total installed capacity of 413 MW were operating under this model. The capacity was mainly run-of-river hydropower and solar PV, as well as diesel generators.

The Ministry of Energy is working to simplify the regulation for systems under 1.5 MW. This simplification concerns metering requirements and billing procedures, for example.

Industry and infrastructure

Chile's electricity system relies on a competitive market and a retail market for large customers. Practically all investments in generation and the regulated transmission and distribution sectors are from the private sector, although ENAP, the state-owned oil and gas company, holds stakes in some generating assets. Most companies are privately owned, although municipality owned companies have responsibilities in some small and isolated systems.

Transmission

Chile's electricity grid traditionally comprised four power systems. The two main synchronous power systems are SING and SIC (Figure 5.7). In a major development, a 600 kilometres (km), 1 500 MW double 500 kV interconnection between them was commissioned in November 2017 and thus a national electricity system was formed (Figure 5.8). The other systems are Aysén (SEA) and Magallanes (SEM), two small isolated systems in the south of Chile. The national transmission grids are owned by eight different companies.

SING covered an area equivalent to 25% of Chile's continental territory which is home to 6% of the population. In November 2017, the former SING hosted 6.4 gigawatts (GW) of power capacity. Large industrial customers, mainly mining companies, account for around 90% of the load in SING.

SIC supplied electricity to more than 90% of the country's population, including in the country's largest consumption centre, the Santiago Metropolitan Region. In November 2017, the installed capacity in the former SIC was around 17.8 GW. Small consumers account for almost 70% of the electricity demand in SIC.

At the end of 2016, the SING transmission grid was 700 km long, and the SIC one 1 800 km. More is being constructed: at the end of March 2017, 30 transmission projects were under construction, equivalent to 2 130 km and a total investment of USD 2.4 billion. The newly formed National Electricity System has a transmission grid of around 3 100 km (end 2017).

With the 6% share of wind and solar PV in 2016, Chile already faces integration challenges. Most commissioned and planned solar PV projects are concentrated in the north of Chile. As a result, in recent years prices in some nodes dropped to zero frequently and curtailment rates increased significantly, which has reduced the plants' revenues. The commissioning of the new transmission line Cardones-Polpaico between Copiapó-Santiago is expected to address some of the integration challenges; however, they have been delayed mainly because of opposition from local communities.

The impact of the PV generation has been incorporated into grid planning. In the 2016 CDEC (*Centro de Despacho Económico de Carga,* now CEN)–SIC proposal for transmission-grid expansion, the base scenario is compared with a "PV scenario" to consider the effects of faster reduction in PV costs. In both scenarios, large volumes of solar PV generation lead to severe congestions in the north of the SIC system (in 2026 for the base scenario and in 2020 for the "PV scenario").

As a result, the proposal for transmission-grid expansion focuses in particular on the northern regions, and recommends the deployment of seven new high-voltage lines from 2020 to 2027 (CDEC–SIC, 2016). The SIC–SING interconnector may trigger further development of the PV sector in the SING system: the great solar potential from the northern regions will become available for the load centres in the central regions.

Cross-border connections

Chile has one cross-border connection, the Andes-Salta line that connects the Antofagasta region and SADI. It was taken into use in February 2016 to export electricity to Argentina (in the past, it had been used for imports). However, the Andean countries are working to create an interconnected regional electricity market. For Chile, this would include an interconnection with Peru and more interconnections with Argentina (which, however, is not an Andean country).

Generation

The SING and SIC systems have had rather different installed capacity mixes. SIC accounts for around three-quarters of the country's capacity and enjoys a diversified set of technologies. According to the CNE, in November 2017, the SIC had an installed generation capacity of 17.8 GW, of which 46.3% was fossil fired (relatively equal shares of natural gas, oil and coal), 37.0% hydropower, solar PV 7.1%, 6.8% wind and 2.7% biomass and biogas.

Figure 5.7 Map of electricity systems and their installed capacity, November 2017

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: In November 2017, the SING and SIC were interconnected and they now form the national electricity system.

Figure 5.8 Map of the interconnected high-voltage electricity grid, end 2017

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Source: CNE, 2017.

The SING system, in turn, relies strongly on fossil fuels. In November 2017, 87.6% of its installed capacity of 5.6 GW was fossil fired, 9.7% solar PV, 1.6% wind, 0.5% geothermall and 0.3% hydropower. The solar PV capacity is growing particularly fast. In November 2017, the single national electricity system (composed of the former SIC and SING) had a total generation capacity of 23.4 GW, or 99.2% of the installed capacity in the country (the remaining 0.8%, or 183 MW, is installed in Magallanes, Aysén, Los Lagos and Easter Island).

The generation sector comprises more than 160 companies, although many of them are subsidiaries of the major companies Engie, ENEL (formerly ENDESA), AES Gener and Colbun. In 2016, these four accounted for 74% of the installed capacity in the country, and 83% of total generation (Table 5.2). Specifically in SIC, around 80% of the capacity and generation was controlled by Engie, AES Generk, Enel and Colbun. In SING, Enel, Engie, and AES Gener controlled around 60% of capacity and 90% of generation.

Table 5.2 The largest electricity generators, 2016

Producer	Total capacity (MW)	Share (%)	Total gross generation (GWh)	Share (%)
AES Gener	4 132	19%	24 275	33%
Colbun	3 852	18%	11 179	15%
ENEL	6 351	29%	17 564	24%
ENGIE	1 971	9%	7 796	11%
Total	16 306	74%	60 814	83%

Source: Generadoras de Chile (2017), *Annual Report 2016*, http://generadoras.cl/documentos.

Wholesale market design

The wholesale electricity market in the national electricity system has two components: a spot market, in which generators buy and sell electricity, and a financial contract market, in which large consumers and distributors buy electricity from generators.

The spot market is an obligatory pool, operated by the CEN. Only generators may sell or buy electricity on the spot market. Power plants are dispatched in a merit order using regulated estimates of their marginal costs (audited variable costs). This is mainly to avoid the negative impacts of very high levels of market concentration. The marginal costs of the system are calculated on an hourly basis for each node of the system.

The financial contract market has two components: one for large customers and another one for distributors. Generators can sell their electricity to large consumers at a freely agreed price. In contrast, electricity sales to distribution companies with regulated customers are organised through tenders for long-term supply (see above).

The wholesale market also includes a market for firm capacity. Generators are awarded according to their firm capacity at a price for capacity calculated by CNE on USD/kW basis. Because all large customers and distributors must purchase financial contracts for 100% of their demand from generators, each hour a given generator is either a net supplier to the system or a net buyer. This is, companies capable of generating more than the amount they have committed in contracts sell to companies with a generation capacity below of what they have contracted.

System integration of VRE

Chile has vast untapped potential for solar power and also significant potential wind power (Chapter 9). Integrating these variable energy sources into the electricity system is a critical part of Chile's efforts to increase the supply of clean and low-cost electricity. Investment in generating capacity is encouraged by a mix of low costs and market-driven support mechanisms, and underpinned by the political goal of raising the share of renewable sources in electricity supply to 60% by 2035 and to 70% by 2050.

Chile is one of the first countries in which wind and solar deployment accelerated based primarily on attractive economics. This was first observed in remote parts of the system, especially in the north of the country, where the supply cost of fossil energy is high and VRE resources excellent. Following this, wind and solar have also taken the majority of the market to meet incremental electricity demand of the main electricity system.

Once it had become clear that there would be a significant influx of variable resources into the system around 2014, the system integration of renewables quickly became a policy priority. Since then, a number of dedicated steps have been taken. The system has been upgraded and adapted across technical, economic and institutional aspects. In addition, several market features and specific measures have been introduced to ensure that solar and wind power are deployed in a way to maximise their net benefit at a system level.

Technical challenges and responses

Chile's transmission system has a fishbone structure, with a main North–South trunk line and smaller branches along the way. To add large amounts of wind and solar generation at remote parts of this trunk line can be challenging, especially where VRE penetration is very high but electricity demand is low. This is the case particularly in Regions III and IV (*Norte Chico*), where, as of December 2017, around 3 100 MW of solar and wind capacity meet a flat and relatively moderate demand of around 1 000 MW. Previously, the bulk of this demand was met by five coal units with an aggregate capacity of 750 MW.

Technical constraints impose a minimum generation from these coal units and restrict the available transmission capacity to export generation to the south. To mitigate these issues, the system operator has implemented an advanced technical system (special protection scheme) to free-up additional transmission capacity. Nevertheless, curtailment is common and nodal wholesale prices in this part of the system are now frequently at zero during the daytime.

Although this area represents a typical "hotspot" of system integration, i.e. an area in which penetration levels are much higher than the system average, some of the issues indicate medium- and long-term system challenges. Major medium-term priorities include to reduce the minimum generation requirements from thermal units, expand the grid systematically and implement advanced system-operation practices.

Regarding system operations, major advances have been made in establishing more-accurate VRE forecasts, which historically have suffered from very low performance levels.

The interconnection between the SING and SIC systems is a major improvement in the grid connectivity, especially in the SING system. Yet, many more grid upgrades are required. One significant example is a USD one billion project for a 753 km connection the area around Cardones with Santiago, the main load centre. The need for additional interconnection between the north and the south of Chile has become more relevant with the increase of solar PV penetration, as discussed above (Ministry of Energy, 2016).

Box 5.1 System-friendly VRE deployment

Planning a more system-friendly deployment of VRE technologies can prove effective in securing electricity supply when demand is growing. For the VRE sector to grow, it is critical to co-ordinate VRE deployment and grid expansion.

However, VRE deployment does not necessarily need to wait for the transmission infrastructure to be expanded. The transmission grid can be developed more cost-effectively on the basis of integrated planning approaches that co-optimise the location of the new generation and grid reinforcements and steer project development towards areas that are closer to demand or less congested, Additional design elements can be introduced in the procurement mechanism for new generation capacity. The Chilean distribution-sector tender system already recognises the temporal component of the energy production value.

A system-friendly design of VRE plants helps to improve the timing and location of electricity generation. For example, wind turbines with longer blades and higher towers have a smoother output profile, whereas solar PV plants facing east and west have lower ramp gradients and slightly higher generation levels in the morning and evening.

Although certain design choices may increase plant-level costs, the overall benefit to the system, for example through avoided grid-reinforcement costs, can outweigh them. If the relevant information and data are available, the costs and benefits from the overall system perspective of such design choices should be quantified.

Dispatchable generation and VRE integration

Most of Chile's electricity generation is dispatchable. Growing shares of VRE, however, are bound to change the role of dispatchable technologies – they will generate less bulk electricity, but become more important as a source of flexibility.

In systems with high shares of VRE, the role of dispatchable generation is to compensate the variable output of wind and PV generation. For this, power plants must be designed to be able to start up and to change their output quickly and on a short notice, and to make room for VRE by having a low minimum output.

Higher shares of variable generation will force plants designed for baseload generation into a cycling mid-merit and peaking application. This is often a challenge for baseload plants.

In the south of the system, the hydropower plants are the most-flexible dispatchable generators, because of their low minimum output, short start-up time and fast ramping capabilities. Options to increase their flexibility include retrofitting, altering reservoir sizes or discharge rates, or optimising turbine size, but these need to be further assessed. Also, irrigation requirements in dry years constrain hydropower generation, as the plants are forced to discharge water and become must-run plants. Options to avoid or minimise such constraints should be studied.

In the fossil-heavy SING system, coal power plants account for around half of the generating capacity, followed by natural gas-fired and diesel plants. Demand in the SING system is notably flat, and generation from most power plants is dispatched for more than 75% of the time.

Coal-fired power plants may need retrofits to improve their flexibility. Currently, coal plants in the SIC system have an average minimum stable output around 55% of the nameplate capacity, and an upward ramp rate of around 2%/min (see Box 4.1). However, in other countries, there are coal plants that can reduce their minimum stable output to around 30% of the rated capacity and increase the ramp rate close to 8%/min.

Adapting market design for VRE

Chile was among the first countries in the world to introduce competitive wholesale power markets. At that time, in the 1980s, variable renewable technologies were not a relevant part of market. As solar and wind technologies mature, market design needs to adapt. In Chile, examples of such adaptations are the tenders for electricity supply for regulated customers, the introduction of an ancillary services market and the reform of retail tariff design.

- Historically, the tenders for electricity supply for regulated customers were held for flat blocks of electricity for a whole year. Although such a design is compatible with wind power in principle, it exposes solar generators to considerable short-term price risk, especially during night-time hours, as they would have had to purchase on the wholesale market the electricity they could not generate. To correct this issue, targeted bidding blocks were introduced in the auctions, in particular a daylight block. Since 2013, the share of new NCRE in the tendered volumes has risen from 0% to close to 50% in 2017. The 2017 auction saw a record-low bid for solar PV of 21.49 USD/MWh for the daytime bidding block.

- Reliable electricity supply rests on additional services to maintain system frequency and voltage within acceptable boundaries during both normal operations and credible contingency events. In the past, these services were predominantly provided as a “by-product” of conventional power generation. As the share of solar and wind power grows, new sources for these ancillary services need to be found to allow more costly conventional generation to back down when electricity of low marginal cost abounds.

In addition, because VREs are fundamentally different generation technologies (they rely on software-controlled power electronics to interact with the grid, in contrast to synchronous generators in conventional plants), new services may need to be introduced. As part of the implementation of the 2016 Transmission Law, a review is underway to determine what type of services could be needed and what would be appropriate remuneration systems and market mechanisms for them.

Chile has also updated the retails tariff design to provide an economically sound basis for the uptake of distributed renewable energy resources, notably roof-top solar PV (see “Net billing” section).

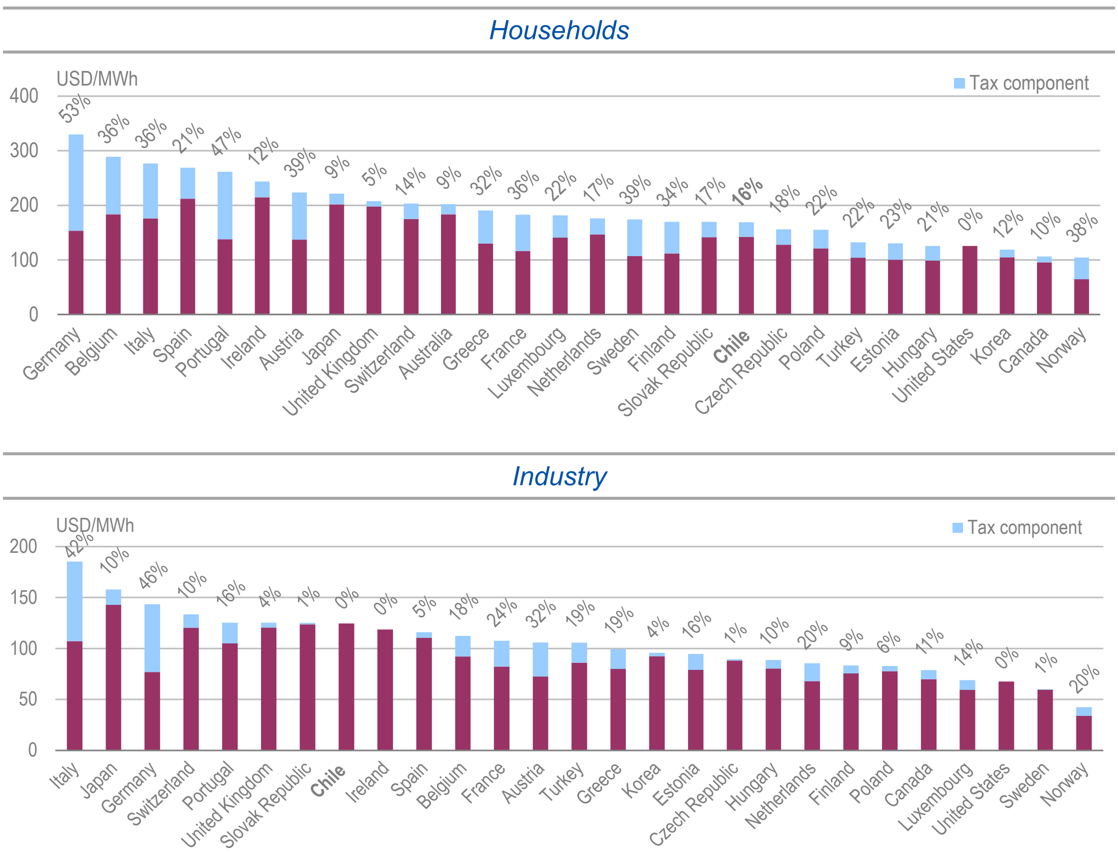
Prices

The National Energy Policy 2050 sets two targets related to electricity prices: In 2035, Chile is among the five OECD countries with the lowest average residential and industrial electricity prices. And in 2050, Chile is among the three OECD countries with the lowest average residential and industrial electricity prices.

In 2016, Chile had the tenth-lowest electricity prices for households in a comparison with IEA member countries (Figure 5.9). The low price is largely because of low taxation, as the pre-tax prices are just above the IEA members' average. Although the IEA average share of tax in electricity price is about 24%, in Chile the share is only 16% (a 19% value-added tax is added on the ex-tax electricity price).

As to electricity prices for industry, Chile was the eighth highest in the comparison with IEA countries, but second highest regarding pre-tax prices (behind Japan). As electricity for industry is not taxed, the high price is caused solely by high levels of generation costs and network charges.

Figure 5.9 Electricity prices in Chile and IEA member countries, 2016



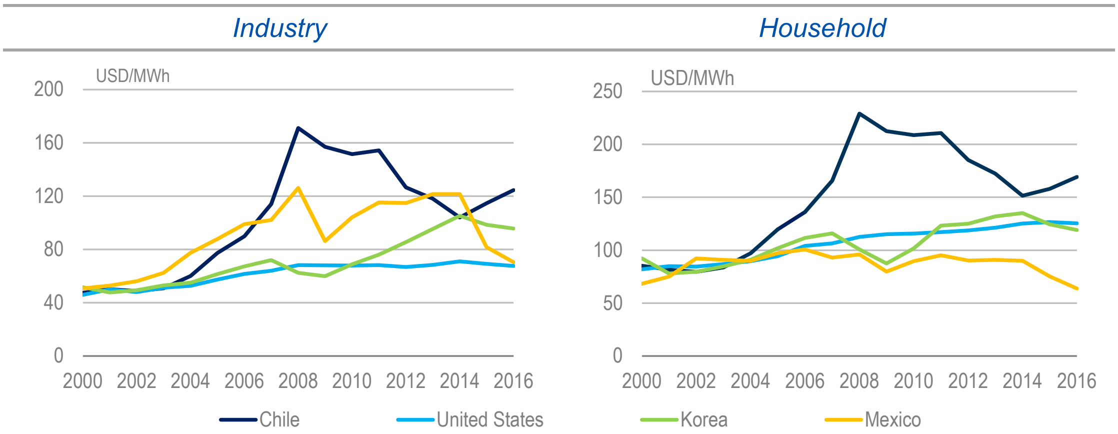
Note: Tax information for the United States is not available.

Source: IEA (2017c), *Energy Prices and Taxes Third Quarter 2017*, http://dx.doi.org/10.1787/energy_tax-v2017-3-en.

Over the past ten years, electricity prices in Chile have fluctuated strongly. In 2008, a combination of drought and the aftermath of Argentina's curtailing of natural gas exports to Chile resulted in electricity prices for both households and industry soaring to record highs (Figure 5.10). As Chile diversified its energy sources, notably by increasing coal-fired generation, electricity prices began to decline, although they did not reach the pre-crisis levels. In the past couple of years, prices have increased again, owing to changes in tariffs and tender results after the gas crisis.

Law 20.928 from 2016 reduces the differences in electricity bills of regulated customers in different areas of the country through modification of the distribution component of residential rates such that no regulated customer (consuming 180 kWh/month) would pay more than 10% above the national average .

Figure 5.10 Electricity prices in Chile, Korea, Mexico and the United States, 2000-16



Source: IEA (2017c), *Energy Prices and Taxes Third Quarter 2017*, http://dx.doi.org/10.1787/energy_tax-v2017-3-en.

Security of supply

Electricity security policies include standards and regulation determined by the Ministry of Energy and the CNE, supervision of SEC and the operation of the system by CEN. CNE determines standards, following a regulated process that includes the opinion of electricity experts, customers and companies. Also, CNE may define one or more ancillary services to maintain system security. Where possible, these services can be allocated through calls for tender.

Reliability of electricity supply

Reliability of electricity supply has increased in recent years. Electricity outages (excluding force majeure) have declined from around ten hours in 2012 to around eight hours in 2016. The National Energy Policy establishes that electricity outages must not exceed 1 hr per year in any location in Chile in 2050. In 2016, the volume of energy not supplied to regulated customers reached 5.7 GWh, 14% less than in 2015. In around 90% of the cases, supply was cut off because of failures in facilities below the transmission level.

Infrastructure risk management

Recently, a new regulation was published that defines new technical standards of service quality for the distribution systems. Among many changes, this regulation seeks to reduce outage and reposition times. It also aims to improve the mechanisms to inform regulated customers and to launch a transition to a smart distribution grid through the implementation of smart meters.

Under the 2016 Transmission Law, the long-term energy planning by the Ministry of Energy considers the objectives of economic efficiency, competition, security and diversification. To minimise supply risks is an essential criterion in the search for optimal planning. Such risks include increased costs or unavailability of fuels, unavailability of infrastructure, natural disasters or extreme hydrological conditions.

In December 2016, the Ministry of Energy's Energy Security and Market Division created the Unit for the Management of Risks and Energy Emergencies, in accordance with the National Policy on Disaster Risk Management. The Unit is responsible for directing, guiding and co-ordinating energy-risk management, strengthening the capacities of national and local actors in emergencies and contingencies in the energy sector (Ministry of Energy, SEC, National Emergency Bureau and companies that operate in the sector).

Since 2014, the Ministry of Energy has a Platform of Priority Facilities,[5] in which several public services commit themselves through an agreement signed between the parties to indicate those services of public utility and activities whose interruption can cause serious damage to the well-being of the population. The object is to identify the installations that should have priority for the supply of energy (both electric and hydrocarbon) in situations of scarcity. The registry is updated regularly.

Assessment

Over the past two decades, Chile's economy has grown strongly (its GDP increased by 81% from 2000 to 2015). Linked to this economic development, electricity demand grew by 82% from 37.1 TWh in 2000 to 67.5 TWh in 2015, or by 4.4% per year.

Electricity demand per head is still low in Chile (around 4 MWh per year, less than half the IEA average of 8.7 MWh), but it is set to grow fast. The government's BAU scenario sees demand more than double by 2050. Generating capacity has already more than tripled over the past 20 years (from around 6 500 MW in 1997 to around 23 000 MW by the end of 2017), and significantly more investment in grids and generating capacity is needed.

Chile does not have significant fossil-fuel reserves, but it has vast untapped potential for renewable electricity, which can help limit CO_2 emissions and air pollution, and reduce import dependency.

The government has introduced legislation to encourage investment in new renewable electricity capacity. The 2016 Transmission Law is a milestone in transforming the electricity sector. To create the CEN and interconnect, in November 2017, the SIC and SING systems to establish the National Electricity System are major achievements.

At the same time, the government has taken measures to increase competition in electricity generation to reduce the generating costs and, eventually, end-user prices.

[5] Priority facilities provide a service of public utility and their suspension due to lack of energy could negatively affect the population. Examples include hospitals, prisons, ports and telecommunications networks.

The government has also set a target for a 60% share of renewable power by 2035 and 70% by 2050. Electricity generation is also the largest source of energy-related CO_2 emissions.

Many countries impose a minimum share of of renewables in the electricity system. Depending on the regional prices of fuels, this may actually result in a more expensive and polluting power mix. In many countries, the final objective is to reduce GHG emissions, (and not renewables promotion itself), and this can be attained in cheaper ways with mechanisms that at the same time promote renewables and take into account the difference between coal and gas. To effectively limit CO_2 emissions from power generation, the government should consider introducing CO_2-intensity limits or higher CO_2 taxes for the sector (see chapter 6).

VRE integration needs to succeed to boost a green, affordable electricity supply

The government has responded in a co-ordinated and systematic way to rising shares of solar- and wind-power generation. Policy, market and regulatory frameworks have been improved to facilitate an efficient uptake of variable resources. The SIC–SING interconnection is a prime example. Also, new interconnections with Argentina are being studied, and previous such studies with Peru are being updated. Increased transmission and cross-border capacity also helps improve the security of supply and to reduce the cost of backup energy. The government is also developing other complementary measures to improve the flexibility of the system, such as demand-side management, the creation of an ancillary-services market and storage. The IEA encourages the government to continue this work with a high ambition.

To attain a 60% share of renewable power by 2035 at least cost, the share of solar PV and wind has to increase considerably. This is possible, because the costs of these technologies are decreasing and the potential is very high for solar and high for wind. However, to integrate a large share of VRE, the flexibility of the power sector must still increase.

The Chilean combination of solar (variable PV and more controllable concentrated solar power [CSP]), wind and hydro could offer a unique opportunity to develop sufficient flexibility, even without fossil sources, but that would require further development of the transmission infrastructure, storage and demand-side response. The government should step up the efforts to facilitate the value-maximising integration of VRE into the electricity systems.

As to thermal generation, the existing power plants operate on a wide range of parameters. Some plants have very long start-up times, very long minimum down times and very low ramp rates. Against this background, a review of the flexibility of existing generation assets is timely. A short-term market design review is recommended to assess generators' incentives to provide flexibility, for example by analysing the costs and benefits of creating a day-ahead market. In a day-ahead market both generators and retailers make binding commitments to sell and buy energy. This also encourages generators to properly forecast their generation. This applies in the same way for both intermittent and dispatchable resources and places the burden of forecasting on the generators. In contrast, in the absence of a day-ahead market, the system operator has to forecast wind and solar power availability and load, which typically is a less efficient option.

The wholesale market also includes a capacity mechanism. The government should consider modifying the capacity payment methodology to reflect the decreasing value of an addional plant. Examples could be taken from capacity markets in the United States or from market-based systems, such as the system-wide tenders in the United Kingdom.

Distribution tenders are driving investment in green, affordable electricity and increasing competition

Wholesale competition in Chile occurs in the contract market, in which generators sell electricity freely to large (non-regulated) customers and through tenders to distributors that supply small (regulated) customers. Around half of the electricity demand in Chile is supplied under these tenders.

The three largest generators in the National Electricity System continue to have a dominant position and the structure of the wholesale spot market for generators intends to ensure that this does not distort competition. Encouragingly, changes in the conditions for distribution tenders and other regulations have increased competition in the contract market. To ensure that the auctions attract the most bidders (including new entrants), the law sets an interval of at least five years between the date of the auctions and the start of the resulting supply contracts. The interval was previously three years, and the extension has, in particular, increased the number of new generators that offer renewable electricity.

The most-recent tenders have been clear successes. The 2016 tender was the largest one to date, with a contracted amount of 12.4 TWh per year for a period of 20 years, starting from 2021 (roughly 20% of the estimated demand for the next decade). The auction attracted a high share of NCRE technologies at an average price of USD 47.6/MWh, around 40% less than in the previous auction. The 2017 tender, although smaller (at 2.2 TWh per year), delivered even lower prices, on average USD 32.5/MWh, and 46% of the volume from new renewables projects. Both the decreasing price and the increasing share of renewable energy sources are very good news.

The tenders are resulting in renewable electricity capacity being built without subsidies. This is an encouraging development, and can set a positive example to many other countries that still subsidise renewable energy. It is also positive that the government announced in 2017 new rules for upcoming auctions, with higher penalties for project cancellations, to minimise unrealistic bids and ensure project delivery.

Incentives needed for innovation

The flip side of the tenders is that they lock regulated consumers in long-term contracts. This is justified from the security of supply perspective, but deters competition for a long time, excludes consumer choice and hinders competition on additional services by retailers. A more general challenge with a concession-based monopoly retail sector, such as the one in Chile, is that it typically requires regulation to foster innovation in electricity supply and demand response. This is a highly topical issue, as technological change through digitalisation is blurring the distinction between generation and consumption.

One way to address the issue would be to gradually reduce the threshold of regulated customers and to look for mechanisms to deal with demand risk for distributors. For example, the demand risk could be reduced through tenders for electricity for shorter terms, and such tenders should be open to all generation capacity available in the market.

Quality of service

It is positive that, in recent years, the reliability performance of the electricity sector has clearly improved: electricity outages have declined from around ten hours in 2012 to around eight hours in 2016. Yet, the National Energy Policy establishes that electricity outages must not exceed one hour per year in any location in Chile in 2050.

For this purpose, SEC should be strengthened to ensure it has the resources and powers needed to carry out the important work to improve the quality of service. To achieve the goal, it is also necessary to continue and tender new transmission lines and improve the distribution system to obtain a well-meshed network.

In addition, to address the system operation aspects, network companies should be given incentives to reduce electricity outages by introducing financial penalties for those that have outages above the average of the sector.

Recommendations

The government of Chile should:

- ☐ Explore market-based mechanisms to encourage investments in electricity supply that are compatible with Chile's climate change objectives. Consider:
  - > facilitating new transmission lines, including future expansion of the SIC-SING interconnection, and continue evaluating new cross-border interconnections.
  - > ensuring that market design sufficiently acknowledge and reward flexibility to enable growth in variable renewable energy production.
  - > facilitating demand-side response and storage, for example by letting them participate in the wholesale spot market.
  - > continuing the efforts to create an ancillary services market.
  - > modifying the capacity payment methodology to reflect the decreasing value of an additional plant.
  - > evaluating the substitution of the actual minimum renewables obligation with a CO_2 intensity limit (CO_2/MWh) for the electricity system as a whole, to both promote renewables and an optimal mix of fossil fuel capacity.
- ☐ Reform the distribution sector, and consider including:
  - > the gradual liberalisation of retail electricity supply by reducing the threshold of regulated customers to allow such customers to move to the liberalised market.
  - > clear market rules for distributors whose main activity would be to buy energy in the market and sell it to non-regulated customers and develop energy-efficiency services for them.

> mechanisms to introduce market signals to regulated customers to promote a more efficient and flexible electricity supply system, for example through time-of-use pricing and real-time pricing.

- Encourage companies to reduce electricity outages by introducing performance-based financial incentives for transmission and distribution regulated activities.
- Strengthen SEC to ensure it has the resources and powers needed to improve the quality of service.

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6. Energy and climate change

Key data

(2015)

Total GHG emissions (2013): 109.9 $MtCO_2$-eq*, +113% since 1990

Energy-related CO_2 emissions**

Total: 81.6 $MtCO_2$, +50% since 2005, +177% since 1990.

By fuel: coal 35%, oil 55%, natural gas 10%

By sector: power and heat generation 40.5%, transport 30.9%, industry 18.9%, residential 3.8%, commercial 3.1%, other energy industries 2.8%

Per GDP: 0.22 $kgCO_2$/USD GDP PPP (IEA average 0.25)

Per capita: 4.5 tCO_2/yr (IEA average 9.9 tCO_2/yr)

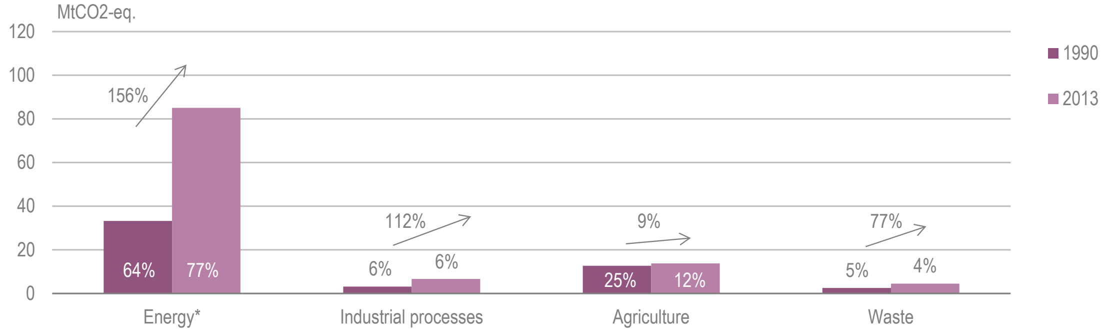
* Excluding land use, land use change and forestry

** All data are from IEA sources and, because of methodology, may differ from the Chilean data.

Overview

Chile's total greenhouse gas (GHG) emissions, excluding forestry and other land-use change, were 109.9 million tons of carbon dioxide equivalents ($MtCO_2$-eq.) in 2013, the latest year for which data are published by the Ministry of Environment (MMA – *Ministerio del Medio Ambiente*) (Figure 6.1). GHG emissions grew by 113% from 1990 to 2013, and by 19% from 2010 to 2013. The energy sector, which includes transport and energy-related industry emissions, accounted for 77% of the total GHG emissions.

Figure 6.1 GHG emissions by sector, 1990 and 2013



**Energy* includes emissions from the energy sector, transport, and manufacturing industries and construction.

Note: Forestry and other land use is excluded (a carbon sink).

Source: Ministry of Environment (2016), *Chile´s Second Biennial Update Report to the UNFCCC*, http://unfccc.int/files/national_reports/non-annex_i_parties/biennial_update_reports/application/pdf/bur2_chile_english2017.pdf.

Chile ratified the Paris Agreement in January 2017 and aims to reduce unconditionally the GHG intensity of its economy by 30% from the 2007 levels by 2030. If international financial support is granted, Chile will increase the commitment to 35-45%. CO_2 is the dominant source of GHG emissions, accounting for 78.4% of total GHG emissions in 2013. The following sections focus on energy-related CO_2 emissions.

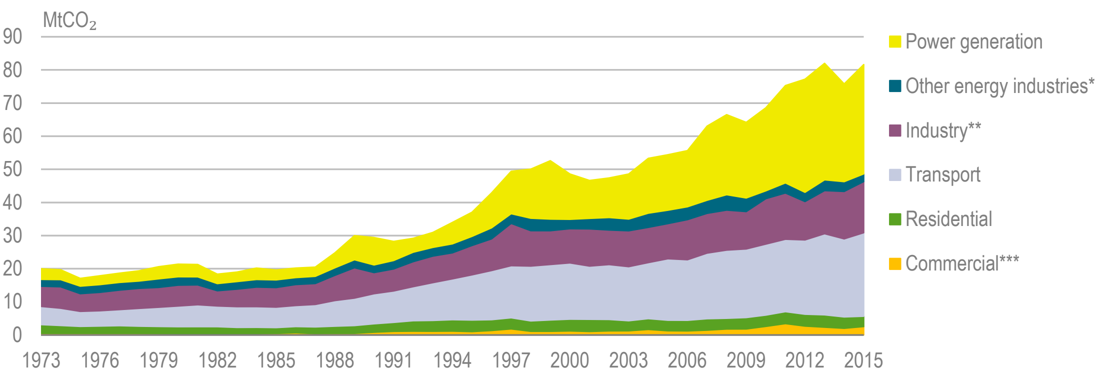
Energy-related CO_2 emissions

Energy-related CO_2 emissions have increased by 50% over the past decade, from 54.4 $MtCO_2$ in 2005 to 81.6 $MtCO_2$ in 2015, in line with economic growth. Carbon intensity in terms of energy-related emissions has been rather stagnant, in contrast to the decreasing trend in many International Energy Agency (IEA) member countries. This is because of the increasing carbon intensity of electricity generation, which surpassed the IEA average in 2011.

Emissions by sector

By sector, power generation is the largest emitter (Figure 6.2), and its share in total emissions has grown rapidly as coal has become more dominant as a fuel for electricity (Figure 6.3). In 2015, the power sector emitted 33.0 $MtCO_2$, or 40% of the total energy-related emissions. Emissions doubled from 2005, as Chile's electricity demand as well as the carbon intensity of electricity generation grew rapidly. Coal was only the third-largest energy source in power generation in 2005, but was the most-important energy source in 2015, when it generated more than one-third of electricity.

Figure 6.2 Energy-related CO_2 emissions by sector, 1973-2015



* *Other energy industries* includes other transformations and energy own-use.

** *Industry* includes CO_2 emissions from combustion at construction and manufacturing industries.

*** *Commercial* includes commercial and public services, agriculture/forestry and fishing.

Source: IEA (2017), *CO_2 Emissions from Fuel Combustion 2017*, www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion----2017-edition---overview.html.

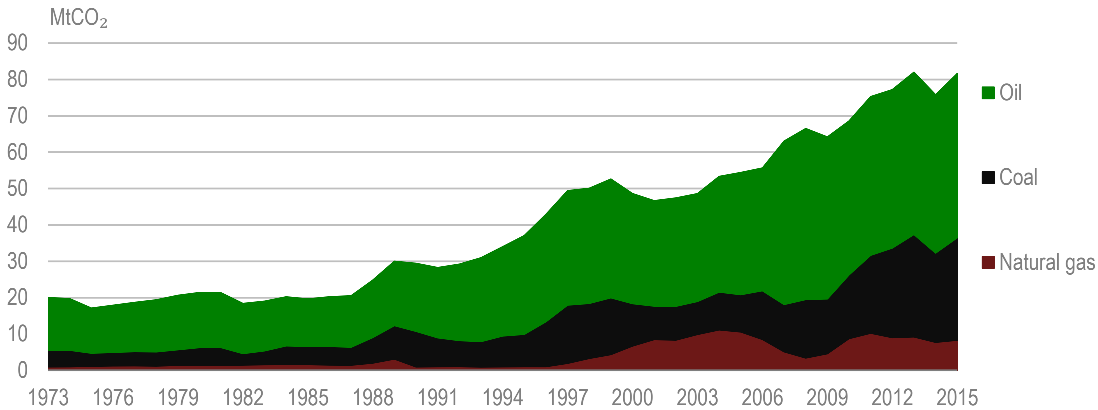
The transport sector is the second-largest emitter, at nearly one-third of the total in 2015. Emissions from transport have increased by 36% from 2005 to 2015, mainly as a result of a rapid growth in car ownership. From 2012 to 2016, the number of vehicles increased by 25%, from 4.0 million to 5.0 million, according to the National Institute of Statistics (INE, 2017).

Industry emitted around 20% of the total, and its emissions increased by 46% from 2005 to 2015. The growing energy demand in industry was mostly met with a higher consumption of oil, which replaced natural gas as the major fuel in the sector. The other sectors (residential, commercial and other energy industries) account for only a small share of the total energy-related emissions.

Emissions by fuel

In 2015, oil generated more than half of the energy-related emissions, coal 35% and natural gas 10% (Figure 6.3). Oil is the largest fuel in transport and also the largest energy source in industry. However, the share of oil in energy-related emissions has declined because of the rapid increase in emissions from coal in power generation. Emissions from coal grew by 175% between 2005 and 2015 and accounted for two-thirds of total growth in energy-related emissions in that period. In the meantime, emissions from natural gas declined by 21%, as gas consumption fell.

Figure 6.3 Energy-related CO_2 emissions by fuel type, 1973-2015



Source: IEA (2017), *CO_2 Emissions from Fuel Combustion 2017*, www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion----2017-edition---overview.html.

Carbon intensity

Growth in population and in economic output drive energy consumption, which tends to lead to increased CO_2 emissions. However, many advanced economies have succeeded in the relative decoupling of economic growth from energy demand and emissions through improvements in energy efficiency and a shift to cleaner energy use.

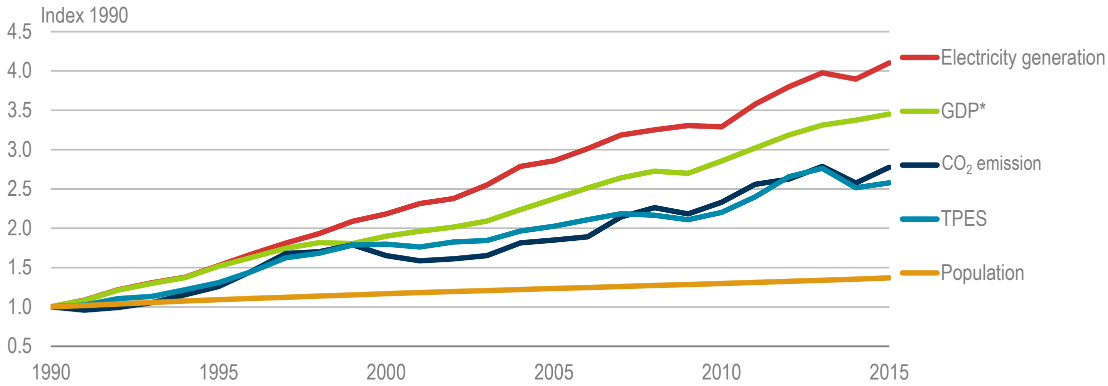
Chile is yet to decouple significantly its economic growth from energy-related CO_2 emissions (Figures 6.4 and 6.5). The carbon intensity of Chile's economy[1] has been rather stagnant over the past decade. It has ranged between 200 and 230 grammes of CO_2 (gCO_2)/United States dollars (USD) of gross domestic product (GDP) using purchasing power parity (PPP). Chile's trend is in contrast to the decreasing trend of the IEA average. In 2015, Chile had the 11th highest energy-related emissions per unit

[1] Here, carbon intensity is analysed in terms of energy-related CO_2 emissions only, so does not include GHG emissions from other sectors, such as methane or nitrogen dioxide emissions from the agriculture sector.

of GDP in a comparison with the 29 IEA member countries (Figure 6.6), just below the IEA average.

The CO_2 intensity of power generation has fluctuated strongly in the past decades (Figure 6.7). In the early and mid-1990s, the intensity correlated mainly with varying availability of hydro power, which was balanced by coal-fired power plants, resulting in annual variations in the CO_2 intensity. From 1999 to early 2000s, CO_2 intensity of power generation decreased because of an increased use of natural gas. However, with the Argentinian energy crisis in 2004-08, the share of natural gas fell and the CO_2 intensity of power generation began rebounding. Chile's CO_2 intensity of power generation surpassed the IEA average in 2011.

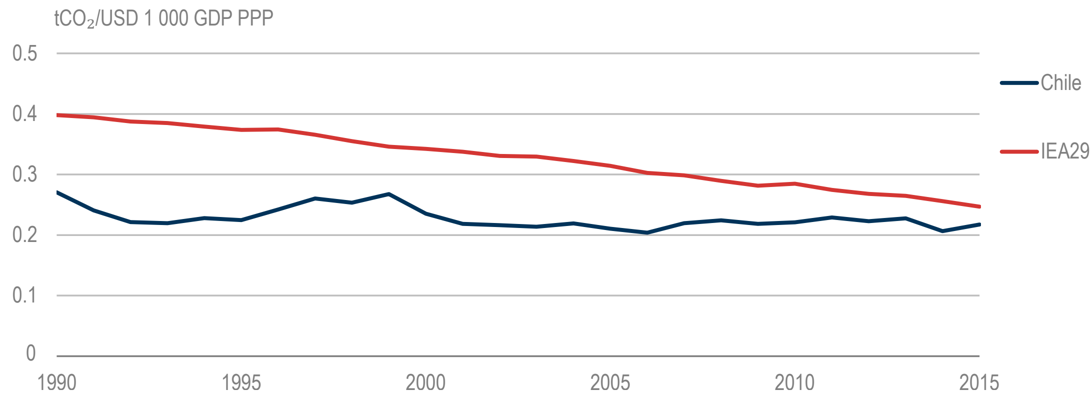
Figure 6.4 CO_2 emissions and main drivers in Chile, 1990-2015



* Real GDP in USD 2010 prices and PPP.

Source: IEA (2017), CO_2 *Emissions from Fuel Combustion 2017*, www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion----2017-edition---overview.html

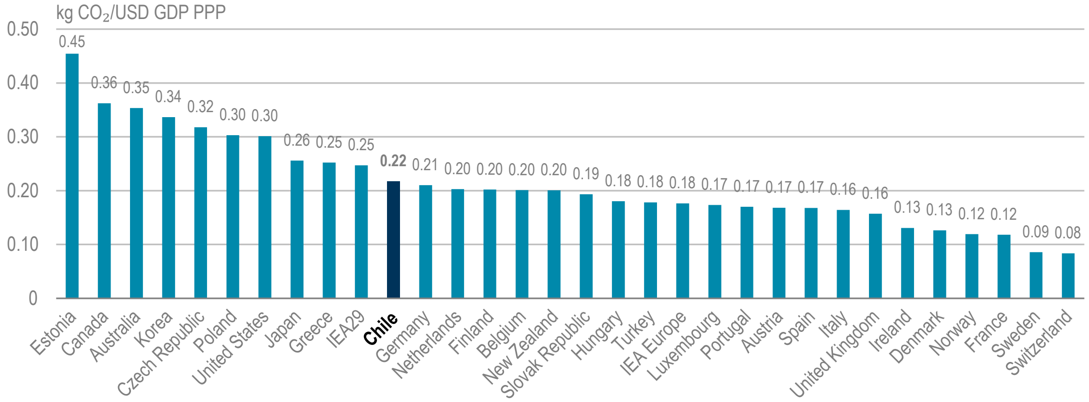
Figure 6.5 Energy-related CO_2 emissions per unit of GDP in Chile and in selected IEA member countries, 1990-2015



Note: tCO_2 = tonnes of CO_2.

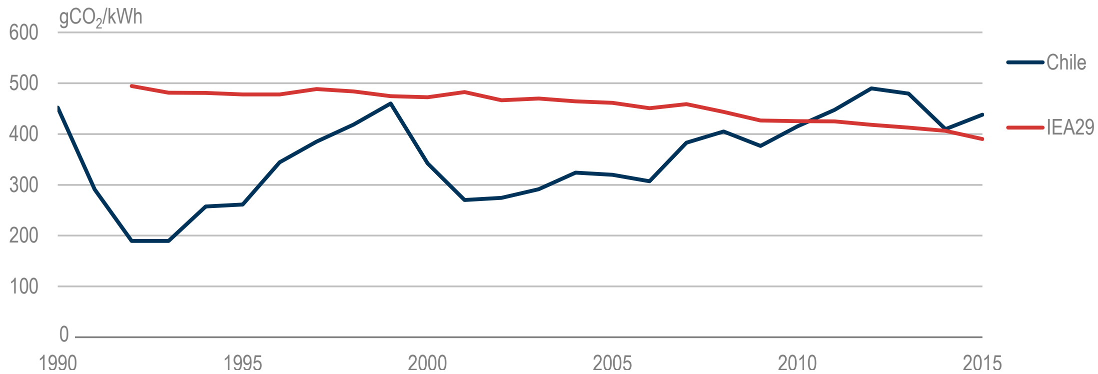
Source: IEA (2017), *CO_2 Emissions from Fuel Combustion 2017*, www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion----2017-edition---overview.html.

Figure 6.6 Energy-related CO_2 emissions per unit of GDP in Chile and in IEA member countries, 2015



Source: IEA (2017), *CO_2 Emissions from Fuel Combustion 2017*, www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion----2017-edition---overview.html.

Figure 6.7 CO_2 emissions per kilowatt hour (kWh) of power and heat in Chile and the IEA average, 1990-2015



Note: Data are not available for IEA29 1990-91.

Source: IEA (2017), *CO_2 Emissions from Fuel Combustion 2017*, www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion----2017-edition---overview.html.

Institutions

The Council of Ministers for Sustainability (CMS – *Consejo de Ministros para la Sostenibilidad*) is the highest-level governing body on climate change policy. It comprises the ministers of environment (chair), agriculture, finance, health, economy, development and reconstruction, energy, public works, housing and urban development, transport and telecommunications, mining and social development.

The MMA, created in 2010, is in charge of developing national climate change policy measures and co-ordinating between institutions at both national and local levels. Within the Ministry, this work is delegated to the Climate Change Department (DCC – *División de Cambio Climático*, which prior to 2017 was the Climate Change Office). The DCC generates GHG data and emissions inventories, develops national climate change strategies, raises public awareness and co-ordinates across institutions.

The Ministry of Foreign Affairs is the focal point for the United Nations Framework Convention on Climate Change (UNFCCC) and other multi- and bilateral international relations on climate change policy.

Several sector ministries also have departments or units on climate change policy. Within the Ministry of Energy, energy-related climate change matters are overseen by the Sustainable Development Division.

The Agency for Sustainability and Climate Change is a public–private committee of the National Economic Development Agency whose mission is to promote the inclusion of the climate change dimension and sustainable development in the private sector and in the territories. Among its areas of action are technology transfer, capacity building, dissemination of knowledge, promotion of entrepreneurship and innovation, financing, establishment and the certification of standards and accreditation of auditors.

In November 2017, the Permanent Presidential Advisory Commission on Climate Change was set up. The Commission includes more than 30 members from the public and private sector. Among the Commission's functions is to develop proposals for the design of instruments and processes that allow defining and implementing the national climate policy, as well as compliance with Chile's international commitments.

Climate targets and policy

Chile is a Party to the UNFCCC. As a Non Annex-1 Country, it has participated in global climate change mitigation efforts through voluntary commitments.

At the UNFCCC Conference of Parties 15 in Copenhagen in 2009, Chile made a commitment to reduce emissions by 20% from the business as usual levels for 2020 (projected in 2007), under the provision of international support. Subsequently, the government developed and registered Nationally Appropriate Mitigation Actions, and various initiatives were carried out to increase the government's capacity for climate actions.

The Paris Agreement was ratified by the Chilean Congress in January 2017. Chile's related National Determined Contribution (NDC) is to reduce the CO_2 intensity of GDP by 30% from the 2007 levels unconditionally by 2030, and by 35% to 45%, subject to international financial support. Related to this, the government has adopted the National Action Plan for Climate Change 2017-22

Regarding the implementation of the NDC, the MMA is assessing options for a tracking approach and has started a process to revise the pre-2020 commitment and to update the NDC.

Energy-related emissions

The National Energy Policy 2050

The *National Energy Policy 2050* supports meeting Chile's NDC. It also envisages the development and implementation of a GHG-emissions mitigation plan for the energy sector and a plan to adapt the energy sector to the impacts of climate change. For 2050, its objective is that “GHG emissions of the energy sector are consistent with international thresholds and national NDCs”.

The National Energy Policy 2050 includes several targets and measures that will support Chile’s mitigation goals in the energy sector. Currently, the largest contributors to mitigation are the quota obligations in support of renewable energy in electricity generation (excluding large hydro) and measures to improve energy efficiency.

The main objectives to 2035 and 2050 that will support climate goals are those on the use of renewable energy in power generation (increasing the share to 60% by 2035 and to 70% by 2050), the promotion of low-emission fuels and the adoption of an energy efficiency law. These policies are explained in more detail in Chapters 7 and 8.

Mitigation Plan for the Energy Sector

The Council of Ministers for Sustainability adopted in November 2017 the “Mitigation Plan for the Energy Sector”, which directly addresses the energy sector’s contribution to Chile’s 2030 climate change mitigation efforts.

The Mitigation Plan shows that meeting the country´s NDC requires additional effort from the energy sector (Table 6.1). The plan projects that compared with the current policies, to implement the measures included in the National Energy Policy 2050 would help avoid a further 17.3 MtCO_2-eq in GHG emissions in 2030. Under the plan’s “additional measures scenario”, the emissions avoided would be even greater, 24.1 MtCO_2-eq.

Under both scenarios, most savings would come from electricity generation and transport, primarily because of a higher efficiency (Table 6.1). In transport, a modal shift will also have a large impact.

Table 6.1 Expected savings in energy-related GHG emissions by sector from the business-as-usual level, 2020, 2025 and 2030 (MtCO_2-eq)

Sector	2020	2025	2030
With measures in the Energy Policy 2050.			
Electricity generation	0.03	2.97	8.78
Transport	0.52	2.53	5.07
Industry and mining	0.41	1.40	2.38
Commercial, public, residential	0.12	0.55	1.09
Total	**1.09**	**7.46**	**17.33**
With additional measures.			
Electricity generation	0.03	2.97	8.78
Transport	0.99	2.53	8.70
Industry and mining	0.41	1.40	3.47
Commercial, public, residential	0.14	0.55	3.19
Total	**1.57**	**7.46**	**24.14**

Source: Ministry of Energy (2017), *Plan de Mitigación de Gases de Efecto Invernadero para el Sector Energía.*

Additional annual investments of USD 1.4 billion will be required to meet the NDC target. The Plan foresees that the target can be met in a way that will actually save money in the medium and long term, because efficiency measures will limit energy demand and low-cost renewable electricity will replace imported fuels. In the National Energy Policy 2050 scenario, the savings average USD 206/tCO_2 avoided in 2030. Energy efficiency in mining, transport and heavy industry is projected to be particularly profitable. In contrast, efforts in power generation would cost USD 164/tCO_2 and in buildings (commercial, public and residential sectors) USD 145/tCO_2 (Ministry of Energy, 2017). As always with scenarios, the outcomes are sensitive to input parameters and other modelling assumptions. In the case of electricity generation, for example, prices for new supply are decreasing much faster than expected just a few years ago (see Chapter 5).

The government considers the Mitigation Plan for the Energy Sector a first step in the process of defining measures to achieve the sector's share of GHG mitigation commitments. It is aware that more is required to meet the NDC. Its list includes monitoring and reporting, and a more profound understanding of: 1) possible trajectories to 2030 (and corresponding measures), along with the determination of sectoral responsibilities; 2) the costs and roles of private and public sectors; and 3) carbon pricing as a facilitative instrument.

Existing carbon tax

In September 2014, the Congress passed a Tax Reform Law that included three new taxes (green taxes) on the emissions of CO_2, sulphur dioxide (SO_2), nitrous oxides NO_x and particulate matter (PM) from boilers and turbines that add up to at least 50 MW of installed thermal capacity, and a tax on NO_x emissions and fuel efficiency for new cars. This was the first green tax in both Chile and the whole of South America. The government considers the tax on CO_2 as the first step the country has taken in putting a price on carbon. Both the reporting and verification processes for the emissions are being developed.

The CO_2 tax covers around 40% of total CO_2 emissions from 93 installations. The tax level was set at USD 5/tCO_2. The level is fixed; there is no provision for a steady increase of the CO_2 tax or for an adjustment mechanism. Thermal power generation by biomass is exempt from the tax.

The tax level on local air pollutants SO_2, NO_x and PM is calculated on a case-by-case basis, and will depend on the population affected by emitting sources and the social costs derived from these pollutants, among other factors.

The green-tax revenue is estimated at USD 170 million for 2018. CO_2 emissions are expected to provide around 85% of the total.

Plans for carbon-pricing instruments

Besides the carbon tax, no other carbon-pricing instruments are currently planned by government authorities. However, possible carbon-pricing pathways are being explored under the Partnership for Market Readiness (PMR, a World Bank initiative), including an evolution and expansion of the carbon tax and a transition to an emissions trading scheme (ETS) (in combination with current carbon tax and/or offsets, or as a stand-alone instrument).

The Mitigation Plan for the Energy Sector states the need to deepen the understanding of the role that carbon pricing should play if the country moves firmly towards a lower GHG-emissions pathway. Specifically, it recommends deepening the analysis and understanding of possible pathways for the carbon tax, such as increasing the tax rate and/or expanding its coverage to other relevant emissions sources. Also, the plan will recommend a thorough analysis of an ETS for the energy sector (which could be in combination with existing carbon tax).

International collaboration on carbon pricing

Chile's high-level commitment to fight climate change by using carbon-pricing instruments is also seen in its membership to specific international coalitions and roundtables that promote the discussion and implementation of carbon pricing, such as the Carbon Pricing Leadership Coalition, the G7 Carbon Market Platform and the New Zealand Ministerial Declaration on carbon markets.

International carbon finance

Chile has been one of the most-active users of the Clean Development Mechanism (CDM) under the UNFCCC. Under the Kyoto Protocol, the emission-reduction projects implemented in non-Annex 1 countries, such as Chile, generate Certified Emission Reduction units (CERs), subject to approval by the CDM Executive Board. The issued CERs can be traded in ETS. The mechanism allows the Annex-1 countries to purchase CERs to meet their emission-reduction commitments and to invest in the most-cost-effective emissions-reduction projects globally.

From 2003 to 2016, Chile registered 102 projects to the CDM Executive Board for validation, with emissions reductions equalling 11.3 $MtCO_2$-eq. Over two-thirds of the registered projects were related to renewable electricity, in total 4.2 GW of installed capacity. This form of finance has, however, not driven investments in renewable energy in Chile, but been a supplementary source of revenue for generators, because project developers tend to see the CDM process as too long, costly and uncertain (OECD/ECLAC, 2016),

Chile has also made extensive use of international resources for climate financing through official development assistance (ODA). In 2014, ODA of USD 254 million was committed for climate change mitigation (USD 251 million) and adaptation (USD 3 million). However, the international finance flows are expected to decrease. Chile was graduated from the Organisation for Economic Co-operation and Development (OECD) Development Assistance Committee list of ODA recipient countries in 2017 and, as a consequence, is no longer eligible for ODA from January 2018.

Adaptation and resilience

Chile is vulnerable to climate change in several ways, although the impacts are projected to vary between the country's regions. In general, scientists predict more hot days and higher average temperatures, less rainfall and more-frequent droughts, especially in the central-south region. Also, extreme weather events are expected to become more frequent and intense.

For the energy sector, the main concern is reduced water availability and droughts. These would constrain hydropower, which generated one-quarter of electricity in Chile in 2016. The severe drought in 2007-08 in the central-south region disrupted hydropower generation.

The IEA has listed major impacts of climate change on energy systems (IEA, 2016). The following are relevant to Chile:

- Increased water temperatures constrain thermal power generation by reducing plant cooling efficiency and increasing cooling water demand.
- Water scarcity constrains concentrated solar power and carbon capture and storage technologies.
- Higher temperatures increase transmission losses and reduce overall transmission efficiency.
- Higher temperatures reduce viscosity of transported fuels.
- Extreme events (e.g. flooding, landslides) and erosion can damage pipelines.
- Rising air temperatures increase cooling demand (mostly electricity) and reduce heating demand (heating fuels, electricity).
- Energy-demand changes, depending on geographic location and access to energy technologies, such as air conditioning.

Under the National Energy Policy 2050, an Adaptation Plan for the Energy Sector is being prepared. The plan will address both the impacts of climate change on energy resources (derived from climate variability) and the potential risks on energy infrastructure as a consequence of extreme weather events. The Ministry of Energy has started the process to prepare such a Plan. Concentrating the analysis of impacts and measures on demand, supply and energy transport (including electricity and fuels), and after several technical workshops conducted regionally, a draft document will be released in late November 2017 and be subject to public consultation for one month. The aim is that a final version of the Plan be adopted by the Council of Ministers for Sustainability in early 2018.

Assessment

Chile is and will be heavily affected by global climate change. Negative impacts are projected on mining, agriculture and forestry, hydropower, drinking-water availability and human health. The impacts will vary across the country's many regions, but droughts and extreme temperatures are expected, especially in the densely populated central region.

Chile should therefore be highly motivated to see progress and sustainable action not only at the local and regional, but also at the global level. Chile ratified the Paris Agreement in January 2017. Its NDC has two energy-related targets: an unconditional target of reducing the GHG-emissions intensity of the economy by 30% below the 2007 level by 2030, and a conditional target of a 35% to 45% reduction in GHG emissions intensity, subject to international financial support.

From 1990 to 2013, GHG emissions increased by 113%, or by 4.9% per year. From 2010 to 2013, the increase was 19%, still at the same fast pace. This trend is obviously unsustainable in the long run, but, fortunately, Chile has significant potential to cut GHGs in all sectors. As energy-related GHG emissions account for around 77% of the total emissions, according to the MMA, it will be the key sector in mitigation efforts.

It appears that additional measures are needed to comply with the NDC. A robust climate change strategy should be created to avoid lock-in effects and to make use of the country's potential to mitigate and adapt to climate change effectively and efficiently. All sectors and all actors must contribute according to their common but differentiated responsibilities. Subtargets and interim targets to 2030 should be set in all sectors. The government could also consider raising its level of ambition in climate policy.

In November 2017, the Permanent Presidential Advisory Comission on Climate Change was set up. The Commission can serve as an independent body to review the climate change policy in a holistic and transparent manner and to recommend policies and measures, if targets appear out of reach. The IEA welcomes the creation of the Commission.

Regarding energy specifically, the targets for 2035 and 2050 in the National Energy Policy 2050 also provide a mid- and long-term basis for a transparent way to monitor the implementation of climate change policy in Chile. A Mitigation Plan for the energy sector was adopted in December 2017 and an Adaptation Plan for the energy sector was under preparation and discussion. According to the Mitigation Plan, energy efficiency and renewable-energy use offer a large and highly cost-effective potential for mitigation.

With all the above in place, Chile will be in a better position to honour its commitments under the Paris Agreement.

Chile is the first country in South America to introduce carbon taxation. The IEA applauds this initiative. The government is also working with the World Bank to evaluate and further develop green taxation (in addition to CO_2, emissions of local air pollutants are also taxed). The carbon tax will be applied on emissions from 2017 onwards, but it is, at least initially, set at a relatively low level of USD 5/tCO_2. Modest carbon prices can lead to some fuel switching in existing operations, make near-to-market low-carbon technologies cost-effective and promote other low-carbon support policies. However, they cannot drive all the necessary low-carbon investments, force early retirement of high-carbon assets or give strong signals for the electrification of heat and transport. It will be critical to monitor the functioning of the carbon tax and adjust the tax level, if needed. Its scope could also be broadened to sectors beyond the current main focus of thermal power generation. Specifically for power generation, the government should consider introducing higher CO_2 taxes or CO_2-intensity limits or more cost-effective carbon pricing instruments.

Under the Kyoto CDM, Chile has successfully attracted international financing for mitigation projects from international financial institutions and as official development aid. From 2018 on, Chile is no longer eligible for ODA, and it is also unclear to what extent other funding sources will be available in the future. The government should therefore also develop concrete strategies to attract climate finance from domestic and private sources.

Given that transport is the second-largest emitting sector and its emissions are growing, the government should consider further measures. For instance, introducing mandatory emission standards for vehicles will effectively limit emissions and help avoid lock-in effects. To facilitate modal shift will address the same issues, and to promote electric mobility is also worth considering.

Relevant for local air pollution, transport fuels are subject to a tax called IEC (Specific Tax on Fuels – *impuesto específico a los combustibles*), which strangely enough is lower for diesel at a monthly tax unit (UTM – *unidad tributaria mensual*) of 1.5/m^3 than for gasoline (UTM 6.0/m^3). This gives the wrong incentive to use diesel cars and also favours diesel in freight transport. The tax on NO_x emissions and fuel efficiency for new cars only partially compensates for this. In general, the government should reform transport-fuel taxation to reflect individual fuel-emission factors adequately. Given that tax rates on both fuels are significantly lower than those in most of OECD countries, the tax on both fuels could be increased and adjusted for the carbon content and wider environmental impact of fuels.

Recommendations

The government of Chile should:

- Strengthen current efforts in climate policy; prepare a comprehensive cross-sectoral climate strategy, informed by cost–benefit analyses of mitigation and adaptation options and by identifying synergies with different sectors.
- Adopt legal instruments to ensure Chile meets its NDC commitment.
- Continue work to develop carbon-pricing measures and consider introducing higher CO_2 taxes or CO_2 intensity limits for power generation or other energy-intensive economic activities, or consider more cost-effective, economy-wide carbon-pricing instruments.
- Adopt policy instruments to mitigate CO_2 emissions from transport, including modal shift and electric mobility.
- Consider reforming transport fuel taxation to reflect individual fuel emission factors adequately.

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7. Energy efficiency

Key data

(2015-16)

TFC (2015): 25.1 Mtoe (oil 55.2%, electricity 23.0%, biofuels and waste 14.6%, natural gas 6.0%, coal 1.3%, solar 0.1%), 15% since 2005

Consumption by sector (2015): industry 43.0%, transport 33.6%, residential 15.6%, commercial and public service including agriculture, forestry and fishing 7.8%

Energy intensity (2016 estimated): 98 toe/USD million PPP (IEA average: 109), –9% since 2006

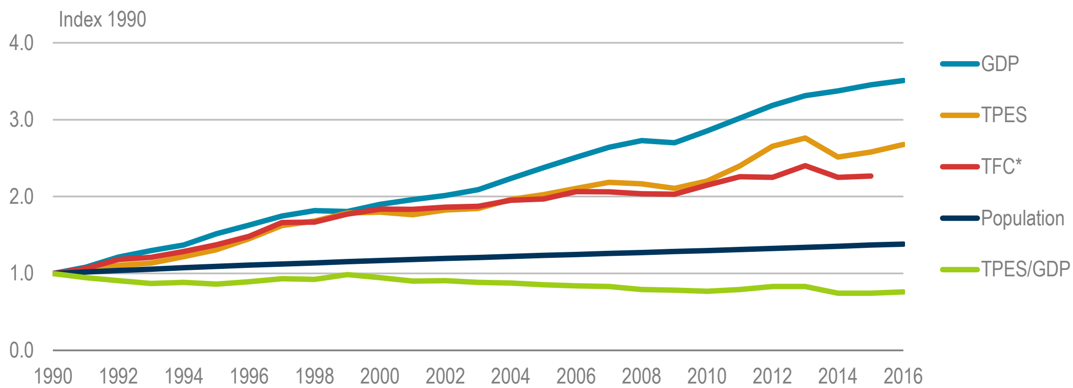
Energy supply per capita (2016 estimated): 2.1 **toe** (IEA average 4.4 toe), +15% since 2006

Overview

The government has made important efforts on energy efficiency by establishing relevant institutions, increasing annual funding and implementing a range of key policy measures. However, the opportunity for further progress on energy efficiency is considerable, and relevant to meet the national climate goals under continuing economic development.

The energy intensity of Chile's economy is falling, but at a relatively slow rate (Figure 7.1). Chile's intensity is lower than the International Energy Agency (IEA) average, but the difference has narrowed in recent decades.

Figure 7.1 Energy-intensity drivers in Chile, 1990-2016



*Consumption data only available to 2015.

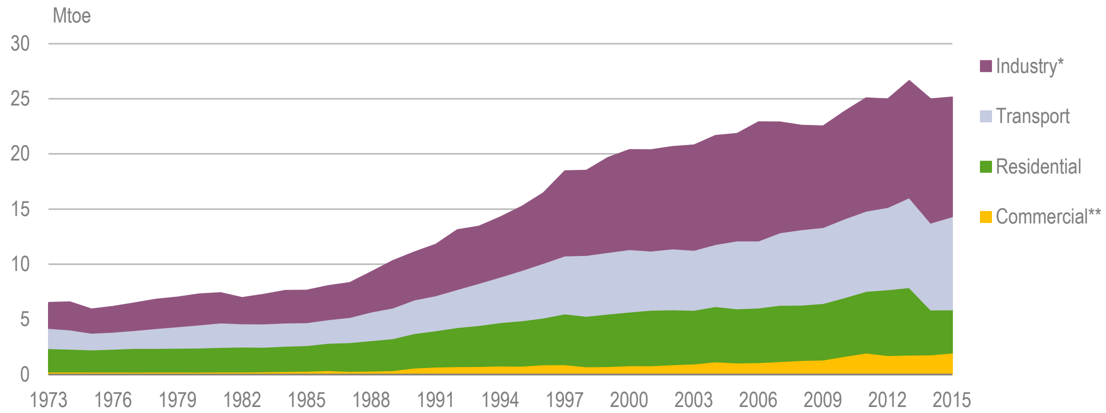
Notes: GDP = gross domestic product; TPES = total primary energy supply; TFC = total final consumption.

Source: IEA (2017), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Final energy consumption by sector

Chile's TFC was 25.1 million tonnes of oil-equivalent (Mtoe) in 2015, up 15% from 2005. Energy demand has increased steadily over the past two decades. The drop from 2013 to 2014 results from a change in 2014 to Chile's methodology for collecting biomass data (Figure 7.2).

Figure 7.2 Total final energy consumption (TFC) by sector, 1973-2015



**Industry* includes non-energy consumption.

***Commercial* includes commercial and public services, agriculture, forestry and fishing.

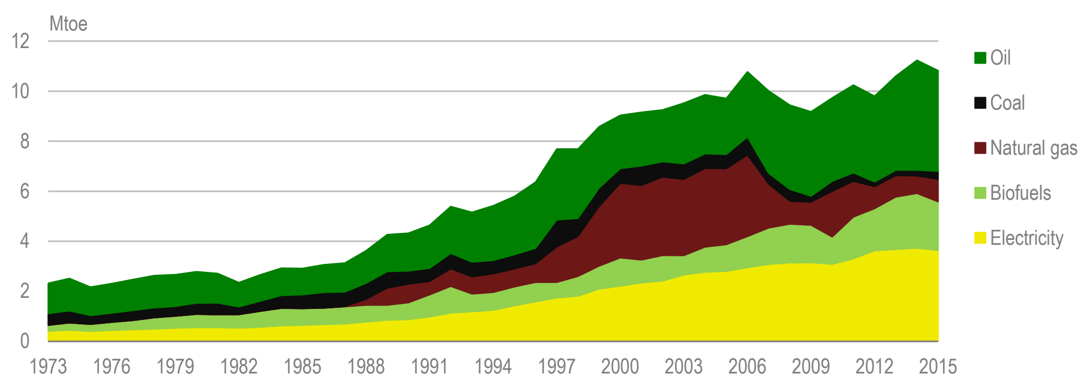
Source: IEA (2017), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Industry

Industry is the largest final energy consumer in Chile. In 2015, its TFC was 10.8 Mtoe, or 43.0% of the total. Energy demand from industry was 11% higher than in 2005, but its share was reduced from 44.5%. From 2005 to 2015, its TFC ranged from 9.7 Mtoe to 11.2 Mtoe. Copper mining and pulp and paper production are the largest energy-consuming subsectors.

In industry, oil and electricity are the dominant energy sources, each accounting for about one-third of its TFC in 2015 (Figure 7.3). The remainder was made up of biofuels (18.0%), natural gas (8.3%) and coal (2.9%).

Figure 7.3 Industry energy consumption by source, 1973-2015



Source: IEA (2017), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

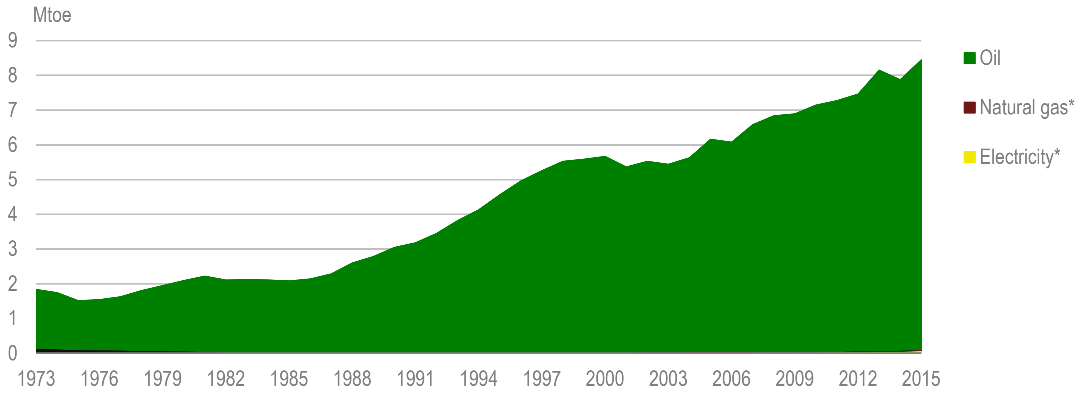
The largest change from 2005 is a significant decrease in the use of natural gas. Natural gas was the most-consumed energy source in industry in 2005, but, because of a curtailment of Argentinian natural gas, it lost its dominance and its share fell from 31% in 2005 to 8% in 2015, largely substituted by oil. Over the same period, the consumption of coal by industry also declined, and the use of other energy sources increased.

Transport

Transport is the second-largest energy-consuming sector, at one-third of TFC. In 2015, its energy consumption reached a new record, 8.4 Mtoe, a 37% increase from 2005 (Figure 7.4). Chile's rapidly increasing vehicle fleet mostly explains this increase.

Oil dominates the transport sector, at 98.7% of its energy demand. Other energy sources are electricity (0.9%) and natural gas (0.3%). Electricity consumption in the transport sector has almost doubled over the past five years, but remains marginal.

Figure 7.4 Transport energy consumption by source, 1973-2015



* Negligible.

Source: IEA (2017), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Residential and commercial

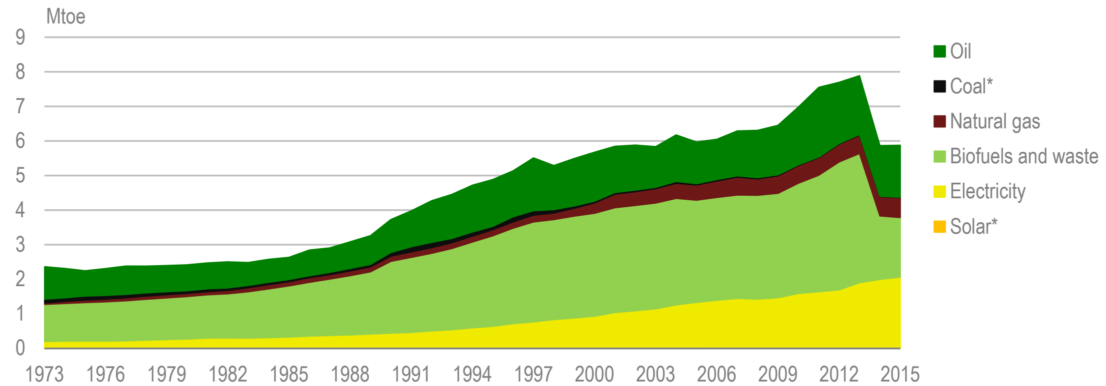
Household TFC totalled 3.9 Mtoe in 2015, or 15.6% of TFC. Residential TFC increased rapidly from 2005 and peaked at 6.1 Mtoe in 2013, but declined steeply in 2014. However, this coincided with the adoption of a new methodology for gathering data on biofuel consumption, under which biofuel consumption in the sector dropped by more than half and overall TFC by one-third in 2014. If biofuels are excluded from the comparison, TFC in the residential sector increased by 14% from 2005 to 2015, similar to the overall energy consumption.

The commercial sector had a TFC of 2.0 Mtoe in 2015, or 7.8% of the total. However, from 2005 to 2015, its energy demand grew faster than in any other sector, on average by 6.3% per year. The sector's consumption in 2015 was 85% higher than in 2005, and accordingly the sector's share in TFC increased from 4.9% in 2005 to 7.8% to 2015.

For the residential and commercial sectors together, the largest energy sources in 2015 were electricity (34.6% of the total) and biofuels (29.3%) (Figure 7.5). Electricity consumption increased by 53% over the past decade to around 2 Mtoe in 2015, consumed in equal shares between the residential and commercial sectors. Biofuels is the largest energy source in the residential sector, accounting for 43.3% of TFC. This is mainly firewood, which is commonly used for heating in the south of Chile (see Table 8.3). In contrast, biofuels use in the commercial sector is negligible.

Oil covered 25% of the TFC in the residential and commercial sectors. Its consumption increased by 25% from 2005 to 2015, driven by strong demand in the commercial sector. Other energy sources are natural gas (9.9%), solar (0.5%) and coal (0.2%). In the period 2005-15, natural gas and solar consumption increased, whereas coal consumption, despite being negligible, declined significantly.

Figure 7.5 Residential and commercial energy consumption by source, 1973-2015



* Negligible.

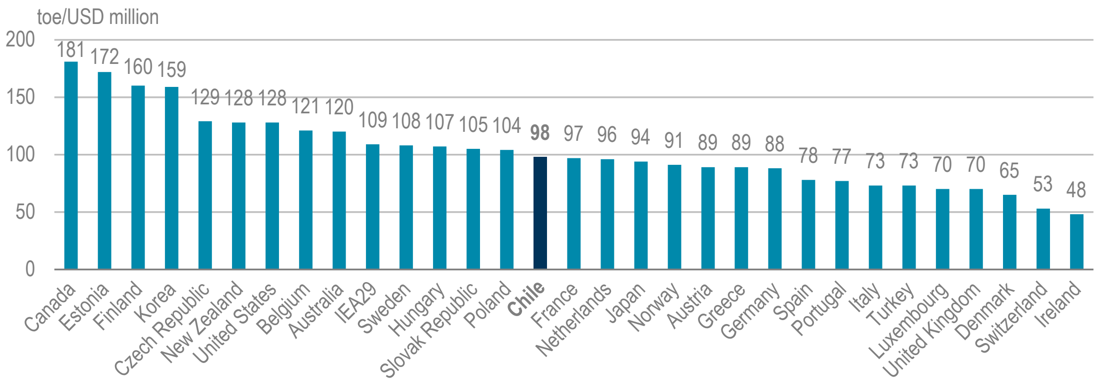
Note: The sharp drop in biofuel consumption in 2014 was caused by a change in Chile's methodology for collecting biomass data (based on a national representative survey for residential, commercial and public sectors).

Source: IEA (2017), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Energy intensity

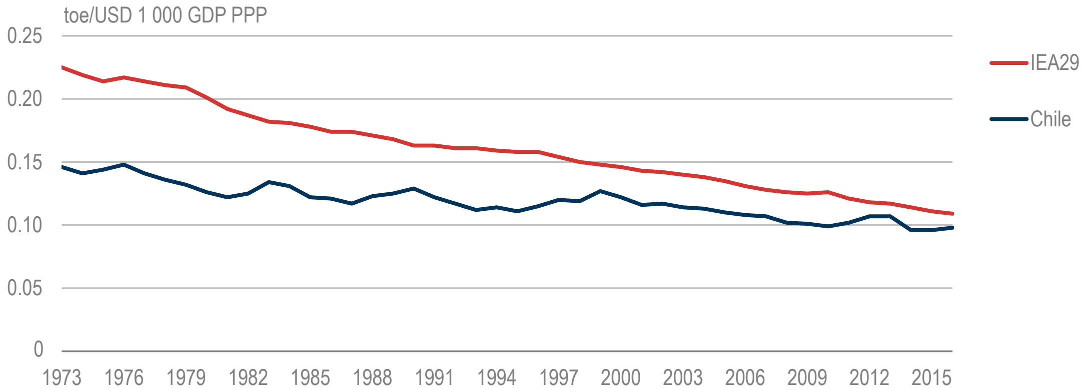
Energy intensity, measured as the ratio of TPES per unit of real GDP at 2010 prices and adjusted for purchasing power parity (PPP), was 98 tonnes of oil equivalent (toe)/United States dollars (USD) million PPP in 2016, a reduction by 9% since 2006. Compared with IEA member countries, Chile's energy intensity is around the median and slightly lower than the IEA average (Figure 7.6). However, as the IEA average is falling at a faster rate, the gap between Chile's energy intensity and IEA average is narrowing (Figure 7.7).

Figure 7.6 Energy intensity (TPES/GDP) in Chile and IEA member countries, 2016



Source: IEA (2017), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

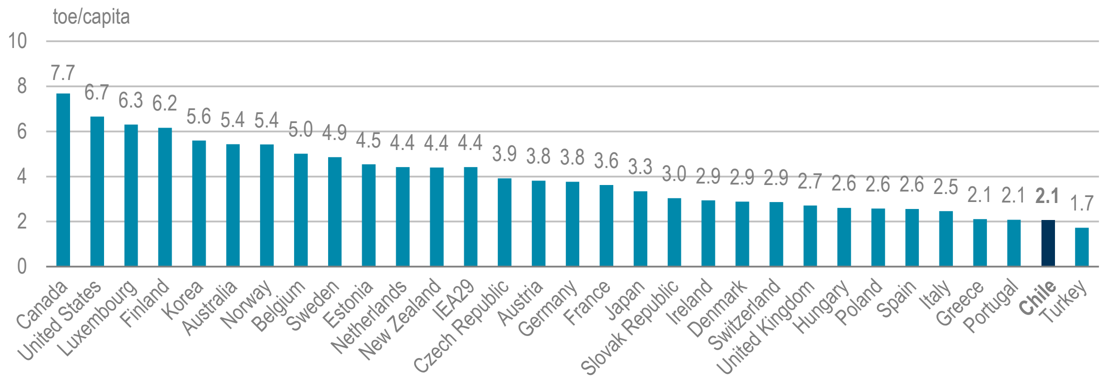
Figure 7.7 Energy intensity (TPES/GDP) trends in Chile and IEA member countries, 1973-2016



Source: IEA (2017), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Primary energy consumption per capita in Chile is 2.1 toe per year. This is less than half of the IEA average and it is lower than in any IEA member country except for Turkey (Figure 7.8).

Figure 7.8 TPES per capita in Chile and IEA member countries, 2016



Source: IEA (2017), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Institutions

Three main entities are involved in energy efficiency policies in Chile. First, the Ministry of Energy, through its Energy Efficiency Division, is responsible for developing and promoting energy efficiency policies, plans, actions and standards. Second, the Chilean Energy Efficiency Agency (AChEE), a public–private not-for-profit foundation created by the Ministry of Energy, is responsible for implementing the government's energy efficiency projects and programmes. The AChEE's board consists of representatives from the Ministry of Energy, Ministry of Finance, the Confederation of Production and Trade and a representative from civil society. Third, the Superintendency of Electricity and Fuels also plays an important role with the regulation of energy efficiency standards and labelling for several energy-consuming products sold in Chile.

Other government ministries involved in energy efficiency include the Ministry of Housing and Urban Development (MINVU), the Ministry of Transport and Telecommunications

(MTT), the Ministry of Environment (MMA – *Ministerio del Medio Ambiente*) and Ministry of Public Works, among others. The Ministerial Regional Secretaries of Energy (15 in total) lead the implementation of energy efficiency strategies across the different regions. The Inter-Ministerial Committee on Energy Efficiency co-ordinates cross-sectoral energy efficiency policies within the government and reports directly to the president of Chile.

Policy

The 2005 National Energy Efficiency Programme set the basis for energy efficiency policy in Chile. In 2007-08, the country had a major nationwide electricity shortfall because of a combination of factors – drought, interrupted gas imports and technical issues with the thermal power plants. At the time, the government turned to energy efficiency as one of the solutions to improve energy security and tackle electricity blackouts. Subsequently, in 2010, the Ministry of Energy was established, with a dedicated Energy Efficiency Division, as well as the creation of AChEE.

Since 2010, the Ministry of Energy has mainstreamed energy efficiency across all sectors. First, the 2012 National Energy Efficiency Action Plan 2020 established the pillars for efficient energy use in the country and a target of 12% energy reduction by 2020. Second, the 2014 National Energy Agenda set a new and more-ambitious energy efficiency target of reducing TFC by 20% by 2025 compared with a business-as-usual (BAU) scenario. In 2015, TFC was 8% below BAU (2010 baseline). Third, in 2015 the Ministry of Energy published the National Energy Policy 2050 which includes a broad set of energy efficiency goals for 2035 and 2050, including:

2035:

- A Consolidated Energy Services Company (ESCO) market in the public and private sectors.
- Industry and transport use energy efficiently and are supported by energy-management systems.
- 70% of the main categories of appliances and equipment sold in the market are considered efficient.
- All procurement of public passenger transport vehicles must include energy efficiency criteria as part of the evaluation.
- 100% of new public and residential buildings apply Organisation for Economic Co-operation and Development (OECD) standards for efficient buildings.

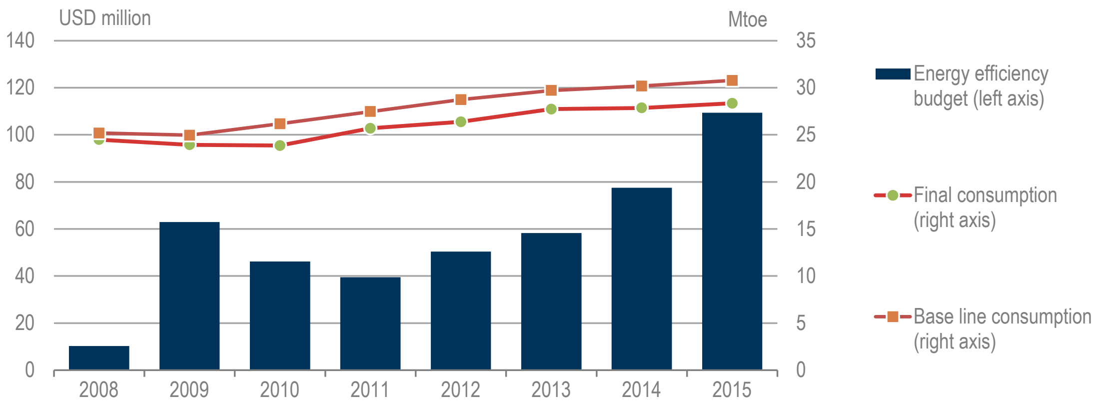
2050:

- Chile is an exporter of energy efficiency services.
- Energy consumption is decoupled from GDP.
- The industry and transport sectors become regional models of energy efficiency.
- 100% of the main categories of appliances and equipment sold in the market are efficient.

- 100% of new buildings apply OECD standards for efficient buildings and have smart energy-management and control systems.
- Chile adopts the highest international standards for energy efficiency for road, air, water and railway modes of transport.
- Bicycles represent at least 10% of modal shares in small and medium-sized cities.
- Rail transport represents at least 15% for freight transport.

To overcome the challenges in reaching the energy efficiency targets mentioned above, the government has been gradually increasing its energy efficiency budget from USD 50 million in 2012 to USD 109 million in 2015 (Figure 7.9).

Figure 7.9 Government budget for energy efficiency, 2008-15



Source: Background information submitted by the Ministry of Energy to the Chile In-depth review team.

Industry

Most energy efficiency policies in the industrial sector are voluntary. They include information and awareness campaigns, capacity building and training, energy audits, pilot projects and energy management systems (AChEE, 2017a). Examples of each of these policies are highlighted below. The Ministry of Energy lacks powers to set mandatory energy efficiency policies for the industrial sector.

The Ministry of Energy and AChEE provide a wide range of training and capacity building for professionals, including comprehensive training and certification – known as Certified Energy Manager – granted by the US Association of Energy Engineers.

The government also provides a subsidy of up to 70% of the costs of energy audits and energy efficiency projects in companies with annual energy costs above CLP 50 million (Chilean pesos). Since 2014, to complement this subsidy, the government has established voluntary agreements with public and private industries, particularly large mining companies and refineries, to conduct energy audits and establish energy-managements systems to meet high international standards; it also organises tailored training and dissemination activities. Based on energy audits performed by the members of the National Mining Council, they could save 5% of their annual energy consumption, with the potential to increase that number significantly if they replicate best practices and successfully implement energy-management systems.

The AChEE has a dedicated Energy Management System programme to support gap analyses and implementation plans for energy-management systems, implementation and certification of the systems, support during the certification process and monitoring of the energy-performance operation and impact of the energy-management systems. To date, around 50 industrial installations have a certified energy management system and some case studies are highlighted in the AChEE's dedicated online platform (AChEE, 2017b).

In April 2017, the Ministry of Energy launched a new and more-ambitious energy efficiency seal (with three categories: bronze, silver and gold) to recognise energy-efficient companies of all sizes, including industrial companies. The seal programme is managed by AChEE and it aims to reward the leading companies that are committed and invest in energy efficiency to reduce their energy costs and increase their competitiveness. The highest category, gold seal, is given to companies that have implemented and validated two energy efficiency measures as well as established a certified energy management system. The energy efficiency measure must be implemented in a process that consumes at least 10% of the total consumption of the installation. This programme builds on a similar seal initiative launched in 2013.

In 2017, the Ministry of Energy co-ordinated with several public institutions to launch a package of actions to promote energy efficiency in small and medium-scale companies such as:

- The Banco Estado, the state-owned bank, has introduced a special credit line for energy efficiency and renewable projects, in partnership with AChEE. The credit line is particularly directed at small businesses and finances up to 80% of the net value of the project with a maximum term of 12 years.

- The National Economic Development Agency (CORFO) can co-finance the cost of the ISO 50001 (International Energy Management System Standard) certification as part of its Quality Promotion Programme.

- The Ministry of Energy has launched "*Gestiona PYME*" webpage where small and medium-sized enterprises can monitor their energy consumption, get free on-line courses and learn about energy efficiency opportunities.

- The AChEE has established several co-financing lines for energy audits and the implementation of energy-management systems.

Buildings

Building energy codes and standards

The minimum energy performance standard (MEPS) for the building envelope was established in 2007 and is included in the General Ordinance for Town Planning and Construction. The standard sets the minimum requirements for the thermal transmittance of roofs, walls, floors and windows for the residential sector in seven thermal zones. Around 65% of the buildings in Chile are below this standard, which indicates the importance of building retrofit programmes to improve the efficiency of the building stock. The government is applying a higher efficiency level for the building envelope to new and existing social housing in areas of Temuco and Padre Las Casas, Talca and Maule, Chillan and Chillan Viejo, Osorno and Coyhaique. It is not clear when they will be applied at the national level. These higher efficiency requirements can enable an average 30% energy reduction in heating for new residential buildings and adapting and extending them to buildings in the education and health sectors is being discussed. However, a lack of studies on the current baseline for buildings in the public and commercial sectors makes it challenging for the government to set adequate standards.

In Chile, around 120 000 residential buildings are built every year and, even though the gap is closing, this is still insufficient to meet the demand in the country. Around 80% of new residential buildings in Chile are social housing built by MINVU and comply with the current building-envelope standard. The remaining 20% of new residential buildings are private housing and there is no formal process to verify their compliance with the standard. MINVU estimates that compliance with the current building-envelope standard represents an additional investment cost of 7% compared with a standard non-compliant building. MINVU is unable to fund the construction of social housing above the minimum standard with their current budget, as this could lead to a reduction in the volume of social housing built and would result in an inability to meet the demand for housing.

For existing buildings, the highest potential for energy savings is in residential buildings built prior to 2000. Therefore, MINVU has been providing subsidies to improve their building envelope, particularly in social housing, and 111 000 were retrofitted (around 3% of the existing residential building stock) between 2008 and 2016.

Energy label for buildings

In 2011, Chile established a voluntary comparative energy label for residential buildings, with categories that ranged from “A” (highest efficiency) to “E” (lowest efficiency), with “E” corresponding to the minimum standard for the building envelope (see above). The objective of the label is to help consumers make an informed decision as well as to encourage the building industry to go beyond the minimum standard. The label takes into account the thermal transmittance of envelope surfaces (i.e. roofs, walls, floors and windows), the building direction, the efficiency of the heating and lighting equipment, and the use of renewable-energy technologies. These elements are assessed and compared with a reference residential building that meets the minimum required under the General Ordinance for Town Planning and Construction. By 2016, a total of 32 000 residential buildings were labelled in Chile. The label is likely to be made mandatory depending upon the approval of a legal framework for energy efficiency.

Public buildings

The Ministry of Energy has a range of energy efficiency policies for public buildings. Since 2011, the Energy Efficiency in Public Buildings Programme, managed by the AChEE, has provided technical support through energy audits, implementation, measurement and verification, as well as capacity building for energy efficiency projects in existing public buildings.

In 2014, the Ministry of Energy and ACHEE, in co-ordination with the Ministry of Health, introduced an energy efficiency-improvement programme for all hospitals defined as High Complexity Hospitals (39 in total). By December 2017, the programme had invested a total of CLP 9 billion across 39 hospitals, with estimated annual savings of CLP 3 billion, mainly from improvements in air conditioning and water heating as well as energy-efficient lighting.

In January 2017, the Ministry of Energy launched *Gestiona Energia,* a mandatory programme under which all public services from the central government are obliged to have a certified energy manager and have to measure the energy consumption and energy intensity of all their buildings. By July 2017, there were more than 2 400 energy managers measuring and reporting the energy consumption of more than 3 500 public buildings.

The Ministry of Public Works has also set energy efficiency requirements as part of their public procurement process. They include standard terms of reference for energy efficiency and environmental comfort requirements for tenders on design and works according to geographic areas and building typology. The aim is to incorporate requirements, performance criteria, energy efficiency and environmental comfort standards as well as verification procedures for tenders in the design and works for public buildings. In line with this term of reference, the Construction Institute created a voluntary Sustainable Building Certificate to evaluate and certify the environmental performance of both new and existing public buildings (CES, 2017). The Ministry of Public Works is gradually enforcing this certification with the goal to ensure 80% of all tenders are certified by 2017.

Appliances and equipment

To improve the energy efficiency of appliances and equipment, the government has established MEPS for the following three products:

- Non-Direction Lamps for General Lighting (2013) – bans incandescent lamps from the market.

- Domestic Refrigerators (2014) – the refrigerators cannot have a performance level below that of an A-level energy label.

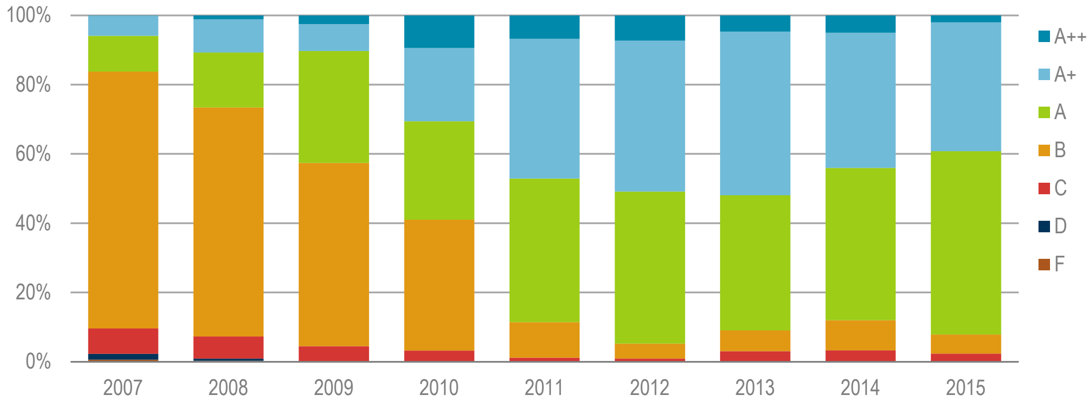
- Three-phase Induction Motors (2017) – applies to 0.75 kilowatt (kW) and 7.5 kW motors and sets the efficiency class at IE2 (High Efficiency). This standard will enter into force in 2018.

These standards set the minimum energy-related requirements that manufacturers must achieve to sell a product in the market. The Ministry of Energy aims to expand MEPS to other appliances and equipment, starting with air conditioning for residential use (up to 12 kW) and wood and pellet stoves.

Chile has one of the most-comprehensive mandatory comparative energy-labelling programmes in the world, with 26 mandatory requirements that cover 38 appliances. The programme coverage has risen remarkably since 2010 when only five appliances and equipment were covered. The label format is based on the European Union energy label, with "A++" being the most efficient and "G" being the least efficient. For lighting, domestic refrigerators and three-phase induction motors, the "G" rating is indexed to the respective MEPS.

Figure 7.10 highlights the positive impact of the energy label on the refrigerator market, which has triggered manufacturers and consumers to move to more-efficient refrigerators (categories "A", "A+" and "A++"). For example, the "A" category share increased from around 10% in 2007 to 53% in 2015. From 2011 to 2015 the share did not change significantly, which indicates there might be an opportunity to update the label levels for refrigerators to continue to move the market to a higher efficiency.

Figure 7.10 Share of refrigerator sales per energy label category, 2007-15



Source: Fundación Chile, 2016.

Beyond standards and labelling, since 2014 the Ministry of Energy's "My Efficient Home Programme" has supported the replacement of one million incandescent bulbs with compact fluorescent and light-emitting diode (LED) lamps, which resulted in an estimated annual savings of 75 gigawatt hours and was complemented with training on the proper use of energy. Furthermore, in 2014, the Ministry of Energy set an ambitious target to replace 200 000 street lights (mostly high-pressure sodium) with LEDs from 2014 to 2018 across 118 municipalities (there are 345 municipalities in Chile) (Ministry of Energy, 2017b). The 200 000 lights represent about 9% of the country's street lighting. By December 2017, 170 000 lights had been replaced in 108 municipalities, saving 39 000 megawatt hours per year.

Transport

Road transport accounts for 83% of transport-energy consumption. All vehicles are imported, and Chile has one of most competitive car markets in the world with a total of 63 brands in the market for light- and medium-duty vehicles,[1] 28 brands for trucks and 16 brands for buses. In 2016, a total of 305 540 light and medium duty vehicles were sold in the market, 20% less than the peak of 378 240 vehicles sold in 2012 (ANAC, 2017). In 2016, Chile had around 4.4 million passenger cars and around 500 000 other motorised vehicles (INE, 2017). Private cars are becoming more popular, but ownership levels, at around 250 passenger cars per 1 000 inhabitants, are low by OECD comparison and half the EU average, for example.

In 2015, the Ministry of Energy and the MTT agreed to move forward on legislation and policies to improve the energy efficiency of the vehicle fleet in Chile. This is in line with the Ministry of Energy's National Energy Policy 2050, which includes the need to improve the energy efficiency of vehicles and their operation as well as to promote a modal shift to more-efficient transport alternatives.

[1] A light-duty vehicle is less than 2 700 kg. A medium-duty vehicle is between 2 701 kg and 3 860 kg.

Chile does not have fuel economy standards for vehicles. However, the Ministry of Energy is considering a proposal for light-duty vehicles, although this is partially dependent on the creation of a legal framework for energy efficiency. Depending on the level and evolution of fuel-economy standards, studies undertaken by *Centro Mario Molina* and *Universidad de Chile* estimate potential savings through the reduced use of fuel of between 1 Mtoe and 1.5 Mtoe per year by 2035, equivalent to USD 750 million to USD 1 150 million per year. This would be equivalent to 13% to 19% of the TFC of the transport sector in 2014.

An energy efficiency label for new light-duty vehicles and their associated incentives has been mandatory since 2013 (Ministry of Energy, 2017c). Prior to that, the label had been voluntary for one year. In June 2017, the energy efficiency label scope was extended to medium-duty vehicles up to 3 600 kilogrammes (kg), and to electric and hybrid vehicles.

The label is a showcase of cross-sectoral co-ordination between the Ministry of Energy, MMA and the MTT. The Ministries are now considering an energy label for heavy-duty passenger vehicles through a comprehensive study that will cover testing procedures, performance tests and pilot testing.

The Ministry of Energy has an online platform to compare the performance of all labelled vehicles available in the market. This platform is also available for smartphones and enables the users to report when car dealers do not comply with the label display. However, information on the impact of the energy efficiency label is not available.

The MTT is subsidising the replacement of taxis with higher-efficiency vehicles, with a limit of a CLP 6.5 million subsidy for a new electric taxi. The funding allocated to the subsidies is determined on a regional level. The MTT (from 2017) also supports the introduction of electric buses in Santiago through a requirement in the procurement process for a minimum quota of 15 electric buses from the selected concessionary. This is likely to bring the total number to 90 electric buses in Santiago. As of November 2017, there were three electric busses operating in the Santiago Metropolitan Area.

AChEE estimates energy-efficient driving techniques could improve vehicle performance by 5% to 13%. Consequently, there is (from 2012) an online platform to encourage the adoption of efficient driving concepts for both private and public drivers (AChEE, 2017c). In addition, since 2015, knowledge about energy-efficient driving practices and techniques is part of the requirements for new class B driver's licenses. In addition, from 2014 to 2017, more than 1 000 public sector drivers were trained as part of an efficient driving project. This resulted in an estimated 7% fuel saving, equivalent to 250 litres of fuel per driver per year. This experience is replicated for freight transport with the aim to reduce fuel consumption by up to 15% in about 180 000 of the heavy-duty trucks in the country. AChEE provided efficient driving training to more than 660 instructors and supervisors of freight and passenger transport companies across the country and in partnership with confederations, associations and companies in the transport sector.

In December 2017, the government adopted a strategy for electric mobility (*Estrategia Nacional de Electromovilidad*), a joint effort by the Ministries of Energy, Transport and Communications, and Environment, in collaboration with industry. Today, the sector is still in its infancy in Chile, as around 200 electricity vehicles are in operation in the country. The strategy's target for 2050 is for electric vehicles to reach the share of 40% of passenger cars and 100% of public transport vehicles. It lays out policies and measures to meet these targets.

Energy service companies

According to the Chilean Energy Service Companies Association (ANESCO A.G.), by 2017 the market revenue from energy efficiency services was estimated at about USD 60 million per year, a significant increase from the USD 15 million estimated in 2014. Most energy efficiency projects are led by large ESCOs. The United Nations Economic Commission for Latin America and the Caribbean estimates the market potential for ESCOs to be around USD 250 million per year in Chile (UN ECLAC, 2015).

In 2016, around 50 energy-performance contracts were active, mostly shared savings, and ranged from USD 40 000 to USD 200 000 each. The majority of the ESCO projects are gradually moving from the private to the public sector, particularly public hospitals, through guaranteed savings contracts driven by government support under the Energy Efficiency in Public Buildings Programme (see "Buildings" section above). There is also some activity in the energy intensive commercial sector such as retail, hotels and office buildings. The main challenge for the ESCO market has been the lack of a regulatory framework as well as limited knowledge of energy efficiency best practices and ESCO models.

Combined heat and power

In 2015, combined heat and power (CHP) plants generated 5.6 terawatt hours of electricity, or 7.4% of the total in the country. AChEE estimates that there is an additional potential for CHP of 875 megawatt electrical (MW_e) in the industrial sector and 1 500 MW_e in other sectors.

In 2012, the Ministry of Energy launched the *Fostering CHP Programme* to co-fund pilot projects and project feasibility studies, build capacity and raise awareness. By 2015, some 40 studies had been co-financed and these have helped identify several projects with paybacks of less than five years. In addition, the Ministry of Energy and AChEE are working closely with the German Agency for International Co-operation on CHP in the industrial and commercial sectors and have implemented six pilot projects to demonstrate its technical and economic feasibility in the country (AChEE, 2017d).

The regulation that sets the requirements for efficient CHP plants (below 20 MW) was formally approved in May 2015 (Decree No. 6 of the Ministry of Energy on Efficient Cogeneration). Regulated final customers that own efficient CHP facilities are covered under the distributed generation policies, are eligible to net billing and receive priority (depending on the fuel source) to dispatch their energy surplus to the distribution network.

There is no policy framework for district heating and there are only a couple of case studies and pilot projects, although the Policy for Use of Wood and Its Derivatives for Heating (2015) and the National Energy Policy 2050 have actions and goals associated with CHP. In 2016, the MMA conducted a study to develop a roadmap for district heating in Chile. The study proposes a number of actions and measures to promote the development of district heating over the short, medium and long term, from 2017 to 2025. In 2017, the MMA, in co-ordination with the Ministry of Energy, announced a strategy for district energy in cities. The aim, in particular, is to help improve air quality in southern cities by reducing air pollution from firewood burning and inefficient heating units.

Technology solutions could include biomass cogeneration and heat pumps, as suggested by the United Nations Environment Programme with which the Ministry is collaborating. Although this strategy does not focus on district heating, it covers some of its aspects and benefits. Nevertheless, the Local Atmospheric Decontamination Plans support evaluating district heating pilot projects and provide co-financing.

Assessment

Since the 2009 IEA in-depth review, Chile has made progress on energy efficiency in several areas. The creation of the Ministry of Energy, the respective energy efficiency division and the AChEE are major steps. In addition, government funding for energy efficiency has increased by more than 30% from 2012 to 2015, which is commendable although there is an opportunity to leverage additional funding through the private sector (e.g. ESCOs, industrial and electricity distribution sectors), through market-based mechanisms (e.g. taxation, energy efficiency auctions for industry or obligation programmes on energy companies). In terms of dedicated energy efficiency programmes, the Ministry of Energy is implementing important measures to improve energy efficiency in the building sector and public lighting that can be expanded and replicated across the whole country. The recent update of the mandatory MEPs for electric motors from the IE1 level (standard efficiency) to the IE2 level (high efficiency) is very positive and will provide significant and long-term energy savings, particularly in the industrial sector.

Overall, the opportunity for further progress on energy efficiency is considerable. Energy efficiency is yet to be seen as a credible resource (on a par with renewable energy) that can help meet national energy and climate change goals as well as contribute to social and economic development. The current energy efficiency target to reduce energy consumption by 20% against BAU by 2025 is unlikely to be met without additional significant and high-impact energy efficiency policies.

To achieve or surpass this target, a suitable legal framework for energy efficiency is required to mandate the implementation of measures in specific sectors. The Ministry of Energy and AChEE have limited power to mandate energy efficiency measures in specific sectors, particularly sectors with high energy consumption such as industry and transport. For example, the AChEE can only direct specific actions, but not oversee or determine levels of energy use that should be complied with. The Ministry of Energy requires a new level of authority to help realise the country's energy efficiency potential. An Energy Efficiency Law, as highlighted in the National Energy Agenda, has been in discussion and development for more than three years and is yet to be sent to the parliament.

Buildings

Despite the lack of a strong legal framework, the government has made some important progress on energy efficiency in buildings. Examples include building-envelope retrofit programmes and voluntary energy labelling for households, pilot projects in public buildings (e.g. hospitals) and energy-management systems. The government was also looking at updating the building-envelope standard for new residential buildings from 2017 which would be a major milestone for the country.

Building energy codes and standards are essential to improve the energy performance and comfort of buildings in Chile. The country does not have energy efficiency standards for non-residential buildings or dedicated energy efficiency programmes for commercial buildings. However, energy efficiency standards exist for social housing (around 80% of the residential new build today) and private residential buildings (about 20% of the new build today).

The challenge is that, unless the budget of the Ministry of Housing is increased, bringing the social housing to a higher efficiency standard would decrease the number of houses built per year. The long-term benefits for consumers in energy-cost savings and health benefits are clear, and, therefore, the government should identify financing mechanisms for efficient social housing (e.g. auctions, passing the additional investment to the tenant/owner or funding from other sources). The additional health benefits from better insulation provide opportunities to work with the Ministry of Health to complement the funding. Generally, the building industry is not going beyond the minimum envelope standard which highlights the importance of regularly reviewing the standard and introducing energy labelling for buildings.

The government should also ensure that private residential buildings comply with the efficiency regulations. Presently, these buildings are required to be in compliance only at the design phase, but there is no verification after construction. In many IEA countries, compliance is verified by public sector building inspectors and the government should consider this approach.

Research shows that mandatory MEPS are by far the most cost-effective energy efficiency policy worldwide. Chile has made some progress in setting new MEPS for appliances and equipment since the 2009 IEA In-Depth Review. MEPS are currently available for lighting (i.e. banning of incandescent lamps), refrigerators and three-phase electric motors (updated in 2017). Chile is a global leader on energy efficiency labelling for appliances, with mandatory labelling for 26 products and this policy has helped move the market to appliances of higher efficiency. The government should continue to update and expand MEPS and labelling levels on a regular basis to ensure the market moves to a higher efficiency.

Poor-quality firewood is commonly used for heating, particularly in the south of Chile. It is an informal market responsible for the degradation of native forests and it contributes significantly to local air pollution. The energy efficiency division of the Ministry of Energy has been heavily involved in trying to resolve this major challenge for the country. The Policy for Use of Wood and Derivatives for Heating (see Chapter 8) is important as a guideline for a more-efficient use of firewood in the short, medium and long term. The policy sets 86 specific actions and timelines with goals from 2016 to 2018. However, it is necessary to have a law that regulates the quality of the firewood used for heating, and even though it was a compromise of the Policy, it has not yet been sent to parliament.

Industry

All the existing energy efficiency measures for the industrial sector are voluntary. They include awards, agreements, energy audits, energy-management systems, information and training, and projects. Consequently, the industrial energy intensity has remained relatively unchanged since 2005. For example, energy-intensive industries are not required to report their energy consumption and implement energy efficiency measures to improve their energy use. An independent study, supported by detailed energy audits, undertaken in collaboration with most energy-intensive industries and industry associations, should be carried out to determine and validate the potential energy savings of the industrial sector and assess the potential energy efficiency measures and respective cost and benefits on industrial productivity and competitiveness, employment, energy security, energy prices, resource management and air pollution, for example. This study would further support the need for an energy efficiency law to regulate the industrial sector.

Transport

The agreement signed between the Ministry of Energy and the MTT to improve the energy efficiency of the vehicle fleet is a significant political step forward for Chile. The expansion of the scope of the energy label to medium-duty vehicles (up to 3 600 kg) and electric and hybrid vehicles will also help to drive the market towards more-efficient vehicles. However, there are no minimum fuel-economy standards for light-duty vehicles in Chile. As all vehicles in Chile are imported, it should be relatively straightforward to align these minimum standards with the major importing countries.

Energy service companies

The ESCO market for energy efficiency has been gradually growing, driven mainly by the large ESCO companies. Most ESCO projects are in the private sector, but there is a shift towards the public sector as a result of the Ministry of Energy's *Gestiona Energia* programme. Nevertheless, the lack of a regulatory framework is partly constraining the ESCO market from growing much further.

Recommendations

The government of Chile should:

- ☐ Establish a robust legal framework for energy efficiency and designate responsibilities to all relevant ministries.
- ☐ Evaluate the costs and benefits of existing energy efficiency programmes and, if necessary, redirect funding and efforts to priority and high-impact programmes to increase the probability of reaching the energy efficiency target by 2025.
- ☐ Continue and expand efforts to improve the efficient use of firewood for heating through efficient heating technologies and more-efficient building envelopes.
- ☐ Expand MEPS to other appliances, equipment and lighting, including firewood stoves.
- ☐ Strengthen building energy standards for the residential sector and set them for the non-residential (i.e. commercial) sector; also strengthen the mechanism to verify compliance during planning and construction to the same level of enforcement as with building safety standards.
- ☐ Introduce fuel-economy standards for light-duty and heavy-duty vehicles.
- ☐ Establish mandatory policy and market-based mechanisms to improve the energy efficiency in industry and through energy-distribution companies.

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8. Renewable energy

Key data

(2016 provisional)

Total supply: 10.1 Mtoe (26.8% of TPES) and 30.6 TWh (39.1% of electricity generation). IEA average: 9.9% of TPES and 23.6% of electricity generation.

Hydro: 1.7 Mtoe (4.5% of TPES) and 19.6 TWh (25.0% of electricity generation)

Biofuels and waste: 7.9 Mtoe (21.2% of TPES) and 6.2 TWh (7.9% of electricity generation)

Wind: 0.20 Mtoe (0.5 % of TPES) and 2.3 TWh (2.9% of electricity generation)

Solar: 0.25 Mtoe (0.7 % of TPES) and 2.6 TWh (3.3% of electricity generation)

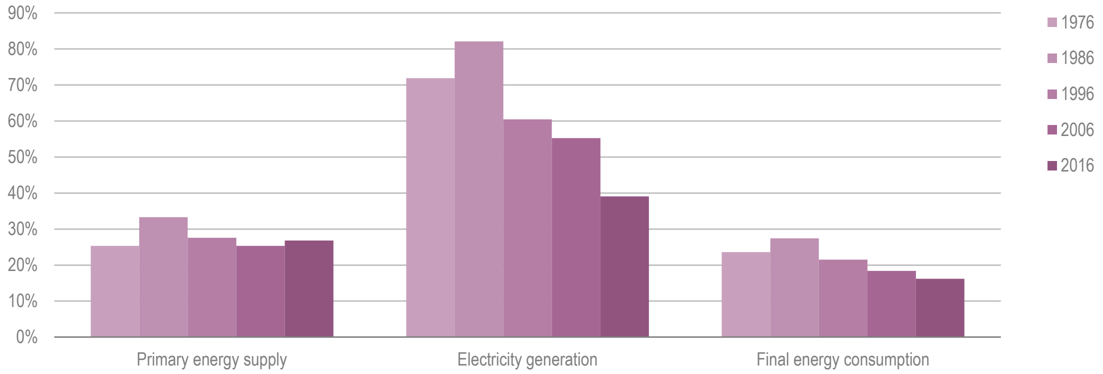
Overview

Chile has enormous potential for various renewable-energy sources. Solar resources, are spectacular: the Atacama Desert in the north boasts a direct normal irradiance of more than 9 kilowatt hours (kWh) per square metre (m^2) per day, the highest in the world. In its extreme south, together with Argentina, it has the best onshore wind resources in the world. It also has a substantial potential for hydropower, geothermal, biomass, waste-to-energy and ocean energy. The development of renewable-energy resources is expected to bring economic and social benefits to the country.[1]

Renewable energy is significant in Chile. Over the past decades, it has accounted for around 25-35% of the total primary energy supply (TPES). The main renewable-energy source is biomass, which is used for both heating and cooking in the form of firewood in the south of the country, but also for electricity generation (Figure 8.1). The remaining share is mostly hydropower, but Chile has also started to capture its rich potential for solar and wind energy.

[1] Studies conducted in Chile suggest that supplying 20% of electricity from non-conventional renewable energy by 2020 would contribute an additional USD 2.3 billion to the GDP (+0.6%) and generate 7 800 jobs (IRENA, 2016).

Figure 8.1 Renewables share of TPES and electricity generation, 1976-2016



Notes: Latest consumption data are for 2015. Data are provisional for 2016.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Supply and demand

Renewable energy in TPES

In 2016, renewable energy accounted for just above 25% of Chile's primary energy supply (Figure 8.2). Compared with International Energy Agency (IEA) member countries, Chile has the seventh-highest share of renewable energy in TPES (Figure 8.3).

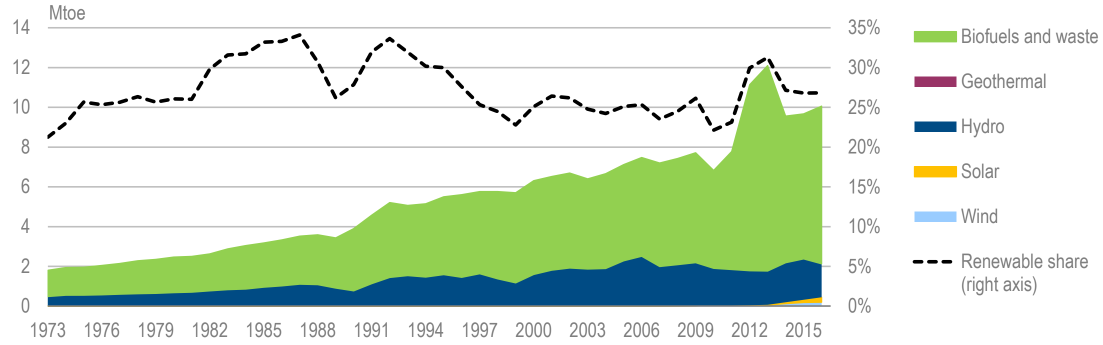
In the past decade, renewable-energy supply grew 35%, but its share in TPES increased only slightly. Most of the increase in renewable energy came from biofuels.

Biofuels (including solid biomass, such as wood pellets, wood chips and straw and biogas) is the largest renewable-energy source and the second-largest energy source after oil in Chile, accounting for over 20% of TPES. The large share of biofuels in TPES results from the extensive use of firewood as a fuel for residential heating and cooking, especially in south-central Chile, and from the burning of by-product waste wood to generate electricity and heat in power plants and the pulp and paper industry (Figure 8.4).

Hydro is the second-largest renewable-energy source, at 4.5% of TPES. Chile's hydro supply has been stable at around 2 million tonnes of oil equivalent (Mtoe), with weather-related annual fluctuations, but the share of hydro in TPES has declined as other energy sources have increased.

Chile recently began to develop its solar and wind capacity. Given that it is still at an initial stage, wind and solar together account for only 1.2% of TPES and for 6.2% of power generation. However, growth has been rapid, and it is expected to continue, thanks to the country's vast potential for wind and solar energy and increasingly competitive costs of renewable-energy generation.

Figure 8.2 Renewable energy in TPES, 1973-2016

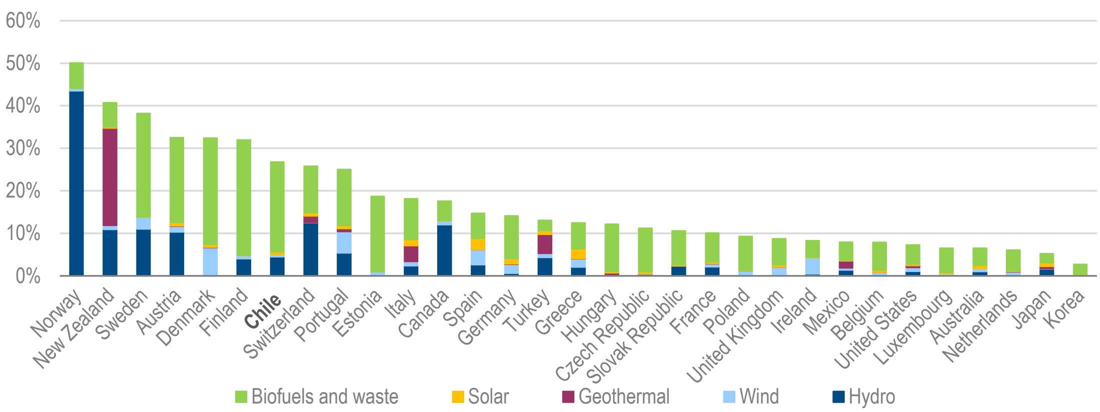


* Negligible.

Notes: The sharp drop in biofuel consumption in 2014 was caused by a change in Chile's methodology for collecting biomass data (based on a national representative survey for residential, commercial and public sectors). Data for 2016 are provisional.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

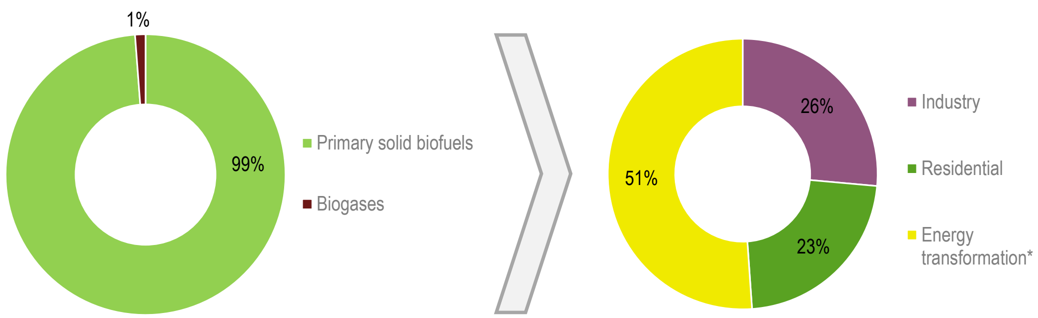
Figure 8.3 Renewable energy as a percentage of TPES in Chile and IEA member countries, 2016



Note: Data are provisional.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Figure 8.4 Supply and consumption of biofuels and waste, 2015



* *Energy transformation* includes power generation and a small share of charcoal production

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Electricity from renewable energy

Renewable energy, especially hydropower, has traditionally played an important role in power generation in Chile. Over the past decade, however, electricity demand has grown significantly along with economic growth, and this growth has largely been met by increased coal power. As a result, the share of renewable energy in electricity generation decreased from 55% in 2006 to 39% in 2016 (Figure 8.5).

In 2016, hydro was the second-largest energy source in power generation after coal, accounting for 25% of the produced electricity. Other renewable energy sources also made a considerable contribution to Chile's power generation. Biofuels and waste, wind and solar together made up 14% of the power generation in 2016. In a comparison with IEA member countries, Chile's share of renewable energy in power generation is the eleventh highest (Figure 8.6).

The share of hydropower in power generation peaked at over 80% in the late 1980s, but has decreased since then to 25% by 2016. Despite new hydropower plants, the increase in hydropower has not kept pace with the growth of power demand. Recurring droughts have contributed to the decreasing share of hydropower in power generation. Moreover, increasing environmental concerns have slowed down the construction of new hydropower plants. Nonetheless, multiple hydropower plants are currently being developed. Hydropower plants also continue to hold the highest installed generating capacity among renewable electricity technologies (Table 8.1).

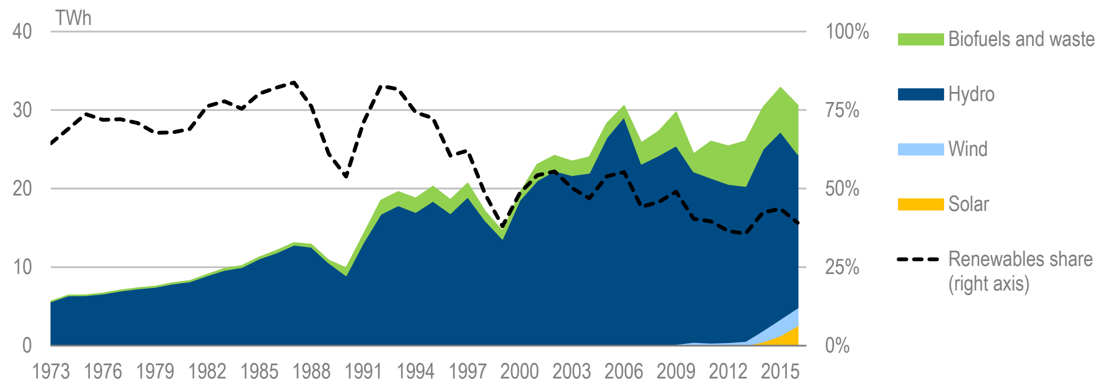
In contrast to hydropower, the use of other renewable sources for power generation has increased rapidly over the past decade, raising their share in electricity generation from 2% in 2006 to 14% in 2016. In 2016, biofuels and waste accounted for 7.9% of the total, followed by solar at 3.3% and wind at 2.9%. As discussed below, Chile has adopted both a law to increase the share of non-conventional renewable energy (NCRE) further and long-term policy objectives to increase the share of all renewable energy in electricity generation (see "Policy objectives" section).

Potential for renewable electricity

Chile has vast untapped potential for solar power and significant potential for wind and hydro. In a 2014 joint study by the Ministry of Energy and the German Agency for International Co-operation (GIZ) (Ministry of Energy/GIZ, 2014), solar photovoltaic (PV) potential was estimated at 1 263 gigawatts (GW), concentrated solar power (CSP) at 548 GW, wind power at 37 GW and hydropower at 12 GW. It is worth noting that the study only considered wind-power capacity with an estimated capacity factor of at least 30%.

The Atacama Desert, located in the North and covering around 140 000 square kilometres, offers the best solar resources in the world with annual Global Horizontal Irradiance (GHI) that reaches more than 2 800 kWh/m^2. GHI declines from north to south. Wind resources are strongest in the very southern part of the country. Favourable wind conditions also exist in the northeast, where the Chilean border expands the most into the Andean region and annual average wind speeds exceed 14 metres per second at a height of 100 metres. The best-suited areas for both solar and wind are located far away from load centres (cities) located in the centre of the country. Climatic conditions and distance from the load centres make deployment in these areas relatively more difficult (see Chapter 5 for more details on the grid integration of renewable energy).

Figure 8.5 Renewable energy in electricity generation, 1973-2016



Notes: Data for 2016 are provisional. tWh = terawatt hours.

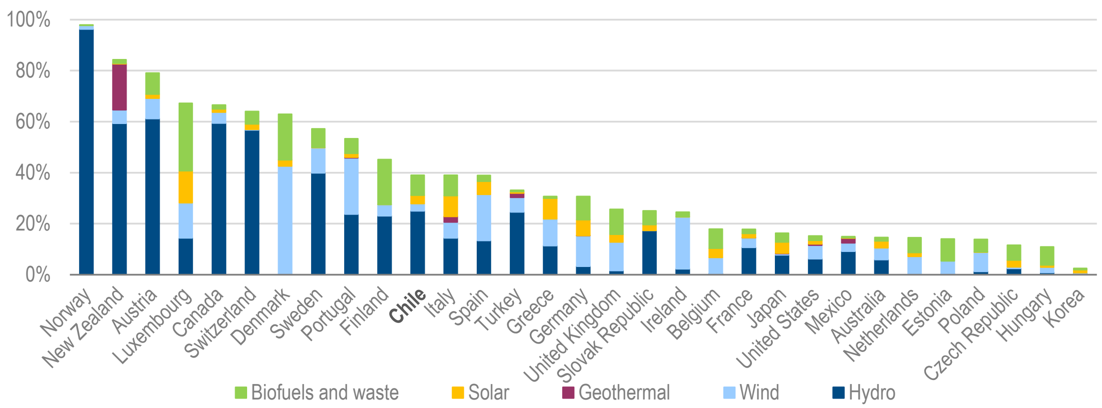
Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Table 8.1 Renewable electricity generating capacity, 1990-2015 (MW)

Technology	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Hydro	2 678	3 589	4430	5224	5467	5946	5992	6094	6378	6498
Solar PV	0	0	0	0	0	0	2	15	242	617
Wind	0	0	0	2	163	184	202	301	731	908
Solid biofuels	0	22	22	36	526	548	832	1240	884	417
Biogases	0	0	0	0	0	0	0	27	42	49
Total capacity	**2678**	**3611**	**4452**	**5262**	**6156**	**6678**	**7028**	**7677**	**8277**	**8489**

Source: IEA (2017b), *Renewables Information 2017*, www.iea.org/statistics/.

Figure 8.6 Electricity generation from renewable sources as a percentage of all generation in Chile and IEA member countries, 2016



Note: Data are provisional.

Source: IEA (2017a), *World Energy Balances 2017*, www.iea.org/bookshop/753-World_Energy_Balances_2017.

Institutions

The Ministry of Energy is responsible for elaborating and co-ordinating national energy policy, including renewable energy policy. The Renewable Energy Division *("*DER" in Spanish*)* of the Ministry of Energy develops and updates policies, plans, programmes and standards regarding renewable energy.

The National Energy Commission (CNE – *Comisión Nacional de Energía*) is responsible for regulations on prices, tariffs and technical norms for energy, including electricity generation from renewable-energy sources.

The responsibilities of the Superintendent of Electricity and Fuels (SEC – *Superintendencia de Electricidad y Combustibles*) include monitoring compliance of electricity generation (including from renewable energy) with laws, rules and technical norms.

The National Electricity Co-ordinator is responsible for the co-ordination of the short-term operation of the National Power System.

The Ministry of National Assets (*Ministerio de Bienes Nacionales*) is responsible for the national policy for the use of state lands for NCRE projects (wind and solar).

Several state institutions issue licences, permits and authorisations for the construction of renewable-energy plants, including but not limited to: Ministry of Housing and Urbanism, Ministry of National Assets, Ministry of Agriculture (National Irrigation Commission [CNR], Agricultural Development Institute, Agricultural Research Foundation, Agricultural and Livestock Service), Ministry of Public Works (General Directorate of Water and Road Management), National Forestry Corporation, Council of National Monuments, Ministry of Environment, Environmental Assessment Service and Production Development Corporation.

Several bodies support electricity generation from renewable-energy sources for own use in various sectors. They include the Institute of Agricultural Development (INDAP), CNR, National Clean Production Council, Ministry of Social Development, Ministry of Education, and Ministry of Housing and Urbanism.

Policy objectives

Chile has short-term and long-term policy targets for the share of renewable energy in total electricity generation. The short-term target, initially adopted in 2008, was to generate 10% of electricity from non-conventional renewable energy (NCRE) by 2024. In 2013, the share was increased by Law 20 698 to 20% by 2025. The Law defines the following energy sources as NCRE: biomass, hydropower with capacity less than 20 MW, geothermal, solar, wind, marine energy and other means of generation determined by the CNE.

The National Energy Policy 2050 sets a target for renewable power (including large hydro) to account for 60% of electricity by 2035 and 70% by 2050, against some 40% by 2015. It also sets a related goal: to promote sustainable hydropower development to increase the share of renewable energy in the electricity mix. The targets are supported by background studies indicating that it will be technically feasible to integrate such shares of renewable electricity into the power system.

Chile does not have quantitative targets for renewable energy in heating and transport. The National Energy Policy 2050 sets a general goal to promote fuels with low levels of greenhouse gas emissions and atmospheric pollutants in the overall energy mix.

Policies and measures in the electricity sector

The government encourages electricity generation from renewable energy in different market segments through several policies and measures, including:

- renewable-energy quota obligation on electricity suppliers
- auctions by the distribution companies to supply electricity to regulated customers
- encouraging distributed generation and self-consumption
- facilitating grid access for renewable-energy plants
- enabling the integration of variable renewable energy into the power system
- improving the framework for geothermal exploration and exploitation
- facilitating the financing of renewable-energy projects and raising awareness.[2]

Renewable electricity is a seamless part of the Chilean electricity system, and therefore most of the items in the list above are discussed in Chapter 5.

Renewable-energy quota obligation

To reach the national renewable-energy target of 20% by 2025, electricity generators with an installed capacity of more than 200 MW must certify that a specified percentage of electricity they sell comes from NCRE sources, either their own or contracted. This percentage increases annually until it reaches 20% in 2025. For contracts signed between the eligible generators and distribution companies or final users in the period from 31 August 2007 to 1 July 2013, the annual quota obligation was set to 5% for the years between 2010 and 2014, and then increasing 0.5% each year from 2015 onwards, until reaching 10% by 2024. Contracts that are signed after 1 July 2013 include a 5% obligation for 2013, with a 1% annual increase from 2014 onwards until reaching 12% by 2020; after that, annual increases are set at 1.5% from 2021 to 2024, and 2% in 2025 to reach 20%.

The legislation also has penalties for companies that do not meet the quota, as well as a model for selling NCRE power surplus to other generators that have a quota obligation. The initial penalty for a non-compliant company is equivalent to 0.4 monthly tax units

[2] This is also relevant to the use of renewable energy in heating and, to some degree, transport. Therefore, it is discussed in a separate section below.

(UTM [*unidad tributaria mensual*]) for each megawatt of NCRE's deficit (~30 USD [United States dollars] per megawatt hour [MWh]). The penalty increases to 0.6 UTM for each megawatt of NCRE's deficit if the company continues to be non-compliant for more than three years.

The quotas set out by law have been systematically exceeded collectively every year by a large margin (by 300% in 2016).

Auctions

Technology-neutral auctions for long-term power-purchase agreements (PPAs) organised by distribution companies have emerged as the key driver for large-scale solar and wind projects. The falling costs of solar- and wind-power generation have increased their price-competitiveness in recent years and have helped to reduce the costs of electricity supply in Chile. These auctions are explained in detail in Chapter 5.

The legislation also allows for specific auctions only for renewable energy, if insufficient progress has been made towards meeting the renewable-energy targets set by law. The Ministry of Energy must monitor the compliance with these targets. Every three years, the Ministry estimates the likely share of electricity generated from NCRE in the forthcoming years, considering the existing and under-construction projects. So far, such auctions have not been needed, as the yearly NCRE target has always been met.

Other auctions

Large non-regulated customers can either negotiate electricity-supply contracts directly with generators, or organize a public auction (individually or aggregated) and subsequently enter into PPAs with the successful bidders. The latest auction, for an aggregated demand for 56.2 gigawatt hours per year, was conducted in December 2016 in which 13 companies participated (GTDT, 2017).

In addition, several Chilean public institutions have conducted auctions to promote renewable-energy deployment in the forestry, food and agriculture industries, as well as in public buildings.

Public solar roofs programme

In 2014, the Ministry of Energy, supported by German BMUB-GIZ,[3] launched the Public Solar Roofs Programme (PSRP) to stimulate the market for rooftop PV solutions by organising tenders to encourage demand from public buildings. The Programme is deployed mainly between the regions of Arica and Parinacota, and Maule. During the first implementation stage in 2015-16, 300 buildings in 26 municipalities were evaluated and 99 projects developed with a capacity between 5 kW and 100 kW. The tenders organized as part of this programme have contributed to developing technical and institutional capacities and to disseminating best practice. The tenders have resulted in a reduction in prices of solar systems from 4.5 USD/W to 1.31 USD/W in less than two years. The prices reached by the programme demonstrate that self-consumption projects

[3] Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and GIZ.

are profitable in Chile and that profitability is likely to increase because the cost of PV systems continues to decline.

Renewable energy for agriculture

Chile has implemented several programmes, often with the support of international and bilateral donors, to stimulate the generation of renewable-energy electricity for own use in agriculture and forestry. These include, among others:

- A tender "NCRE pilot projects in the food and forestry sector" launched by the Ministry of Energy and the Foundation for Agricultural Innovation (FIA) in 2014. Of 50 proposals, 16 were awarded for a total amount of CLP 697 million (around USD 1.2 million) in co-financing.
- A programme between the Ministry of Energy and the CNR, has introduced a specific tender according to Law 18.450 on promoting irrigation (enacted in 2016). In 2016, CNR conducted a tender that allocated resources to 14 projects (hydro and PV), which will benefit around 550 farmers.
- NCRE Programme for Small Agriculture, a joint effort between the Ministry of Energy and the Ministry of Agriculture, through CNR and INDAP, has conducted four tenders to finance self-consumption projects based on NCRE for small agriculture across the country under the Law on Net Billing.
- Improving permitting and licencing regulations applicable to self-consumption NCRE projects for irrigation channels.

Framework for geothermal electricity

Chile's long mountain range with many active volcanoes indicates a high potential for geothermal power. To reduce the economic risks of geothermal projects, the government is funding and carrying out geothermal exploration campaigns through SERNAGEOMIN, the governmental geological survey.

Geothermal energy has a special legal status compared with other renewable-energy sources. Law 19.657 on Geothermal Energy Concessions, enacted in 2000, and several regulations adopted and amended since then, provide a framework for the exploration and exploitation of geothermal resources through concessions. An exploration concession is granted for two years and can be renewed for two additional years, with a maximum area of concession of 20 000 hectares (ha). An exploitation concession gives the developer the right to carry out drilling, construction, commissioning and the operation of a geothermal power plant, with the production and processing of geothermal fluids into electrical or thermal energy. It has an indefinite duration, with a maximum area of concession of 20 000 ha (Faría, 2014). In early 2017, there were 11 valid exploration concessions and 12 valid exploitation concessions. The Ministry of Energy evaluates the applications for exploration, exploitation and extensions.

In 2014, the Ministry of Energy started consultation with indigenous people before granting applications for geothermal energy exploitation concessions according to Convention No. 169 of the International Labour Organization. The first consultation process began in September 2014 on applications for Pampa Lirima 1-2-3 exploitation concessions. In January 2017, the process led to an agreement between the Ministry of

Energy and the communities that could be affected by the concessions. At the beginning of 2017, there are two other processes undergoing consultation.

The government, supported by international donor funding, is working to reduce the risks in the geothermal sector (Box 8.1). One example of risk mitigation actions is the 2015 auction for electricity supply, which included special conditions for geothermal projects: companies with only one successful test of a commercial well could make an offer, obtain a block and make use of postponement or exit clauses if the geothermal exploration was delayed or unsuccessful. Therefore, the whole electricity sector would share the geothermal exploration risk.

Box 8.1 Geothermal Risk Mitigation Programme

In 2013-14, the government obtained USD 53 million from the "Clean Technology Fund" (CTF), of which USD 50 million were designated to the Risk Mitigation Programme in geothermal exploration (MiRiG), implemented by IADB and USD 3 million to a technical assistance programme, implemented by the World Bank. In 2015, the government and CTF agreed to add another USD 25 million to MiRiG. The World Bank contributed an additional USD 500 000 to the technical assistance project, from the Bank's Energy Sector Management Assistance Program (ESMAP).

The MiRiG is being implemented with the Cerro Pabellon project as the first beneficiary (it belongs to the Empresa Geotermica del Norte S.A., a company created by Enel Green Power and the National Oil Company, ENAP). Two other projects, Mariposas (EDC) and Licancura III (Transmark), were also selected.

The World Bank has been working, with ESMAP financing, on the technical assistance programme since March 2015 on the following topics:

- Technical documentation and/or regulatory support.
- A technological visit to Nicaragua under the framework of the Indigenous and Tribal Peoples Convention No. 169 and the consultation process for geothermal exploitation applications.
- Call for a study to assess how to co-ordinate the Chilean geothermal industry to contract drilling equipment and services efficiently.
- Creation of the Geothermal Energy Working Table, a public–private entity that aims to analyse the systemic impact of geothermal energy development on the interconnected electrical systems, as well as potential benefits and co-benefits in the short and long term, and the tools needed for its development.

Source: Submission by the Ministry of Energy of Chile.

Allocation of public land for renewable-energy projects

Since 2010, the Ministry of Energy has collaborated with the Ministry of National Assets to create procedures for the land registration and management of public assets, and auctions to allow investors to use the public lands in a concession mode to develop NCRE and energy-infrastructure projects. This has contributed to the development of non-conventional renewable-energy projects.

In January 2016, Chile auctioned 3 000 hectares of public land with a high resource potential for the construction of renewable-energy projects in several locations (IRENA, 2016; Kenning, 2016). As of end-2016, 15% of the installed wind-power capacity (189 MW) and 70% of solar capacity (1 126 MW) is located on public lands. Furthermore, 45% of the wind and solar projects under construction are located on public land.

In May 2017, the Ministry of National Assets adopted new provisions to simplify further the use of public land for renewable-energy projects. The new regulation extended the maximum term of use from 30 to 35 years, and extended the timeframe for the construction of power plants to a maximum of ten years from the conclusion of the concession agreement. It also reduced the amount of securities to be provided to the state by the project developer for each construction phase. The regulation applies both to concessions awarded at auction and to direct concessions (Bellini, 2017).

Policies and measures in heating and transport

Chile has the potential to use the following renewable-energy sources for heating purposes:

- cleaner and more efficient use of firewood
- solar water heating
- direct use of low temperature geothermal energy
- biogas and waste-to-energy.

Biogas, as well as liquid biofuels, could also be used in transport.

Cleaner and more efficient firewood use

Firewood is used by over 1.7 million households in the country, of which 1.4 million are in the centre-south region (Table 8.2).

In Chile, firewood is not considered a formal fuel, as around 90% of its sales are informal. The origin of the firewood is often not controlled and the marketing of the firewood is generally not subject to any energy- or forestry-related regulations. As the firewood is mostly humid, burning it causes significant local air pollution. The pollution is exacerbated by inefficient firewood stoves and poorly insulated houses (for example, around 65% of houses in the centre-south are well below the current building-envelope standard). In Aysen, inefficient burning of low-quality firewood has resulted in declaring certain areas as saturated with fine particulates and the establishment of Local Atmospheric Decontamination Plans.

In 2015, the Ministry of Energy launched their milestone *Policy for Use of Wood and Derivatives for Heating* to limit air pollution from burning firewood, diversify energy sources and promote independence from energy imports (Ministry of Energy, 2015). The policy aims to transform the firewood market into a formal one that contemplates the sustainable production of firewood for energy and its efficient use.

Table 8.2 Average household consumption of firewood and derivatives for seven regions with highest penetration (2015)

Region	Penetration (%)	Number of households	Estimated consumption (m^3)
VI – O'Higgins	57.8	147 251	495 811
VII – Maule	64.1	205 185	727 610
VIII – Biobio	73.7	429 041	2 339 741
IX – Araucania	91.2	267 253	2 113 883
X – Los Lagos	96.3	240 452	3 287 407
XI – Aysen	99.3	31 314	549 442
XIV – Los Rios	94.6	108 945	1 539 273
Total for south-centre region	*77.0*	*1 425 441*	*11 053 167*
Total	**37.6**	**1 721 032**	**11 926 411**

Note: See www.minenergia.cl/archivos_bajar/2016/03/politica_lena_2016_web.pdf.

The policy is divided into six strategic areas and an action plan that covers: i) more efficient buildings; ii) sustainable and good-quality wood; iii) other energy uses for wood derivatives for heating; iv) more efficient technologies for heating; v) institutional framework and vi) education. This policy is consistent with the Local Atmospheric Decontamination Plans, which aims to replace 121 000 inefficient firewood stoves with efficient stoves using wood pellets or certified firewood over ten years from 2015. By 2017, around 20 000 inefficient firewood stoves had been replaced by local governments and the Ministry of Environrnent under the Local Atmospheric Decontamination Plans.

In line with this policy, the Ministry of Energy is implementing a series of measures to improve the quality of the firewood and the efficiency of firewood stoves for heating and cooking, the *More Dry Firewood* programme and information campaigns on energy labelling of firewood stoves and pellet heaters.

From 2014 to 2017, the *More Dry Firewood* programme helped 504 small and medium-sized producers of firewood in the south-central regions of the country to construct or commission collection and drying centres for firewood, purchase machinery to increase the drying times of firewood and receive training in business management and drying and marketing of firewood with quality standards.

In 2014, the Ministry of Energy introduced certification for firewood stoves of specific sizes that establishes emission limits for particulate matter. A mandatory energy efficiency label was introduced for firewood stoves (2015) and pellet heaters (2017) to help consumers make an informed decision based on energy performance.

In April 2017, the government also launched a district energy strategy to tackle the use of firewood for heating and further improve the air quality[4] at the local level, particularly in

[4] http://drustage.unep.org/newscentre/chile-makes-bold-air-quality-commitment-new-energy-strategy.

the southern regions. Together with UNEP, the Ministry of Environment is developing a Sustainable Heating Strategy,

Local and regional authorities also try to take measures to address this issue; for example, the use of firewood (but not pellets) is prohibited in the province of Santiago under its Local Atmospheric Decontamination Plan.

Solar water heating

Chile has three mechanisms to encourage installing solar water heaters (SWHs) for residential water heating:

- a tax exemption for SWH installation in new housing (from 2017)
- a subsidy to incorporate SWH into housing reconstruction programmes (2014-17)
- Ministry of Housing and Urban Development (MINVU)'s Family Heritage Protection Programme for existing public housing (from 2011).

With these measures, more than 90 000 homes have hot water supported by solar thermal systems.

Tax benefits for installing SWHs were initially granted from 2010 to 2014, and the programme was extended until 2020. The benefit applies to new houses and apartments with SWH installed between 1 January 2015 and 31 December 2020 in accordance with the technical requirements set by law and having a municipal acceptance certificate. Construction companies can deduct the cost of the SWH, its installation and five years of maintenance from their income tax or any other tax.

The tax benefit varies according to the value of the dwelling (land + construction costs):

- less than 2 000 UF,[5] the benefit covers up to 100% of the investment.
- between 2 000 and 3 000 UF, a linear decrease of the benefit from 100% to 0%
- more than 3 000 UF, no tax benefit.

The level of tax benefit per housing depends on the size of the solar thermal system: the benefit is the biggest for the smallest systems. The level of the benefit declines each year between 2015 and 2020.

In response to housing reconstruction needs because of the natural disasters that occurred in 2014 and 2015, the government introduced a subsidy for the installation of SWH as part of the housing reconstruction programme. In total, some 5 200 buildings received the subsidy.

For existing public housing, MINVU and the Ministry of Energy have created a subsidy for the installation of SWH. From 2011 to 2015, the subsidy was granted to 28 000 buildings.

[5] "UF" is the Chilean indexation unit.

Solar thermal energy in mining

Chile's mining industry proactively develops solar thermal projects in the isolated northern regions. In 2013, the world's then-largest solar thermal plant was inaugurated in the Antofagasta region, which supplies 85% of the heat demand of the Gabriela Mistral (Gaby) copper mine, owned by the state company Codelco. The business model adopted by Codelco for the Gaby copper mine is an interesting example of increasing industrial competitiveness and reducing energy-supply risks. A ten-year heat supply PPA was signed with a solar thermal plant owned and operated by the Chilean–Danish consortium Energía Llaima/Sunmark (IEA, 2015; IEA RETD TCP, 2017).

Geothermal energy for heating

Despite significant geothermal potential, the use of low-temperature geothermal energy in Chile is limited because of the lack of knowledge, an immature market and an underdeveloped regulatory framework. In 2016, the Ministry of Energy created a programme to promote the direct use of geothermal energy for heating applications. This programme, financed with public funds, the CTF and World Bank's ESMAP, focuses on the following areas.

Analysis of regulation

Analysis of the existing laws and regulations has been conducted with a view to create an attractive regulatory framework for direct-use geothermal projects. Two guides for developers have been prepared on the procedures to obtain underwater and surface-water rights.

Awareness and education

The programme to raise awareness on geothermal energy includes the following actions:

- handbooks to facilitate the implementation of geothermal projects
- seminars organised with the Universidad de Chile
- a study on heat pumps in Chile conducted by the Ministry of Energy, as well as a best-practice guide on the use of geothermal heat pumps
- a directory of Chilean installers and companies associated with the installation of geothermal heat pumps
- co-operation with GNS Science (New Zealand) and the government of New Zealand.

Potential

The Programme works with the National Service of Geology and Mining (SERNAGEOMIN) and the Universidad de Chile to collect, analyse and make available relevant technical information, such as geology, hydrogeology and geophysics, to help identify favourable locations to develop geothermal projects at the least cost. Furthermore, an "online explorer" of geothermal potential is being developed (see "Raising awareness" section below).

Biogas

The Ministry of Energy implements a four-year programme, "Promoting the development of energy from biogas among selected small and medium-sized agribusinesses", until November 2018. It is financed by a USD 1.7 million grant from the Global Environment Facility. Its goal is to promote a local market for anaerobic digestion technology for bovine slurries in medium-sized dairy farms in the regions of Los Rios and Los Lagos to mitigate methane emissions and provide a local energy source.

The programme has three major components:

- developing policy and raising awareness
- improving technical capabilities and skills
- investment and project portfolio to develop approximately 20 operating biogas projects in both regions, with a demonstration effect.

A regulation on biogas plant safety was published in February 2017 and entered into force in August 2017. It introduces the minimal safety requirements for biogas plants; regulates the stages of design, construction, operation, maintenance, inspection and end of operations; standardises the direct thermal use and combustion of biogas for to generate electricity, as well as flaring. The design and construction requirements set out in the regulation will not be mandatory for biogas plants registered with SEC before its entry into force.

Transport

Bioethanol is allowed to be used in Chile as oxygenate mixed with gasoline at 2% or 5%. However, there are no specific measures to promote biofuels in transport.

In the late 2000s to early 2010s, Chile had five biofuel consortiums, which conducted five-year programmes for the research and development of a biofuels value chain, including biomass production at a low cost, biomass logistics supply, processes and technologies to produce biofuels and its by-products.

Key results and conclusions of these consortiums included:

- Biodiesel, bioethanol and biogas from micro and macro algae were proved technically feasible but not financially viable in Chile at that time.
- Synthetic biodiesel produced by biomass gasification and the subsequent Fischer–Tropsch synthesis, as well as ethanol from lignocellulosic biomass, could not compete in price with fossil fuels.
- The potential use of bioethanol in Chile could be the production of additives for gasoline oxygenation. The results of the analysis indicate that there was a potential market for the use of bio ethyl *tert*-butyl ether as an additive; however, some financial and legal barriers need to be removed first.

Cross-cutting measures

Support for financing renewable energy

Chile has some experience with venture capital in the renewable-energy sector. In the late 2000s, the National Economic Development Agency CORFO6 offered a credit line for environmentally friendly technologies; it contributed up to 40% of equity (with the remaining 60% provided by private investors), and absorbed part of the investment risks. According to IRENA, the facility has triggered the emergence of Chilean venture capital funds interested in renewable-energy investments, such as the IM Trust Energías Renovables (IRENA, 2016).

In 2016, the Ministry of Energy and CORFO created a loan facility for self-consumption NCRE projects under a programme financed by the German Development Bank (*Kreditanstalt fur Wiederaufbau*, KfW). The NCRE loan has been available for banking since April 2016. At the same time, CORFO has been working with the State Bank (*Banco Estado*) to develop a loan focused on PV systems. Products for micro, small- and medium-sized enterprises, as well as alternatives for individuals, were expected to be launched in 2017.

Since December 2016, the Ministry of Energy's website has had a "Search Engine for Funding", which provides access to over 40 public financing instruments available to co-finance self-consumption projects based on renewable energy. Institutions such as CNR, INDAP and the Technical Co-operation Service (SERCOTEC) award public funding and provide information on various tax benefits and loan options. This online tool is updated regularly.

Raising awareness

The Ministry of Energy has various online geographic tools, called "Explorers", that are available to the public free of charge. They are the result of collaboration between the Ministry of Energy, the German Agency for International Co-operation (GIZ) and many other Chilean institutions. These tools offer a preliminary assessment of the energy potential of any site defined by the user, although they do not replace on-site measurements. All these tools are available at www.energia.gob.cl/energias-renovables.

In addition to the Explorers and the Search Engine for Funding above, the Ministry of Energy and other institutions conduct information campaigns, training and seminars, and publish guidebooks – often financed by bilateral or multilateral technical assistance projects – to raise awareness about renewable-energy opportunities and facilitate project implementation.

Assessment

Renewable energy has been an important contributor to the Chilean energy mix for many decades. Historically, biomass has been the largest renewable-energy source. About half

[6] See more details on CORFO in Chapter 9.

of the total biomass used is consumed in the residential sector in the form of traditional firewood used for heating and cooking. It is highly encouraging that, in addition to biomass and traditional large hydro, Chile has begun to capture its vast potential for solar and wind energy.

As Chile has national targets only for renewable electricity, most policy instruments apply mainly to the electricity sector. Chile successfully promotes electricity generation from renewable energy in different market segments through a combination of policies and measures, including a renewable-energy quota obligation for distribution companies. Technology-neutral energy auctions have been the main driver for growth in large-scale electricity from renewables that competes, without additional support, with traditional generation. Recently, electricity-sector legislation was amended to enable higher shares of solar and wind power to enter the system (this and other matters related to renewable electricity are discussed in Chapter 5).

Beyond the electricity sector, the IEA recommends that the government pay more policy attention to renewable energy in the heating and transport sectors. As part of its overall energy strategy, the government should define an overall renewable strategy in which the long-term renewable-energy objectives should be combined with mid-term implementation policies for electricity, heat and transport in the short (2020-25) and medium term (2030-35). Defining such a solid and consistent strategy will give direction to the market.

In developing a renewable-energy strategy, it makes sense to evaluate carefully the full socio-economic costs and benefits of various renewable-energy technologies and applications. The criteria that need to be considered include health (especially in the case of biomass), energy security (national production, variability of wind and of solar PV, and controllable hydro, geothermal and CSP), emissions reduction, innovation and the development of new economic sectors in Chile, and the opportunities for local development.

The largest share of renewable energy is biomass, especially firewood. Government policy in this respect is struggling to find an effective approach. As firewood is not recognised as a fuel, it cannot be regulated and also has no base for taxes. This is understandable, but does not lead to a level playing field.

The inefficient burning of low-quality firewood is the largest cause of air pollution, especially in cities in southern Chile. It is estimated that air pollution is responsible for 4 000 premature deaths and USD 8 billion in costs per year in medical expenses and lower labour productivity (another cause for air pollution is local transport). The external costs of burning mostly humid and of low-quality firewood are extremely high. Nevertheless, firewood is an important energy source in Chile, especially in the south, where nearly 80% of households use firewood to heat and/or cook, so the role of biomass for people’s comfort and economic activity cannot be underestimated.

The government is trying several approaches to reduce the negative impacts of firewood use. In this context, the IEA welcomes the 2015 *Policy for Use of Wood and Its Derivatives for Heating*. Although the IEA recognises that it is not easy to find policies to tackle the informal firewood market, it strongly urges the government to adopt more-ambitious policies and measures to stimulate the efficient and clean use of firewood. Such measures could include:

- Regulation and enforcement. In those places in which alternative heating options are available (e.g. sustainable and dry firewood, pellets, heat pumps, solar thermal or natural gas), the burning of other wood could be banned. To give an incentive to gas companies, the remuneration regulation for these companies should be changed to allow them to include the costs of new connections in their asset base. These measures need to be combined with enforcement, marketing and training.

- Promoting alternatives. Several options exist. Heat pumps are one; their operational costs are probably lower than using certified firewood, but people are unaware of this. In more-densely populated areas, (small-scale) district heating with sustainable biomass or natural gas could be feasible. Demonstration projects of district heating and heat pumps could be supported with soft loans and other financial incentives, and targeted awareness by raising campaigns could result in a larger roll out. In sparsely populated areas, solutions such as liquid petroleum gas (LPG) or sustainable firewood offer alternatives.

- Financing and subsidies. The government could continue and intensify the support for drying of wood and turn the informal sector into a formal one through a certification system. For specific consumers, such alternatives might be too expensive. Temporary subsidy schemes to introduce alternatives and improve the insulation of houses could be considered, together with strict enforcement of a policy not to burn unsustainable firewood. As the health benefits of these alternatives are very large, the government could consider the transfer of a small part of the health budget to the initial support of them. For financing, the government could also look at the private sector; a ban on uncertified wood offers commercial opportunities for LPG and forestry companies, and it could offer financing schemes to make the necessary investments in LPG heaters and for storage in which to dry wood. The government has already supported the market for solar thermal systems. There are already more than 90 000 homes that have hot water supported by solar thermal systems.

Furthermore, more attention can be given to waste-to-energy. The largest landfills in the country are capturing biogas and generating electricity. However, the treatment of municipal waste remains a challenge for many municipalities. The population objects to creating new landfills, but waste continues to be produced. In addition to avoiding waste creation and recycling materials, a viable solution may also be the high-temperature burning of waste to produce biogas to generate electricity, as demonstrated in several IEA member countries. National policy measures are needed to encourage local governments to move in this direction.

Recommendations

The government of Chile should:

- ☐ Formulate an overall short- (2020-25), medium- (2030-35) and long-term (2050) strategy on renewable energy that includes policy measures not only on electricity, but also on transport and heating.
- ☐ Evaluate the full socio-economic costs and benefits of renewable energy in all sectors (electricity, transport and heating) in terms of energy security, emissions reductions, innovation, health and local development.

- Implement the policy to improve air quality by significantly reducing the use of low-quality firewood within five years through regulation, enforcement, best-practice dissemination and alternative heating options.
- Develop an action plan on municipal waste-to-energy.

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9. Energy technology research, development and innovation

Overview

Spending on energy technology research, development and innovation (RDI) – particularly by the business sector – has been historically very low, and Chile has been the lowest overall research and development (R&D) performer in the Organisation for Economic Co-operation and Development (OECD), at under 0.5% of GDP. However, as Chile is a party to Mission Innovation, the government has set the goal of doubling public spending on clean energy RDI by 2020. It has also made significant efforts to develop a strategy for energy with science, technology and innovation (STI),[1] and to strengthen academia–industry links, international co-operation and technology diffusion.

A major initiative, the Solar Energy Program 2016-25, has been launched recently to develop an export-oriented national solar power industry. Other important initiatives include the proposals for a Chilean Lithium Programme and for a Solar and Mining Technology Institute that will focus on solar, mining and lithium. Several other programmes are being implemented, in co-ordination with local and international partners. The objective of the National Energy Policy 2050 is for Chile to become an exporter of technology and services for the solar industry by 2035. For 2050, the aim is that the scope of the exports broadens and innovations help reduce energy consumption in Chile.

Institutions

Public sector

Several public and private entities are active in energy technology RDI. The public system for the support of STI has three levels: strategic, political and executive (Figure 9.1).

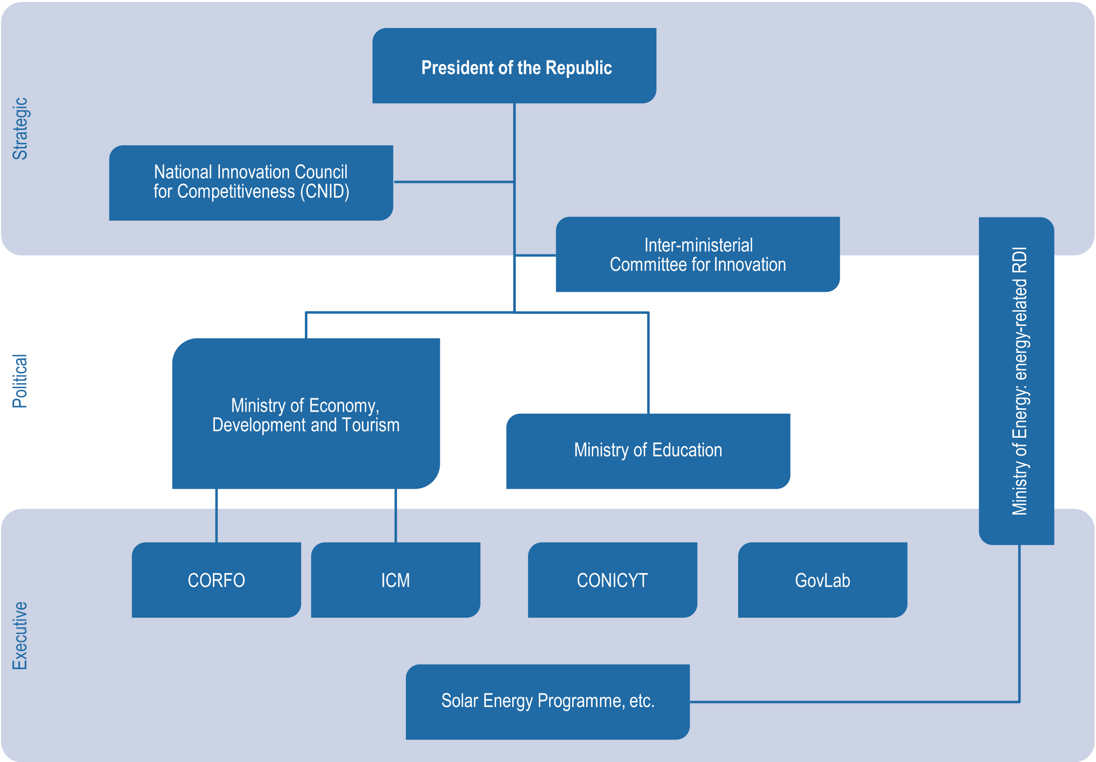
On the strategic level, the National Innovation Council for Competitiveness (CNID – *Consejo Nacional de Innovación para el Desarrollo*) advises the president of the republic on the identification, formulation and execution of policies, plans and programmes related to innovation. These include science fields, specialised training and development, transfer and dissemination of technologies.

[1] IEA and OECD publications generally refer to RDI, but in Chile, science, technology and innovation (STI) is more commonly used. This chapter uses the acronyms RDI and STI interchangeably.

At the policy-design level, the Inter-ministerial Committee for Innovation reports to the president and approves and implements the government's innovation policy. The Ministry of Economy, Development and Tourism (MEDT) is responsible for the overall implementation of the innovation strategy, and it co-ordinates other ministries involved in science and innovation in specific sectors.

In January 2017, the Chilean president signed a bill to create a new dedicated Ministry of Science and Technology. The Ministry will advise the president of Chile on the design, formulation, co-ordination, implementation and evaluation of policies, plans and programmes related to science and technology. It is also expected to provide grants, loans and other assistance to developing science and technology in the country, and to build relations with foreign organisations. Also, a Research and Development Agency is expected to be created to execute RDI policies. The National Council for Science, Technology and Innovation will be established as a permanent body and an Inter-ministerial Information Technologies and Communication Committee will be created to strengthen the overall institutional framework (Government of Chile, 2017).

Figure 9.1 Institutional structure for public RDI in Chile as of early 2017



Note: The Ministry of Science and Technology, the Research and Development Agency and other new bodies are not reflected in this figure, because the new institutional structure had not been officially finalised by the time of drafting this publication.

Source: IEA based on the information provided by the Chilean government.

Several executive agencies implement the national RDI programmes. The key agency is the National Economic Development Agency (CORFO [*La Corporación de Fomento de la Producción*]), which focuses on innovation, entrepreneurship and technology promotion and transfer. CORFO, as well as the National Institute for Intellectual Property (INAPI) and the Millennium Scientific Initiative (ICM), report to the MEDT.

Another implementing agency, the National Commission for Scientific and Technological Research (CONICYT), is responsible for basic and applied scientific research, and advanced training and education. It reports to the Ministry of Education.

The Government Laboratory (GovLab [*Laboratorio de Gobierno*]) is a recent structure initiated by the Chilean president. It is mandated to develop, facilitate and promote user-centred innovation processes within the Chilean state institutions.

The sector ministries – including the Ministry of Energy – co-ordinate implementing the national RDI strategy with the entities at the three institutional levels, but especially with the executive institutions. The Ministry of Energy signs collaboration agreements with both CORFO and CONICYT, which transfer funds for specific initiatives. Through these agreements, the Ministry of Energy is linked to a number of universities, research centres, companies and entrepreneurs.

At the regional level, the Ministry of Energy is represented by Regional Ministerial Secretariats. They co-ordinate with the *Major* (Head of the Regional Government) of each region. Two regions – Magallanes and Aysén – have a specific regional long-term energy policy and a long-term energy roadmap, respectively, and both consider the development of science and innovation in their territories, looking for technology adaptation and/or the development of new solutions for local challenges.

The Centre for the Development of the Solar Energy Industry (CDIES [*Centro de Desarrollo de la Industria de la Energía Solar*]) is focused on developing a national solar energy industry through the Solar Energy Program (see below). The Minister of Energy is the President of the Board of CDIES and of the Solar Energy Program.

The National Commission for Nuclear Energy (CChEN) is in charge of regulating, inspecting and controlling all issues related to nuclear security and radioactive facilities, as well as authorising lithium exploitation. It has a division for nuclear-applications research, focusing on health, industry, mining, agriculture and food.

Role of the private sector

The Ministry of Energy has a co-ordinating role with universities and industry through national R&D centres and International Centres of Excellence (ICE) (see below for more details).

Historically, overall business-innovation performance in Chile is significantly below the OECD's median (OECD, 2016). The national innovation survey, conducted by the Ministry of Economy, shows that in 2013, private companies spent rather little on innovation related to electricity, gas and water supply. In 2014, they spent even less.

Stronger private-sector participation in energy RDI is encouraged under several programmes. In particular, the Solar Energy Program, one of the so-called "intelligent specialisation initiatives"[2] for the energy sector, was built as a participative process that involves more than 170 people from more than 100 public and private organisations. Several other programmes co-ordinated by the Ministry of Energy also encourage the

[2] Chile's intelligent specialization policy programmes are public–private initiatives that focus on improving competitiveness via co-ordinated actions in economic subsector and/or value chains.

private sector to participate. These include the International Apprenticeships Programme, the Cluster for Energy Efficiency and the challenge for entrepreneurs called "*Imagina Energía*".

Policies and strategies

General RDI

In August 2014, the MEDT launched the Innovation Plan for 2014-18, which guides the activities of STI institutions in all sectors, including energy. The Innovation Plan recommends strengthening the STI institutional framework. MEDT also implements, with the participation of other ministries and state services, the Chilean Growth, Innovation and Productivity Agenda (GIPA). Both the Innovation Plan and GIPA aim to stimulate the diversification of production, promote sectors with a high growth potential, boost the productivity and competitiveness of firms and support export growth.

Energy technology RDI

The National Energy Policy 2050 sets the following objectives for Chile on energy RDI:

- By 2035, to become an exporter of technology and services for the solar industry.
- By 2050, to become an exporter of technology and services for specific energy innovations. Innovative policies in the energy industry are expected to contribute to achieving a reduction in energy consumption.

The Policy sets the following guidelines towards achieving these objectives:

- define a policy for science, technology and innovation in energy
- reduce barriers to innovation and entrepreneurship in energy
- strengthen and co-ordinate Chile's technological capacities to carry out RDI in energy.

Table 9.1 outlines the key actions to take under these three guidelines.

In late 2015, the Ministry of Energy approved a strategy for science, technology and innovation in energy (Energy STI Strategy) for the short and medium term. The mission of this strategy is "Accelerating the transformation process of the Chilean energy system by the timely identification of the sector's opportunities and the generation of an ecosystem with actors who seek and implement solutions in a harmonious way with the society and the environment."

The strategy aims to address the following areas within five years:

- the quantity of highly qualified people in energy RDI
- engagement of private sector in RDI activities
- collaboration and co-ordination of RDI initiatives of the energy sector
- effectiveness in the use of private and public resources for RDI.

Table 9.1 National Energy Policy 2050 guidelines and planned actions

Guideline 18: Define a policy for STI in energy
Co-ordinate the development of a policy for science, technology and innovation in energy (2015-18)
Continue the national Strategic Programme for the Solar Industry and analyse other strategic technological planning processes (2016-30)
Establish a technological monitoring mechanism to identify new opportunities in the energy sector (2016-30)
Strengthen the role of the National Centre for Sustainable Energy Innovation and Promotion (CIFES) in implementing the policy for STI in energy (2017-20)
Guideline 19: Reduce barriers to innovation and entrepreneurship in energy
Identify and remove regulatory barriers to energy innovation (2016-30)
Install a process to monitor the latest national and international technological advances applicable to the Chilean energy sector (2016-30)
Promote innovation management programmes in energy companies (2016-18)
Promote mechanisms to incorporate highly skilled human capital into the energy sector (2016-19)
Promote the adoption and transfer of new technology, and co-ordinate pilot initiatives (2017-30)
Guideline 20: Strengthen and co-ordinate Chile's technological capacities for carrying out RDI in energy
Develop a policy to attract and train human capital for the energy sector (2016-18)
Design and implement technological programmes with a strategic focus on energy (2017-30)
Strengthen the equipment and human capital at technological entities to stimulate the demand for innovation in energy (2017-30)
Execute portfolios of projects in applied research and collaborative technological development in energy (2017-30)
Generate and maintain the technological capacities to supply energy-related goods and services of public interest (2018-30)

Source: National Energy Policy 2050.

The Ministry of Energy has identified the following priority objectives, aligned with the Strategy's mission and the four key areas in which work is needed:

- identify STI areas for the development of the energy sector
- support the development of new knowledge-intensive markets for/from the energy sector
- contribute to a way of working based on a collaborative culture of STI
- lay the foundations to generate a sustainable impact and to contribute to the challenges of the energy sector.

The Energy STI strategy is based on three pillars, which include several initiatives:

- Analysis of technology trends and challenges in the energy sector:
  - technological intelligence
  - prioritisation of strategic areas
  - definition of roles
  - public innovation.
- Development of science and technology:
  - development of human talent for R&D
  - improvement of science and technology capabilities
  - science and technology ecosystem.
- Encouragement of innovation and entrepreneurship:
  - systematisation of innovation practices in companies
  - creation of an innovation and entrepreneurship network
  - social innovation and entrepreneurship.

The energy STI strategy is expected to be implemented starting from 2017, building on the initiatives and programmes already running.

Public funding for energy RDI

Before adopting the Energy STI strategy, public funding for energy-technology RDI was directed to initiatives without priority setting. The most-important initiatives are discussed in Energy RDI Programmes below.

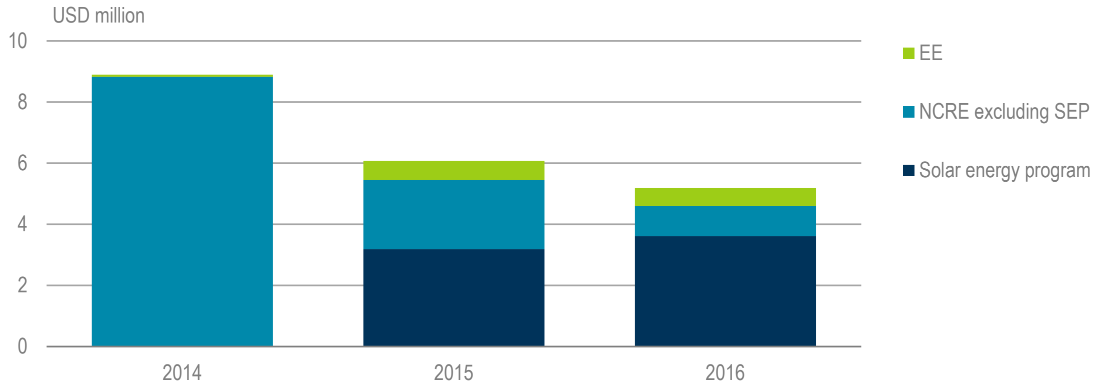
In February 2015, the government created a special fund, the Strategic Investment Fund (FIE – *Fondo de Inversión Estratégica*). The FIE supports initiatives aimed to improve productivity, diversify the economy and increase the value added of the national production, with a focus on solar energy.

The total level of public funding through various programmes dropped from nearly USD 9 million in 2014 to around USD 6 million in 2015 and slightly over USD 5 million in 2016. From 2014 to 2016, most public spending was directed to RDI on renewable energy technologies (NCRE, excluding large hydro). The funding for energy efficiency was USD 68 000 in 2014, but was increased nearly tenfold in 2015 and 2016 (Figure 9.2).

Public funding for RDI in the energy sector, although quite small by international standards, has been the key to drive research and innovation in Chile because private funding has been historically limited, as discussed above.

In the framework of Mission Innovation,[3] Chile has set the goal of doubling its budget in clean-energy R&D to USD 9 million by the year 2020 from the 2015-16 levels, while encouraging greater levels of private sector investment in transformational clean-energy technologies.

Figure 9.2 Public spending on energy R&D, 2014-16



Notes: EE = energy efficiency; SEP = Solar Energy Program.

Source: Ministry of Energy (2017) *Science, technology and innovation in the energy sector*, Presentation, April 2017.

Energy RDI Programmes

Overview

The key energy RDI programme is the Solar Energy Program, which aims to leverage the natural resources (subsoil, sun) in Chile's Atacama Desert (Box 9.1) to develop a national export-oriented solar-power industry. Another related initiative is the proposal for a lithium strategy and the creation of a "Solar and Mining Technology Institute", which will be financed by a 27-year agreement between CORFO and the Albemarle Corporation (formerly RockWood Lithium), in which the latter will contribute USD 5 million per year, increasing gradually up to USD 8 million per year.

The programme "Attracting ICEs on R&D for Competitiveness", led by the CORFO, has resulted in the creation of 13 centres of excellence since 2010. The objective of these centres is to create links between universities, research centres, industry and public sectors to promote technology clusters and train cutting-edge research professionals. Three of these centres are related to energy: solar energy (Fraunhofer CSET), marine energy (MERIC) and solar and energy efficiency (Engie-Lab). These are discussed in more detail in International collaboration below.

[3] Mission Innovation involves 22 countries and the European Union. It aims to strengthen and accelerate public and private global clean-energy innovation. Each participating country will seek to double its governmental and/or state-directed clean-energy R&D investment over five years. New investments are to be focused on transformational clean-energy technology innovations that can be scalable to varying economic and energy-market conditions.

Box 9.1 Natural resources in the Atacama Desert

Chile's Atacama Desert possesses significant natural resources. Its holds the world's largest copper and non-metallic mineral reserves, which have sustained a significant mining industry – the country's main export sector – for over a century. Atacama also possesses one of the world's largest reserves of lithium. However, Chile's mining industry is challenged by access to water and cost-effective and sustainable energy.

The sun is another abundant natural resource. Atacama receives the highest levels of solar irradiation in the world. However, the desert's drastically changing temperatures and dry, dusty and sandy conditions complicate optimal PV electricity generation.
Based on this abundance of natural resources, Chile has prioritised two areas for energy technology RDI: solar-energy industry that takes into account the conditions of the north of Chile and value chains for producing lithium batteries.

Source: Ministry of Energy.

Solar Energy Programme 2016-25

The Solar Energy Programme is the Chilean "intelligent specialisation initiative" for the energy sector. It is managed by the CDIES (a CORFO Committee) and has an advisory board that includes 25 members from the public, private, academia and social sectors. An initial portfolio of 50 initiatives was identified, with the total budget of USD 800 million. For 2015 and 2016 the public-sector budget for the programme was more than USD 6 million, and the private sector budget more than USD 1 million. The programme's roadmap to 2025 has several objectives, listed in Table 9.2.

Table 9.2 Solar Energy Programme's objectives to 2025

Baseline 2015	Goals 2025
1.57% of the electricity is generated by solar 743 MW solar installed	10% of the electricity generated by solar More than 3.2 GW solar installed
LCOE of PV at USD 80 MWh	LCOE of PV at USD 25/MWh
3 000 estimated jobs related to solar energy USD 1 486 m of solar investment 17% of local value added – USD 175 million	45 000 jobs related to solar energy USD 9 380 m of solar investment 55% of local value added – USD 5 159 million
5 MW_e distributed PV installed 10 GW_{th} SST installed	250 MW_e distributed PV installed 2 000 GW_{th} SST installed
No solar services and products exports	Exportation of engineering, tech services, structures and panels

Source: Ministry of Energy, 2017.

The SEP roadmap is based on three pillars: industrial development, technological development and strengthening the quality and infrastructure.

The programme's available resources are allocated through CORFO´s funds via public tenders, which invite universities and/or private actors to resolve the challenges listed in the roadmap. The Solar Energy Programme has launched several calls and received applications from private corporations, universities and/or R&D centres. As of 2017, active projects include: testing ten prototypes of new solutions, the design of an open innovation platform, a meteorological network for solar radiation, the master plan design of towns in the north of the country for testing solar technologies and a portfolio of high-level R&D projects focused on PV systems adapted to the radiation conditions of the north.

Proposal for a lithium programme

In June 2014, the Chilean president created a National Lithium Commission to develop a policy proposal for the future of this strategic resource. The Commission included the Ministry of Energy and representatives of the public and private sector, native peoples of the regions where lithium is located and workers' representatives.

The Commission's proposes to create a legal and institutional framework for the lithium exploration and exploitation stages, maximize the industry's long-term profitability and added value and promote sophistication and the diversification of the industry through R&D. This would position Chile as one of the most-important exporters of the mineral and its related products.

The main proposals related to RDI are as follows:

- Reinforce the role of the state as the only owner of lithium resources, maintaining the denomination of a "strategic mineral", because of its high potential for energy applications. The state should maximise the profitability of the exploitation in the long term, and invest the profits on related science and productive developments, promote public–private associations to add value and improve the economic and social performance of the lithium sites.

- Create new policies to promote R&D for exploitation activities as well as to develop new products and processes, for example lithium carbonate to be used in batteries and other energy-storage technologies.

- Create a cluster that links universities and the industry to research and innovation centres, and promotes public–private associations.

- Carry out studies to link and quantify the relations of lithium with the solar market, especially related to batteries and molten salt for concentrated solar power (CSP) plants, and identify opportunities in the value chain to add value through R&D.

CORFO has signed an agreement with Rockwood Lithium (now Albemarle Corporation) that allows them the exploitation of lithium in the north of Chile, paying, among other taxes, an important contribution to the creation of the "Solar and Mining Technology Institute". The Institute, expected to start operation in 2018, will contain three research areas: solar, mining and lithium.

Biofuel consortiums

In the late 2000s, the Ministry of Energy promoted the development of second-generation biofuels to take advantage of Chile's presumably large bioenergy potential (available algae along 4 300 kilometres of coastline, as well as forests). Through CORFO's committee InnovaChile, in 2008 and 2009, it conducted two calls for proposals for a Research–Business–Technological Consortium in the production of biofuels from lignocellulosic material, and micro and macro algae. As a result, five technology consortia were created with public funding of CLP 13.5 billion (USD 24 million) and private investment of CLP 9.2 billion (USD 16.5 million). These consortia implemented five-year programmes for research and development of the greater part of the biofuels value chain, including biomass production at low cost (micro and macro algae, and energy plantations), biomass logistics supply and processes and technologies to produce biofuels and their by-products.

Each consortium achieved various results in the production and commercialisation of biofuels and secondary products. They also managed to strengthen local capacities and scientific and technological skills. However, it was proved that the production of biodiesel, bioethanol and biogas from micro and macro algae was technically feasible, but not financially viable in Chile at that time.

International collaboration

Chile participates in several international R&D bodies and platforms, including Mission Innovation and the Clean Energy Ministerial. It participates in three of the IEA Technology Collaboration Programme (TCPs): Advanced Motor Fuels, Photovoltaic Power Systems and Concentrating Solar Power. Discussions are underway to join the TCP that focuses on Clean Energy Education and Empowerment, and MERIC also participates as an observer in the Ocean Energy Systems TCP.

Bilateral co-operation

In the 22nd Conference of the Parties in 2016 (COP22), CORFO signed a co-operation agreement with the Moroccan Agency for Sustainable Energy to boost the solar industry, R&D and the implementation of future projects between Chile and Morocco.

The Solar Energy Program co-operates with the German International Development Agency to promote solar energy, focusing on concentrating solar technologies.

In December 2012, the Ministry of Energy and CORFO launched a call to install a centre of excellence in solar energy. The contest was awarded to the Centre for Solar Energy Technologies–Fraunhofer Chile Research (CSET-FCR), an R&D centre focused on solar energy. Its operations began in February 2015, based on the wide technological expertise of the Fraunhofer Center in Germany, one of the world's leading centres for applied R&D in this field. *Pontificia Universidad Católica de Chile* (Engineering Faculty) is a joint executor and SOITEC and Solar Springs are partners of the centre.

CSET's objective is to help develop applications for solar-energy systems, both large and small scale in various industrial sectors. The estimated cost of the centre is CLP 15.404 billion for eight years (around USD 25 million), of which 40% will come from the Ministry of Energy through CORFO.

CSET will be dedicated to R&D applied to:

- Solar electricity: resource assessment, analysis of technologies, CSP and concentrating photovoltaic power and their adaptation to the high radiation conditions in northern Chile.
- Solar heat: use of solar thermal processes (hot and cold) in mining and other industries.
- Solar water treatment: desalination and disinfection of water using solar energy.

CSET will help to develop specialised technological services to support the creation of a group of goods and service companies of international scope with a local component.

Marine Energies Research International Centre

In December 2013, the Ministry of Energy and CORFO launched a call to establish an international centre of excellence on marine energy. It was awarded to the Marine Energies Research International Centre (MERIC), a consortium created by DCNS, a French company, with Enel Green Power Chile, Pontificia Universidad Catolica de Chile, Universidad Austral de Chile, Fundacion Inria Chile and Fundacion Chile, and Chilectra (now Enel Distribution) as an associate company. In operation since October 2015, it aims to help develop a strong, sustainable and competitive marine economy and industry in Chile through applied research, technology development and innovation.

The estimated cost of the centre is CLP 10.677 billion (around USD 17 million) over eight years, of which 58.4% will come from the Ministry of Energy through CORFO.

MERIC has two main lines of research:

- Site development and understanding of the Chilean environment, which includes assessment and characterisation of resources and sites, characterisation of corrosion processes, biofouling, social acceptability and ecosystem assessment.
- Development of technologies in Chile: technological adaptation to local restrictions, identifying local restrictions, small-scale desalination for remote areas, test bank and validation of marine energy conversion technologies.

The initial activities have also revealed the need for a legal analysis of the gaps and potential improvements to the legislation on the use of the coastline and issuance of maritime concessions.

Engie Lab (Laborelec)

The Engie Lab is run by Laborelec Chile, a research and competence centre in electrical power technology, and part of the ENGIE group. It focuses, in particular, on two topics, which include the following initiatives.

Solar-energy integration

- Hybridisation of conventional and solar-energy generating systems.
- PV plant efficiency improvement.
- PV – development of monitoring systems and performance evaluation methodologies.
- Predictive maintenance models for PV in a desert environment.
- Behavioural analysis and control of PV power plants.
- Novel methodologies for the operation and maintenance of PV power plants.

Low-carbon footprint technology: conventional power plants

- Efficiency improvement for conventional coal and gas-fired power plants.
- Operational strategies for lower carbon footprint of conventional power plants.
- Life-cycle analysis and prediction of conventional power plants.
- Improvement of power-plant equipment availability and reliability through novel prognostic techniques.

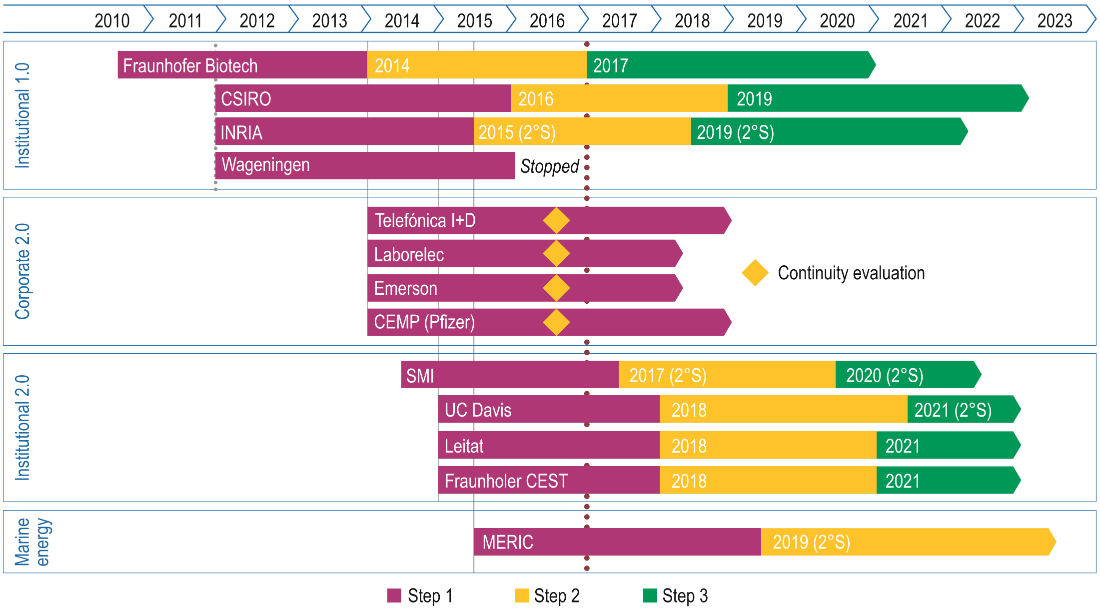
Other international centres of excellence (ICEs)

Several other ICEs include certain components related to energy:

- CSIRO: Chile's ICE in Mining and Mineral Processing. It investigates, among other issues, energy recovery from mineral pipelines and improving energy efficiency in mining operations.
- INRIA: ICE in the areas of information and communication technologies. It includes a WINDPOS project that focuses on stochastic modelling of air flow and power generation inside a wind farm.
- Telefonica: includes two initiatives, mSOS and OptimalCrop, which aim to reduce energy use in mining and agriculture.

Figure 9.3 demonstrates the timeframe for operating the 13 ICEs.

Figure 9.3 International centres of excellence



Source: CORFO.

Monitoring and evaluation

The Chilean STI strategy is in the early stages of implementation, and its evaluation methodology has not been fully designed yet. Nevertheless, the existing STI programmes have been assessed using different methods.

Many international excellence centres have a "continuity milestone". At the pre-determined milestone date, their results are evaluated to determine the continuity of public funding.

The FIE (Strategic Investment Fund), which funds many national innovation programmes, evaluates the applications in a process that includes national or international experts and the following criteria: public–private collaboration commitment, positive side effects, comparative advantages development, growth potential and/or jobs creation and private-funding engagement.

The Solar Energy Programme, financed through CORFO, will be evaluated – in line with the 2025 roadmap's schedule – according to CORFO's project-management system.

The financial resources of the Chilean ministries are administered through the Information System for Financial Management of the State (*SIGFE)*. The funds transferred to other institutions (public and/or private) are monitored through a project management system. Its objective is to guarantee the appropriate use of the funding. SIGFE, together with the Public Directorate of Budgets (DIPRES), monitors the most important programmes.

Assessment

Strengthening the science and technology innovation system would arguably help Chile to boost productivity, and diversify the economy. In recent years, Chile has improved the priority-setting framework and policies, with the Agenda for Productivity, Innovation and Growth addressing some of the longstanding issues in these areas. For the energy sector, STI policy and the recent Energy STI strategy developed by the Ministry of Energy are broadly aligned with the country's overall energy policy, which aims to diversify the energy supply by developing Chile's significant renewable-energy potential. This linkage between the energy policy and STI policy is positive, and the IEA urges the Chilean government to continue and enhance its efforts to strengthen the STI on renewable energy. Nevertheless, STI policy could specifically address the issue of firewood combustion by facilitating consumers' access to sustainable sources.

RDI spending – particularly by the business sector – is very low, and Chile remains the lowest overall R&D performer in the OECD, at under 0.5% of GDP. The IEA welcomes the government's commitment to Mission Innovation to double energy RDI funding by 2020. Increasing public funding for energy RDI is important to meet the ambitious energy and STI policy objectives. At the same time, given the pressures on government budgets, stronger incentives for private-sector investments in innovation should be encouraged, such as venture capital, pre-commercial public procurement or programme co-operation with investment promoters.

Through the establishment of ICEs, Chile has made significant efforts to strengthen the linkages between the national research community and industries. International co-operation and technology diffusion have increased through the National Economic Development Agency CORFO. CORFO and the Ministry of Energy have recently launched an ambitious initiative, the Solar Energy Program 2016-25, which aims to develop an export-oriented national solar-power industry.

Chile´s efforts to leverage international research co-operation are to be commended. The ICEs are good examples of joint R&D institutions that aim to ease access to international resources, skills and technology, while promoting national innovation and capacities and strengthening links between research and Chilean businesses. The IEA also welcomes Chile’s intention to participate in other IEA TCPs.

To maximise the impact of RDI activities under resource constraints, it is important to align the capabilities of all the participants in the innovation system (scientists, technical experts, government, and companies) in setting out objectives and priorities based on the assessment of their strengths and weaknesses. The plan to implement a national monitoring and evaluation programme is a first step in this regard. Monitoring and evaluation RDI programmes should be continued regularly. It is also very important to assess constantly the country’s RDI challenges, keeping in mind the energy-policy objectives. On the basis of such regular monitoring and assessment, the government should adjust its RDI portfolio to the national energy-policy priorities if and when needed.

Close collaboration between public and private key RDI players is critical to achieving the goals cost-effectively. The government’s efforts to facilitate innovation clusters appear to be successful and should be continued. In a broader context, the government is encouraged to develop a long-term policy for science, technology and innovation in energy, as laid out in the National Energy Policy 2050.

To succeed in the long term, energy research relies on the contributions of dedicated and talented individuals. A common challenge in many countries is the limited interest of students for natural sciences and engineering. Also in Chile, the energy community should more clearly raise this concern to the national education policy makers. In addition, Chile would benefit from increasing the volume of vocational education to ensure enough technical experts will be available in the future. Efforts should also be made to ensure sufficient RDI capacity by further international integration, taking advantage of foreign expertise in research areas of interest to Chile.

Recommendations

The government of Chile should:

- ☐ Increase funding for energy RDI.
- ☐ Introduce stronger incentives to attract private funding for energy-technology development; continue facilitating technology clusters in sectors with high international potential.
- ☐ Continue to develop the monitoring and evaluation of programmes.

- Continue to assess its RDI challenges and to adjust its RDI portfolio as national energy policy priorities change.
- Encourage academic and vocational students to opt for subjects critical to energy RDI.

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ANNEX A: Organisations visited

REVIEW CRITERIA

The Shared Goals, which were adopted by the IEA Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews (IDRs) conducted by the IEA. The Shared Goals are presented in Annex C.

REVIEW TEAM AND PREPARATION OF THE REPORT

The IEA in-depth review team visited Chile from 15 to 19 April 2017. The team met with government officials, energy suppliers, interest groups, and other organisations. This report was drafted on the basis of the review team's preliminary assessment of the country's energy policy and information on subsequent policy developments from the government and private-sector sources. The members of the team were:

IEA member countries

Ambassador Jean-Christophe Füeg, Switzerland (team leader)

Dr. Pieter Boot, the Netherlands

Mr. Jesús Ferrero, Spain

Mr. Franzjosef Schafhausen, Germany

Mr. Masataka Yarita, Japan

IEA secretariat

Mr. Aad van Bohemen, IEA

Mr. David Morgado, IEA

Mr. Miika Tommila, IEA

The team is grateful for the co-operation and assistance of the many people it met throughout the visit. Thanks to their kind hospitality, openness and willingness to share information, the visit was highly informative, productive and enjoyable. The team expresses its gratitude to Minister Andrés Rebolledo and Undersecretary Jimena Jara and their staff at the Ministry of Energy. In particular, the team wishes to thank Ms. Paula Estevez, Mr. Javier Bustos, Ms. Bárbara Eguiguren and Ms. Corissa Petro for the professionalism they displayed throughout the review process. The team also thanks the GIZ for its support in the review process.

The report's Executive summary was drafted by Miika Tommila and Joerg Husar, chapter 1 by Joerg Husar and Alexandro Maya, chapter 2 by Sean Calvert, chapters 3 and 4 by Alexandro Maya and Joerg Husar, chapter 5 by Miika Tommila and Alexandro Maya, chapter 6 by Miika Tommila and Hwayun Lee, chapter 7 by David Morgado and chapters 8 and 9 by Elena Merle-Beral. Hwayun Lee and Oskar Kvarnström drafted the supply and demand sections of the report. Miika Tommila managed the review process and reviewed the report.

The report was prepared under the guidance of Aad van Bohemen, Head of Energy Policy and Security Division. Helpful comments and updates were provided by the following IEA staff: Emanuele Bianco, Pedro Cespedes Ruiz, Jean-Baptiste Dubreuil, Carlos Fernandez Alvarez, Rebecca Gaghen, Jaime González-Puelles, Cesar Alejandro Hernandez, Volker Kraayvanger, Raimund Malischek, Simon Mueller, Cedric Philibert, Carrie Pottinger, Joe Ritchie and Samuel Thomas. Alexandro Maya provided research and drafting support throughout the report.

Oskar Kvarnström and Hwayun Lee prepared the figures and Bertrand Sadin prepared the maps. Roberta Quadrelli and Rémi Gigoux provided support on the statistics. Therese Walsh managed the editing process, and Astrid Dumond and Katie Russell managed the production process.

ORGANISATIONS VISITED

Abastible

Association of Natural Gas Distributors (AGN)

Association of Small and Medium Hydroelectric Plants (APEMEC)

CEDEUS

Centro Mario Molina

Chile Sustentable

Chilean Agency of Energy Efficiency (ACHEE)

Chilean Association of Renewable Energies (ACERA)

Chilean Association of Solar Energy (ACESOL)

Chilean Economic Development Agency (CORFO)

Chilean Generators Association

Chilean Nuclear Energy Commission (CCHEN)

Civil Society Council of the Ministry of Energy (COSOC)

Confederation of Production and Trade (CPC)

Copec

Electrogas

Enex (Shell)

Engie

Esmax (Petrobras)

Federation of Chilean Industry (SOFOFA)

Fundación Casa de la Paz

Gas Sur

GasAndes

Gasco Magallanes

GasPacífico (Innergy)

GasValpo

GIZ

GNL Chile

GNL Mejillones

Lipigas

Metrogas

Mining Council

Ministry of Energy

Ministry of Environment

Ministry of Housing and Urban Development (MINVU)

Ministry of National Assets

National Association of Automotive of Chile (ANAC)

National Association of Energy Efficiency Companies (ANESCO)

National Energy Commission (CNE)

National Irrigation Commission

National Petroleum Company (ENAP)

NorAndino

Office of the Superintendent of Electricity and Fuels (SEC)

Pontificia Universidad Católica de Chile

Programa de Energía Solar

Sonacol S.A.

Universidad Adolfo Ibáñez

Universidad de Chile

ANNEX B: Energy balances and key statistical data

Chile

Energy balances and key statistical data

Unit: Mtoe

SUPPLY		1973	1990	2000	2010	2014	2015	2016E
TOTAL PRODUCTION		**5.08**	**7.93**	**8.58**	**9.21**	**13.48**	**12.91**	**13.03**
Coal		0.96	1.45	0.24	0.25	2.77	2.09	1.68
Peat		-	-	-	-	-	-	-
Oil		1.79	1.17	0.43	0.61	0.44	0.30	0.26
Natural gas		0.53	1.41	1.60	1.55	0.66	0.85	1.03
Biofuels and waste[1]		1.33	3.13	4.72	4.90	7.38	7.30	7.94
Nuclear		-	-	-	-	-	-	-
Hydro		0.48	0.77	1.59	1.87	1.99	2.05	1.68
Wind		-	-	-	0.03	0.12	0.18	0.20
Geothermal		-	-	-	-	-	-	-
Solar/other[2]		-	-	-	0.00	0.12	0.14	0.25
TOTAL NET IMPORTS[3]		**3.39**	**6.66**	**16.78**	**21.38**	**21.94**	**23.29**	**24.47**
Coal	Exports	0.00	-	0.03	-	1.58	0.59	0.61
	Imports	0.20	1.13	2.94	3.81	5.64	5.68	6.55
	Net imports	0.20	1.13	2.92	3.81	4.06	5.09	5.94
Oil	Exports	0.06	0.21	0.86	0.63	0.57	0.49	0.42
	Imports	3.55	6.11	11.92	16.00	16.38	16.26	16.28
	Int'l marine and aviation bunkers	-0.31	-0.37	-0.96	-0.91	-0.85	-0.70	-0.70
	Net imports	3.19	5.52	10.09	14.46	14.96	15.07	15.16
Natural Gas	Exports	-	-	-	-	-	-	0.31
	Imports	-	-	3.67	3.01	2.91	3.13	3.68
	Net imports	-	-	3.67	3.01	2.91	3.13	3.37
Electricity	Exports	-	-	-	-	-	-	-
	Imports	-	-	0.10	0.08	-	-	-
	Net imports	-	-	0.10	0.08	-	-	-
TOTAL STOCK CHANGES		**0.03**	**-0.57**	**-0.19**	**0.26**	**-0.18**	**-0.09**	**0.02**
TOTAL SUPPLY (TPES)[4]		**8.50**	**14.01**	**25.17**	**30.85**	**35.24**	**36.11**	**37.52**
Coal		1.20	2.50	3.07	4.46	6.61	7.17	7.62
Peat		-	-	-	-	-	-	-
Oil		4.97	6.47	10.48	15.01	15.40	15.29	15.43
Natural gas		0.53	1.14	5.21	4.47	3.63	3.98	4.41
Biofuels and waste[1]		1.33	3.13	4.72	4.93	7.38	7.30	7.94
Nuclear		-	-	-	-	-	-	-
Hydro		0.48	0.77	1.59	1.87	1.99	2.05	1.68
Wind		-	-	-	0.03	0.12	0.18	0.20
Geothermal		-	-	-	-	-	-	-
Solar/other[2]		-	-	-	0.00	0.12	0.14	0.25
Electricity trade[5]		-	-	0.10	0.08	-	-	-
Shares in TPES (%)								
Coal		*14.1*	*17.8*	*12.2*	*14.5*	*18.8*	*19.8*	*20.3*
Peat		-	-	-	-	-	-	-
Oil		*58.5*	*46.2*	*41.6*	*48.6*	*43.7*	*42.3*	*41.1*
Natural gas		*6.2*	*8.2*	*20.7*	*14.5*	*10.3*	*11.0*	*11.7*
Biofuels and waste[1]		*15.6*	*22.4*	*18.8*	*16.0*	*20.9*	*20.2*	*21.2*
Nuclear		-	-	-	-	-	-	-
Hydro		*5.7*	*5.5*	*6.3*	*6.1*	*5.6*	*5.7*	*4.5*
Wind		-	-	-	*0.1*	*0.4*	*0.5*	*0.5*
Geothermal		-	-	-	-	-	-	-
Solar/other[2]		-	-	-	*0.0*	*0.3*	*0.4*	*0.7*
Electricity trade[5]		-	-	*0.4*	*0.3*	-	-	-

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Unit: Mtoe

DEMAND							
FINAL CONSUMPTION	**1973**	**1990**	**2000**	**2010**	**2014**	**2015**	**2016E**
TFC	**6.52**	**11.10**	**20.38**	**23.86**	**24.98**	**25.15**	**..**
Coal	0.71	0.63	0.64	0.42	0.24	0.33	..
Peat	-	-	-	-	-	-	..
Oil	3.84	5.49	9.19	12.09	13.64	13.87	..
Natural gas	0.04	0.90	3.29	2.35	1.29	1.51	..
Biofuels and waste[1]	1.31	2.75	4.11	4.28	4.02	3.67	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	0.00	0.03	0.03	..
Electricity	0.63	1.33	3.16	4.71	5.75	5.75	..
Heat	-	-	-	-	-	-	..
Shares in TFC (%)							
Coal	*10.8*	*5.7*	*3.1*	*1.8*	*1.0*	*1.3*	..
Peat	-	-	-	-	-	-	..
Oil	*58.9*	*49.4*	*45.1*	*50.7*	*54.6*	*55.2*	..
Natural gas	*0.6*	*8.1*	*16.1*	*9.9*	*5.2*	*6.0*	..
Biofuels and waste [1]	*20.0*	*24.8*	*20.1*	*17.9*	*16.1*	*14.6*	..
Geothermal	-	-	-	-	-	-	..
Solar/other [2]	-	-	-	*0.0*	*0.0*	*0.0*	..
Electricity	*9.6*	*12.0*	*15.5*	*19.7*	*23.0*	*22.9*	..
Heat	-	-	-	-	-	-	..
TOTAL INDUSTRY[6]	**2.32**	**4.33**	**9.04**	**9.73**	**11.24**	**10.82**	**..**
Coal	0.46	0.52	0.59	0.40	0.23	0.32	..
Peat	-	-	-	-	-	-	..
Oil	1.21	1.51	2.13	3.33	4.40	4.03	..
Natural gas	0.00	0.75	2.98	1.83	0.70	0.90	..
Biofuels and waste[1]	0.24	0.67	1.13	1.09	2.19	1.94	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	-	-	-	..
Electricity	0.41	0.87	2.21	3.08	3.73	3.64	..
Heat	-	-	-	-	-	-	..
Shares in total industry (%)							
Coal	*20.0*	*12.1*	*6.5*	*4.1*	*2.0*	*2.9*	..
Peat	-	-	-	-	-	-	..
Oil	*52.2*	*35.0*	*23.6*	*34.3*	*39.1*	*37.2*	..
Natural gas	*0.1*	*17.2*	*33.0*	*18.7*	*6.2*	*8.3*	..
Biofuels and waste [1]	*10.2*	*15.5*	*12.5*	*11.2*	*19.5*	*18.0*	..
Geothermal	-	-	-	-	-	-	..
Solar/other [2]	-	-	-	-	-	-	..
Electricity	*17.6*	*20.2*	*24.4*	*31.7*	*33.2*	*33.6*	..
Heat	-	-	-	-	-	-	..
TRANSPORT[4]	**1.84**	**3.05**	**5.67**	**7.14**	**7.87**	**8.45**	**..**
OTHER[7]	**2.36**	**3.73**	**5.68**	**6.98**	**5.87**	**5.88**	**..**
Coal	0.11	0.11	0.05	0.02	0.01	0.01	..
Peat	-	-	-	-	-	-	..
Oil	0.94	0.95	1.42	1.67	1.47	1.50	..
Natural gas	0.04	0.15	0.30	0.51	0.56	0.58	..
Biofuels and waste[1]	1.07	2.08	2.98	3.19	1.84	1.72	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	0.00	0.03	0.03	..
Electricity	0.20	0.44	0.93	1.59	1.97	2.03	..
Heat	-	-	-	-	-	-	..
Shares in other (%)							
Coal	*4.8*	*2.9*	*0.9*	*0.3*	*0.2*	*0.2*	..
Peat	-	-	-	-	-	-	..
Oil	*39.7*	*25.5*	*24.9*	*23.9*	*25.0*	*25.5*	..
Natural gas	*1.6*	*4.0*	*5.3*	*7.3*	*9.5*	*9.9*	..
Biofuels and waste [1]	*45.4*	*55.7*	*52.4*	*45.7*	*31.3*	*29.3*	..
Geothermal	-	-	-	-	-	-	..
Solar/other [2]	-	-	-	-	*0.5*	*0.5*	..
Electricity	*8.5*	*11.8*	*16.4*	*22.7*	*33.5*	*34.6*	..
Heat	-	-	-	-	-	-	..

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2010**	**2014**	**2015**	**2016E**
ELECTRICITY GENERATION[8]							
Input (Mtoe)	1.44	3.08	6.11	9.63	13.90	15.23	..
Output (Mtoe)	0.75	1.58	3.45	5.20	6.15	6.48	6.73
Output (TWh)	8.77	18.37	40.08	60.43	71.57	75.39	78.31
Output Shares (%)							
Coal	*14.0*	*35.5*	*21.1*	*27.9*	*36.3*	*37.1*	*41.0*
Peat	-	-	-	-	-	-	-
Oil	*20.5*	*9.6*	*4.3*	*14.0*	*6.6*	*4.2*	*3.8*
Natural gas	*1.1*	*1.0*	*26.1*	*17.7*	*14.3*	*15.1*	*16.1*
Biofuels and waste [1]	*0.6*	*5.2*	*2.3*	*3.7*	*7.4*	*7.4*	*7.9*
Nuclear	-	-	-	-	-	-	-
Hydro	*63.8*	*48.6*	*46.2*	*35.9*	*32.3*	*31.7*	*25.0*
Wind	-	-	-	*0.5*	*2.0*	*2.8*	*2.9*
Geothermal	-	-	-	-	-	-	-
Solar/other [2]	-	-	-	*0.2*	*0.7*	*1.7*	*3.3*
TOTAL LOSSES	**1.98**	**2.92**	**4.77**	**7.27**	**10.21**	**10.69**	**..**
of which:							
Electricity and heat generation[9]	0.69	1.50	2.67	4.43	7.79	8.75	..
Other transformation	0.30	0.47	0.82	1.38	0.95	0.53	..
Own use and transmission/distribution losses[10]	1.00	0.96	1.29	1.46	1.46	1.41	..
Statistical Differences	**-**	**-0.01**	**0.01**	**-0.28**	**0.06**	**0.28**	**..**
INDICATORS	**1973**	**1990**	**2000**	**2010**	**2014**	**2015**	**2016E**
GDP (billion 2010 USD)	40.83	76.23	144.79	217.54	257.20	263.13	267.31
Population (millions)	10.07	13.18	15.40	17.09	17.84	18.05	18.20
TPES/GDP (toe/1000 USD)[11]	0.21	0.18	0.17	0.14	0.14	0.14	0.14
Energy production/TPES	0.60	0.57	0.34	0.30	0.38	0.36	0.35
Per capita TPES (toe/capita)	0.84	1.06	1.63	1.80	1.98	2.00	2.06
Oil supply/GDP (toe/1000 USD)[11]	0.12	0.08	0.07	0.07	0.06	0.06	0.06
TFC/GDP (toe/1000 USD)[11]	0.16	0.15	0.14	0.11	0.10	0.10	..
Per capita TFC (toe/capita)	0.65	0.84	1.32	1.40	1.40	1.39	..
CO_2 emissions from fuel combustion ($MtCO_2$)[12]	20.0	29.4	48.6	68.6	75.8	81.7	..
CO_2 emissions from bunkers ($MtCO_2$)[12]	1.0	1.2	3.0	2.8	2.6	2.1	..
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-10**	**10-13**	**13-14**	**14-15**	**15-16**
TPES	3.0	6.0	2.1	7.8	-8.9	2.5	..
Coal	4.4	2.1	3.8	14.3	-0.7	8.4	..
Peat	-	-	-	-	-	-	..
Oil	1.6	4.9	3.7	1.8	-2.8	-0.7	..
Natural gas	4.7	16.4	-1.5	-3.1	-10.7	9.8	..
Biofuels and waste[1]	5.2	4.2	0.4	28.0	-28.6	-1.1	..
Nuclear	-	-	-	-	-	-	..
Hydro	2.8	7.6	1.6	-3.1	17.1	3.4	..
Wind	-	-	-	18.3	158.3	46.8	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	146.6	160.0	17.9	..
TFC	3.2	6.3	1.6	3.7	-6.3	0.7	..
Electricity consumption	4.5	9.0	4.1	6.0	2.6	-0.1	..
Energy production	2.7	0.8	0.7	17.6	-10.0	-4.2	..
Net oil imports	3.3	6.2	3.7	2.5	-3.8	0.7	..
GDP	3.7	6.6	4.2	5.1	1.9	2.3	..
TPES/GDP	-0.7	-0.6	-2.0	2.6	-10.6	0.1	..
TFC/GDP	-0.5	-0.3	-2.5	-1.3	-8.0	-1.5	..

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Footnotes to energy balances and key statistical data

[1] Biofuels and waste comprises solid biofuels, liquid biofuels and biogases. Data are often based on partial surveys and may not be comparable between countries.

[2] Other includes solar photovoltaics, solar thermal and ambient heat used in heat pumps.

[3] In addition to coal, oil, natural gas and electricity, total net imports also include biofuels and waste.

[4] Excludes international marine bunkers and international aviation bunkers.

[5] When applicable, 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 includes residential, commercial and public services, agriculture/forestry, fishing and other non-specified.

[8] Inputs to electricity generation include inputs to electricity, CHP and heat plants. Output refers only to electricity generation.

[9] Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil-fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 33% for solar thermal and 100% for hydro, wind and solar photovoltaics.

[10] Data on "losses" for forecast years often include large statistical differences covering differences between expected supply and demand and mostly do not reflect real expectations on transformation gains and losses.

[11] Toe per thousand USD (United States dollars) at 2010 prices and exchange rates.

[12] "CO_2 emissions from fuel combustion" have been estimated using the IPCC Tier I Sectoral Approach from the *2006 IPCC Guidelines.* In accordance with the IPCC methodology, emissions from international marine and aviation bunkers are not included in national totals.

ANNEX C: 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 IEA partner regions, 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 the meeting of 4 June 1993 Paris, France.)

* Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

ANNEX D: Glossary and list of abbreviations

In this report, abbreviations and acronyms are substituted for a number of terms used within the International Energy Agency. While these terms generally have been written out on first mention, this glossary provides a quick and central reference for the abbreviations used.

Acronyms and abbreviations

BAU	business-as-usual
CCGT	combined-cycle gas turbine
CCR	cost of capital rate
CDM	Clean Development Mechanism
CEN	National Electricity Co ordinator
CER	Certified Emission Reduction
CHP	combined heat and power
CLP	Chilean peso
CNE	*Comisión Nacional de Energía*
CNG	compressed natural gas
CSP	concentrated solar power
CTF	Clean Technology Fund
DSM	demand-side management
EIA	environmental impact assessment
ENAP	Empresa Nacional del Petróleo
ESCO	Energy Services Company
ESMAP	Energy Sector Management Assistance Program
ETS	emissions trading scheme
FIA	Foundation for Agricultural Innovation
FSRU	floating storage regasification unit
GDP	gross domestic product
GHG	greenhouse gas
GHI	Global Horizontal Irradiance
GIPA	Growth, Innovation and Productivity Agenda
ICE	International Centres of Excellence
IDR	in-depth review
IEA	International Energy Agency
ISO	independent system operator
LED	Light-emitting diode
LNG	liquefied natural gas
LPG	liquid petroleum gas
MEDT	Ministry of Economy, Development and Tourism
MEPS	Minimum energy performance standard
MERIC	Marine Energies Research International Centre
MTT	Ministry of Transport and Telecommunications
NCRE	Non-Conventional Renewable Energy
NDC	Nationally Determined Contribution

NTS	National Transmission System
ODA	official development assistance
PM	particulate matter
PPA	power purchase agreement
PPP	purchasing power parities
PSRP	Public Solar Roofs Programme
R&D	research and development
RDI	research, development and innovation
RON	research octane number
SIC	Central Interconnected System
SING	*Sistema Interconectado del Norte Grande*
SRP	satellite regasification plant
STI	science, technology and innovation
SWH	solar water heater
TCP	Technology Collaboration Programme
TFC	total final energy consumption
TPES	Total primary energy supply
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar
VRE	variable renewable energy

IEA/OECD possible corrigenda on: www.oecd.org/about/publishing/corrigenda.htm

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ENERGY POLICIES BEYOND IEA COUNTRIES

Chile

2018

Chile's energy policy has evolved dynamically in recent years. In response to changes in the domestic and international environment, significant institutional and policy reforms as well as major infrastructure projects have been carried out. The National Energy Policy 2050 was adopted in 2015, following an exceptionally inclusive public consultation. The electricity sector, in particular, has developed quickly.

This second review of Chile's energy policies by the International Energy Agency finds that the country has emerged as a world-class destination for solar and wind energy developers. New legislation encourages investment in generating capacity across the electricity sector. The expanded role of the state in energy planning has helped to boost project development, especially in electricity transmission. The country now also has an interconnected national electricity system.

Integrating growing shares of variable renewable energy requires a flexible power system. More transmission infrastructure, storage, and demand-side response are needed. The government should now ensure that the electricity market design and infrastructure facilitate the integration of solar and wind power. By exploiting its vast renewable energy potential, Chile can help reduce electricity prices and dependency on fuel imports.

Renewables and energy efficiency can also help limit carbon emissions and air pollution. Chile should make more use of mandatory energy performance standards for products, equipment, vehicles and buildings. Efficient and clean use of firewood and alternative heating technologies can be supported through policies, regulation and financial incentives. Energy and climate aspects should also be an integral part of the long-term policies for transport and urban development.