HOME

2nd National Communication of Chile

to the United Nations Framework Convention on Climate Change

Ministerio del Medio Ambiente

Gobierno de Chile

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SECOND NATIONAL COMMUNICATION OF CHILE TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

Santiago, 2011

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I N D E X

Preface to the Second National Communication on Climate Change

The Government of Chile is pleased to present this document, the "Second National Communication of Chile to the United Nations Framework Convention on Climate Change" to the nation and the international community in fulfillment of its principal commitment as a signatory of the Convention. This document reports on the activities and initiatives implemented and the information generated in Chile over the past decade in a wide variety of areas linked to climate change.

Since the First National Communication was published in February 2000, the field of climate change has grown exponentially and the Government of Chile has intensified its official commitment to address this phenomenon and its effects. To this end, the Government of Chile has formulated public policy, adjusted its institutional framework, improved inter-institutional coordination and restructured the budget allocations of its public institutions. It has also conducted in-depth analyses of the nation's vulnerability to climate change and the adaptation opportunities available. Additionally, information on the implications of mitigating greenhouse gas emissions has been updated, thereby enabling gaps to be more effectively identified and scoped in order to balance the country's economic growth with the goal of becoming a low carbon country.

Like other developing countries, Chile has voluntarily agreed to participate in global initiatives to mitigate greenhouse gas emissions, pledging to carry out actions that will enable the country to achieve a 20% limitation of its GHG emissions growth by 2020.

Clearly, decisions associated with climate change made in both the public and private sectors should address more than only scientific information. This view is shared by civil society and its representative organizations, which recognize the urgent need to apply adaptation and mitigation measures and to join forces in addressing climate change issues within their areas of interest.

Progress is still insufficient in the area of climate change, and it is crucial that Chilean society as a whole take on this commitment urgently. The international assistance received to intensify and speed up our efforts will also impact significantly in such efforts.

This National Communication is a case in point. Its preparation has involved the collaboration of professionals from several government ministries as well as scientific, technical and social organizations and private sector entities in Chile, all under the coordination of the Ministry of the Environment's Office of Climate Change and with the financial support of the Global Environment Facility.

In this regard, I would like to thank each and every professional and executive from the many public institutions that worked together to prepare this Communication over the past three years, as well as the academics and consultants who provided valuable information. I would also like to thank the civil society organizations that considered the information that was generated and contributed their opinions and ideas. Thank you all for giving life to this publication, which reflects the current challenges our country faces in addressing climate change.

María Ignacia Benítez
Minister of the Environment of Chile
Santiago, Chile, August 2011.

EXECUTIVE SUMMARY

This Second National Communication has been prepared to fulfill Chile's reporting commitments as a Party to the United Nations Framework Convention on Climate Change (UNFCCC). It reports on the national advances made to implement the Convention in the period from February 2000, when the First National Communication was published, through 2010.

In accordance with the guidelines for preparing national communications, this report contains the results of the National Inventory of Greenhouse Gas (GHG) Sources and Sinks, the main advances made in addressing the country's vulnerability and adaptation to climate change, GHG mitigation measures adopted, and other information deemed relevant at the national level, taking into account the advances in international negotiations made mainly at the Conferences of the Parties held in 2007, 2009 and 2010. Lastly, it outlines some of the country's barriers, gaps and needs that exist related to national capacities, financing, and technical support that were identified during the preparation of this report.

This report was prepared by the Government of Chile with funding from the Global Environment Facility and support from the Office of the United National Development Program in Chile, which served as the implementing agency for the project for the preparation of the Second National Communication.

1. NATIONAL CIRCUMSTANCES

1.1 MAIN CHARACTERISTICS OF THE COUNTRY

Territory

Chile is a tri-continental country with territory that extends along the southwest portion of South America and includes Easter Island in Oceania as well as part of Antarctica to the south. The nation's territory also includes the Archipelago of Juan Fernández, the islands of San Félix, San Ambrosio, and Salas y Gómez, as well as the 200-mile Exclusive Economic Zone with its corresponding continental shelf.

Continental Chile is located between 17° 30' and 56° 30' Latitude South, while Chile's Antarctic Territory covers the area between 53° and 90° Longitude West and the South Pole. It is bordered by Peru in the North, and Bolivia and Argentina in the East, the South Pole in the South and the Pacific Ocean in the West along 8,000 kilometers of coastline.

In addition to its extensive coastline, the country has three main north-south morphological features: the Andes Mountains in the East, the Coastal Mountains in the West, and the Intermediate Depression, which runs between these two mountain chains but is often interrupted by transversal mountain chains. These chains give the country a rugged and broken topography, with flat areas accounting for no more than 20% of the entire continental territory. The country's coastal plains, archipelagos and islands also are populated and are host to important economic activities.

Climate

Chile has a multiplicity of climates. In general terms, the country has a temperate climate with some variations caused mainly by latitude and altitude. These variations give rise to desert, tropical, Mediterranean, temperate, and polar climates, among others.

The Pacific Ocean has a powerful moderating effect on temperature variations in the coastal zone. Recent studies have shown a shift in historic temperature trends, which have decreased along the coast and over the ocean and increased in the Central Valley and the mountains.

Ecologically, the presence of biomass and specific plant formations in a given zone depends on the existing climate. According to Luebert and Pliscoff, Chile has four macro-bioclimate zones: tropical, Mediterranean, temperate and antiboreal (Figure 1).

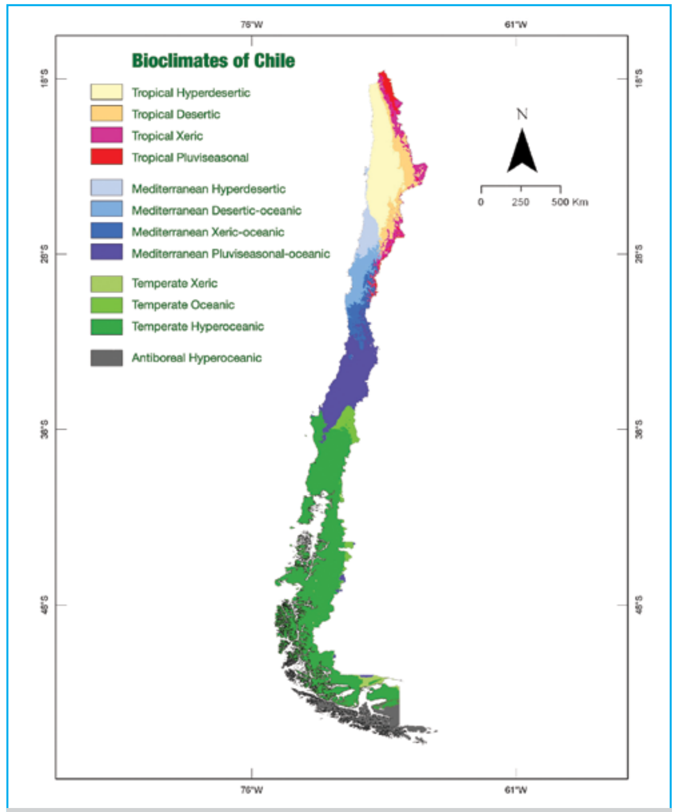

Figure 1. Bioclimates of Chile
Source: Luebert and Pliscoff, 2006

Population and Social Development

Chile's population grew quickly in the 20th Century, but growth has slowed in the past decade and is expected to decelerate even more toward the middle of the 21st Century.

The country's development has improved the quality of life of its inhabitants, and in 2010 Chile ranked 45th globally in the United Nations Human Development Index.

Economy

Since 1990, Chile has experienced rapid economic growth and diversification and increased its reliance on exports. These developments can be explained by the country's stable government, political institutions capable of generating and maintaining consensus on key issues, and effective public policies.

The effects of the country's export-driven development policy can be seen in its balance of trade, which has been positive since 1999 and grew substantially during the 2002–2007 period. Mining accounts for more than 50% of the total value of all goods exported by Chile. Regarding imports, intermediate goods such as fuel predominate, representing 50% of the total value of imports.

Photo: Ministry of the Environment Government of Chile

TABLE 1. Chile's Key Indicators

Information		Source
Geography		
Total Area (km^2)	2,006,096	Military Geographical Institute
Population in 2000	15,397,784	National Statistics Institute
Population in 2010	17,094,275	National Statistics Institute
Projected population in 2050	20,204,779	National Statistics Institute
Rural population (% of the total, 2009)	11%	World Bank
Forested Area (2007)	22%	National Forestry Corporation
Human Development		
Human Development Index (2010)	0.783	UNDP
Literacy Rate (2008)	99%	World Bank
Life Expectancy at Birth (2010)	78.8	World Bank
Infant mortality per 1000 live births (2007)	7	World Bank
Potable water coverage (2009)	99.8%	Superintendency of Sanitation Services
Sewerage coverage (2009)	95.6%	Superintendency of Sanitation Services
Public spending on Education as a % of GDP (2008)	4.2%	Ministry of Education
Public spending on R&D 2008 (millions 2008 US$)	351.7	Ministry of Economy
Economic Activity		
GDP (PPP) estimated for 2011 (millions of 2011 US$)	276,053	International Monetary Fund
GDP (PPP) per capita estimated for 2011 (US$)	15,866	International Monetary Fund
GDP (PPP) growth in 2009	-0.8%	International Monetary Fund
GDP (PPP) growth in 2010	6.3%	International Monetary Fund
Estimated GDP (PPP) growth in 2011	6 -7%	Chilean Central Bank
Goods and services exported (% of GDP, 2009)	38%	World Bank
Sectoral Activity		
Renewable energy (% of energy mix in 2009)	29%	Ministry of Energy
Imports of primary energy (% of energy use, 2009)	62%	Ministry of Energy
Consumption of fossil fuel as primary energy (% of total, in 2009)	71%	Ministry of Energy
Water consumption by irrigation (as a % of total national water use)	84.5%	General Directorate of Water

1.2 ENVIRONMENTAL POLICY AND INSTITUTIONAL STRUCTURE

Environmental Policy

The country´s comprehensive development strategy includes national policies oriented to foster sustainable development. Chile's Constitution guarantees its citizens the basic right to live in an environment free of pollution and makes the State responsible for safeguarding and preserving nature and the country's environmental heritage.

The country faces numerous environmental challenges, however, such as achieving compliance with primary air quality standards in several of its cities. One especially important issue is agricultural soil degradation. The amount of land affected by water and wind erosion, salinity, contamination, gravel extraction and other activities has increased dramatically, and it is estimated that virtually all of the country's soils display some level of degradation. The absence of effective soil management and soil conservation objectives has led to a major loss of fertility as well as much desertification and flooding.

In regard to water resources, freshwater extraction increased by 160% between 1990 and 2002. The Government of Chile estimates that by 2017, water demand by households, mining and industry will have practically doubled over 1992 levels, and agricultural use will have risen by 20%. Water for irrigation accounts for most of the water consumed in Chile, and major advances are being made to use this water more efficiently, with irrigation improvement programs being a central feature of the country's agrarian policies.

The Ministry of the Environment and the new environmental institutional framework

The year 2010 witnessed the completion of Chile's new environmental institutional structure, a process that began in 2006 and transformed the country's multisectoral model, in which environmental matters were coordinated by the National Environmental Commission (CONAMA), into a more centralized model under the newly created Ministry of the Environment.

Today, the Chilean Ministry of the Environment is the national entity responsible for working with the President of the Republic on the design and application of environmental policies, plans and programs. Also under the purview of the Ministry are all efforts to protect and conserve the country's water, biological diversity, and renewable resources through the promotion of sustainable development and comprehensive environmental policies and regulatory frameworks. One of the Ministry's major areas of responsibility in this context is the development of the country's response to climate change. For the first time the country's legislation includes a government mandate that specifically addresses this issue, affirming that "the Ministry shall be especially responsible for proposing policies and formulating plans, programs and plans of action in the area of climate change" (Art.70, letter h of Law 20.417 of 2010). The Ministry will face major challenges in implementing this mandate on climate change, which is one of five focal areas covered by the country's new environmental institutional framework. To facilitate organizational and administrative aspects, the Office of Climate Change was formally created with its own annual budget and permanent staff to carry out its work.

Institutional structure for climate change in Chile

In 1994, Chile ratified the United Nations' Framework Convention on Climate Change and subscribed to its Kyoto Protocol, convinced that a global response was required to address a phenomenon with such important environmental consequences, particularly for vulnerable nations like Chile.

Recognizing the need to coordinate local efforts and foreign policy on climate change, in 1996 the Government of Chile issued a Supreme Decree establishing the institution that would address this task. The National Advisory Committee on the Global Climate was composed of representatives of the public and academic sectors and its mandate provided for including other institutions and private entities. In 2006, the Committee played a key role in preparing the *National Climate Change Strategy,* the focal areas of which include adaptation, mitigation, and the promotion and creation of capacities. In 2008, the *National Climate Change Action Plan* was passed, representing a concrete step toward implementing the National Strategy.

In recognition of the issue's importance, and to strengthen inter-institutional efforts, particularly in the context of international climate change negotiations, in 2009 a presidential instruction led to the creation of the Inter-Ministerial Committee on Climate Change. The members of this Committee include representatives from Chile's Environment, Foreign Affairs, Agriculture, Energy, Economy, Finance, Mining, Public Works, and Transportation and Telecommunications ministries. The Committee also has a Technical Group that meets more frequently to address technical issues and advise the ministerial representatives.

In 2010, in order to broaden the exchange of information and expand the dialogue on climate change between the Government and other stakeholders, two working groups were formed: one public-private, the other public-civil society. These groups were formed to increase stakeholder opportunities for involvement and participation in the process to address climate change in Chile.

National Climate Change Action Plan

In 2008, CONAMA introduced the National Climate Change Action Plan for 2008-2012 as a short-term response to the priorities and objectives of the National Climate Change Strategy. The Action Plan sets out a series of public policy objectives for different public entities with climate change duties and responsibilities. The Plan also serves as guide for industry, the academic sector and non-governmental organizations by setting out the topics that Chilean society as a whole should address in confronting the impacts of climate change. By limiting its implementation period to five years, the Plan is intended as a short-term measure for generating the information needed by the end of the period to prepare longer-term national and sectoral adaptation and mitigation plans. The Action Plan contains some strategic considerations that should be taken into account as Chilean society confronts the challenges of climate change. These can be summarized as follows:

- Climate change as a key issue in Chilean public policy and regulations.
- Adaptation as a foundation for Chile's future development and as an early response to the impacts of climate change.
- Mitigation as a way to improve the quality of growth, reduce overall greenhouse gas emissions and decrease the cost of adaptation.
- Innovation in Chile's financial and business sectors to increase opportunities for investment in mitigation and adaptation projects.
- Assessment of future climate change commitments and their likely effects on international trade for a long-term strategic perspective.
- Development of a basic foundation of climate change-related knowledge to support decision-making. This knowledge will be generated by means of comprehensive research, systematic climate observation, and citizen training, education and awareness-raising.

Sectoral institutional framework

In the decade covered by this National Communication, several changes in the public sector have strengthened climate change-related actions in Chile. Notable among these are the creation of the Ministry of Energy, which was formed to foster the development of a comprehensive energy policy coherent with the objectives of security, quality and competitiveness of the country's energy supply and local and global environmental protection; the creation in 2009 of the Center for Renewable Energies, to serve as a technological antenna for the development of renewable energies in Chile; and in 2005, the launching of the country's National Energy Efficiency Program, later renamed the Chilean Energy Efficiency Agency. This public-private institution has the mission of promoting, strengthening and consolidating the efficient use of energy and coordinating and implementing public-private initiatives in different sectors that consume energy at the national and international levels.

For its part, the Ministry of Agriculture refocused the efforts of some of its agencies toward climate change, and in 2008 the Ministry created the Council on Agriculture and Climate Change, presided by that institution's highest authority. The Council's other members include representatives from the public, private and academic sectors.

A notable development in the area of water resources was the creation in 2008 of the Glaciology and Snow Unit within the Ministry of Public Works' General Water Directorate (DGA). This Unit is intended primarily to establish and implement a national glaciology program that will develop a glacier inventory, study and monitor glaciers in Chile, define present and future responses to climate change in regard to glaciers, and identify adaptation strategies for different climate scenarios.

2. NATIONAL INVENTORY OF GREENHOUSE GAS SOURCES AND SINKS

2.1 GLOBAL CONTEXT

Chile is not a relevant source of greenhouse gases (GHGs). According to international statistics, which consider only national CO_2 emissions from hydrocarbons, Chile accounts for around 0.2% of global GHG emissions, a percentage that has remained stable in recent years. Of global emsiisons from bunker fuels are not accounted, Chile´s contribution in 2008 was 0.26% of emissions from all countries (IEA, 2010) as presented in Figure 2. According to the International Energy Agency (IEA, 2010) Chile ranked 61st in the world for per capita CO_2 emissions in 2008, producing 4.35 tons CO_2 per person, slightly above the global average of 4.23 tons of CO_2 per person. Nevertheless, the country's emissions are growing significantly, mainly as a result of growth in its energy sector.

2.2 METHODOLOGY

The National Inventory of Greenhouse Gas Sources and Sinks (INGEI) presented in this Second National Communication was prepared in accordance with the guidelines for National Communications of the United Nations Framework Convention on Climate Change. It also follows the methodologies proposed by the Intergovernmental Panel on Climate Change (IPCC) for Convention signatories, as well as the guidelines proposed in the UNFCCC's Decision 17/CP.8, pertinent to non-Annex 1 countries presenting their second national communication. In brief, the revised 1996 IPCC guidelines were used, as well as their 2000 and 2003 codes of good practice; 2000 was the reporting year, and the formats used were those established under the Convention for annual inventory reports. In addition, the country voluntarily decided to include the results of its 2006 emissions inventory to provide a more up-to-date and relevant reflection of national sinks and sources. The 2006 data represents the most recent inventory information available across all sectors. The report also provides a time series of estimated sources and sinks from 1984 to 2006 for all sectors and subsectors.

A summary of GHG sources and sinks in Chile for 2000 and 2006, expressed in CO_2 equivalents (CO_2eq) is presented in Table 2. Meanwhile, Figure 3 represents the global CO_2 equivalent trend for the 1984-2006 period, for the five INGEI sectors, as well as the balance of sources and sinks, which in Chile's case is positive for the entire period analyzed. Figure 4 presents the percentage participation of each INGEI sector in Chile for both CO_2 emission and capture.

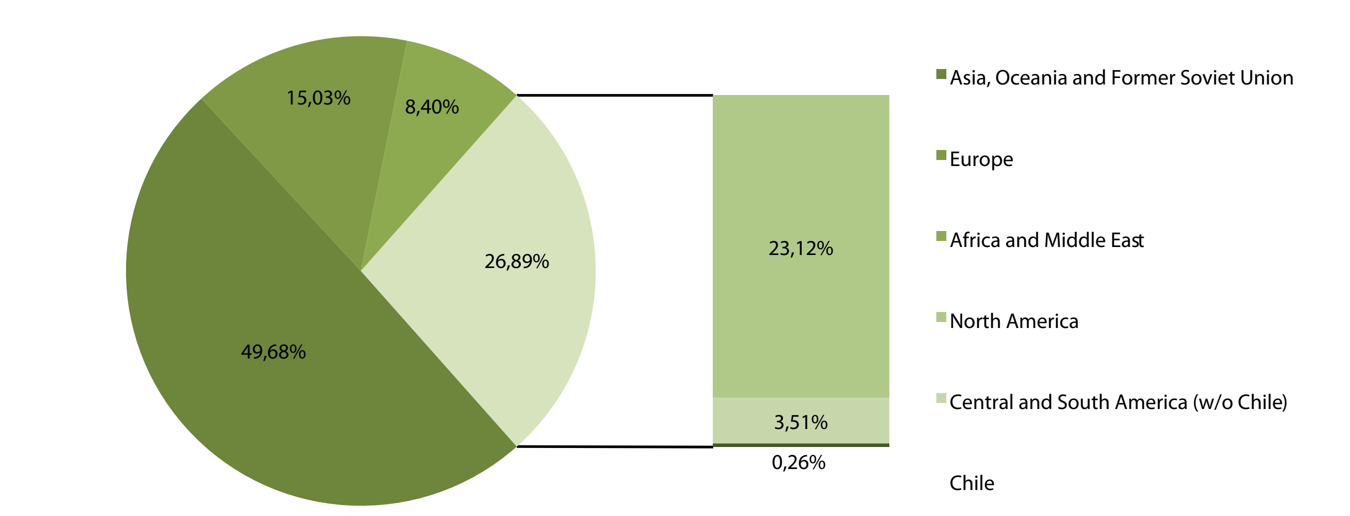

Figure 2. CO_2 emissions global distribution and Chile´s contribution in 2008
Source: Ministry of Environment, based on IEA, 2010

TABLE 2. GHG Sources and Sinks in Chile for 2000 and 2006

Sector	Type	2000	2006	% variation
		Gg of CO_2eq	Gg of CO_2eq	
Energy sector	Source	51,279	57,806	13%
Industrial processes sector	Source	4,447	5,361	21%
Agriculture sector	Source	13,103	13,401	2%
LULUCF	Sources and sinks	-27,446	-19,386	29%
Waste sector	Source	2,028	2,489	23%
National total	**Global balance**	**43,410**	**59,672**	**37%**

Source: Ministry of Environment, 2011

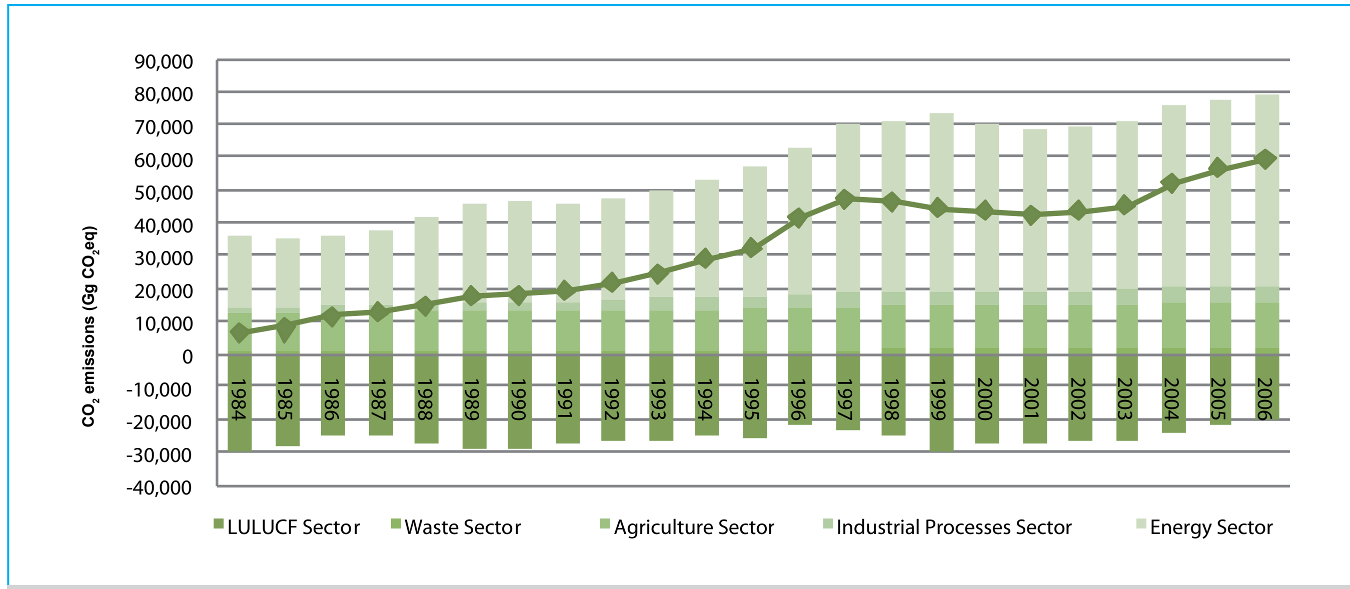

Figure 3. Sectoral contributions and balance of Chile's National GHG Inventory (INGEI), 1984-2006.
Source: Ministry of Environment, 2011

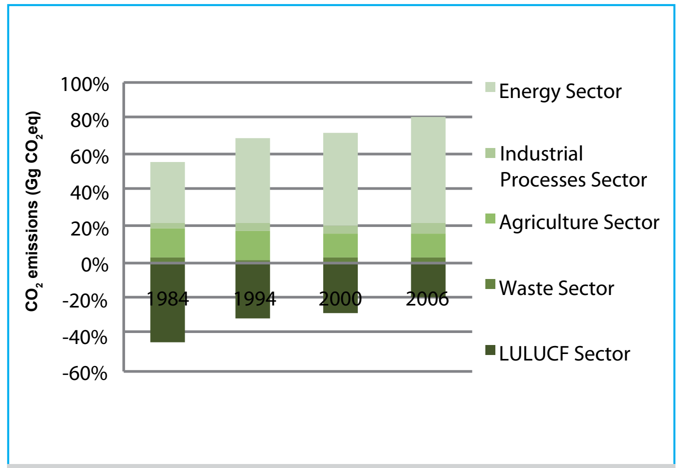

Figure 4. Participation of INGEI sectors in Chile in terms of GHG sources and sinks, in CO_2eq.
Source: Ministry of Environment, 2011

At the sectoral level, the importance of the Land Use, Land Use Change and Forestry sector (LULUCF) for CO_2 capture in Chile is notable, although net capture gradually decreased from 1984 to 2006. In absolute terms, the energy sector is a major source of emissions in the country, and its importance is growing.

In regard to sources and sinks for the three main GHGs in Chile's inventory (carbon dioxide, CO_2; methane, CH4; and nitrous oxide, N2O), CO_2 accounts for the greatest release of GHGs. In 2000, this gas accounted for 55% of all net emissions of CO_2eq in the annual inventory, rising to 65% in 2006. For its part, over the same time span (2000–2006), CO_2 capture through natural photosynthetic processes decreased from 29.8 million tons to 22 million tons of CO_2, according to the emissions estimation methods established for the preparation of inventories. This represents a decrease of 26%. After CO_2, CH4 has the greatest impact on the country's emissions. In 2000, this compound represented 27% of all net releases of CO_2eq in the annual inventory, compared to 21% in 2006. The agricultural sector accounts for most methane released. N2O represented

18% of all net emissions of CO_2eq in the national inventory (INGEI) in 2000, dropping to 15% of CO_2eq by 2006. The agricultural sector accounted for most emissions of this gas in both 2000 (88%) and 2006 (87%).

2.3 MEMO ITEMS FOR GHG EMISSIONS

In accordance with the reporting methodology established for country GHG emissions under the UNFCCC, some types of emissions do not need to be included in the total reported in national inventories, but can be reported separately from other GHG emissions in a Memo Item. Such emissions of greenhouse gases include those resulting from fuel used for international transport (called bunker fuels) and CO_2 emissions from firewood and biogas burned to generate energy. These are reported in Table 3, below.

TABLE 3. Memo items: GHG emissions not included within the consolidated totals for 2000 and 2006.

Type	2000 (Gg)	2006 (Gg)	% Variation
International Transport	3,068	5,275	72%
Firewood and biogas	16,721	18,563	11%

Source: Ministry of Environment, 2011

International transport emissions have increased significantly over time, with those originating from international shipping overtaking those from national shipping in recent years. This trend coincides with Chile's increasing participation in the international shipping trade, as most of the country's exports are transported by sea.

3. CHILE'S VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE

3.1 CHILE'S VULNERABILITY TO CLIMATE CHANGE

Chile is highly vulnerable to climate change. The country has an extensive low-lying coastline; arid, semi-arid and forest ecosystems; a susceptibility to natural disasters; areas that are susceptible to drought and desertification; urban zones troubled by air pollution; and mountain ecosystems such as those of the Coastal and Andes mountain ranges. Studies conducted in Chile in recent years on the impacts of and vulnerability to climate change confirm the country´s high vulnerability and have added to our knowledge of the phenomenon of climate change and its potential negative effects on our country's plans for sustainable development.

Meteorological/climatic variables

Trends observed

New climate trends are already evident in Chile, as seen in changes in precipitation and temperatures throughout the country. Studies of temperature changes for the period from 1979 to 2006 (Falvey and Garreaud, 2009; Carrasco et al, 2008) report that in the ocean and on the coast temperatures have tended to drop, while those in the Central Valley, and particularly the Andes Mountains—where most of Chile's water resources are stored—, have risen (Figure 5).

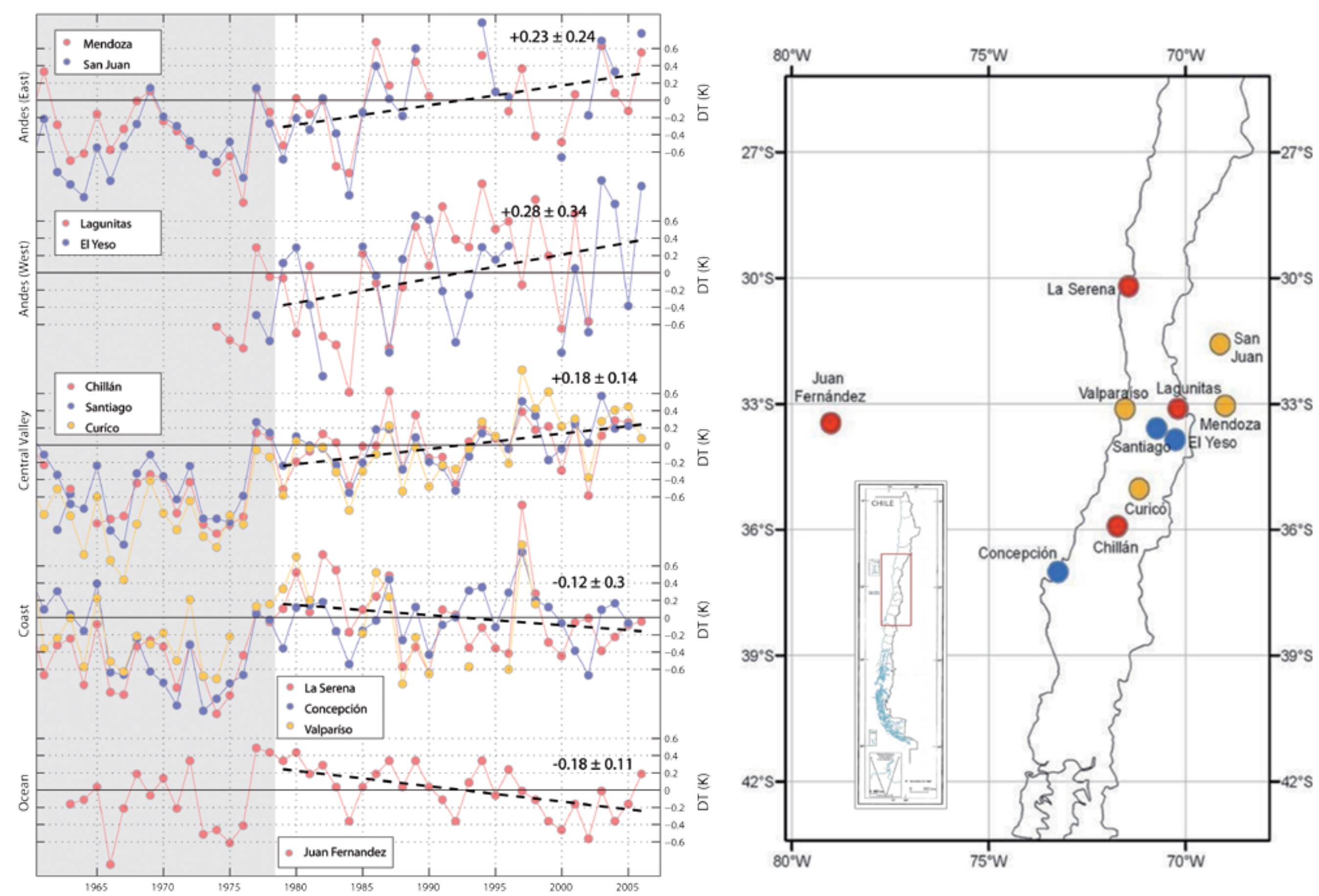

Figure 5. Time series data on temperature anomalies in Central Chile (27.5 °S– 37.5 °S).
Source: Falvey and Garreaud, 2009.

Projections

To obtain more detailed information on meteorological projections for Chile's territories, in 2006 CONAMA commissioned the University of Chile's Department of Geophysics to conduct a study, entitled "Estudio de la variabilidad climática en Chile para el siglo XXI" (Study of Climatic Variability in Chile for the 21st Century) (U. of Chile, 2006). The study used the PRECIS regional climate assessment model designed by the United Kingdom's Meteorological Office, an instrument that has been widely used in constructing regional climate change scenarios. The exercise considered two of the GHG emission scenarios defined by the IPCC: A2 (severe) and B2 (moderate). The global-scale projections used with the PRECIS model were from the Hadley Centre Coupled Model (HadCM3) global climate model, also developed by the UK Meteorological Office. Modeling of the national scenario considered continental Chile and used a spatial resolution of 25x25 km^2 for the 2071-2100 period. As a way of validating the model, modeling for the 1961-1990 period was also used to contrast the surface climate changes associated with scenarios A2 and B2 with data from recent years. Later, near-term projections were also carried out for the periods 2011-2040 and 2041-2070 under the A2 scenario, once again using the global climate model HadCM3 (ECLAC, 2009).

The projections point to an overall increase in temperature (warming) toward the end of the century in all regions, with greater warming under the A2 scenario. Under this scenario, the mean temperature for continental Chile is projected to rise by 2° to 4°C over its present level, with greater increases in the Andean regions and lower increases toward the south. Only in southern Chile and under scenario B2 are temperatures projected to rise by less then 1°C (Figure 6). Seasonally, there is more warming in summer, exceeding 5°C in some sectors of the high Andes.

An uncertainty analysis conducted on projected precipitation (ECLAC, 2009) showed that precipitation in Chile is very likely to decrease in the Regions of Coquimbo and Los Lagos, and this variability will be greater than that occurring naturally, even in the near future. In the Magallanes Region (50°S to 55°S), there is strong agreement among the models that precipitation will increase (5% to 10% more than at present) but not above natural variability. In the Altiplano and the "Norte Grande" (north of latitude 27°S), projections display a high dispersion. Figure 7 shows the percentage of models projecting an increase in precipitation in a certain location for the 2010–2040 period, revealing a strong consensus among the models that the precipitation will not increase across almost all of continental Chile.

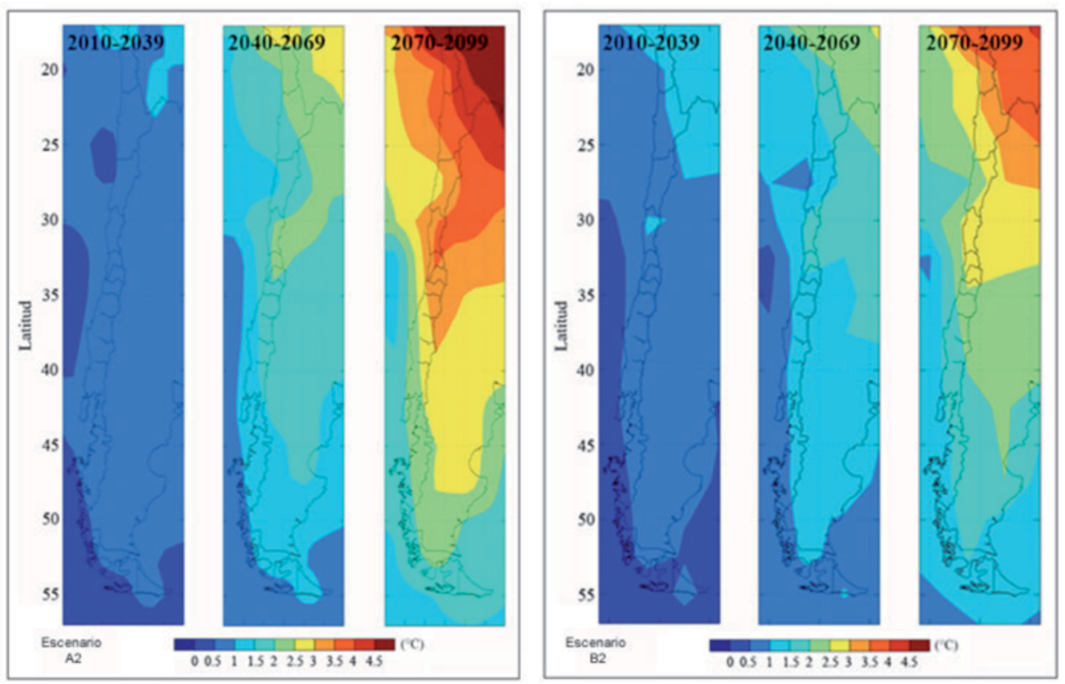

Figure 6. Projected temperature variation for scenarios A2 and B2
Source: ECLAC, 2009

Photo: Ministry of the Environment Government of Chile

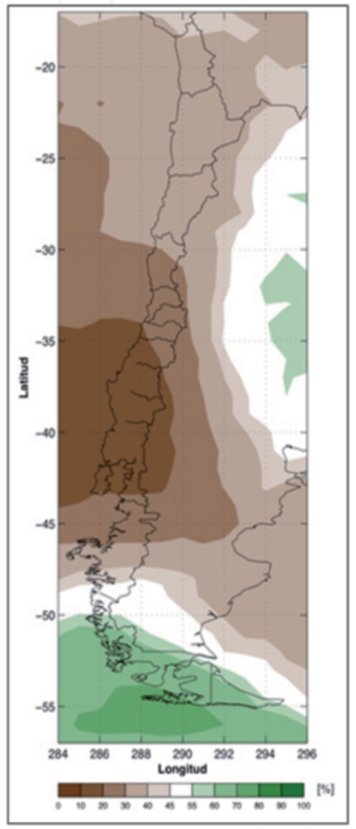

Figure 7. Percentages from models projecting an increase in precipitation in Chile for the 2010–2040 period.
Source: ECLAC, 2009

Water Resources

In Chile, the availability of water resources is closely tied to the climate, and it is therefore expected that changes in temperature and precipitation predicted by the models used to forecast the continental Chilean climate in the 21st Century will affect these resources, especially under the most severe scenarios (A2).

The expected temperature increases associated with climate change will reduce the mountainous area capable of storing snow over successive years. This occurs as the 0°C isothermal line, or snow line, shifts to higher altitudes, leading to an increase in melt water and river volume during winter months and a reduction in water reserves stored as snow (Carrasco *et al*, 2005).

Glaciers

Glaciers act as strategic water reserves, as they not only supply water to river basins in summer, but are the single most important source of replenishment for rivers, lakes and groundwater in arid regions and during periods of drought. Chile has the highest continental concentration of glaciers in the Southern Hemisphere. According to an inventory supplied by the Glaciology and Snow Unit of the General Directorate of Water, in 2007 the country's 1,835 glaciers composed an total area of 15,500 km^2. Non-inventoried ice is estimated to cover an additional 4,700 km^2, meaning that the country has more than 20,000 km^2 of ice reserves, 75% of which is found in the Northern and Southern Patagonian Ice Fields located in the Aisén and Magallanes Regions.

Studies conducted on Chile's glaciers indicate that many of them are in retreat. Of 100 glaciers assessed by Rivera *et al*. in 2000, 87% displayed shrinkage associated with changes in historic patterns of climatic variables. For example, in the last 50 years the Cipreses glacier, which feeds the Cachapoal River basin with its runoff, has been retreating at a rate of 27 meters per year, 3 times as fast as the rate observed since 1860 (Rivera *et. al*, 2007). It is estimated that increases in temperature and solar radiation in the mountains and decreases in precipitation will continue to shrink the area covered by Andean glaciers; this in turn will continue to impact the availability of water in basins with significant meltwater runoff, mainly those located between the Aconcagua and Cachapoal rivers and some in the north of the country. This effect will become increasingly apparent in summer and fall, when the supply of water from precipitation and melting snow usually drops.

Hydrologic analysis of selected basins

Studies conducted by researchers from the University of Chile and the Catholic University of Chile between 2008 and 2010 used hydrologic models to carry out the first ever quantification of the impacts climate change on water resources in Chile. The research looked at the impacts that predicted changes in temperature, evapotranspiration and precipitation under the A2 scenario of the HadCM3 would have on hydrologic resources eight river basins located along the central valley of Chile, located from the Regions of Coquimbo to La Araucanía. Figure 8 shows the results of this exercise.

home

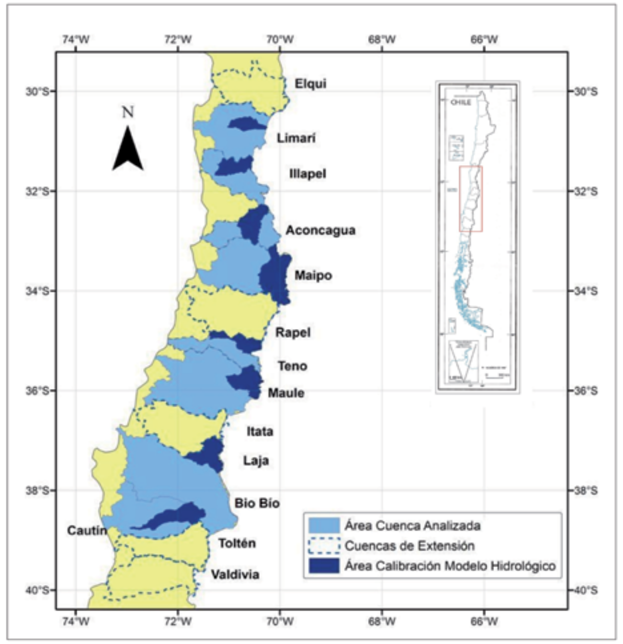

Figure 8. Map of water basins analyzed in Chile, area of calibration for hydrologic models and related basins
Source: U.de Chile, Civil Engineering Department, 2010

In general terms, the results of these modeling exercises forecast major impacts from climate change on water resources, with the available water flow decreasing in all river basins. These reductions will be greater in the most northern and southern regions analyzed (the Limarí and Cautín basins) while the rest of the basins show slight reductions in flow levels in the short-term and significant reductions starting in the mid-term. The results also show variations in the timing of increased flow levels produced by melting snows in some river basins, which in some cases would shift from spring and summer to winter months.

Due to the projected changes in availability and seasonal distribution of the water flows, practically all of the river basins analyzed show a major increase in the number of months with hydrologic deficits, based on a comparison of historic and future monthly flow and stress levels. This will greatly affect the availability of water resources by different productive sectors in Chile, with low-flow levels occur more frequently.

Soil Resources

Erosion has a significant effect on soil resources in Chile, and therefore on agricultural productivity. Erosion processes are determined primarily by variables such as precipitation intensity, slope and plant cover. Climate change can affect precipitation and plant cover both directly and indirectly, and may accelerate erosion that already affects much of Chile's agricultural land. A study conducted by experts at the AGRIMED Center of the University of Chile analyzed the impact of climate change on soil resources for the territory between the Valparaíso and Los Lagos Regions. Cross-referencing zones with a high erosion risk with areas that would present a decrease in natural plant cover, the researchers identified the zones that were most vulnerable to severe soil loss. The study concluded that parts of Chile's Central Valley that are highly important for agriculture and forestry could be the most affected by the projected climate change. In irrigated zones, which are generally on flat or very slightly sloped land, soil loss from rainfall erosion is expected to be lower in general.

Agriculture, Livestock and Forestry Sector

The agriculture, livestock and forestry sector is one of the socioeconomic systems that is most dependent on climate. As such, the study of this sector´s vulnerability to the impacts of climate change has been a central concern in Chile recent years. Initial assessments have been focused on determining how this phenomenon will affect the sector's future productivity.

Researchers from the AGRIMED Center of the University of Chile applied the SIMPROC simulation model to evaluate the impact of climate change on irrigated and dry-farmed crops, pastureland and fruit production. The SIMPROC model was calibrated based on current productivity data and then used to analyze the effects of climate anomalies projected under emission scenarios A2 and B2 for two periods, 2046–2065 and 2070–2100, including the impact on water available for irrigation (ECLAC, 2009). The main results, expressed as yields of irrigated and dry-farmed wheat, corn, potatoes, beans and beets sowed at the optimum date as well as impacts on grasslands, fruit and forestry plantations, are presented in Tables 4 to 7.

TABLE 4. Projected yields of wheat, corn, potatoes, beans and beets under A2 scenario for the 2070–2100 period

Crop	Irrigated	Dry-farmed
Wheat	• A reduction in yields is expected, mainly in the foothill and coastal zones, where the current potential will drop to levels similar to those of the Central Valley	• A decrease in yields is expected in northern and central Chile owing to more droughts. On the coast and in the Central Valley, yields will drop by 10 to 20%. • From the foothills of the Biobío Region to the south, in all zones a gradual increase is observed in yields on the order of 30%, reaching 100% in some foothill zones of the Regions of Los Ríos and Los Lagos.
Corn	• A drop in yields of between 10 and 20% is expected throughout the Central Valley in the Regions of Coquimbo to Biobío. • On the coast and in the foothills, yields are expected to rise by up to 50%. • In La Araucanía Region to the south, yields will increase from between 60 and 200% above current levels.	• Yields will continue to be marginal, with productive potential equaling less than four tons per hectare.
Potatoes	• In future scenarios, the northern zone will see 10 to 20% lower yields. • In north-central Chile to the O'Higgins Region, yields will diminish by up to 30%. • Between Talca and Temuco the present situation will continue, but only in the Central V alley, whereas on the coast and in the foothills yields are expected to rise by up to 50%. • Yields will increase by up to 150% from La Araucanía Region southward, and up to 200% in the Los Lagos Region.	• In general, and especially in the central zone, low productivity will continue. Increases are expected on the coast of the Biobío Region, and from the Los Ríos Region to the Aisén Region.
Beans	• Yields of beans will remain stable in future scenarios across the north, central and south-central part of the country. From La Araucanía Region to the south, productivity will increase from 10 to 20%, and up to 100% in the Los Lagos Region. • In general, yields will tend to remain similar—around 4.5 tons per hectare per year—across the central and southern zones of the country.	• Dry-farmed beans will continue to produce the same low yields. However, increases of around 100% are expected on the south-central coast and from Los Ríos Region to Aisén. • In Central Chile, planting dates will remain the same. In some places on the southern coast and foothills zones, however, the planting date will shift from October to September.
Beets	• In the Central Valley, between the Valparaíso and Maule Regions, yields will increase by up to 50% in some districts. • On the coast and in the foothills, yields will drop to levels comparable to the Central Valley. • From the La Araucanía Region to the south, the rise in winter temperatures will potentially increase production.	• Under the current climate scenario, beets grow better in coastal areas, reaching yields of up to 40 tons per hectare. • On the coast between the Maule and La Araucanía Regions, future scenarios show expected yield to decrease by up to 50%. • In the Central Valley and foothills, increases in almost all districts are expected from the Valparaíso Region to the south. • In the La Araucanía and Los Ríos Regions, changes in fall planting dates are expected, which will allow yields to increase in most districts.

Source: ECLAC, 2009.

TABLE 5. Grassland productivity for the A2 scenario for the 2070–2100 period

Grassland	• A drop in annual productivity is expected for grasslands between the Coquimbo and Los Lagos Regions, associated with more intense dry periods. • Toward the south, yields will increase by up to 20%. In the far southeastern Andes Mountains, drops in productivity are expected as a result of a reduction in solar radiation of up to 15%. • In the Altiplano zone, grassland productivity will increase over present levels as precipitation increases, as expected under future scenarios. • In the far south, grassland productivity will increase in the western Andes Mountains as a result of higher rainfall, temperatures and solar radiation.

Source: ECLAC, 2009.

TABLE 6. Productivity of fruit plantations under the A2 scenario for the 2070–2100 period.

Fruit plantations	• Area suitable for fruit growing could spread south to the Regions of La Araucanía, Los Ríos and Los Lagos. • Species that are highly climate-dependent (grapevines, for example) could undergo changes in their organoleptic properties (aroma, flavor, color), and therefore, in their quality. • In general, temperature increases are expected to prolong the life-cycle of some major pests, which could have serious consequences for fruit health. • Projected climatic conditions could lead to the spread of fungal and bacterial diseases. • Climate changes could increase the potential for growing subtropical species (oranges, for example) in almost all regions. • It is highly likely that climatic conditions under the new scenarios will improve the quality of fruit, as temperature increases may decrease acidity. • In the north of Chile, productive potential will increase considerably, especially in the valleys of the Tarapacá Region. • In the Central Andean foothills, climatic conditions will enable an increase in the economically viable fruit growing area.

Source: ECLAC, 2009.

Photo: Ministry of the Environment Government of Chile

TABLE 7. Productivity of forest plantations under the A2 scenario for the 2070–2100 period

Forest plantations	**Pinus radiata (Monterey Pine)** • A considerable deterioration of productive potential is expected in the north-central zone (between the Coquimbo and Metropolitan Regions), becoming less severe toward the south, where it may be moderate or slight in the central zone (Metropolitan, Valparaíso and O'Higgins Regions). The deterioration disappears in the La Araucanía Region, where productive potential will actually improve significantly, with major increases between the Los Ríos Region and the Island of Chiloé.	**Eucalyptus globulus** • A deterioration in productive potential is expected in the Coquimbo Region as a result of decreased precipitation. • Along the central coast, an increase in productive potential is expected due to milder winter temperatures, with a similar expectation for the foothills zone. • From the La Araucanía Region to the south, an increase in productive potential is expected, with notable increases in the Los Ríos and Los Lagos Regions.

Source: ECLAC, 2009.

Productive and socioeconomic vulnerability and adaptability of the agriculture, livestock and forestry sector

The productive and socioeconomic vulnerability and adaptability of the agriculture, livestock and forestry sector to climate change were also evaluated in the studies conducted by researchers from AGRIMED and the Catholic University. The analyses included intrinsic adaptation by agricultural producers as climate patterns shift. Using the district level as the spatial scale, the following variables were evaluated: changes in land use, changes in net income and changes in labor.

The study concluded that vulnerability to impacts on agricultural productivity is greater in zones with a higher prevalence of annual crops (the valleys of Coquimbo Region, the central valley of Maule Region and southward), while in the Los Ríos and Los Lagos Regions, the greatest vulnerability is due to the lack of irrigation infrastructure. The central regions, where fruit production predominates, are less vulnerable. In terms of social vulnerability, the most affected zones are those that are most intensely agricultural in which the population displays low human development indices, such as the Coquimbo, Maule and La Araucanía Regions. Thirdly, an assessment of economic vulnerability focused mainly on capital invested in supplies and technology, as well as linkages with foreign markets for each subsector. In this case, crops that require more technical management and/or are more profitable are more economically vulnerable, as the potential losses are greater. In this case, results indicate that the effects of climate change on crops grown for export in central Chile and technologically intensive crops could result in a significant economic loss for the country.

Biodiversity

International studies conducted in recent years on the impacts of climate change on biodiversity show that the recent rise in the average global temperature has induced a series of biological and ecological responses in plants and animals. These studies also predict, with a significant degree of certainty, shifts in species distribution ranges and phrenology.

Chile's great range of latitude and altitude leads to a wide variety of environmental conditions that sustain biological diversity. The climatic patterns that result from these two gradients mean that Chile has some areas with the lowest annual rainfall on the planet and others with the highest number of rainy days annually.

Chile's biodiversity hotspots for conservation priorities are zones that concentrate a minimum of 1,500 species of endemic vascular plants and an original habitat that has been significantly degraded by anthropic activity. The two areas of Chile that have been classified as hotspots are the Mediterranean and temperate climate zones and the Chilean Altiplano, as illustrated in Figure 9.

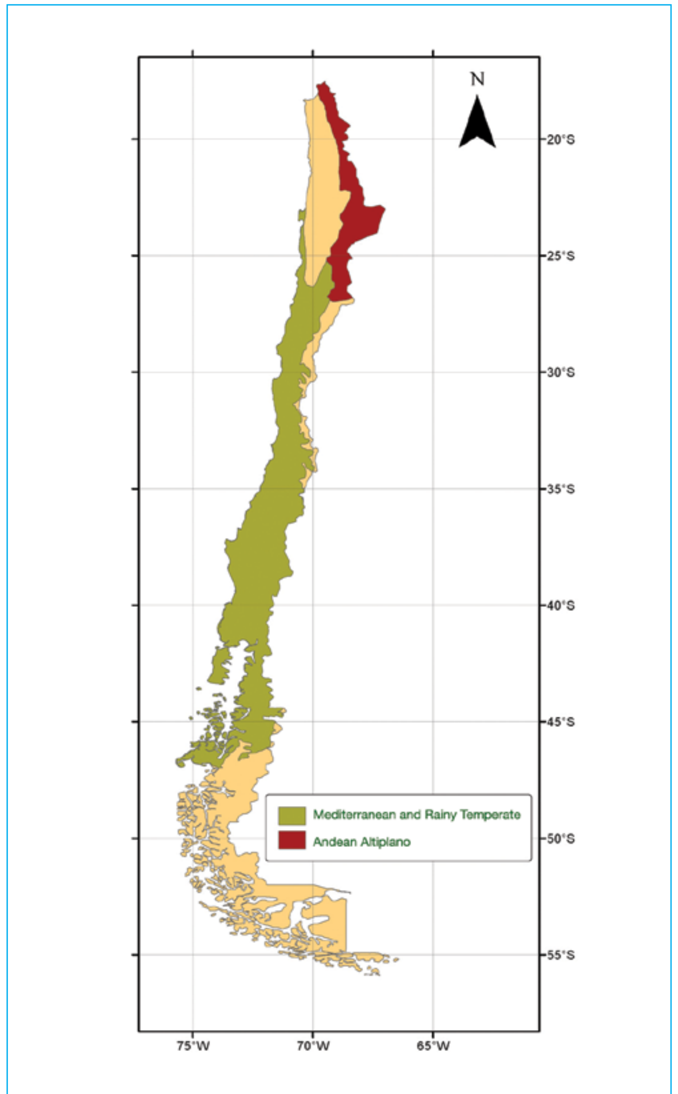

Figure 9. Biodiversity hotspots of Chile
Source: WWF, 2004

A CONAMA-funded study conducted in 2009–2010 by the Institute for Ecology and Biodiversity and the Center for Advanced Studies in Ecology and Biodiversity of the Catholic University assessed the vulnerability of Chile's biodiversity to climate change. Methodologically, the study compared current and expected distribution of species and ecosystems under a climate change scenario to identify possible adaptation measures. Analysis of the way in which species responded to climate change showed that in general, even while most distribution areas will shrink for species with limited dispersion, the number of species that would become extinct is quite small (two species of flora). The greatest variation in vegetation estimated for the end of the century would occur in Chile's central zone, where the ecosystems would undergo greater change. For example, the projection for ecosystems characteristic of Chile's central zone indicate that the area of distribution of inland Mediterranean spiny forest and low desert Andean scrub formations will be considerably reduced. In this context, the Mediterranean hotspot vegetation appears highly vulnerable to the impact of future climate change.

3.2 ADAPTATION TO CLIMATE CHANGE

The Government of Chile is taking concrete steps to promote adaptation to the effects of climate change in different areas such as water resources and the agriculture and livestock sector. The following sections describe some of these measures.

Water resources

In regard to water resources, one notable measure has been the glacier protection and conservation policy passed in February 2009 by the Governing Council (Council of Ministers) of CONAMA. This policy promotes the study and appreciation of Chile's glaciers in the national and international context. To this end, a national registry of glaciers was created and a set of research priorities was defined by the General Directorate of Water of the Chilean Ministry of Public Works, which has been systematically implementing a series of initiatives to protect Chile's glaciers since 2008. This policy seeks to establish measures that would preserve and conserve the country's glaciers, in order to ensure the continuity of the natural and productive processes that they sustain and the environmental services they supply. The policy also aims at identifying glacier typologies and conditions for their use and providing for the design of instruments and the institutional mechanisms to implement them.

Agriculture, Livestock and Forestry sector

The area that has implemented the greatest number of actions for climate change adaptation has been the forestry, agriculture and livestock sector, which has undertaken a series of studies financed by agencies of the Ministry of Agriculture (ODEPA and FIA primarily) and supported by CONAMA, or in some cases by the Ministry of the Environment with its own budget. These studies have generated information about the vulnerability of Chile's agriculture and livestock sector with the goal of enabling the design of concrete measures for the medium and long term. Spheres of action pertinent to this sector include the use and changeover of crop varieties; improvement and adjustment of current irrigation practices; changes in irrigation systems; sustainable management of groundwater; tree planting; increasing the availability of water; more efficient and effective fertilization; preparation and application of compost; the use and incorporation of agricultural waste; the controlled use of fire; and the management of herd-irrigation-pasture and livestock infrastructure.

In regard to instruments that support the development and implementation of adaptation measures, while it is true that all instruments that currently exist or have been applied in the recent past in Chile originated to address concerns other than climate change, this does not mean that they are not suitable for supporting adaptation measures or reducing the vulnerability of the agriculture and livestock sector to climate change.

4. MITIGATION OF GREENHOUSE GAS EMISSIONS

4.1 MITIGATION IN CHILE

Chile affirms the need to stabilize global atmospheric concentrations of greenhouse gases (GHGs) at a level that prevents hazardous anthropogenic interference with the planet's climate system by reducing total emissions and protecting and improving GHG sinks and deposits through suitable mitigation measures. The country's contributions to international efforts in this regard are grounded in the principle of common yet differentiated responsibilities and are intended to support the aims of the United Nations Framework Convention on Climate Change (UNFCC) while also generating social and environmental co-benefits within the country.

Although Chile´s emissions are relatively low on a global scale, the country recognizes that the rate of economic growth over the last decades, which is expected to continue, emissions are expected to increase at a fast pace. For this reason, the Government has the political will to act to limit the rate at which GHG emissions rise, by adopting nationally financed actions and enhance the level of mitigation, to the extent that technical and financial support from Annex I countries allows.

In this context, by the year 2020, current emission levels in developing countries must be mitigated through the implementation of nationally appropriate mitigation actions (NAMAs) applied within a framework of sustainable development. These actions should be subject to measurement, reporting and verification processes. Chile will be responsible for implementing unilateral NAMAs and NAMAs supported by Annex I countries through technology transfer, financing and capacity building, which should also be subject to rigorous measurement, reporting and verification processes.

Table 1: Chile and the Copenhagen Accord

- Chile associated itself with Copenhagen Accord on 29 January 2010.
- On 26 August 2010, Chile presented information for inclusion in Appendix II of the Copenhagen Accord: *Chile will take nationally appropriate mitigation actions to achieve a 20% deviation below the "Business as Usual" emissions growth trajectory by 2020, as projected from year 2007. To accomplish this objective Chile will need a relevant level of international support. Energy efficiency, renewable energy, and Land Use and Land Use Change and Forestry measures will be the main focus of Chile's nationally appropriate mitigation actions.*

In accordance with its commitments under the Convention, Chile considers it necessary to take firm and concrete steps toward achieving a lower carbon economy (Table 1). In this context, the Chilean Government began working in 2010 on several instruments that will provide information for decision-making about mitigation. In the next few years, the Government of Chile will design and implement a strategy for mitigating its emissions.

Some concrete advances that are expected in this area include:

- Strengthening capacities related to the country's emissions inventories through the implementation of a national GHG Inventory Office (more details of this can be found in Chapter 6 of this National Communication);
- Integration of sector-specific efforts to prepare emission projections for the coming years, to establish a Government-sanctioned national baseline that will enable ministries to conduct their emission projection exercises in a complementary fashion and from a common foundation;
- Generation of information to enable Chile to produce NAMAs in the short term, especially in the energy and LULUCF sectors.

Beginning in 2011, the Government of Chile will also embark on an extensive exercise to prepare long term mitigation scenarios based on a methodology developed and applied in South Africa prior to the 15th Conference of the Parties. This exercise will include input from different stakeholders in identifying possible future climate actions and estimating their costs, social implications and barriers to their implementation. The exercise will take two to three years and is expected to generate the best information possible for configuring public policy in this area in the remaining years of the decade.

At present, a variety of sector-specific initiatives are already being organized by different ministries to generate preliminary information about possible mitigation actions in Chile. These analyses do not claim to be exhaustive, but are rather intended to be indicative. In any case, one of the steps in the near future will be to look for a way to prioritize these various options.

4.2 ANALYSIS BY SECTOR

Energy Sector

The country's energy policy is founded on the legal and regulatory role carried out by the State through its Ministry of Energy and related agencies, with the private sector taking responsibility for the investments. This arrangement means that way policies are defined does have an impact on limiting increases in greenhouse gas emissions. The following are some of the main definitions that have been identified by the Administration of President Sebastián Piñera Echenique:

- Increase energy availability to meet the rise in demand related to the average economic growth rate of 6% per year projected up to 2020.
- Increase the security of energy supply in the short, medium and long term, by encouraging energy generation projects that reduce the risks of failure and reinforcing fuel supply to enable the effective and timely response to eventualities and contingencies.
- Promote competitive and sustainable investment in the sector.
- Work toward having 20% of the energy generated in Chile supplied by nonconventional renewable energy sources–our own local and global resources–by 2020.
- Achieve greater energy independence and increase private investment in hydrocarbon exploration and development.
- Improve current regulations governing access to energy resources, in order to increase investment in renewable energies in Chile.
- Carry out further studies and strengthen the institutional framework to enable the future development of any cost-efficient energy source.
- Promote research programs on energy and raise the awareness of younger generations about energy savings and energy efficiency.
- Improve information available about the country's energy resources in order to formulate a policy to promote energy efficiency and energy saving projects.
- Advance in energy efficiency certification and establish energy efficiency standards for residential construction, domestic appliances, lighting and vehicle fleets.

In the decade covered by this National Communication, the Government of Chile has been active in establishing a suitable regulatory framework for mitigating GHG emissions in the energy sector. Notable advances in this area include incentives for the use of non-conventional renewable energies, the Geothermal Law and the 2008 Law on Non-conventional Renewable Energies (NCRE). Others include the tax exemption for solar thermal systems in 2009 and the regulatory framework for the energy efficiency incentive, which includes energy efficiency labeling, home heating regulations, and minimum energy performance standards. Over the same decade, the Government of Chile created several institutions to oversee the implementation of this wide range of instruments.

In regard to Non-conventional Renewable Energy (NCRE), the Government has developed a policy that supports competitive energy generation based on these energy sources by identifying barriers to their introduction and creating lines of action intended to remove those barriers. The barriers themselves include a lack of information, precarious infrastructure, uncertainty about new technologies and difficulties in accessing credit. In cases such as geothermal energy, among others, the barriers are associated with the high cost of exploration. Nevertheless, in four years Chile has doubled its installed capacity of NCRE for electricity generation, which rose from 286 MW (representing 2.4% of total installed capacity) in late 2005 to 600 MW (4% of the total capacity) by the end of 2009, and continues to rise. Furthermore, of the energy projects submitted to the Environmental Impact Assessment System (SEIA in Chile) between 2004 and the end of 2009, 2000 MW of the total 2,553 MW were for wind power.

In the area of energy efficiency, Chile has channeled most of its efforts through the National Energy Efficiency Program and the Chilean Energy Efficiency Agency. Since 2009, these programs have enabled the implementation of pre-investment and loan programs that have advanced energy efficiency in the industrial, residential, public and commercial sectors.

The country's energy sector has great potential for mitigating GHG emissions in both generation and consumption. On the other hand, there is uncertainty about the penetration rates of these technologies and about the improvement of technical capacities that will enable these technologies to be taken advantage of in Chile. Some variables that contribute to this uncertainty include the future price of generation and consumption technologies, future international fossil fuel prices, and the rate of national economic growth.

Agriculture, Livestock and Forestry Sector

Chile's agriculture and livestock sector, which includes the forestry, agriculture and livestock subsectors, is recognized as carbon neutral, meaning that the emissions counted in the GHG inventories from this sector's activities are equal (in tons of CO_2 equivalent) to those captured through forestry activity.

While the Ministry of Agriculture's regulatory frameworks and incentives are not explicitly directed at addressing climate change, the Ministry has made available to this sector several instruments that lead to the mitigation of GHG emissions.

According to the Ministry of Agriculture, GHG emissions associated with this sector's activities can be reduced by increasing energy efficiency and productive efficiency, applying better agricultural practices in both productive and environmental terms, reducing forest fires, increasing the forestry sector's capacity for capturing GHG emissions through sustainable native forest management and decreasing soil degradation.

Projections

As there are no official sector-specific estimates that project emissions for the agriculture, livestock and forestry sector, this National Communication presents projections based on the results of the 2010 study "Análisis de opciones futuras de mitigación de GEI para Chile asociadas a programas de fomento en el sector silvoagropecuario" (Analysis of future GHG mitigation options for Chile associated with development programs in the agriculture, forestry and livestock sector). These include projections of emissions for some subsectors. The subsectors analyzed were livestock, annual and perennial crops, degraded soil, and forestry.

Table 8 shows projected annual GHG emissions (Gg CO_2eq) for the subsectors considered here. The study indicated that in all of these subsectors, the trend is toward increased emissions (or decreased carbon capture, in the case of forestry) as a direct result of increased agricultural and livestock production and the new focus of the program Incentive System for the Recovery of Degraded Soils, which emphasizes productive activities. For forestry plantations, annual capture decreases primarily because the area forested is decreasing each year. Without the incorporation of new acreage, carbon capture would decrease gradually between 2020 and 2050.

TABLE 8. Projected GHG emissions for selected subsectors of the agriculture, livestock and forestry sector for use in development instruments.

Subsector	2020	2030	2050
	(Gg CO_2eq/year)		
Forestry	-150.0	-149.4	-96.1
Degraded soils	-33,8	0	0
Annual and perennial crops	1,371.1	1,428.5	1,527.2
Livestock	5,534.4	5,800.3	6,266.6
Total	6,721.8	7,079.4	7,697.7

Source: CCG UC, 2011

Photo: MInistry of Agriculture. Government of Chile

Transportation Sector

Chile's transportation sector, like that of most countries, accounts for a high percentage of national GHG emissions because of its high consumption of fossil fuels. According to figures from the 2006 GHG emissions inventory, emissions of CO_2eq from this sector in Chile are caused mainly by road transport (92.3%), followed by domestic air flights (5.1%), maritime transport (2.2%), and finally rail transport (0.4%).

Projections

Two studies commissioned in 2009 by the Government of Chile examined emission trends and mitigation options for the transportation sector. They predicted a rise in GHG emissions based on the impact associated with projected fuel consumption in this sector (Figure 10).

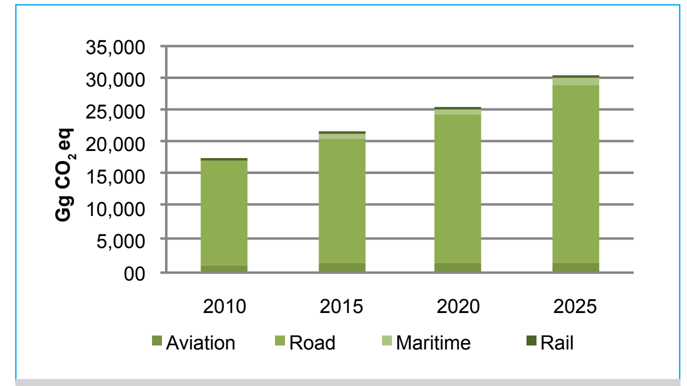

Figure 10. Projected emissions of CO_2eq in Chile's transportation sector (2010-2025)
Source: Ministry of Environment, based on information from a study by Sistemas Sustentables, 2010

Chile's road transport sector has been especially active in seeking sector-specific options that benefit the environment and also contribute to mitigating GHG emissions. These options can be classified as follows:

- Promoting the penetration of low carbon vehicle technologies
- Restructuring the urban transit system
- Switching the technology of vehicle fleets
- Promoting alternative modes of transport
- Implementing energy efficiency measures in high priority fleets

Copper Mining Sector

Chile is the largest cooper producer in the world, accounting for 34% of global cooper production. As such, copper mining is highly important to the national economy. The copper sector is also a major energy consumer, through its direct consumption of fuels and electricity. Copper extraction and production in Chile involves a series of processes that range from ore extraction (from open pit or underground mines), to concentration and refining, to pyrometallurgy in the case of copper sulfide and to hydrometallurgy (extraction by solvents and electrowinning) in the case of ore that can be lixiviated. These operations consume energy at different rates.

The approach to emissions mitigation in the Chilean copper mining industry has mainly consisted of exploring ways to improve the energy efficiency of industrial processes associated with copper production. Energy efficiency has been an important tool in this regard, as it can lower production costs and thereby improve competitiveness. For this reason the copper industry has been a leader in energy efficiency applications in Chile.

Projections

Studies conducted by the Ministry of Mining's Chilean Copper Commission show that projected indirect emissions from copper production—those generated by electricity use in mining operations—represent over 73% of the sector's emissions (Figure 11). This is primarily because of the projected importance of fossil fuels in the country's electricity-generating grids that supply the sector´s principal mining operations.

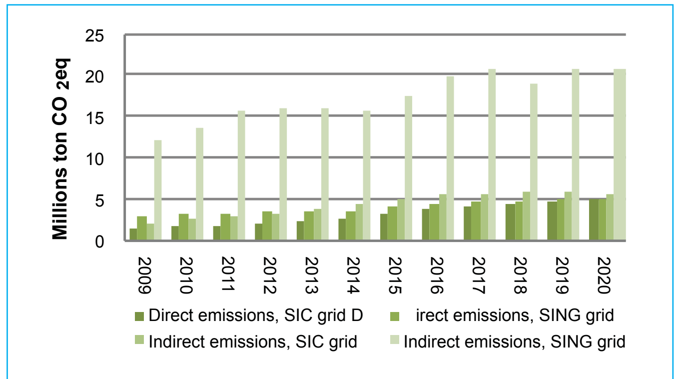

Figure 11. Projected direct and indirect GHG emissions of Chile's cooper mining sector, by electricity grid

Source: "Estudio prospectivo de emisiones de gases de efecto invernadero de la minería del cobre en Chile". Chilean Copper Commission, 2009

4.3 MULTI-SECTOR ACTIONS

Carbon Offsets

Since the Kyoto Protocol was adopted in 1997, Chile has remained actively interested in promoting and implementing projects under the Protocol's Clean Development Mechanism (CDM), taking a leading role in Latin America and globally in terms of the number of projects registered and methodologies approved. The country took an early interest in making use of the CDM early on, establishing its Designated National Authority (DNA) in 2003. As of 2010, this office has approved a total of 73 national letters of approval, and by the end of 2010 the Executive Board of the CDM had registered 42 of these projects. The Chilean projects registered are expected to achieve an aggregate reduction of 4,957,224 tons of CO_2 equivalent. The most common projects in Chile are hydroelectric projects, followed by methane capture in landfills and agroindustrial activities.

Carbon footprint

As part of its effort to mitigate GHG emissions in the agriculture, livestock and forestry sector, in 2009 the Ministry of Agriculture commissioned the Institute for Agriculture and Livestock Studies (INIA) to analyze the carbon footprint of Chilean agriculture and livestock exports, in order to maintain the country's competitiveness in international markets. The English standard (PAS 2050: 2008 BSI, based on ISO 14067) was used to assess life cycles of specific varieties of fruit, vegetables, grains, dairy and animal products. In general, the main GHG emission sources in these categories are energy sources, supplies used, and the animals themselves in the case of animal products. International long-distance transport is a minor contributor to Chile's product carbon footprint.

In 2010, the Ministry of the Environment commissioned a study to characterize its own GHG emissions and design a plan to reduce its institutional carbon footprint, becoming the first ministry to do so.

Photo: Ministry of the Environment Government of Chile

5. ADDITIONAL INFORMATION PERTINENT TO ACHIEVING THE CONVENTION'S OBJECTIVE

5.1 TECHNOLOGY TRANSFER

In Chile, policies and programs that support innovation are promoted by public and private entities that together make up the country's technology transfer system. This system operates on different levels, depending on the institutions involved. These different levels include:

- General coordination entities
- Implementing agencies
- Sector-specific and regional entities
- Institutions focused on technology research and promotion

The last decade in Chile has been a time of technological experimentation, with the identification of more and better opportunities for addressing climate change, the development of specific technical knowledge, the country's participation in emerging international technology markets and the creation of a legal, regulatory, and support framework for technology transfer. Public sector initiatives have produced a series of instruments aimed at developing and encouraging the adoption of non-conventional renewable energies in Chile and the application of energy efficiency measures in different GHG producing sectors. These include instruments of support for the NCRE project pre-investment and investment stages and other instruments that support innovation, financing and investment in this area. Over the past decade, the private sector has also participated very actively in implementing the Kyoto Protocol's CDM, allowing Chile to remain a leader in CDM projects, a notable achievement for an economy of its size.

5.2 SYSTEMATIC OBSERVATION OF CLIMATE VARIABILITY AND CLIMATE CHANGE

In Chile, climate and climate variability are systematically observed through the monitoring of key meteorological, atmospheric, oceanographic and terrestrial parameters. This monitoring is carried out using modern equipment and automated communication devices, relying on the country's installed capacity for operating equipment and processing the information generated.

In Chile, systematic climate observation programs are operating at the national level with the close involvement of research organizations and government institutions. National institutions also participate in international climate research and observation systems. However, gaps have been identified in meteorological, atmospheric and oceanographic research and observation, and there are some priority areas in which additional knowledge and information would lead to an improved understanding of the national and regional climate system.

The creation of the Glaciology and Snow Unit under the Ministry of Public Works' General Directorate of Water in 2008 has led to the implementation of several public sector activities to monitor glaciers, including the collection and systematization of information to build a National Glacier Registry, which is expected to be finalized in 2011.

5.3 RESEARCH PROGRAMS

Chile has several research programs focused on different aspects of climate change such as climate change science, vulnerability and adaptation, mitigation of emissions, and, still in the early stages, emission factors. Specific public sector agencies support these programs, mainly by providing funding, while investigators situated in academic and other research centers carry out this work.

Chilean researchers also participate on an ongoing basis in several networks oriented toward environmental sustainability and global change, both in Latin America and internationally. Chilean experts also collaborate with the Intergovernmental Panel on Climate Change (IPCC), the United Nations' principal scientific and technical entity for climate change.

Over the past decade, research centers in Chile have established or strengthened lines of investigation in areas related to climate change such as meteorology, oceanography, glaciology and vulnerability and adaptation to climate change.

5.4 INFORMATION ABOUT EDUCATION, TRAINING AND AWARENESS-RAISING RELATED TO CLIMATE CHANGE

Chile has seen some notable changes between 2000 and 2010, especially in regard to public participation in the climate change debate and public access to information about this phenomenon. Changes in this area have come from institutions and initiatives to promote the development of public education and awareness programs; initiatives and programs geared specifically to primary, secondary and tertiary educational levels; and campaigns for public education, training and awareness led and/or promoted by different segments of Chilean society.

5.5 BUILDING LOCAL AND NATIONAL CAPACITIES FOR CLIMATE CHANGE, FINANCIAL RESOURCES AND TECHNICAL SUPPORT

Capacity building at the local and national levels has generally been focused on improving dissemination of information, education and research on climate change, improving the quality of information available, and increasing capacities for climate observation. It has also sought to develop institutional capacities to respond to the challenges of mitigation and adaptation and to develop and transfer technologies for mitigation and adaptation, reinforcing international cooperation and establishing synergies between climate change and other global environmental problems. Capacities have also been developed to in the private sector, among non-governmental organizations, and in local community groups, according to their different interests.

The international technical and financial collaboration that Chile has received during the decade covered in this report has been crucial for the development, promotion and strengthening of activities related to climate change in the country. A notable supporter of these efforts has been the Global Environment Facility (GEF) and its implementing agencies. Support has also come from international environmental cooperation agreements signed by the Government of Chile and from bilateral cooperation initiatives.

The funding that the Government of Chile has provided for managing climate change in the country has enabled the creation of permanent working groups charged with addressing climate change from within their ministries and the allocation of budgets to implement their activities.

6. BARRIERS, GAPS AND NEEDS RELATED TO FINANCIAL AND TECHNICAL MATTERS AND CAPACITIES

For Chile, the important task of fulfilling its commitments under the UNFCCC will involve overcoming obstacles, filling in important gaps, and meeting various needs related to financial and technical matters and the development of local capacities.

As a developing country, Chile is committed to contributing to efforts aimed at mitigating and to adapting to the impacts of climate change that are occurring at the national and global level. The work already done and the achievements made to date reflect the equitable balance between national efforts and international support. This collaboration has enabled such advancements as the establishment of a new environmental institutional framework, the generation of technical capacities and the development of new lines of work. The country's achievements to date demonstrate how national efforts can be supported by developed countries to achieve the ultimate objective of the Convention.

6.1 FINANCIAL RESOURCES AND TECHNICAL SUPPORT

In moving toward low carbon development, Chile's central challenges will revolve around generating permanent and sufficient national and international funding mechanisms for implementing climate change mitigation and adaptation projects and for measuring, reporting and verifying GHG reductions. Other challenges will include strengthening the country's research and development capacities.

6.2 SECTOR-SPECIFIC NEEDS

The list below identifies some areas in which Chile expects to carry out additional sector-specific efforts to establish and strengthen its climate change-related capacities.

- National greenhouse gas emissions inventory
- National water resources affected by climate change
- Systematic observation of climate variability and climate change
- Electricity generation from renewable sources and energy efficiency
- Transportation
- Development of infrastructure focused on adaptation to climate change
- Agriculture, livestock and forestry activities
- Biodiversity
- Warning systems for climatic events and natural disaster management
- Strengthening participation in national climate change actions

Beginning in 2011, Chile will embark on a campaign to implement the diverse actions required of developing countries under the Cancun Agreements. The country will also take action on mitigation by working to design and implement NAMAs that will allow Chile to follow through on its voluntary commitment to achieving a 20% reduction in its emissions growth trajectory by 2020, as projected from the year 2007. The approaching challenges are significant, but future achievements will allow the country to advance along a path of low carbon sustainable development.

CHAPTER 1

National Circumstances

PHOTO: MINISTRY OF THE ENVIRONMENT

HOME

1. GEOGRAPHY AND SOCIAL DEVELOPMENT

1.1 TERRITORY

Chile is a tri-continental country with territory that extends along the southwest portion of South America and includes Easter Island in Oceania as well as part of Antarctica to the south. The nation's territory also includes the Archipelago of Juan Fernandez, the islands of San Felix, San Ambrosio, and Salas y Gomez, as well as the 200-mile Exclusive Economic Zone with its corresponding continental shelf.

Continental Chile is located between 17° 30´ and 56° 30 Latitude South, while Chile's Antarctic Territory covers the area between 53° and 90° Longitude West in the South Pole. The country covers a total area of 2,006,096 km^2, not counting its offshore marine territory, the exclusive economic zone, or the continental shelf. This territory is distributed as follows: 755,915 km^2 in continental America, 1,250,000 km^2 in Antarctica and 181 km^2 in Oceania. It is bordered by Peru in the north, and Bolivia and Argentina in the east, the South Pole in the south and the Pacific Ocean in the west along its 8,000 kilometers of coastline.

Chile's Antarctic territory is connected to the country by the Southern Antilles Loop, with the northern point of the Antarctic peninsula just 1000 km from South America.

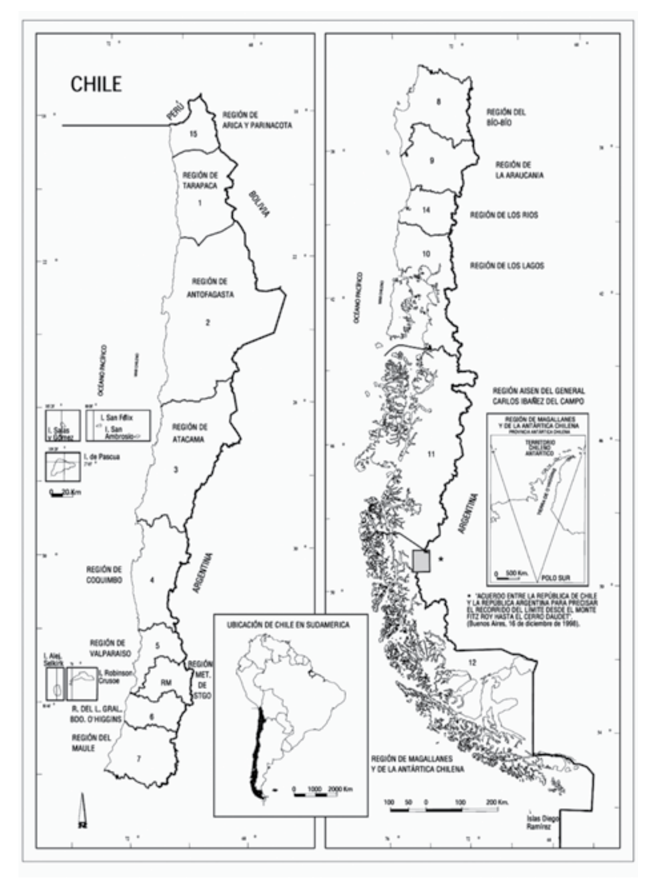

Figure 1. Map of Chile's Tricontinental Territory
Source: INE, 2008

The country has three main north-south morphological features: the Andes Mountains in the east, the Coastal Mountains in the west, and the Intermediate Depression, which runs between these two mountain chains but is often interrupted by transversal mountain chains, giving the country a rugged and broken topography, with flat areas accounting for no more than 20% of the entire continental territory. The country's coastal valleys, archipelagos and islands are also populated and play host to important economic activities.

1.2 CLIMATE

Chile has many different climates that result from a variety of environmental factors and give the country some unique characteristics. In general, however, the territory has a temperate climate with some essential variations caused mainly by differences in latitude and altitude. These variations give rise to desert, tropical, mediterranean, temperate and polar climate systems, among others.

The Pacific Ocean has a powerful moderating effect on temperature variation in the coastal zone. Because of this, coastal temperatures oscillate less, and mainly with latitude, with annual averages between 6°C in the far south, 15°C on the central coast, and 17°C in the far north. In contrast, in areas less influenced by the coast, temperature variability and oscillation tend to be greater, with more marked seasons that follow the solar cycle.

Recent studies (Falvey and Garreaud, 2009; Carrasco et al., 2008) have shown a shift in historic temperature trends, which decreased along the coast and over the ocean and increased in the Central Valley and the mountains in the 1979-2006 period. More details of this shift can be found in Chapter 3.

In regard to precipitation, three annual distribution patterns can be identified in the country. Central and South-central Chile have well defined annual cycles characteristic of a Mediterranean climate with higher rainfall in winter and much less in summer, increasing to the south. In the extreme south of the country, west of the Andes Mountains, it rains abundantly all year round. A third type of precipitation cycle is found in the Altiplano zone, where rains are moderate in summer and very occasionally intense.

South of Latitude 30°S, precipitation is highly variable on a decadal scale. This is linked to changes in the Southern Oscillation and therefore to those derived from interannual oceanic-atmospheric anomalies such as El Niño and La Niña. It is possible to detect the influence of the Pacific Decadal Oscillation. In general terms, the El Niño phenomenon is associated with an increase in precipitation in the south-central part of the country and coincides with the occurrence of major hydrometeorological disasters (IDB-UN, 2007).

Ecologically, the presence of biomass and specific plant formations depends on the type of climate in a given zone. According to Luebert and Pliscoff (2006), Chile has four macrobioclimate zones (Figure 2).

Tropical macrobioclimate

This climate extends in the high Andes from the far north of Chile to 31°S and descends in altitude diagonally northward to 23°S on the coast. It includes tropical pluviseasonal, xeric, desertic and hyperdesertic bioclimates, and the antitropical bioclimatic variant.

The predominant plant and animal life are particularly sensitive to water availability and only exist where groundwater comes to the surface or in valleys watered by small watercourses flowing down from the Andes and that, generally, discharge into endorheic basins. The tropical pluviseasonal bioclimate envelops the entire Chilean Altiplano region and features regular precipitation in the warm season, increasing in intensity to the northeast, and gradually lessening and becoming more irregular to the south, which means that the maximum vegetative activity occurs in the warm months, especially January and February.

Mediterranean macrobioclimate

This macrobioclimate is distributed mainly in the central zone, from the coastal band at latitude 23°S, moving inland at 25°S until reaching 39°S in the Intermediate Depression. This zone varies with longitude, with a marine Mediterranean climate on the coast and a dry climate inland. In addition, it displays latitudinal variations that affect rainfall, which results in regions with twelve months of no rainfall and others, in the south, with only one month without. This variation can be altered by local factors such as high humidity and persistent fog in the northern coastal sector, increased precipitation in the preAndean sector, or the penetration of marine air masses inland through valleys.

This macrobioclimate has a wide range of vegetation types. In the north, xerophytic formations predominate, changing to bushes and scrub in places with higher precipitation. Southward, the higher rainfall favors the proliferation of mesophytic and hydrophytic plant types, as well as sclerophyllous forest, typical in Central Chile, and rainforest in the south-central zone.

Temperate macrobioclimate

This macrobioclimate covers the most land area in the country. It extends from the southern limit of the Mediterranean zone (latitude 39°S) to the far south of Chile (latitude 56°S), but excludes the southwestern sector of Tierra del Fuego and some parts of the Magellanic Archipelago. This is a zone of lush vegetation, with forests associated with high humidity.

Antiboreal macrobioclimate

This type covers the southwestern zone of the Magellanic Archipelago and is characterized by peat bogs, deciduous forest and scrub, steppe and marginal grasslands.

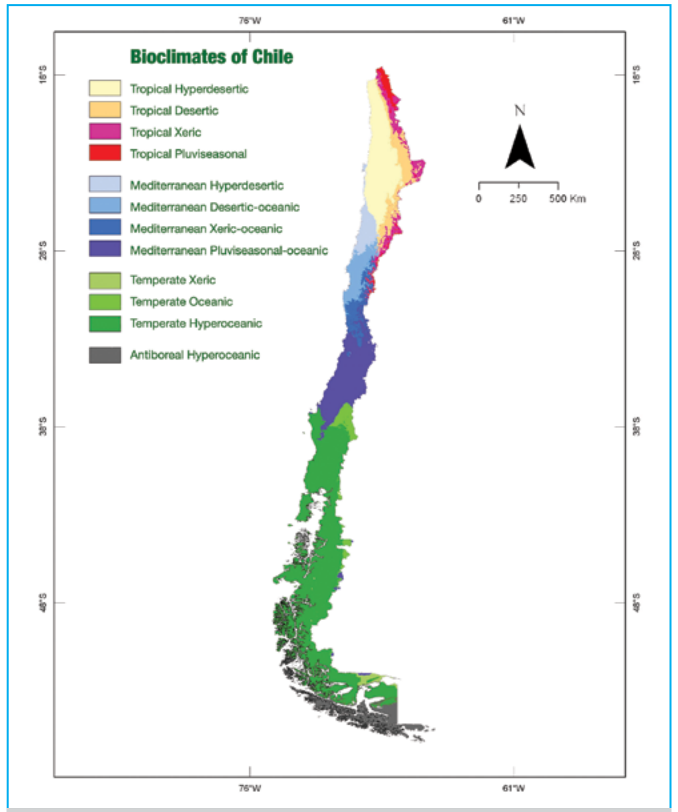

Figure 2. Bioclimates of Chile
Source: Luebert & Pliscoff, 2006

1.3 POPULATION

Chile is divided into fifteen political-administrative regions, which are territorial units with unique geographic features and their own social, economic and cultural characteristics. The central government is located in the Metropolitan Region, which is home to 40% of the nation's entire population and claims the highest population density (433.5 inhabitants/km^2).

Chile's population grew quickly in the 20th Century, but growth has slowed in the past decade and is expected to decelerate even more towards 2050. In 2009 the population was estimated at 16,928,873 inhabitants, 49.5% of male and 50.5% female. The population is projected to rise to 20,204,779 by the middle of this century (9,904,861 male and 10,299,918 female) (Figure 3). The average population density is 22 inhabitants per square kilometer. Just 13% of Chileans live in rural areas, and more than 4 million live on the coast.

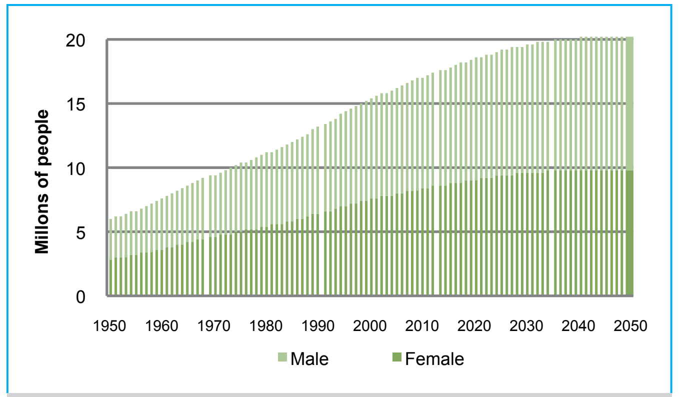

Figure 3. Historic and Projected Population Growth by Gender, 1950–2050 (millions of people)
Source: INE 2011

The employed workforce numbers around 6.5 million people, 40% of them concentrated in the Metropolitan Region. Across the country, most jobs are found in the service and commercial sectors.

Chile's climate and geographic conditions have led the bulk of the population to settle in the country's central valleys, a situation that has led to the land use patterns observed in the continental territory.

Most of the territory consists of land lacking in vegetation, grasslands, scrubland and forest (Figure 4). Urban areas comprise a very small portion of the total area, but have been increasing over the past ten years.

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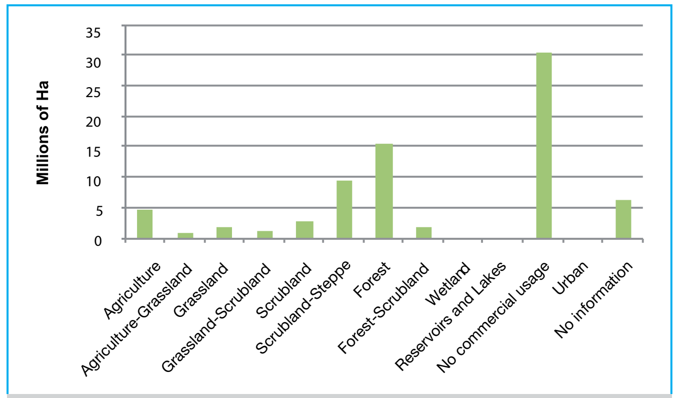

Figure 4. Types of Land Use, by Area (Millions of Ha)
Source: Ciren 2004

1.4 SOCIAL DEVELOPMENT

The life expectancy of Chileans is 78.8 years, and the country has a literacy rate of 96.5% (UNDP, 2009). Infant mortality stands at 7.9 per 1000 live births (MINSAL, 2007), while 95.6% of the population is connected to a sewer system and 99.8% has access to drinking water.

The country's development has improved the quality of life of its inhabitants and the evolution of its Human Development Index (HDI) is irrefutable proof of these changes (Figure 5). Between 1980 and 2010, Chile's HDI rose by 0.9% annually, growing from 0.607 to 0.783 (Figure 5), which situates the country in 45th place among the 169 countries with comparable data, above the regional average.

In regard to poverty reduction, a major advancement was achieved in the 1990s, when the number of people living in poverty dropped by close to 20%, as Figure 6 shows. In the past decade this trend has continued, albeit more slowly.

Nevertheless, in terms of income distribution, in 2000 the average income of the country 10% richest citizens was 38 times higher than that of the poorest 10% (De Ferrantis et al., 2003). This enormous disparity among households reflects inequalities in areas such as opportunities, human capital and access to productive assets, among other things. Despite the above, the survey conducted regularly by the Government of Chile to aid in the design and assessment of Chile's social policies (Mideplan, 2006) showed a sharp drop in income disparity in 2006, with a significant reduction in the gap between the richest and poorest income deciles, from 38 to 28.5. Meanwhile, the country's Gini coefficient dropped to 52.2 points after having fluctuated around 55 points in the 1990s (Larrañaga and Herrera, 2008).

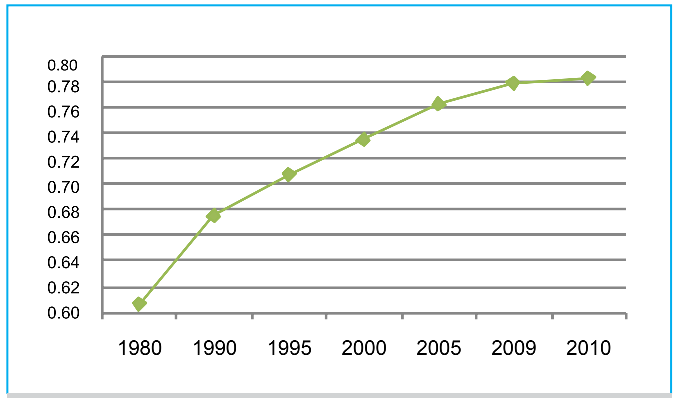

Figure 5. Evolution of Chile's Human Development Index
Source: UNDP, 2011

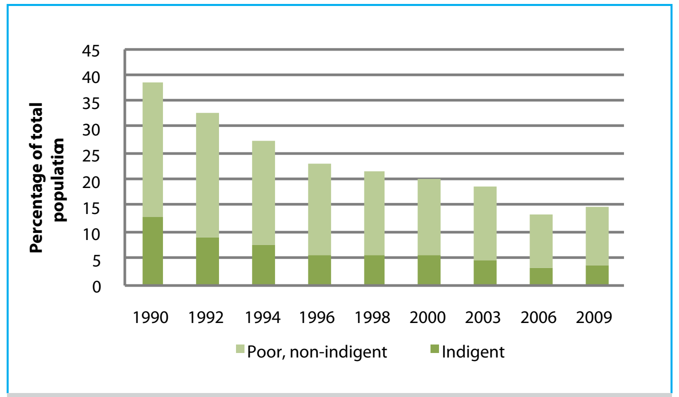

Figure 6. Evolution of poor and indigent populations in Chile, as a percentage of total population
Source: Mideplan, 2011

1.5 EDUCATION

Chile's educational system is organized into four levels: early childhood education, primary education, secondary education and higher education. Public spending on education in 2008 amounted to 4.2 % of the GDP (Ministerio de Educación, 2010) and the country has virtually universal education. The net enrollment rate for primary education was 96.6% for children 6 to 13 years of age, while in secondary it was 80.5% of students 14 to 17 years old. In regard to higher education, in 2008, 768,851 students enrolled in undergraduate programs in Chile (Ministerio de Educación, 2010).

1.6 SCIENCE, TECHNOLOGY AND INNOVATION

In regard to science, technology and innovation, three components interact concertedly: the Government, universities and research centers, and private entities.

The Government formulates policies for the science, technology and innovation system and supports research in Chile through agencies attached to certain ministries and through independent decentralized agencies that fund much of the work undertaken by companies and universities. The latter, along with research centers, carry out most of the basic research in the country, and develop a significant portion of new applications and technologies. For its part, the corporate sector, which includes private and public companies, spends a significant percentage of national earnings on research and development.

Table 1 shows the breakdown of funding sources for 2007 and 2008 in this area, while Table 2 shows the breakdown of project spending by implementing agency. It is worth noting that companies and institutions of higher education are major beneficiaries of available funding. Figure 7 shows the breakdown of state spending on science, technology and innovation by research area in 2008.

TABLE 1. Spending on Research and Development in Chile, by source of financing (millions of US$)

	2007	2008
Source of Financing	**M US$**	**M US$**
Private sector	109.1	153.8
Government	99.9	118.8
Other sources in Chile education	59.9	67.4
Foreign Sources	11.7	11.7
Total	280.6	351.7

Source: 6ta. Encuesta de Innovación, 3era. Encuesta de I+D and 1er. Censo de Gasto

TABLE 2. Spending on Research and Development in Chile, by implementing sector (millions of US$)

	2007	2008
Sector	**M US$**	**M US$**
Private sector	98.0	142.2
Government	28.0	34.0
High education	120.8	143.6
Non-profits private institutions (IPSFL)	34.7	31.9
Total	281.5	351.7

Source: 6ta. Encuesta de Innovación, 3era. Encuesta de I+D and 1er. Censo de Gasto Público en I+D (MINECON, 2009).

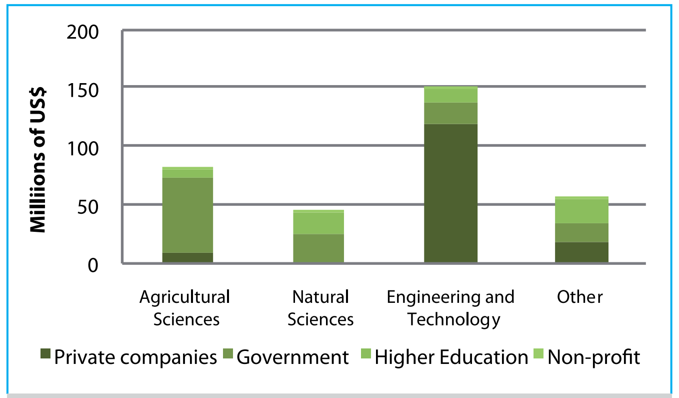

Figure 7. Distribution of R+D Expenditure by Scientific Discipline in 2008
Source: 6ta Encuesta de Innovación, 3era Encuesta de I+D and 1er Censo de Gasto Público en I+D (MINECON, 2009)

1.7 TECHNOLOGY TRANSFER

In Chile, policies and programs to support innovation are promoted by public and private entities that are part of the country's technology transfer system. This system operates on different levels at which institutions in the public and private spheres work together. Chapter 5 of this Communication describes in detail how this system is addressing issues related to adaptation and greenhouse gas mitigation in the broader framework of climate change.

2. ECONOMY PROFILE

2.1 CHILE'S ECONOMY

As Figures 8, 9 and 10 show, in the last twenty years Chile has seen the rapid growth and gradual diversification of its economy, led by its exports. These developments can be explained by the country's stable government and political institutions, which have been able to generate and guide consensus on key issues and formulate suitable public policies (Marshall, 2005). Thus, Chile's political economy in recent years has focused on instruments that promote economic growth and control inflation. Fiscal policy in particular, within a structurally balanced framework[1], has continued to play a stabilizing role in the country's economic cycle.

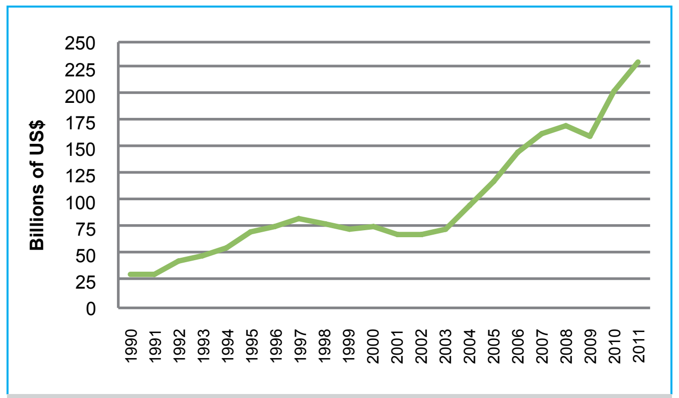

Figure 8. Evolution of GDP, 1990–2011 (Billions of US$, 2011 prices)
Source: International Monetary Fund, World Economic Outlook Database, April 2011

The effects of the country's export-focused development policy can be seen in its balance of trade, which has been positive since 1999 (Figure 9). Of the total value of exports, mining has held the greatest share since 2003 (Figure 10), accounting for more than 50% of the total value of all goods exported. In regard to imports, intermediate goods (lubricants, fuel and petroleum, among others) represent the largest share of imported goods, with more than 50% of the total value.

While Chile's economy is based on natural resource extraction (mining, forestry, agriculture and livestock activity), the contribution of the financial and personal services sector represents the greatest percentage of GDP, followed by manufacturing industries. This is because of the forward and backward chaining of these primary activities with other economic activities such as services transportation and communication, among others (Figure 11).

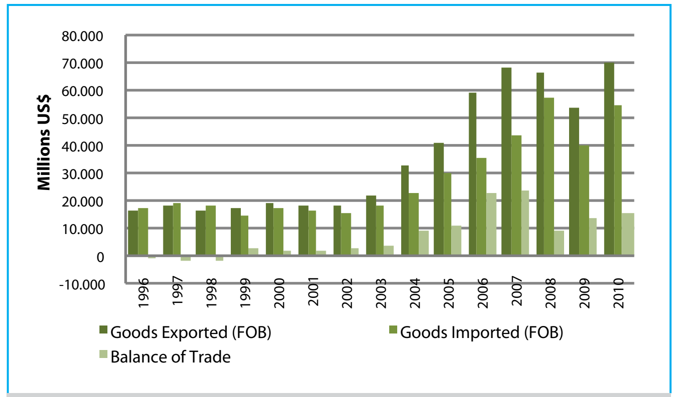

Figure 9. Evolution of Exports, Imports and Balance of Trade, 1996–2008, Million of US$ (FOB)
Source: Banco Central 2010

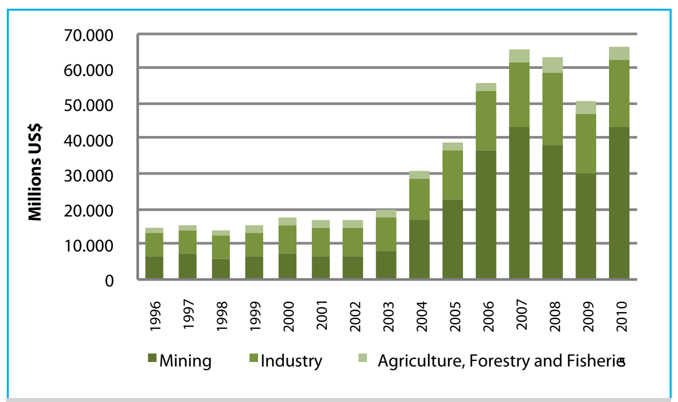

Figure 10. Evolution of Exports by economic sector, 1996–2008, in Millions of US$ (FOB)
Source: Banco Central, 2011

[1] The policy of structural balance involves estimating fiscal revenues that are obtained regardless of the economic cycle, and authorizing spending in line with that level of revenue.

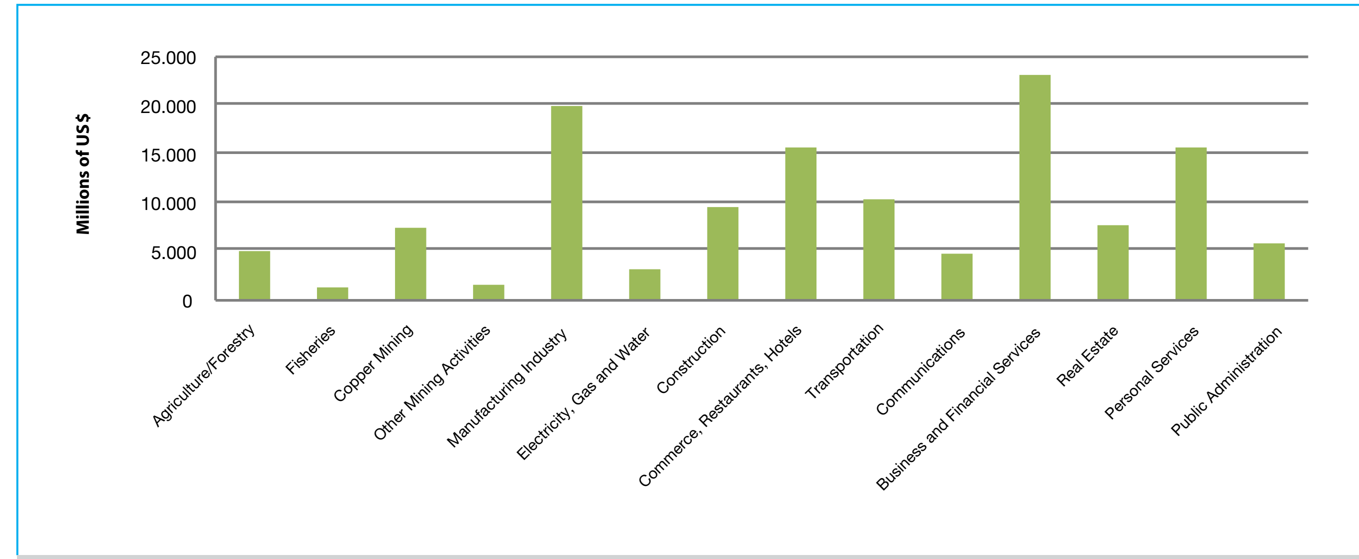

Figure 11: GDP by economic activity in 2010 (constant prices, 2003 base year), Millions of US$
Source: Banco Central, 2011

From 1997 to 2007, Chile's economy grew by an average of 4% annually (Banco Central, 2009), more than the South American average of 3%. However, after several years of robust expansion, economic growth slowed as a result of the global economy deceleration, stricter financing conditions, and drops in production, consumption and investment. The drop in the price of copper in the second half of 2008 prompted a reduction in the country's current account surplus by the end of the first decade of the new century. The economic growth trend, however, has reappeared in 2010 and economic growth rates for 2011 are expected to be high once again.

2.2 ENERGY SECTOR

In Chile, electricity generation, transmission, and distribution are handled by private companies that are regulated and enforced by the Government. The Government also produces studies to determine future demand and therefore to estimate the need for investment in energy generation and transmission. The electricity market includes 37 generating companies, 5 transmission companies and 36 distributors that collectively provided an aggregate supply of 58,672 GWh in 2010 (Ministerio de Energía, 2011).

2.2.1 Electricity generation

Most electricity generated in Chile comes from one of two main sources: hydropower and thermoelectric power. The country's geography has led to an energy transmission system composed of four independent grids with a combined capacity, in late 2010, of 15,558 MW, which is the country's total installed capacity.

The Northern Interconnected System (SING) is made up of generating plants and interconnected transmission lines that supply the regions of Arica & Parinacota, Tarapacá, and Antofagasta. Approximately 90% of sales are to non-regulated customers, i.e. mining and industrial companies that require more than 2 MW. Current legal provisions allow these clients to be exempt from the price regulation scheme that affects regulated clients. The installed capacity of the SING is 3,574 MW, as of December 2010, and the energy supplied is overwhelmingly thermoelectric, being 99.6% supplied by thermoelectric plants fueled by coal, fuel, diesel and natural gas combined cycle. Only two hydroelectric plants exist in this grid –Chapiquiña and Cavancha– supplying 0.4% of the total installed capacity.

The Central Interconnected System (SIC) is the country's main electricity grid, supplying more than 90% of Chile's population. It extends from Taltal (in Antofagasta Region) to the Island of Chiloe, covering an area of 326,412 km^2. According to the National Energy Commission (CNE), its installed capacity as of December 2010 is 11,845.1 MW, 45.10% of which comes from hydroelectric plants, 53.55% from thermoelectric plants, and 1.36% from wind generation. As of December 2010 this grid represented 76% of the country's installed capacity.

The Aysen Electricity Grid is located in the south of Chile and services an area of 108,494 km^2 with an installed capacity of 48.98 MW as of December 2010. Of this total, 57.2% comes from thermoelectric plants, 38.8% from hydroelectric power dams and 4.0% from non-conventional renewable energies. This system represents 0.3% of the country's installed capacity.

Lastly, the Magallanes Electricity Grid supplies Punta Arenas, Puerto Natales and Porvenir, covering an area of 38,400 km^2. It has an installed capacity of 89.1 MW, equal to 0.6% of the country's installed capacity. 100% of the power generated is thermoelectric (diesel and natural gas).

2.2.2 Electricity coverage and energy demand

National electricity coverage reached 96% in 2009. Most expansion in recent years has been in rural zones, where 90% of the population has access to electricity thanks to the Rural Electrification Program (PER) administrated by the National Fund for Regional Development and implemented by the National Energy Commission with co-funding from the Global Environment Facility.

The demand for energy in Chile is determined by the final consumption of three large groups of sectors: transportation, industrial & mining, and commercial, public and residential (CPR). The transportation and industrial-mining sectors have tripled their consumption since 1980, while the residential sector consumes 2.4 times what it did in 1980.

The relative importance of electrical energy is notable and grew from 11% of final energy consumed in 1980 to 19% in 2006. Relative consumption of natural gas also increased, from 5% to 23.42% between 1997 and 2004, but dropped again to 6.23% in 2008 when the supply of natural gas from Argentina was reduced. The use of firewood and petroleum derivatives has also tended to decline in relative importance (Figure 12).

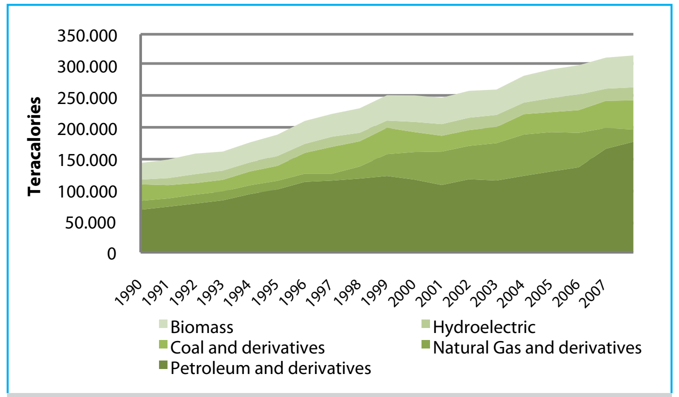

Figure 12: Evolution of final energy consumption in Chile by energy source, 1990–2008
Source: Universidad de Chile, Depto. Ingeniería Industrial, 2009.

2.3 FORESTRY, AGRICULTURE AND LIVESTOCK SECTOR

The forestry, agriculture and livestock sector has undergone profound transformations in recent decades. Since the 1980s the sector has successfully consolidated its participation in international markets through a development policy that is founded upon full economic openness to foreign markets, organizing production around Chile's comparative advantages, and developing its competitive advantages (Odepa, 2005). Figure 13 tracks the evolution of forestry, agriculture and livestock exports from 1990 to 2010, by subsector.

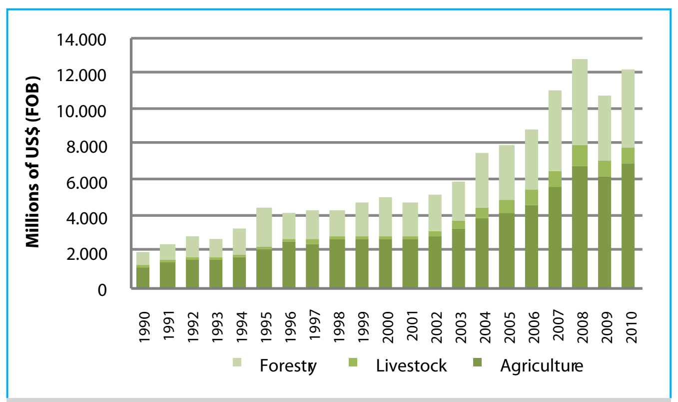

Figure 13. Evolution of Agricultural and Forestry Exports, 1990–2008.
Source: Ministerio de Agricultura, ODEPA, 2011

As a result of these transformations, the agro-food business has become one of the pillars of Chile's economic development and in many subsectors is now internationally important. Chilean fruits and vegetables, seeds, wine and agri-business products are a significant component of Chile's exports, accounting for 18.3% in 2008, two-thirds of which correspond to industrial products. Added to this is the recent penetration of Chilean dairy products and red meats into foreign markets.

Land under cultivation amounts to close to 5% of the national territory and is highly concentrated in Central Chile. The VII National Agriculture, Livestock and Forestry Census of 2007 reported that the area under cultivation had stabilized at around 8.5 million hectares, which have shifted their productive focus over the last two decades to increase the proportion of land used for growing fruit and wine grapes. About 13% of all cultivated land is irrigated, and the use of technical irrigation systems is on the rise, replacing more traditional methods.

Statistics from the Chilean Wood Corporation (CORMA, 2008) indicate that forests in Chile cover an area of 15.7 million hectares, 13.6 million of which correspond to native forest and 2.1 million to forestry plantations. Chile's forestry industry is based mainly upon plantations of *Pinus radiata*, *Eucalyptus globulus* and *Eucalyptus nitens*. Around 45,000 hectares are planted each year and approximately 60,000 are replanted, which ensures sustainable production in the sector.

2.4 FISHING SECTOR

Chile's extensive coastline is a great benefit to its fishing industry. The exclusive economic zone (200 nautical miles) along its thousands of kilometers of coastline contains highly productive ecosystems that offer advantages unseen anywhere else on earth, producing fishing resources that are highly valued and in high demand in global markets. The industry is concentrated mainly on salmon production, followed by the extraction of baby mussels, seaweed, scallops, abalone, Japanese and Chilean oysters, and other species.

The sector is divided into two subsectors, according to the origin of the produce: extractive (industrial and small-scale) and aquaculture. Aquaculture has seen major growth in recent years, led by the boom in the salmon sector (Figure 14).

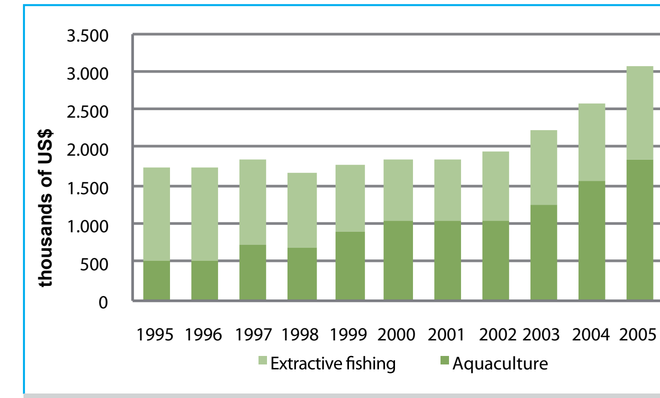

Figure 14. Value of fishery resources, thousands of US dollars
Source: SUBPESCA

2.5 MINING SECTOR

Chile is a country with abundant mineral reserves. Metal mining is focused on the production of copper, iron, molybdenum, manganese, lead, zinc, gold and silver (Figure 15). The products of greatest interest are copper and molybdenum, the latter being a byproduct of copper processing. The abundance of these minerals has made mining the country's primary productive activity for the last several decades.

Ownership of Chile's copper mines is shared between private companies and the State. The independently-operated public entity CODELCO (National Copper Corporation) is the largest in the country and the main copper producer in the world.

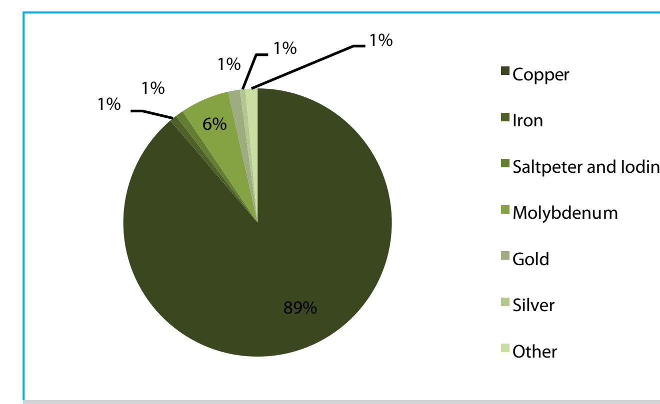

Figure 15. Mining products, share of exports
Source: Ministerio de Mineria 2011

Table 3 presents some key indicators for Chile to summarize the information provided in this chapter.

TABLE 3. Key Indicators for Chile

Area		Source
Geographic		
Surface area (km²)	2,006,096	Instituto Geográfico Militar (IGM)
Population in 2000	15,397,784	Instituto Nacional de Estadísticas (INE)
Estimated population for 2010	17,094,275	INE
Estimated population for 2050	20,204,779	INE
Rural population (% of the total, 2009)	11%	World Bank
Forested area (2007)	22%	Corporación Nacional Forestal (CONAF)
Human Development		
Human Development Index (2010)	0.783	UNDP
Literacy Rate (2008)	99%	World Bank
Life expectancy at birth (2010)	78.8 years	World Bank
Infant mortality per 1,000 live births (2007)	7.9	Ministerio de Salud
Potable water coverage (2009)	99.8%	Superintendencia de Servicios Sanitarios (SISS)
Sewer system coverage (2009)	95.6%	SISS
Public spending on education, as % of GDP (2008)	4.2%	Ministerio de Educación
Economic Activity		
GDP (PPP) estimated in 2011 (Billion of 2011 US$)	276.053	International Monetary Fund
GDP (PPP) per capita, estimated in 2011 (US$)	15,866	International Monetary Fund
GDP growth (PPP) in 2009	-0.8%	International Monetary Fund
GDP growth (PPP) in 2010	6.3%	International Monetary Fund
Estimated GDP growth (PPP) in 2011	6 - 7%	Banco Central de Chile
Goods and services exported (as % of GDP, 2009)	38%	World Bank
Sectoral Activity		
Renewable energy (as % of the energy mix, 2009)	29%	Ministerio de Energía
Importation of primary energy (as a % of energy used, 2009)	62%	Ministerio de Energía
Consumption of fossil fuels as primary energy (as % of total, in 2009)	71%	Ministerio de Energía
Water consumed as irrigation for agriculture (as a % of national water consumption)	84.5%	Dirección General de Aguas

3. ENVIRONMENTAL POLICY

National policies focused on sustainable development are part of the country's comprehensive development strategy. Chile's Constitution guarantees its citizens the basic right to live in an environment free of pollution and makes the State responsible for safeguarding and preserving the country's natural and environmental heritage (Gobierno de Chile, 2002).

Chile faces numerous environmental challenges, however, such as achieving compliance with primary air quality standards in several of its cities. Chile's Environmental Performance Review (OECD-ECLAC, 2005) reports improvements in the country's environmental institutions, the implementation of pollution control and air pollution prevention plans (which has enabled significant reductions in emissions of particulate matter and sulfur oxides - SO_x), as well as the establishment of air quality standards and air pollutant emissions. Nevertheless, the country continues to face major challenges in regard to air quality and health in the Metropolitan Region, where the 6 million inhabitants of Greater Santiago are exposed to high levels of air pollution, which translates into respiratory illnesses and premature deaths.

This problem is due mainly to emissions from industry and transportation, aggravated by the city's location in a valley surrounded by the Andes and Coastal mountain chains, with little wind and rain to disperse emissions. Air pollution is worse in the cold months, from April to September, owing to the natural phenomenon of thermal inversion (OECD-ECLAC, 2005). Additionally, air pollution problems have begun to emerge in smaller localities such as Andacollo and Calama, associated with the mining industry; in Tocopilla, from the operation of thermoelectric plants; in Rancagua, Temuco, Talca, Concepción and other localities in the south-central part of the country, mainly owing to the use of wet firewood for residential heating and cooking. All of these zones require significant air pollution control efforts and the resources to implement them.

Another especially important issue is agricultural soil degradation. The amount of land affected by water and wind erosion, salinity, contamination, gravel extraction and other activities has reached high levels, and it is estimated that virtually all of the country's soils display some level of degradation (OECD-ECLAC, 2005). The absence of effective soil management and soil conservation objectives has led to a major loss of fertility as well as desertification and flooding.

In regard to water resources, freshwater extraction increased by 160% between 1990 and 2002. The Government of Chile estimates that by 2017, water demand by households, mining and industry will have practically doubled over 1992 levels, and agricultural use will have risen by 20%. It should be noted that irrigation accounts for most of the water consumed in Chile—84.5% of the national total—and major advances are being made to use this water more efficiently, which has made irrigation improvement programs a central feature of the country's agrarian policies (Odepa, 2008). In addition, in the regions of the north, the lack of water has translated into increased competition among the main water consumers: the mining industry, growers of intensive irrigated crops and local populations (OECD-ECLAC, 2005).

Chile's biodiversity has a very high level of endemism, which is a result of its topography and geographic isolation and physical barriers such as the Andes Mountains, the Pacific Ocean and the Atacama Desert. Nevertheless, in regard to biodiversity conservation, the country lacks a national territorial planning system that would enable the identification of areas of high biological diversity located outside of formally protected zones. This gap hinders advances on the issue of species representativity within the current National Protected Areas System (SNASPE).

The area under the SNASPE system, area in private conservation initiatives and that set aside under international conventions (such as RAMSAR sites, for example) accounts for close to 20% of the country's continental landmass. While this figure sets Chile above the level established in international conventions and forums on protected areas (10–12%), it should be noted that most of these areas are in the far north and south of the country and in non-productive zones, which makes it likely that they are not adequately covering the country's biodiversity.

Photo: Ministry of the Environment Government of Chile

Photo: Ministry of the Environment. Government of Chile

4. INSTITUTIONAL STRUCTURE

The decade since Chile's First National Communication was presented to the UNFCCC was a fertile period for the creation of public ministries with a relevant role in meeting Chile's commitments under the UNFCCC, most notably the Ministry of the Environment and the Ministry of Energy.

4.1 THE MINISTRY OF THE ENVIRONMENT AND THE NEW ENVIRONMENTAL INSTITUTIONAL FRAMEWORK

The year 2010 witnessed the inauguration of Chile's new environmental institutional structure, a process that began in 2006 and transformed the country's multisectoral model, in which environmental matters were coordinated by the National Environmental Commission (CONAMA), into a more centralized model under the newly created Ministry of the Environment.

Today, the Chilean Ministry of the Environment is the national public entity responsible for working with the President of the Republic on the design and application of environmental policies, plans and programs. Also under the purview of the Ministry are all efforts to protect and conserve the country's water, biological, and renewable resources through the promotion of sustainable development and comprehensive environmental policies and regulatory frameworks (the organizational flowchart is presented in Figure 16). The Ministry also includes the purview of other ministries through the Ministerial Committee for Sustainability, a body that deliberates environmental policy and regulations in general. The Committee is composed of the Minister of the Environment, as chair, and her counterparts in the ministries of Agriculture, Finance, Health, Economy, Development & Tourism, Energy, Public Works, Housing and Urban Development, Transportation & Telecommunications, Mining, and lastly, Planning.

This institutional change was driven mainly by the need to streamline and better define environmental competencies; to have a Ministry responsible for environmental policies; to have a completely technical Environmental Assessment Service as well as a centralized and efficient enforcement system; and, urgently, to manage issues related to biodiversity and protected areas.

The main legal instrument supporting this process is Law N°20,417 of 2010, creating the Ministry of the Environment, the Environmental Assessment Service, the Superintendency of the Environment and the Environmental Tribunals. One of the Ministry's major areas of responsibility in this context is the development of the country's response to climate change. For the first time in history the country's legislation includes a government mandate that specifically addresses this issue, affirming that "the Ministry shall be especially responsible for proposing policies and formulating plans, programs and plans of action in the area of climate change" (Art.70, letter h). The Ministry will face major challenges in implementing this mandate on climate change, which is one of five focal areas covered by the country's new environmental institutional framework, the other four being Air, Water, Solid Waste, and Natural Resources and Biodiversity. To facilitate organizational aspects, the Office of Climate Change was formally created under the Office of the Undersecretary, with its own annual budget for conducting research and consultants to assist with its work. This Office also is responsible for participating in international negotiations related to the implementation of the Convention, as well as acting as Coordinator of the Committee for the Designated National Authority for the Clean Development Mechanism. It is also the focal point for the Intergovernmental Panel on Climate Change (IPCC) and the technical secretariat for Interministerial committees on climate change.

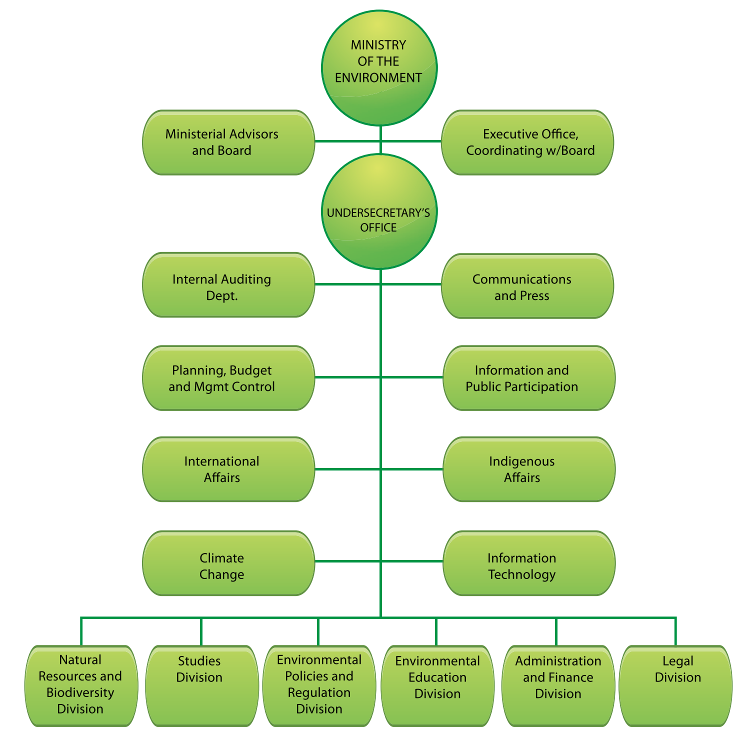

Figure 16. Organizational Chart for the Ministry of the Environment of Chile
Source: Ministerio del Medio Ambiente, 2010

4.2 INSTITUTIONAL FRAMEWORK FOR CLIMATE CHANGE IN CHILE

In 1994, Chile ratified the United Nations' Framework Convention on Climate Change and subscribed to its Kyoto Protocol later on, convinced that a global response was required to address a phenomenon with such important environmental consequences, particularly for more vulnerable nations. Since then, Chile has attended and participated in international discussions and initiatives in this area and has met its commitments as a developing country. In this context, recognizing the need to coordinate local efforts and foreign policy on climate change, in 1996 the Government of Chile issued a Supreme Decree establishing the institution that would address this task: the National Advisory Committee on Global Climate Change.

The Committee was chaired by CONAMA, the coordinating body created by law in 1994 to oversee environmental management in Chile and uphold the constitutional right of all citizens to live in an environment free of pollution. The vice-chair of the committee is held by the Ministry of Foreign Affairs and its other members include representatives from the public and academic sectors and its mandate provided for the inclusion of representatives from other institutions or from private entities.

The Committee was designed to advise and coordinate the efforts of different institutions working on climate change and, among other things, to play a key role in discussions of Chile's position in international negotiations. It has also been instrumental in the creation of instruments in Chile. For example, the Committee was responsible for approving the First National Communication on Climate Change, a report that contains a national inventory of greenhouse gas emissions and identifies mitigation options, vulnerabilities and adaptation measures. Taking into account the nature of Chile's vulnerability to climate change, the importance of fulfilling its international commitments and the need to improve knowledge about the impact of climate change, in 2006 the Committee played a key role in preparing the National Climate Change Strategy. This strategy's main focal areas included adaptation, mitigation and capacity development. To operationalize the strategy, in 2008 the Executive Board of CONAMA approved the National Climate Change Action Plan. This landmark document is described in detail in the following section.

In 2003 Chile established its Designated National Authority for the Kyoto Protocol's Clean Development Mechanism. In the following years a series of capacity building initiatives were carried out in the public and private sectors, and alliances were forged to position Chile as a key actor in relation to the CDM.

As is apparent, there has been much coordination and significant new developments around climate change at the national level, which has provided the country with a suitable institutional framework for facing the challenges this phenomenon presents. To recognize the seriousness of this phenomenon and to strengthen inter-institutional efforts, particularly in the context of international climate change negotiations, in 2009 a presidential instruction led to the creation of the Interministerial Committee on Climate Change. The members of this Committee include representatives from Chile's Environment, Foreign Affairs, Agriculture, Transportation & Telecommunications, Energy, Economy, Finance, Mining and Public Works ministries. The Committee also has a Technical Group that meets more frequently to address technical issues and advise the ministerial representatives.

In 2010, in order to broaden the exchange of information and expand the dialogue on climate change between the Government and other stakeholders, two working groups were formed: one public-private, the other public-civil society. These groups were formed to increase stakeholder opportunities for involvement and participation in strengthening responses to climate change in Chile.

4.2.1 National Climate Change Action Plan 2008-2012

In 2008, CONAMA introduced the National Climate Change Action Plan for 2008-2012 (CONAMA, 2008) as a short-term response to the priorities and objectives of the National Climate Change Strategy. This instrument was prepared through a consultative process that principally involved the public ministries and agencies represented on CONAMA's Executive Board, academic institutions and research centers in Chile (CONAMA, 2008). The Plan was approved and made public by the President of the Republic Michelle Bachelet in December 2008.

The Action Plan sets out a series of public policy objectives for different public entities related with climate change and its adverse effects. It also serves as a guide for industry, the academic sector and non-governmental organizations by setting out the topics that Chilean society as a whole should address in confronting the impacts of climate change. With its limited implementation period of four years, the Plan is intended as a short-term measure designed to generate key information by the end of the period that will be used to prepare longer-term national and sector-specific adaptation and mitigation plans.

The Plan emerged out of an analysis of the national situation in regard to climate change, and strategic approaches to this situation. It has been widely disseminated within Chile and abroad and includes both the situation analysis and strategic considerations, as its base, as well as details of actions to be taken and the entities responsible for them. These are structured around three areas of action: adaptation to the impacts of climate change, mitigation of emissions, and the creation and development of capacities. The Plan also has nine annexes with additional information related to climate change in Chile, such as recommendations for adaptations published in the First National Communication, the IPCC methodology for GHG inventories, information on CDM, and other materials.

The analysis takes into account state-of-the-art climate change science in Chile and abroad, the country's vulnerability, and the actions needed for adaptation. It includes GHG emissions from the energy sector, advances in analyzing emission scenarios, and mitigation potential. It also delves into the country's capacity to design and implement policies, strategies and actions for adaptation and for mitigating emissions from legal, institutional and public policy perspectives. It further assesses national capacities for participating in international negotiations, meetings and reviews of IPCC reports, international and national cooperation initiatives on climate change, clean development mechanisms, and the carbon offset market, among others.

In addition to the above, the analysis focuses on the country's social, economic and environmental vulnerability, the need to adapt to changes, and the challenges that this represents. Vulnerability was assessed based on the results of the compilation reports prepared by the IPCC and the United Nations' Framework Convention and on in-country studies. These indicate that Chile is a vulnerable country, as it meets 7 of the 9 criteria of vulnerability set out in the Convention. The vulnerability of coastal zones and their fishing resources was also identified. Volume II of the IPCC's Fourth Assessment Report of 2007 (IPCC, 2007) indicates that Chile will be subject to a series of changes in its precipitation patterns, crop productivity, the occurrence of extreme events, and anomalies associated with El Niño and La Niña events. A high impact is expected to occur on the availability of water resources, which will affect the availability of hydroenergy, agricultural and forestry resources.

Based on the analysis, the Plan offers some strategic considerations for addressing the challenges that climate change poses to Chilean society. These can be summarized in the following six points:

- Climate change is a key issue for national public policy and regulation.
- Adaptation is a pillar of the country's future development and must be an early response to the impacts of climate change.
- Mitigation is a way to improve the quality of growth, reduce overall greenhouse gas emissions and reduce the costs of adaptation.
- Chile's financial and business sectors must create opportunities for innovation that increase investment in mitigation and adaptation projects.
- Future climate change commitments and their likely effects on international trade must be assessed to generate a long-term strategic perspective.
- A basic foundation of climate change related knowledge must be developed to support decision-making. This knowledge will be generated by means of comprehensive research, systematic climate observation, and citizen training, education and awareness-raising.

The priority areas outlined in the Plan will be implemented as different types of actions and sector-specific responsibilities (Table 4). The main actions proposed in the area of adaptation are: generating local climate scenarios, determining the impacts of climate change and the corresponding adaptation measures, and formulating national and sector-based plans for adaptation to climate change. Specifically, the Plan affirms the need to determine impacts on water resources by analyzing the vulnerability of Chile's water basins; the impacts on biodiversity by identifying the most vulnerable ecosystems, habitats and species; and the impacts on the forestry, agriculture and livestock sector by estimating possible climate scenarios. It also calls for estimating the impact on hydropower generation in Chile, on infrastructure, and on coastal and riverside zones, determining the vulnerability of the country's fishery resources, and lastly, identifying the impacts of climate change on the health of the population.

The actions for mitigation include designing a system to update greenhouse gas (GHG) inventories; assessing the total and sector-specific potential for reducing GHGs; preparing indicators to monitor the impact of actions taken; preparing GHG mitigation plans, policies and strategies for Chile; and generating mitigation scenarios for different timeframes. Lastly, the Plan calls for a national program and sector-based plans for mitigating GHGs.

In the area of capacity building and development a series of actions are contemplated under the Plan, including: a national program of education and awareness raising about climate change; a national fund for researching biodiversity and climate change; technical and economic assessment for a climate change monitoring network; and a national registry of glaciers. Other components of the Plan include developing Chile's negotiating strategies, strengthening the country's institutional framework for addressing climate change, designing development instruments for reducing GHG emissions and for adaptation, and preparing the Second National Communication.

TABLE 4. National Climate Change Action Plan Programs, by priority area and institutions responsible.

PROGRAMACIÓN DE ACCIONES 2008 – 2012						
ADAPTATION	**2008**	**2009**	**2010**	**2011**	**2012**	**INSTITUCIÓN EJECUTADORA**
Generate climate scenarios at the local level	●	●	●			DMC
Determine the climate change impacts on and adaptation measures for:	●	●	●			
Water resources: Determine the level of vulnerability for watersheds		●	●			DGA, CONAMA, INIA, CNR, NAVY
Biodiversity: Identify the most vulnerable ecosystems, habitats and species		●	●			CONAMA, IGM
Agriculture, livestock and forestry sectors: Update available information about the vulnerability of these sectors to climate scenarios	●	●				MINAGRI, CONAMA, INFOR
Energy: Determine the vulnerability of hydroelectric energy generation in Chile	●	●	●			CNE
Infrastructure and urban and coastal areas: Evaluate the impacts on major infrastructure in coastal and waterfront areas and incorporate into planning instruments.		●	●	●	●	MOP, MINVU, DIRECTEMAR, SSM
Fishing: Assess the vulnerability of fishing resources		●	●			ECONOMIA
Health: Strengthen the healthcare systems ability to respond to climate change			●	●	●	MINSAL
Formulate National and Sectoral Plans for adapting to the effects of climate change			●	●	●	CONAMA/SECTORS
MITIGATION						
Update the country's Greenhouse Gas Emissions Inventories	●	●				
Create a system to annually update the national and regional inventory of GHG emissions and sinks	●	●				CONAMA, MINMINERIA
Evaluate the country's potential to mitigate greenhouse gases		●	●			
Determine the potential total and sectoral reduction in emissions	●	●				
Propose a set of impact indicators to be applied to a wide range of plans, policies and strategies	●	●				CNE, MTT, MINECOM, MINVU, MINAGRI, CONAMA, CNE, MTT, MINECOM, MINVU, MINAGRI, CONAMA
Create mitigation scenarios for Chile		●	●			
Develop GHG mitigation scenarios for given time horizons (2015, 2020, etc.)		●	●			CNE, MINAGRI, CONAMA
Formulate a National Program and Sectoral GHG Mitigation Plans	●	●	●			CONAMA / SECTORS
CAPACITY BUILDING						
Develop a National Climate Change Education and Awareness Program		●	●			MINEDUC
Create a National Fund for Research on Biodiversity and Climate Change	●	●				CONICYT
Carry out a technical and financial assessment of the climate change monitoring network		●	●			DMC, INIA, DIRECTEMAR, SHOA
Develop a national glaciers registry	●	●	●			DGA, CONAMA, MINDEFENSA
Develop negotiation strategies for Chile in the post-Kyoto context		●	●	●	●	CNACG
Strengthen national institutions so they are prepared to address climate change	●	●				CONAMA, MINREL
Design development instruments to reduce emissions and for adaptation		●	●			CORFO, CONAMA, CNE, INIA, CIREN, INFOR, MTT
Prepare the Second National Communication (2NC)	●	●	●			CONAMA

Source: National Climate Change Action Plan, 2008

In 2010, some progress has been made toward implementing the National Plan of Action, such as initiating vulnerability studies and researching potential adaptation mechanisms for sectors such as forestry, agriculture and livestock, water, biodiversity, and hydropower generation, among others. Advancements have also been achieved in mitigation strategies for the energy and non-energy sectors and in developing new capacities for dealing with climate change. Public institutions that do not have the budget to fulfill their responsibilities have made more limited progress on specific actions. A mid-term evaluation of the Plan is scheduled for 2011 and is expected to generate a systematic overview of progress to date and provide additional information that could shift the emphasis placed on certain actions in the Plan.

4.3 SECTORAL INSTITUTIONAL STRUCTURE

4.3.1 Energy

In December 2009, Chile's National Congress passed Law 20.402 creating the Ministry of Energy (MINENERGIA), which was officially opened on 1 February 2010. This Ministry is envisioned as a high level agency that works with the President of the Republic to govern and administrate Chile's energy sector. Its creation is clear proof of the importance of energy subjects in our country. The Ministry's organizational structure is shown in Figure 17.

The Ministry of Energy's primary objective is to prepare and coordinate the implementation of plans, policies and

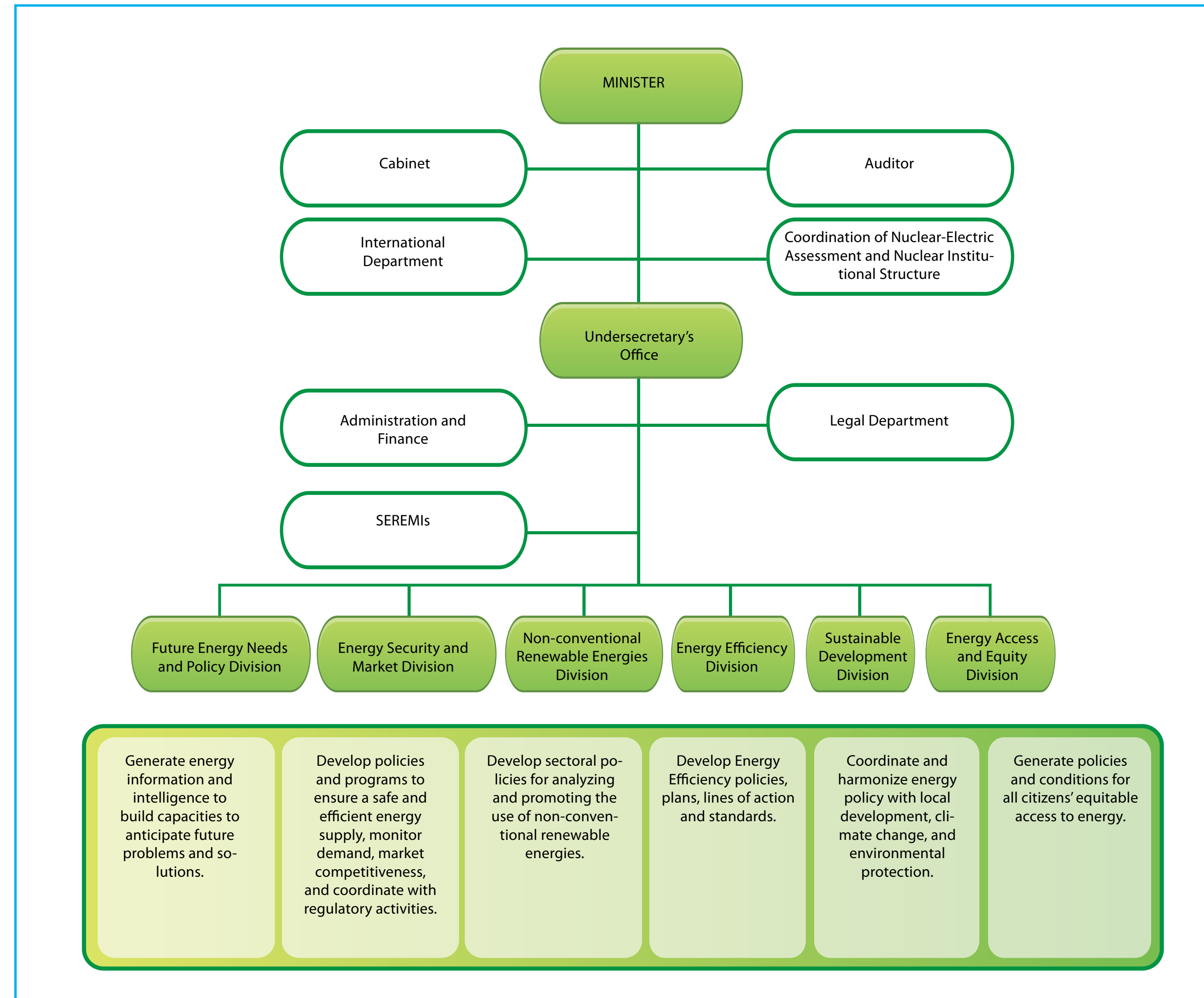

Figure 17. Organizational Chart of the Ministry of Energy of Chile
Source: Ministerio de Energía, 2010.

standards to ensure the sector's effective operation and development, to ensure these instruments are complied with, and to advise the Government on energy-related matters. The Ministry was created through a broad-based national consensus process and it provides an opportunity to develop a comprehensive energy policy that is coherent with national objectives to ensure a secure, high quality and competitive energy supply and to protect the local and global environment.

Institutions under the Ministry's purview that play a key role in the sectoral mitigation of greenhouse gas emissions include the Center for Renewable Energies (CER), the National Energy Efficiency Program (PPEE) and the Chilean Energy Efficiency Agency (AChEE). These organizations are further described in Chapter 4 of this National Communication.

4.3.2 Agriculture

The Ministry of Agriculture (MINAGRI) is the government institution tasked with promoting, guiding and coordinating agriculture, livestock and forestry activity in Chile. Under Law Decree 294 of 1960, the Ministry's "action shall be directed, fundamentally, towards increasing national production, conserving, protecting and expanding its renewable natural resources, and improving the nutritional status of the population".

To efficiently promote the sector's development, MINAGRI operates within the public sector, carries out research and technology transfer, and provides services (see Figure 18).

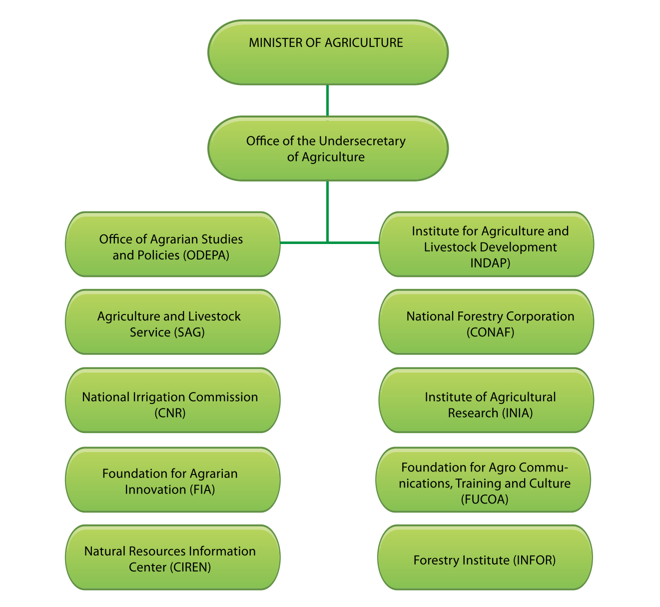

Figure 18. Organizational Chart of the Ministry of Agriculture of Chile
Source: Ministerio de Agricultura, 2010

Public institutions under the purview of MINAGRI that have a role to play in mitigating climate change in Chile are as follows:

- Office of Agrarian Policy and Studies (ODEPA): This centralized public service was created in 1992 with the institutional mission of "strengthening the operation of the Ministry of Agriculture and the public and private agencies involved in the agriculture, livestock and forestry sectors by providing special expertise and information."
- Institute for Agriculture and Livestock Development (INDAP): This entity is focused on the productive and commercial development of small-scale, family-based agriculture, promoting this sector's market participation and sustainable competitiveness.
- National Forestry Corporation (CONAF): This is a corporation under private law charged with fostering the country's development through the conservation of its forest heritage and the sustainable use of its forest ecosystems for the benefit of Chilean society as a whole.
- Foundation for Agrarian Innovation (FIA): This sectoral agency seeks to increase the competitiveness of Chile's agricultural sector by promoting innovation and undertaking initiatives within the sector.
- Institute of Agricultural Research (INIA): INIA is the country's principal investigative institution in the agriculture and livestock area. Its mission is to generate, adapt and transfer technologies that will contribute to the quality and security of Chile's food supply and allow it to respond competitively and sustainably to the country's principal development challenges.
- Forestry Institute (INFOR): This is a government technology institute tasked with creating and transferring top quality scientific and technological knowledge related to the sustainable use of forest resources and ecosystems; to develop forestry products and services; and to generate economic, social and environmental information of use to the forestry sector.
- Natural Resource Information Center (CIREN): This institution provides information on renewable natural resources and has the largest georeferenced database on soils, water resources, climate, fruit and forest plantations in Chile, as well as a rural property inventory.

Council on Climate Change and Agriculture

In May 2008, the Ministry of Agriculture created the Council on Climate Change and Agriculture, which is chaired by the Minister and includes representatives from industry, the public sector and the academy. It represents one of the most important advancements at the national level.

The Council's main objective is to work with stakeholders in different sectors to build a common understanding of how climate change will impact activities in the agriculture, livestock and forestry sectors and to define major lines of action to address this impact.

Functionally, the Council supports the Ministry in defining the main features and priorities of a climate change adaptation program for the agriculture, livestock and forestry sectors and in defining potential mitigation measures to be implemented in each sector.

The Council is advised by the Interministerial Technical Committee, which coordinates meetings and presentations and formulates proposals for the Council to consider. Specifically, the Committee prioritized the analysis of climate change mitigation and adaptation actions for the 2008–2012 period that were included in the National Climate Change Action Plan.

Among the Council's main achievements is its contribution to the design of the National Climate Change Action Plan and the follow up on its implementation, the coordination of carbon footprint studies for key products, and the preparation of the sector's position for the COP in Copenhagen in late 2009. The Council has also defined a communication strategy for climate change mitigation and carbon footprint studies and strategic focal areas for the sector's mitigation and adaptation plans included in the Action Plan.

The commitments outlined in the Action Plan have been properly executed thanks to the coordinated efforts of different public institutions. Under the Plan's priorities for the agriculture, livestock and forestry sector, several activities have been carried out since 2008, including a series of studies on potential carbon capture, carbon footprint estimations for selected export products and the mitigation potential of Law Decree 701 and the Native Forest Law 20.283.

4.3.3 Mining

In regard to climate change in the mining sector, two public institutions merit special mention for the 2000-2010 period: the Chilean Copper Commission (COCHILCO), under the purview of the Ministry of Mining, and the National Energy Efficiency Program (PPEE).

COCHILCO has collected and compiled information related to GHG emissions for all companies in Chile's industrial copper mining sector. This work is contained in the following publically available reports:

- Coeficientes unitarios de consumo de energía de la minería del cobre. 1995-2006 (2007)
- Coeficientes unitarios de consumo de energía de la minería del cobre. 2001-2007 (2008)
- Emisiones de gases de efecto invernadero de la minería del cobre de Chile. 1995-2006 (2008)
- Emisiones de gases de efecto invernadero de la minería del cobre de Chile. 2001-2007 (2008)
- Integrated updates: Consumo de energía y emisiones de gases de efecto invernadero de la minería del cobre de Chile. 2008 (2009) and Consumo de energía y emisiones de gases de efecto invernadero asociadas a la minería del cobre de Chile, 2009 (2010).

Early on, the National Energy Efficiency Program included a line of action for identifying potential energy efficiency applications for the mining sector. Under this line of action, in 2006 the Mining Energy Efficiency Working Group was established with the main objective of encouraging the country's largest mining companies to manage their energy consumption, exchange experiences, study the application of energy efficiency indicators that may be suitable for these companies, and formulate innovation projects in this area. The Working Group is a voluntary technical board made up of representatives of Chile's large metal and non-metal mining companies, ENAMI, the EEPP and the Mining Undersecretary's Office.

home

4.3.4 Water Resources

A notable development in the area of water resources was the creation in 2008 of the Glaciology and Snow Unit within the Ministry of Public Works´ General Directorate of Water. This Unit is intended primarily to establish and implement a national glaciology program that will develop a glacier inventory, study and monitor glaciers in Chile, define present and future responses to climate change in regard to glaciers, and identify adaptation strategies for different climate scenarios. This includes defining strategic priorities to quantify and monitor glaciological variables in representative glaciers; building and regularly updating a Public Inventory of Glaciers based on recent satellite images; implementing the Glacier Monitoring Network in priority geographic zones, and identifying suitable parameters for quantifying the interaction between climate and glaciers in representative zones. Particularly relevant aspects in this area include recent variations in glaciers, snow accumulation, air temperature, mass-energy balances, changes in glacier elevation and variations in discharge flows.

Photo: Ministry of the Environment Government of Chile

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CHAPTER 2

National Inventory of Greenhouse gas emissions and removals

PHOTO: MINISTRY OF THE ENVIRONMENT

1. CHILE'S NATIONAL GREENHOUSE GAS INVENTORY (INGEI)

In the global context, Chile is not a significant source of greenhouse gases. According to statistics from the International Energy Agency, taking into account only national CO_2 emissions from hydrocarbon combustion, the country's share of total emissions is approximately 0.2% (IEA, 2009; IEA, 2010). While this percentage has remained stable over recent years, the growth in total emissions from Chile is similar to the average global growth rate. Ignoring global emissions associated with international maritime and air transport, Chile's contribution in 2008 corresponded to 0.26% of CO_2 emissions from all countries (IEA, 2010), as shown in Figure 1. In the latest publication by the International Energy Agency (IEA, 2010), Chile ranks 61st in the world in terms of per capita CO_2 emissions for 2008, with emissions of 4.35 tons of CO_2 per inhabitant. Nonetheless, the country's emissions are increasing significantly, mainly due to growth in the energy sector.

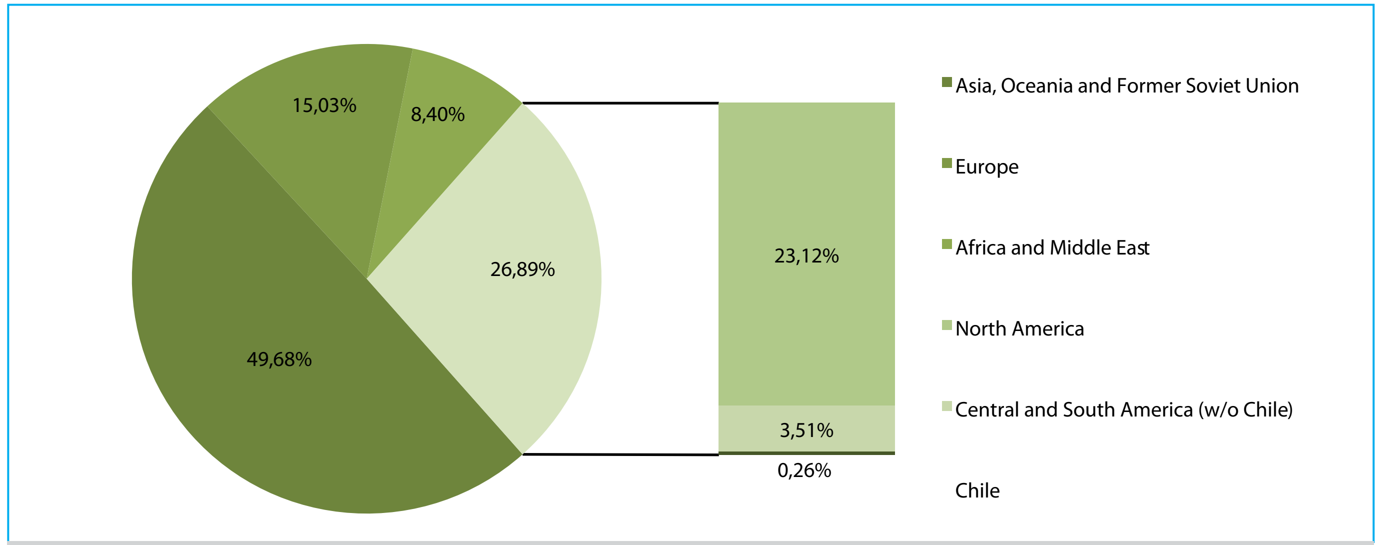

Figure 1. Global CO_2 emissions and Chile's contribution, 2008
Source: Ministry of the Environment, based on IEA, 2010

National emissions inventories are designed to provide detailed information on countries' contributions to global warming. They identify which sectors generate the largest share of emissions and even show specific contributions by province or region if data is available. An inventory should also help guide country's efforts to formulate more effective mitigation strategies.

Chile's National GHG Inventory was built in accordance with the recommendations of the United Nations Framework Convention on Climate Change (UNFCCC) for the preparation of national communications. Methods proposed by the Intergovernmental Panel on Climate Change (IPCC) for signatories of the Convention were also used, as were the recommendations proposed in Decision 17/CP.8 of the UNFCCC relating to countries presenting their second national communications. Specifically, the revised IPCC 1996 guidelines were used, along with the Good Practice Guidances for 2000 and 2003; the reporting year 2000 was defined for the inventory, and the Convention's annual inventory formats were completed with Chile´s data. Chile also has voluntarily included the results of its 2006 emissions inventory, since the time elapsed since the year 2000 may affect the representativeness of GHG emission and removal figures for the country, whereas 2006 is the most recent year in which all sectors were inventoried. The chapter also presents the results of GHG emission and removal estimations from 1984 to 2006 in time-series format for all sectors and subsectors of the National Inventory. Furthermore, emissions associated with the Memo Items set forth in the Convention are also reported alongside the National Inventory. Finally, this chapter contains a preliminary overview of the uncertainty associated with the results presented and identifies gaps that should be addressed to improve the accuracy of Chile's inventory.

In this regard, it is increasingly important that the country update its inventory more frequently to obtain information on short-term changes and medium term trends for each sector and category.

The inventory presented in this Chapter was supported by UNDP-UNEP´s "National Communications Support Programme" (NCSP) and Fundacion Bariloche. Officials from these institutions provided technical comments of the contents of this inventory. This support is very appreciated.

2. METHODOLOGICAL ASPECTS

2.1 GENERAL CHARACTERISTICS OF INVENTORIES

In the context of the UNFCCC, an inventory is an exhaustive numerical listing, by source, of annual GHG emissions and removals that result directly from human activity in the reporting country.

In creating their inventories, countries should observe the following basic principles:

- Completeness: the inventory must be complete in terms of gases, categories, and territorial coverage.
- Accuracy: it must be constructed with as much detail as possible to ensure results are accurate and prevent, where possible, over- or under-estimations of emissions and/or removals.
- Transparency: it must be based on publically available activity data and considering explicit assumptions.
- Consistency: each category must employ the same methodological approach, including the same emission factors and activity data over the years indicated unless an objective reason exists to proceed otherwise.
- Comparability: internationally accepted methodologies should be followed.

2.1.1 Methodology used to report inventories to the UNFCCC

GHG emissions and removals can be quantified using the calculation methods provided by the IPCC for the preparation of national inventories. The following methodological documents have been prepared by the IPCC and are now available for use:

- Revised 1996 IPCC Guidelines
- IPCC Good Practice Guidance and Uncertainty Management, published in 2000
- IPCC Good Practice Guidance for LULUCF, published in 2003
- 2006 IPCC Guidelines

As agreed by the Parties of the Convention (Decision 17/CP.8 of January 2003) countries not listed in Annex I, such as Chile, must draw up annual inventories using the 1996 methodology plus the 2000 and 2003 GPG, where possible. Within this framework, greenhouse gas sources and sinks must be reported for each sector, category, and subcategory. The six sectors considered are: Energy; Industrial Processes; Solvent and Other Product Use; Agriculture; Land Use, Land Use Change and Forestry (LULUCF); and Waste.

The gases to be included are, first, greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorcarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6); and secondly, indirect greenhouse gases: carbon monoxide (CO), total nitrogen oxides (NO_X), non-CH_4 volatile organic compounds (NMVOCs), and sulfur oxides (SO_X).

GHG emissions are calculated using activity data for each sector for which emissions and emission factors are assessed. These factors are needed to quantify emissions and removals, and several default values are listed in the IPCC documents mentioned above, although specific values may also be used. Depending on the sector being analyzed, there may be several local and/or international sources of publically available activity data. For the Energy sector, the National Energy Balance prepared annually by the Ministry of Energy is the most significant source of information used for building Chile's inventory.

Lastly, the global warming potential (GWP) of each non-CO_2 gas is used so values may be added together. This enables emissions (and removals) of all gases to be expressed in terms of CO_2 equivalents (CO_2eq = Gas x GWP).

2.1.2 Key categories in the Inventory

The IPCC sets out three methods for estimations of GHGs (tiers 1, 2, and 3), the use of which depends on the specific category's importance to total national emissions and the availability of country-specific activity data and/or emission factors.

Tier 1 is the default method and the simplest methodology. It is applied when country-specific emission factors or activity data are not available. However, this method carries the risk of failing to adequately reflect national circumstances. Tier 2 uses the same methodological procedure as Tier 1, but employs activity data and/or emission factors that are specific to the country or to a region of the country. This method will always achieve more accurate estimations of greenhouse gas emissions/removals and should be applied in key categories. Tier 3 corresponds to country-specific methodologies (models, censuses, and other), the application of which is recommended provided they have been duly validated and, in the case of models, published in peer-reviewed journals.

In order to determine which method should be used for each category, key categories must first be identified. Key categories are those whose collective contribution is deemed to have a significant influence on the total inventory, expressed as 95% in the IPCC 2003 Good Practice Guidance. Once these are identified, the most precise method possible for each category can be chosen based on the level of information that is available.

2.2 CHARACTERISTICS OF THE CHILEAN INVENTORY

2.2.1 Preparation of the Inventory and institutional arrangements

The Chilean Ministry of the Environment (MMA) is the successor institution of the National Commission for the Environment (CONAMA) and the technical body responsible for the preparation of this Communication. The Ministry has structured its work on the Inventory under its Office of Climate Change, which is tasked with preparing emissions reports and the Inventory as a whole. Both the first and second National Communications relied heavily on the work of studies conducted by experts external to CONAMA, some of whom are permanent employees in the public sector, and others in the private sector (see Table 1)[1].

[1] All tables in this chapter were prepared by the authors of this chapter, except where otherwise indicated.

TABLE 1. National GHG Inventory - Bibliographic Sources

	Study name	Sectors/subsectors covered	Entity/Consulting firm responsible
1.	Inventario nacional de emisiones de gases de efecto invernadero (National Greenhouse Gas Inventory)	Energy, industrial processes, solvents and other products	Poch Ambiental (2008)
2.	Complementos y actualización del Inventario de GEI para Chile en los sectores de Agricultura, LULUCF y residuos antrópicos (Complements and Update of Chile's GHG Inventory for the Agriculture, LULUCF and Waste sectors)	Agriculture, LULUCF, and Waste	Instituto de Investigaciones Agropecuarias (Inia) of the Ministry for Agriculture of Chile (2010)
3.	Desarrollo y aplicación de una metodología local de cálculo de emisiones bunker para gases de efecto invernadero (Development and Application of a Methodology for calculating GHG Emissions from Bunker Fuels)	National and international air and maritime transport	Sistemas Sustentables (2010)

The first and second studies mentioned in the table above were financed by the GEF project for the preparation of Chile's Second National Communication, while the third was funded from the budget of CONAMA's Division of Studies. Technical experts in specific ministries collaborated in the preparation of all studies. The first and third studies were prepared in collaboration with technical staff from CONAMA and the Ministry of Energy's National Energy Commission (CNE), while for the second study CONAMA experts worked with those from the Ministry of Agriculture. All studies were conducted in the context of inter-ministerial cooperation agreements, which ensured the participation of all parties. The corresponding time series were re-calculated in each instance. The first study covered the period from 1984 to 2006, while the other two studies covered the period from 1984 to 2007.

Emissions associated with copper mining facilities are obtained from the Chilean Copper Commission, COCHILCO, which falls under the purview of the Ministry of Mining. COCHILCO conducts an annual survey of all major copper mining companies in the country and calculates annual coefficients for energy, fuel, and electricity consumption for this industry. These results are used to calculate GHG emissions for the sector, which are published periodically (COCHILCO 2009; COCHILCO 2010). The exchange of information between the Ministry of Energy and COCHILCO allows the validation of these results, making it suitable for use in the inventory. COCHILCO's emissions results for Chile's copper industry are therefore used in the National GHG Inventory.

Finally, it should also be pointed out that as of 2010 three Chilean experts are active members of the UNFCCC roster of experts reviewing Annex I greenhouse gas inventories: Sergio González (nominated as an agricultural sector expert; researcher at the Ministry of Agriculture's Institute of Agricultural Research, INIA), Aquiles Neuenschwander (nominated as LULUCF sector expert; staff member at the Ministry of Agriculture's Foundation for Agrarian Innovation), and Fernando Farias (nominated as an energy sector expert; staff member at the Ministry of the Environment's Office of Climate Change). All of these individuals participated actively in building the Chilean GHG inventory.

2.2.2 Methods and information sources

The IPCC methodologies (1996 version plus Good Practice Guidances) cover the sectors, categories, and subcategories shown in Table 2. The Method column of the table indicates the Tier used. The emission factors of some certain key categories were refined, as shown in Table 2.

Photo: Ministry of the Environment. Government of Chile

TABLE 2. Methodologies applied in the Chilean inventory, by category and subcategory

Sector	Category	Subcategory	Method	Emission factor
Energy	Energy industry	Electricity and heat generation; petroleum and natural gas refining; solid fuel conversion; other energy industries	Tier 1	Default
	Manufacturing, construction, and mining	Industrial processes and production of: iron and steel, non-ferrous metals, chemicals, cellulose and paper, food/drink/tobacco processing, cement, saltpeter, misc. mining	Tier 1	Default
	Transport (*)	Air, road, rail, maritime	Tier 1	Default
	Public, residential, and commercial	Energy consumption for commercial, public, and domestic use	Tier 1	Default
	Fishing	Energy use in the agriculture/livestock and fishing industries	Tier 1	Default
	Fugitive emissions	Aviation industry Tier 2; coal production; petroleum and natural gas production; ozone and SO_2 precursors	Tier 1	Default
	Wood fuel and biogas	Use of wood fuel and/or biogas as an energy source	Tier 1	Default
Industrial processes	Mineral products	Production and use of cement, lime, limestone, dolomite, sodium carbonate; production and use of asphalt, ammonia, nitric acid, adipic acid, silicon carbide and calcium carbide	Tier 1	Default
	Chemical industry	Paper and cellulose, food and beverages	Tier 1	Default
	Metal production	Iron and steel, copper, lead, silver and zinc, molybdenum	Tier 1	Default
	Other	Methane, ethylene, formaldehyde, phthalic anhydride, expandable polystyrene, low density polyethylene, polypropylene, sulfuric acid	Tier 1	Default
	Consumption of HCFCs and SF_6	Halocarbons (HFC), perfluorocarbons (PFC) and sulfur hexafluoride (SF_6)	Tier 1	Default
Solvent and other product use	Paint production	Water- and oil-based	Tier 1	Default
	Paint use	Industrial and residential	Tier 1	Default
	Adhesive use	Emissions from adhesive use	Tier 1	Default
	Use of domestic solvents	Emissions from domestic use	Tier 1	Default
Agriculture	Enteric fermentation	Cattle	Tier 2	Value tier 2
		Other livestock	Tier 1b	Default
	Manure management – methane emission	Hogs	Tier 2	Value tier 2
		Other livestock	Tier 1b	Default
	Manure management – nitrous oxide emission	Other manure management systems	Tier 2	Value tier 2
	Rice cultivation	Irrigation, permanent or intermittent flooding	Tier 1b	Default
		Rainwater irrigation	Tier 1b	Default
		At elevation	Tier 1b	Default
	Agricultural land	Direct and indirect emissions, direct pasturing	Tier 1b	Default
	Burning of agricultural waste	Grains, deciduous fruit trees	Tier 1b	Default
Land use land use change, and forestry (LULUCF)	Forest land (FL)	Forests lands with no land use change	Tiers	Country-specific value tier 2
		Other land becoming forest land	1b and 2	Default
	Grassland and scrubland (GS)	Grassland and scrubland with no land use change	Tier 1b	Default
		Other land becoming grassland and scrubland	Tier 1b	Default
	Agricultural land (AL)	Cropland with no land use change	Tier 1b	Default
		Other land becoming agricultural land	Tier 1b	Default
	Settlements (S)	Urban land with no land use change	Tier 1b	Default
		Other land becoming urban land	Tier 1b	Default
	Wetlands (WL)	Wetlands with no land use change	Tier 1b	Default
		Other land becoming wetlands	Tier 1b	Default
	Other land	Other land with no land use change	Tier 1b	Default
		Other uses becoming other land	Tier 1b	Default

Sector	Category	Subcategory	Method	Emission factor
Anthropogenic Waste	Solid urban waste	Final disposal of solid urban waste	Tier 1b	Default
	Liquid waste	Treatment of wastewater and domestic sludge	Tier 1b	Default
		Treatment of wastewater and residual sludge	Tier 1b	Default
	Incineration of hospital waste	Incineration of human remains and cadavers; incineration of hospital waste	Tier 1b	Default
	Nitrous oxide released by human feces	Human feces produced by the urban population	Tier 1b	Default

(*) For domestic air transport, the IPCC 2006 Tier–2 methodology was used as this allowed the use of LTO statistics without completely disaggregating LTO by type of aircraft (Sistemas Sustentables, 2010).

For the activity data associated with the sectors for which emissions were evaluated in Chile, a number of different local and international sources were used. It should be noted that since 2008 the team charged with preparing the National Energy Balance has been implementing a process to refine its information sources (principally by expanding the coverage of its surveys) and gradually adopt the applicable guidelines of the International Energy Agency.

It also should be noted that the great majority of methods applied to assess emissions for the Chilean inventory correspond to Tier 1. For this reason, Chapter Six of this Communication, which addresses sectoral capacity building and strengthening needs, identifies needs related to improving the national greenhouse gas emissions inventory.

2.2.3 Geographical scope of information used

Subject to the availability of regional data, three sectors of the Chilean inventory (Agriculture, LULUCF, and Waste) were disaggregated at the regional level for each of the country's 15 administrative regions, which corresponds to Level b of the 2006 IPCC inventory methodology. In the other three sectors of the inventory – Energy, Industrial Processes, and Solvents and Other Product use – emissions were estimated using aggregate activity data for the national level.

As an example of regional disaggregation of information in specific zones of the country, Figure 2 presents methane emissions (in tons) for the category of enteric fermentation in the Agriculture sector, a key category in the Chilean inventory. The information is broken down for each of the country's 15 administrative regions.

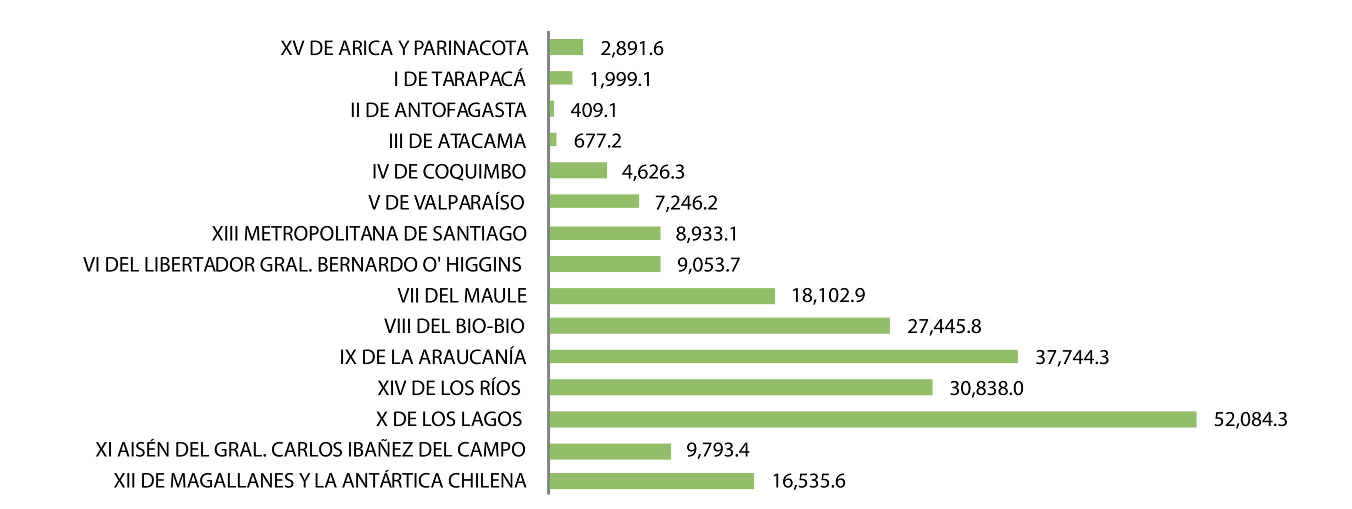

Figure 2. Regional distribution of methane emissions (tons) in the category "Enteric fermentation" in the agriculture sector, 2000
Source: The authors, based on INIA, 2010

2.2.4 Assessment of key categories in Chile's National GHG Inventory

The key categories in an inventory are those that, taken together, contribute the highest absolute percentage of emissions or removals to the inventory. Given their relative importance, these categories should be the focus of ongoing efforts to improve emissions estimates. Key categories for Chile were identified using the methodology indicated in the IPCC 2000 Good Practice Guidances, inventory reporting software, and national emissions and removal data from the 2000 national inventory. Key categories were identified in two modes – one taking into account LULUCF, and one excluding this sector. The results are presented in Table 3. Taken as a whole, the categories selected represent at least 95% of emissions or removals in this year's inventory, in absolute values. As seen in Table 3, key categories exist in all sectors, which means that an ongoing effort must be made to improve information in all of these sectors.

TABLE 3. Key categories identified for Chile's National GHG Inventory, 2000

Gas	Key category	Sector	Annual emissions (excl LULUCF) Gg CO_2eq	Cumulative % (excl LULUCF)	Annual emissions (inc LULUCF) Gg CO_2eq	Cumulative % (inc LULUCF)
CO_2	Forest lands with no land use change	LULUCF			28,784.2	28.0%
CO_2	Stationary combustion (Solids)	Energy	15,842.8	22.4%		43.4%
CO_2	Mobile combustion: on-road vehicles	Energy	15,002.3	43.7%		58.0%
CO_2	Manufacturing, construction, and mining industries	Energy	12,142.6	60.8%		69.8%
N_2O	Cropland (direct and indirect)	Agriculture	6,562.5	70.1%		76.2%
CH_4	Domestic enteric fermentation	Agriculture	4,796.0	76.9%		80.8%
CO_2	Other sectors: residential	Energy	3,508.8	81.9%		84.3%
CO_2	Emissions from the iron and steel industry	Industrial processes	1,816.8	84.5%		86.0%
CH_4	Solid waste disposal sites	Waste	1,796.8	87.0%		87.8%
CO_2	Cement production	Industrial processes	1,683.4	89.4%		89.4%
CH_4	Fugitive emissions from petroleum and gas operations	Energy	1,277.9	91.2%		90.7%
CH_4	Manure management	Agriculture	1,241.1	93.0%		91.9%
CH_4	Forest lands with no land use change	LULUCF		93.0%	1,233.1	93.1%
CO_2	Land becoming forest lands	LULUCF		93.0%	1,026.2	94.1%
CH_4	Other (Energy)	Energy	741.0	94.0%		94.8%
CO_2	Mobile combustion: aircraft	Energy	663.0	94.9%		95.4%
CO_2	Lime production	Industrial processes	653.3	95.9%		

home

2.2.5 Conversion factors applied

In order to express emissions in the required format, the conversion factors shown in Table 4 were applied. Additionally, global warming potentials (GWPs) used to transform estimates of non-CO_2 gases into CO_2 equivalents (CO_2eq) were as follows: 1 for CO_2, 21 for CH_4, 310 for N_2O, and 23900 for SF_6.

TABLE 4. Conversion factors applied.

Conversion factors	
C to CH_4	1.33
C to CO	2.33
C to NMVOC	1.22
N to N_2O	1.57
N to NO_x	1.17
C to CO_2	3.67

3. GHG EMISSIONS IN CHILE

3.1 SUMMARY OF THE 2000 AND 2006 NATIONAL GREENHOUSE GAS INVENTORIES

Results for the year 2000 for the three greenhouse gases (CO_2, CH_4, and N_2O) and other non-GHG gases subject to complementary reporting under the Convention (CO, NOX, NMVOC, and SO_x) are shown in summary in Table 5, in the format agreed to under the Convention (Table 1 of Decision 17/CP.8 of the UNFCCC).

TABLE 5. GHG emissions in Chile, 2000

GHG source categories	CO_2 Emission (Gg)	CO_2 Capture (Gg)	CH_4 (Gg)	N_2O (Gg)	CO (Gg)	NO_x (Gg)	NMVOC (Gg)	SO_x (Gg)
Total national emissions and sequestration	**53,623.5**	**-29,819.2**	**559.8**	**25.2**	**284.4**	**5,611.5**	**484.0**	**1,372.9**
1. Energy	**48,730.0**	**0.0**	**104.3**	**1.1**	**261.8**	**1,592.0**	**260.2**	**408.0**
1.A. Fuel combustion (sectorial method)	48,730.0		40.0	1.1	261.2	1,591.1	254.2	399.0
1.A.1. Energy industries	15,842.8		0.3	0.2	47.0	4.1	1.1	350.3
1.A.2. Manufacturing, construction, and mining	12,142.6		0.7	0.1	33.5	7.1	1.3	0.0
1.A.3. Transport	16,013.3		2.7	0.2	157.1	960.0	181.5	0.0
1.A.4. Commercial, institutional, residential	4,146.7		0.9	0.0	5.9	5.1	0.7	0.0
1.A.5. Fishing	584.7		0.2	0.0	0.8	0.9	0.1	0.0
1 .A.6 Wood and biomass fuel (non-CO_2)			35.3	0.7	16.9	613.9	69.6	48.6
1 .B. Fugitive fuel emissions			64.3		0.6	0.9	6.0	9.0
1.B.1. Solid fuels			3.4		0.0	0.0	0.0	0.0
1 .B.2. Petroleum and natural gas			60.9		0.6	0.9	6.0	9.0
2. Industrial processes	**4,153.6**	**0.0**	**5.9**	**0.5**	**6.4**	**14.0**	**223.8**	**964.9**
2.A. Mneral products	2,336.8				0.0	0.0	174.4	1.0
2.B. Chemical industry	0.0		5.9	0.5	2.9	0.0	0.6	63.0
2.C. Metal production	1,816.8		0.0	0.0	0.1	1.6	0.2	885.4
2.D. Other production (pulp and paper, food and beverages)	NA		NA	NA	3.3	12.4	48.6	15.5
2.E. Halocarbon and sulfur hexafluoride production								
2.F. Halocarbon and sulfur hexafluoride consumption								
2.G. Other (specify)	NE		NE	NE	NE	NE	NE	NE
3. Solvent and other product use	**NE**			**NE**			**NE**	
4. Agriculture			**295.6**	**22.2**	**2.8**	**55.5**	**0.0**	**0.0**
4.A. Enteric fermentation			228.4					
4.B. Use of manure			59.1	1.0			0.0	
4.C. Rice cultivation			5.5				0.0	
4.D. Cropland				21.2			0.0	
4.E. Burning of savannahs			NO	NO	NO	NO	NO	
4.F. On-site burning of agricultural waste			2.6	0.1	2.8	55.5	0.0	
4.G. Other (specify)			NE	NE	NE	NE	NE	
5. Land use, land use change and forestry	**703.1**	**-29,819.2**	**63.4**	**1.1**	**13.4**	**3,950.0**	**0.0**	**0.0**
5.A. Change in standing inventory of forests and other wood biomass	613.5	0.0						
5.B. Woodland and grassland conversion	0.0	-1,033.6	0.6	0.0	0.1	5.1		
5.C. Abandonment of cultivated lands		0.0						
5.D. Soil CO_2 emission and sequestration	86.3	-28,785.5						
5.E. Other (specify)	NE	NE	NE	NE	NE	NE		
6. Waste	**36.9**		**90.6**	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**
6.A. Solid waste disposal			85.6		0.0		0.0	
6.B. Wastewater treatment			5.0	0.0	0.0	0.0	0.0	
6.C. Waste incineration	36.9				0.0	0.0	0.0	0.0
6.D. Other (indirect N_2O emissions)			NA	0.3	NA	NA	NA	NA
7. Other (specify)	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Memo items								
International transport	**3,059.8**		**0.1**	**0.0**	**5.6**	**3.0**	**1.2**	**0.3**
Air	1,045.1		0.1	0.0	5.6	3.0	1.2	0.3
Maritime	2,014.7		0.0	0.0	NE	NE	NE	NE
Biomass CO_2 emissions	**16,721.5**							

Terms: NE, Not Estimated; NO, Not Occurring; NA, Not Applicable.

Additionally, Chile has voluntarily decided to include the results of its 2006 inventory, as the most recent year for which information is available in the country for all inventory sectors. These results are summarized in Table 6, following the same format.

Photo: Ministry of the Environment. Government of Chile

TABLE 6. Chilean inventory of anthropogenic GHG emissions not controlled under the Montreal Protocol and GHG precursors, 2006

GHG source categories	CO_2 Emission (Gg)	CO_2 Sequestration (Gg)	CH_4 (Gg)	N_2O (Gg)	CO (Gg)	NO_x (Gg)	NMVOC (Gg)	SO_x (Gg)
Total national emissions and sequestration	**60,795.9**	**-22,043.4**	**591.7**	**27.1**	**316.3**	**6,745.2**	**427.3**	**947.0**
1. Energy	**55,117.2**	**0.0**	**110.0**	**1.3**	**291.5**	**1,544.8**	**248.8**	**432.7**
1.A. Fuel combustion (sectorial method)	55,117.2		41.6	1.3	290.9	1,543.8	242.1	422.7
1.A.1. Energy industries	20,681.5		0.3	0.2	60.8	5.3	1.4	368.6
1.A.2. Manufacturing, construction, and mining	13,119.7		0.7	0.1	36.8	6.8	1.4	0.0
1.A.3. Transport	16,970.2		2.6	0.2	168.6	873.6	165.4	0.0
1.A.4. Commercial, public, residential	4,033.8		0.7	0.0	5.5	4.3	0.6	0.0
1.A.5. Fishing	312.1		0.2	0.0	0.4	0.9	0.1	0.0
1 .A.6 Wood and biomass fuel (non-CO_2)			37.1	0.8	18.8	652.9	73.3	54.1
1 .B. Fugitive fuel emissions			68.3		0.6	1.0	6.7	10.0
1.B.1. Solid fuels			1.8		0.0	0.0	0.0	0.0
1 .B.2. Petroleum and natural gas			66.5		0.6	1.0	6.7	10.0
2. Industrial processes	**4,902.6**	**0.0**	**6.4**	**0.7**	**8.6**	**18.3**	**178.5**	**514.3**
2.H. Mineral products	3,007.4				0.0	0.0	137.0	1.2
2.I. Chemical industry	0.0		6.4	0.7	4.0	0.0	2.3	83.5
2.J. Metal production	1,895.2		0.0	0.0	0.1	1.7	0.2	408.8
2.K. Other production (pulp and paper, food and beverages)	NA		NA	NA	4.5	16.6	39.0	20.8
2.L. Halocarbon and sulfur hexafluoride production								
2.M. Halocarbon and sulfur hexafluoride consumption								
2.N. Other (specify)	NE		NE	NE	NE	NE	NE	NE
3. Solvent and other product use	**NE**			**NE**			**NE**	
4. Agriculture			**291.9**	**23.5**	**1.6**	**32.4**	**0.0**	**0.0**
4.H. Enteric fermentation			216.4					
4.I. Use of manure			69.3	1.2			0.0	
4.J. Rice cultivation			4.7				0.0	
4.K. Cropland				22.2			0.0	
4.L. Burning of savannahs			NO	NO	NO	NO	NO	
4.M. On-site burning of agricultural waste			1.5	0.04	1.6	32.4	0.0	
4.N. Other (specify)			NE	NE	NE	NE	NE	
5. Land use change and forestry	**739.3**	**-22,043.4**	**71.3**	**1.4**	**14.6**	**5,149.7**	**0.0**	**0.0**
5.F. Change in standing inventory of forests and other wood biomass	613.5	0.0						
5.G. Woodland and grassland conversion	0.0	-1,033.6	0.6	0.0	0.1	5.1		
5.H. Abandonment of cropland		0.0						
5.I. Soil CO_2 emission and sequestration	122.5	-21,009.8						
5.J. Other (specify)	NE	NE	NE	NE	NE	NE		
6. Waste	**36.9**		**112.1**	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**
6.E. Solid waste disposal			107.5		0.0		0.0	
6.F. Wastewater treatment			4.6	0.0	0.0	0.0	0.0	
6.G. Waste incineration	36.9				0.0	0.0	0.0	0.0
6.H. Other (indirect N_2O emissions)			NA	0.3	NA	NA	NA	NA
7. Other (specify)	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Memo items								
International transport	**5.259,5**		**0,1**	**0,0**	**6,5**	**3,5**	**1,4**	**0,4**
Air	1.210,3		0,1	0,0	6,5	3,5	1,4	0,4
Maritime	4.049,2		0,0	0,0	NE	NE	NE	NE
Biomass CO2 emissions	18.563,2							

Terms: NE, Not Estimated; NO, Not Occurring; NA, Not Applicable.

The National Inventory also included the correlation of emissions associated with the consumption of sulfur hexafluoride (SF_6) released in the country annually. For 2000, these emissions amounted to 0.83 tons of SF_6 or 19.8Gg CO_2eq, while in 2006 they amounted to 4.72 tons of SF_6 or 115.9 Gg CO_2eq. These values do not appear in Tables 5 and 6, but are included in the total CO_2 equivalent figure for the country given below in Table 7.

Chile's CO_2 equivalent (CO_2eq) emissions for both years are shown in Table 7, with a total value of 43.41 million tons CO_2 eq in 2000, and 59.67 million tons CO_2 eq in 2006.

TABLE 7. GHG sources and sinks in Chile, 2000 and 2006, in Gg CO_2eq

Item	Type	CO_2 eq 2000 [Gg]	CO_2 eq 2006 [Gg]	% Change
Energy sector		**51,279**	**57,806**	**13%**
Energy industry		15,897	20,75 1	31%
Manufacturing, construction, and mining		12,191	13,170	8%
Transport		16,123	17,062	6%
Commercial, institutional and residential		4,176	4,058	-3%
Agriculture and Fishing		590	316	-46%
Fugitive emissions		1,350	1,435	6%
Wood fuel and biogas	Non-CO_2 GHG emission	952	1013	6%
Industrial Processes Sector		**4,447**	**5,361**	**21%**
Mineral products		2,337	3,007	29%
Chemical production		273	342	25%
Metal production		1,817	1,895	4%
Other products		NE	NE	
Consumption of halocarbons and SF_6		20	116	484%
Agricultural Sector		**13,103**	**13,401**	**2%**
Enteric fermentation		4,796	4,544	-5%
Manure management		1,550	1,819	17%
Rice cultivation		115	99	-14%
Cropland		6,563	6,893	5%
Burning of agricultural waste		79	46	-42%
Other		NE	NE	
Land use change and forestry sector (LULUCF)		**-27,446**	**-19,386**	**29%**
Forest lands ssland and scrubland	sequestration	-85,006	-93,010	9%
	emissions	56,768	72,799	28%
Grassland and Scrubland	sequestration	-122	-122	0%
	emissions	609	607	0%

Item	Type	CO_2 eq		% Change
		2000 [Gg]	2006 [Gg]	
Agricultural land	Sequestration	-74	-74	0%
	emissions	245	281	15%
Settlements	sequestration	-23	-23	0%
	emissions	110	110	0%
Wetlands		NE	NE	
Other Land		46	46	0%
Other		NE	NE	
Anthropogenic Waste		**2,028**	**2,489**	**23%**
Solid waste		1,797	2,258	26%
Liquid waste		105	97	-8%
Incineration of waste		37	37	0%
Other		89	97	9%
National Total **Memo items: Values not included in the total**		**43,410**	**59,672**	**37%**
International transport		3,068	5,275	72%
Maritime		2,022	4,065	101%
Air		1,045	1,210	16%
Wood and biogas	CO_2 emission	16,721	18,563	11%

3.2 DESCRIPTION AND INTERPRETATION OF TRENDS IN AGGREGATE GHG VALUES

Figure 3 shows the overall growth trend in CO_2 equivalents over the 1984-2006 period for the five sectors included in the inventory, as well as the balance of emissions and removals, which is positive in Chile throughout the period analyzed. Between 1990 and 2006, net GHG emissions for the country increased by 232%, including a 37% rise from 2000 to 2006. Excluding the LULUCF sector, the increase in GHG emissions from 1990 to 2006 was 68%, and 12% from 2000 to 2006. These increases are congruent with the country's economic growth during this period.

The importance of the LULUCF sector is clear in terms of CO_2 sequestration in Chile, although net carbon capture has decreased steadily between 1984 and 2006. In absolute terms, the Energy sector contributes a major and increasingly large percentage of national emissions (an 85% increase between 1990 and 2006). The second largest share is attributed to Agriculture, although emissions from that sector increased least between 1990 and 2006, rising by just 10%. The largest percentage increase has come from Waste (142%), although the overall impact of this sector is low.

As figures 3 and 4 show, the main cause of the significant increase in global emissions is the Energy sector, where emissions grew by 168% between 1984 and 2006. Other sectors also displayed significant increases, but their lower contribution means they have less impact on the national balance. Most notable are the growing contribution of the Energy sector and the steady reduction in GHG sequestration by the LULUCF sector.

Photo: Ministry of the Environment. Government of Chile

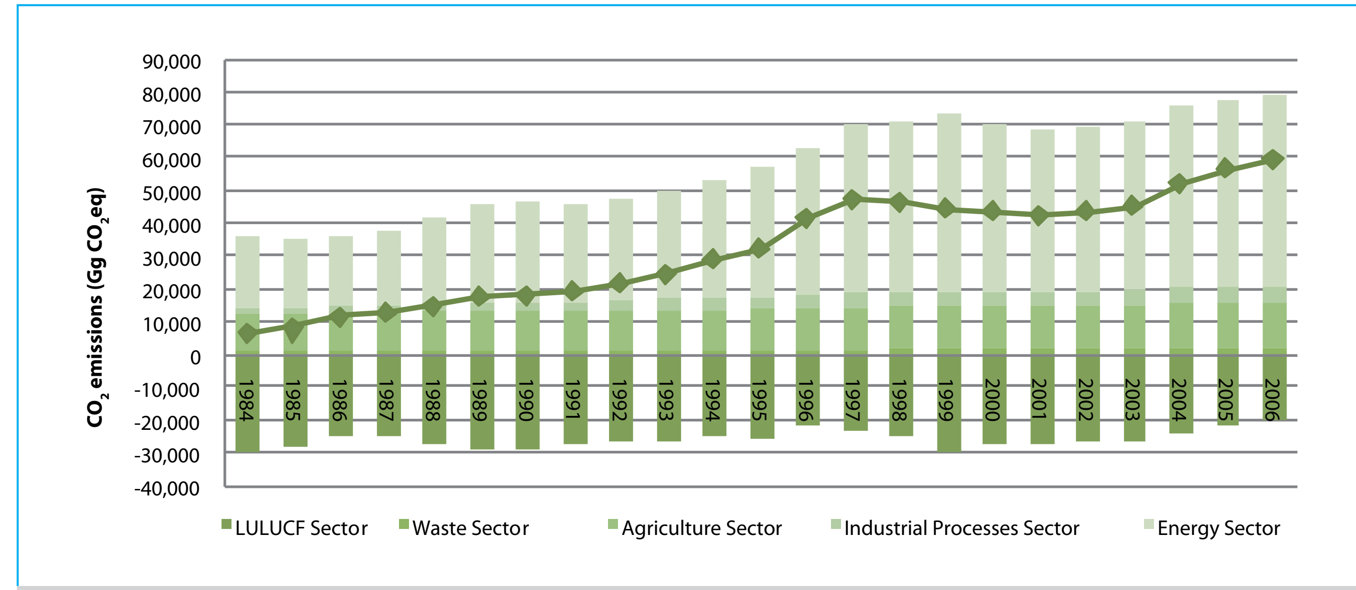

Figure 3. GHG emissions, removals, and balance by sector, 1984-2006[2]

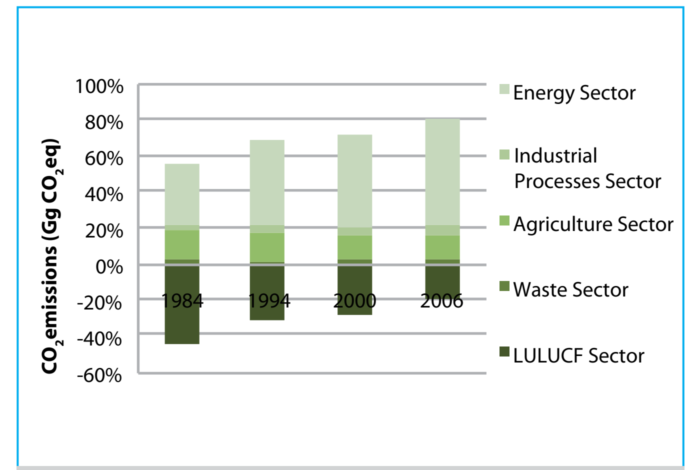

Figure 4. Percentage contribution to GHG emissions and removals by sector in the Chilean inventory (INGEI)

3.3 DESCRIPTION AND INTERPRETATION OF TRENDS FOR INDIVIDUAL GHGS

The IPCC 1996 revised methodology stipulates that national communications should include GHG emissions separated for each type of gas. Table 8 summarizes national emissions and removals of the three main GHGs in the Chilean inventory: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

TABLE 8. National GHG emissions and removals for 2000 and 2006

Year	CO_2 (emissions)	CO_2 (removals)	CO_2 (emission removal)	CH_4	N_2O
	[Gg]	[Gg]	[Gg]	[Gg]	[Gg]
2000	53,623	-29,819	23,804	560	25
2006	60,796	-22,043	38,753	592	27

3.3.1 Carbon dioxide: CO_2

CO_2 is the main GHG released in Chile. In 2000 it represented 55% of total net CO_2eq emissions in the annual inventory, while in 2006 its share had risen to 65%. In both 2000 and 2006, 92% of the CO_2 released – not taking into account the LULUCF sector in the country – came from the Energy sector, with the remaining 8% derived from Industrial Processes. Between 2000 and 2006, non-LULUCF CO_2 emissions increased from 52.9 million tons of CO_2 to 60.1 million tons. Taking into account the LULUCF sector, net emissions of CO_2 in the country increased by 63%, from 23.8 million tons in 2000 to 38.7 million tons in 2006.

[2] Except where otherwise indicated, all figures in this chapter have been prepared by the authors of this chapter.

CO_2 sequestration, arising mainly from natural photosynthesis, dropped by 26%, from 29.8 million tons in 2000 to 22 million tons in 2006, as measured by the accounting methodologies stipulated for national inventories.

3.3.2 Methane: CH_4

CH_4 is the GHG with the second most significant impact on the country's emissions, after CO_2. In 2000 it represented 27% of CO_2eq emissions in Chile's annual inventory, and in 2006 it contributed 21%. The Agriculture sector contributes most methane emissions, accounting for 53% of all national methane emissions in 2000, dropping to 49% in 2006. The second largest emitter of CH_4 was the Energy sector, with 19%, which remained unchanged in 2006. Meanwhile, the Waste sector released the third-largest proportion of methane, equal to 16% of the total in 2000 and increasing to 19% in 2006. Finally, Industrial Processes contributed 1% of all methane released in Chile in both 2000 and 2006. During this period, emissions of CH_4 excluding the LULUCF sector increased from 496.4 thousand tons to 520.5 thousand tons. Including the LULUCF sector, emissions increased from 559.8 thousand tons to 591.7 thousand tons.

3.3.3 Nitrous oxide: N_2O

N_2O represented 18% of total CO_2eq emissions in the Chilean inventory in 2000, and 14% of CO_2eq in 2006. 88% of emissions of this GHG came from the Agriculture sector in 2000, dropping slightly to 87% in 2006. Meanwhile, the LULUCF sector contributed 5% of nitrous oxide emissions in 2000 and 6% in 2006. The Energy sector is the third largest emitter of this GHG, contributing 5% in both 2000 and 2006. The Industrial Processes and Waste sectors contributed 2% and 1% respectively in both years. Between 2000 and 2006 N_2O releases excluding the LULUCF sector rose from 24,000 tons to 26,000 tons of N_2O. Including LULUCF, emissions rose from 25,000 tons of N_2O in 2000 to 27,000 tons in 2006.

3.4 DETAILED DESCRIPTION AND INTERPRETATION OF EMISSION TRENDS BY SECTOR

3.4.1 Energy Sector

Energy consumption in Chile has kept growing in recent years, and a significant proportion of this increased demand has been met by fossil fuels, which generate significant amounts of GHGs.

Table 9 provides information on CO_2 emissions arising from apparent fuel consumption in the country for 2000 and 2006, which is defined as the difference between fuel production and imports, and the sum of exports, international consumption, and variations in fuel stocks. During this period the country saw a significant rise in the consumption of gas fuels, associated with the temporary availability of more natural gas from bordering countries. This factor acted as a buffer against increased CO_2 emissions associated with the consumption of fossil fuels.

TABLE 9. CO_2 emissions associated with apparent consumption of fossil fuels in Chile, 2000 and 2006

Fuel type	2000 [Gg CO_2]	2006 [Gg CO_2]	Percentage variation
Liquid	24,852	26,767	7.7%
Solid	11,429	13,544	18.5%
Gas	12,448	14,744	18.4%
Total	**48,729**	**55,055**	**13.0%**

Source: INGEI Chile.

This sector of the Inventory includes emissions associated with the consumption of fossil fuels (solid, liquid, and gas) in the country, as well as fugitive emissions, which in Chile correspond mainly to estimates of methane released in the transmission and distribution of natural gas. The wood fuel and biogas category includes emissions of CH_4 and N_2O derived from the consumption of these fuels and waste from the pruning of fruit trees that is used as a source of energy. CO_2 emissions associated with the consumption of wood for fuel and biogas, as well as waste from the pruning of fruit trees used in the country as a source of energy, are included in "Memo Items", as stipulated by the IPCC emissions reporting methodology.

The categories and subcategories included in the Energy sector are shown in Table 10. CO_2 emissions for the wood fuel category are excluded here as they are included in the LULUCF sector, under forestry.

TABLE 10. Categories and subcategories in the energy sector

Sector Energy	Category	Subcategory
Energy	Energy industries	Electricity and heat generation, petroleum and natural gas refining, solid fuel conversion, other energy industries.
	Manufacturing industries, construction, and mining	Industrial processes for the production of iron and steel, non-ferrous metals, chemicals, pulp and paper; food/beverages/tobacco processing, cement, saltpeter, misc. mining.
	Transportation	Air, road, rail, maritime.
	Commercial, institutional, residential	Energy consumption in commercial, institutional and domestic use.
	Agriculture, fisheries	Use of energy in agriculture/ livestock activity and fishing.
	Fugitive emissions	Aviation industry Tier 2, coal production, petroleum and natural gas production, ozone precursors and SO_2.
	Wood fuel and biogas	Use of wood and biogas as an energy source.

As Figures 5 and 6 show, the category that contributed most to emissions in 2006 was the 'Energy industries' category, with 36%. Given this sector's relatively steady contribution of 25% in 1984 and 1994, the overall increase was 281% over the course of the time series. This category shows a significant upward trend since 2003. Transportation continued to account for a significant, albeit slightly decreasing, relative contribution (32% in 1994; 30% in 2006), but shows a 177% increase in overall emissions between 1984 and 2006. The contribution of the 'manufacturing industries, construction and mining' category dropped from 29% in 1984 to 22% in 2006, although its emissions actually increased by 110% over the time period. The 'commercial, institutional and residential' category maintained its relative share of 10% off all emissions, increasing 76% in overall terms between 1984 and 2006. No other category contributed more than 6%.

Manufacturing, construction, and mining includes emissions from fossil fuels consumed by Chile's copper industry. Data are based on information provided by COCHILCO. According to these figures, emissions associated with the consumption of fossil fuels in this industry increased by 34%, from 2.607 million tons of CO_2 in 2000 to 3.499 million tons of CO_2 in 2006.

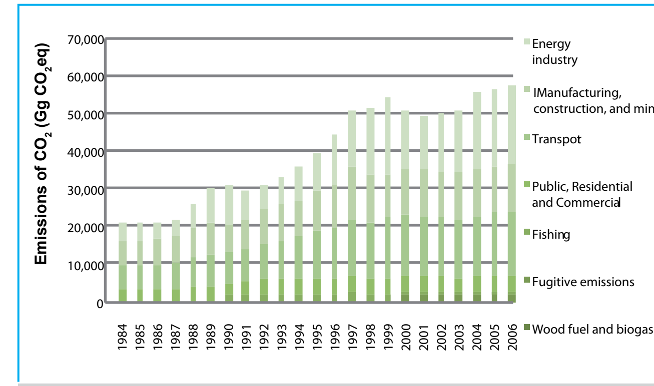

Figure 5. GHG emissions from the energy sector, by category, 1984-2006

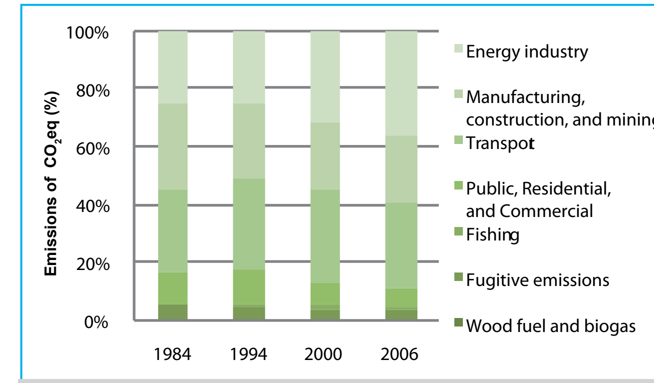

Figure 6. Percentage contribution to GHG emissions by category in the energy sector

In 2006, the energy industry released 20,751 Gg of CO_2eq, mainly via electricity and heat generation, which accounted for 79% of those emissions. This represents an increase of 160% since 1994, as shown in Figure 7.

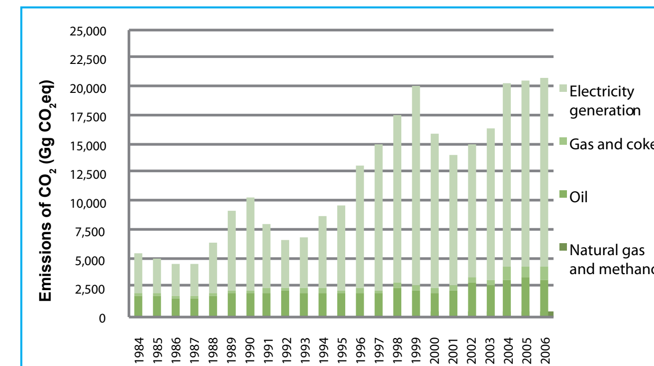

Figure 7. GHG emissions by subcategory in the energy industry, 1984-2006

As Figure 8 shows, the transport sector is dominated by the road transport subcategory, which in 2006 accounted for 92% of all emissions in the category, by far the largest share. In second place, with a 5% contribution in 2006 is domestic air transport. All other categories combined contribute 3% of this sector's emissions.

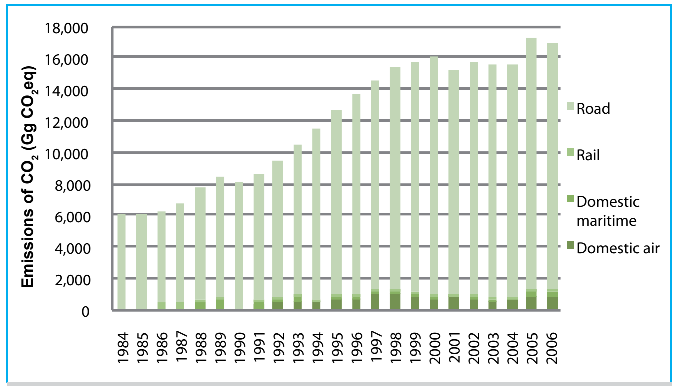

Figure 8. GHG emissions from transport subcategories, 1984-2006

Methodology

The 1996 IPCC methodology considers emissions from fossil fuel combustion and fugitive emissions from different productive processes separately. The first quantifies CO_2 emissions using two specific calculation methods:

- Apparent consumption or energy balance
- Final consumption of fuels

The methodology also includes a method for quantifying releases of gases other than CO_2 (CH_4, N_2O, NO_X, CO, NMVOC, and SO_2) and fugitive emissions from coal mine operations, petroleum refining, and natural gas extraction, transport, storage, and distribution. Table 11 summarizes the information used to calculate each type of emission.

TABLE 11. Inputs for energy sector calculations

Category	Tier	Gas released	Information used
Emissions from the combustion of fossil fuels and biomass	1	CO_2	Reference levels or apparent consumption
			End use
		CH_4, N_2O, NO_X, CO, NMVOC	End use (emission factor depending on combustion)
		SO_2	End use (emission factor depending on sulfur content)
	2	CH_4, CO_2, N_2O, NO_X, CO, NMVOC and SO_2.	Aviation industry and maritime emissions
Fugitive fuel emissions	1	CH_4	Coal production
		CH_4	Petroleum and natural gas production
		CO, NO_X, NMVOC and SO_2	Ozone precursors and SO_2 from refining

Photo: Xstrata Copper

In this inventory the Tier 2 method for 'aviation and maritime industries' emissions was used, which also allowed bunker emissions to be calculated. Details of this methodology are included under the section on GHG emissions from international transport (bunker fuels), in this chapter.

Comparison between Energy sector emissions calculated with the Reference Approach versus the Sectoral Approach

The "Reference Approach" for the National Inventory involves a simple calculation of GHG emissions generated annually in the country by the apparent consumption of fuels; that is, the difference between fuel production and imports and the sum of exports, international consumption, and variations in fuel stocks. These values are derived from the country's National Energy Balance. This approach was used to calculate CO_2 emissions associated with fossil fuel consumption for 2000 and 2006 in Chile, which amounted to 50,417 Gg CO_2 and 54,970 Gg CO_2, respectively. Comparing these figures with those obtained using the "Sectoral Approach" (Tables 5 and 6) – 48,730 Gg CO_2 for 2000 and 55,117 Gg CO_2 for 2006 – we observe that emissions calculated for 2000 using the Reference Approach were 3.35% higher than those calculated using the Sectoral Approach. This was not the case for 2006, however, when CO_2 emissions calculated using the Sectoral Approach were 0.27% greater than those calculated using the Reference Approach. It should be noted that in any case, the country's National Energy Balance does not distinguish between national and international consumption (and therefore emissions) in air and maritime transport, and calculations associated with the Reference Approach therefore include an overestimation of consumption, and thus an overestimation of greenhouse gas emissions. Between 2000 and 2006, consumption of fuels for international transport increased by almost 90%, as shown in the Memo Item on GHG emissions later in this chapter.

3.4.2 Industrial Processes

General aspects

Emissions calculated for this sector include those resulting from the physical and/or chemical processing of raw materials and productive processes, but not emissions from energy use, which fall within the energy sector. Gases released include CO_2, NMVOC, SO_2, N_2O, and PFC. Categories and subcategories included in this sector are shown in Table 12.

TABLE 12. Categories and subcategories of the industrial processes sector

Sector	Category	Subcategory
Industrial processes	Mineral products	Production and use of cement, lime, limestone, dolomite, sodium carbonate; production and use of asphalt, ammonia, nitric acid, adipic acid, silicon carbide and calcium carbide
	Chemical industry	Pulp & paper, food and drink
	Metal production	Iron and steel, copper, gold, lead, silver, zinc, molybdenum
	Other production	Methane, ethylene, formaldehyde, phthalic acid, expandable polystyrene, low density polyethylene, polypropylene, sulfuric acid
	Consumption of HCFCs and SF_6	Halocarbons (HFC), perfluorocarbons (PFC) and sulfur hexafluoride (SF_6)

As shown in Figure 9, two categories account for a significant and growing share of GHG emissions from this sector: mineral production and metal production, which represented 56% and 35% of emissions in the sector in 2006, respectively, a total of 91% of all emissions from this sector that year.

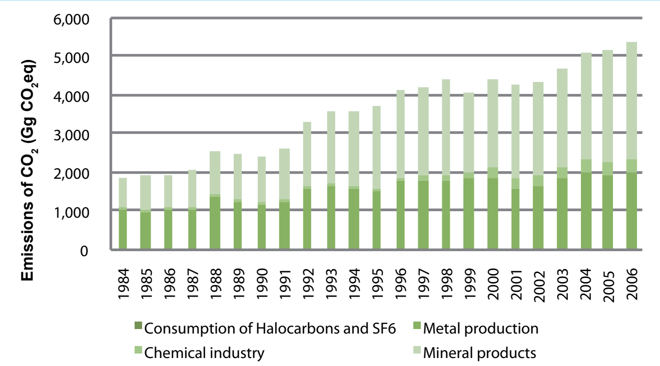

Figure 9. GHG emissions from the industrial processes sector, by category, 1984-2006

Figure 10 shows that the relative contribution of emissions from the mineral production category increased significantly to 56% in 2006. Meanwhile, the metal production category, in which all emissions are from steel production, reduced its share of this sector's emissions by 20% over the time period measured.

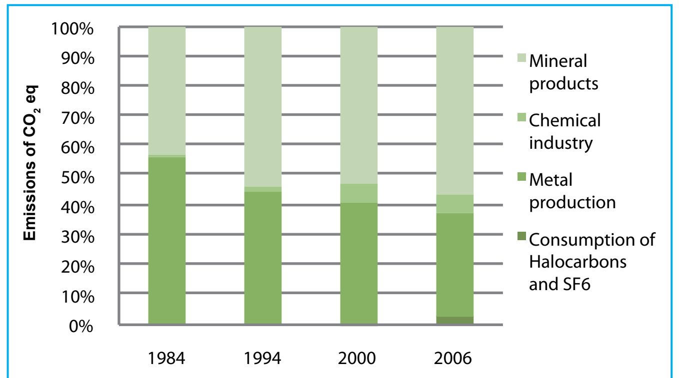

Figure 10. GHG emissions by subcategory in the industrial processes sector, percentage contribution

Figure 11 shows a breakdown of the mineral production category into its two main component subcategories –cement and lime– and the trends observed. As the graph shows, cement and lime production were the main sources of CO_2, with cement contributing 68% and lime 32% in 2006.

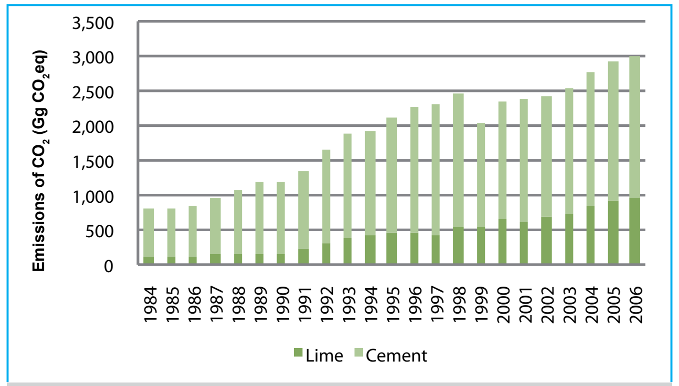

Figure 11. GHG emissions by subcategory in the mineral products category, 1984-2006

It should be noted that this inventory included the calculation of annual emissions associated with the consumption of sulfur hexafluoride, SF_6, under the industrial processes category "Consumption of HFC, PFC, and SF_6". In 2000, this corresponded to the release of 0.83 tons of SF_6, or 19.8 Gg CO_2eq, and in 2006 to 4.72 tons of SF_6, or 115.9 Gg CO_2eq.

Methodology

The methodology included multiplication of the activity data by the corresponding emission factors listed in the revised IPCC 1996 guidelines (Tier 1, by default, for each category in this sector). Table 13 shows the inputs used to calculate values for the categories in this sector.

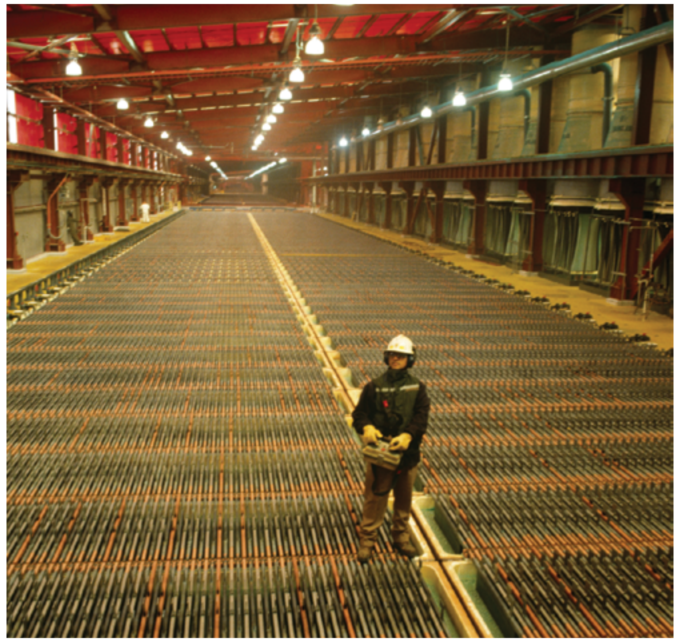

Photo: Chilean Copper Commission (COCHILCO)

TABLE 13. Inputs used for Industrial Processes sector calculations

Category	Tier	Gas released	Input data
Cement production	1	CO_2	Cement production
	1	SO_2	Cement production
Lime production	1	CO_2	Calcite usage
	1	No emissions	Dolomite usage
	1	CO_2	Calcium carbonate usage
Misc. mineral products production and use	1	CO, NO_x, NMVOC , and SO_2	Asphalt production and surfacing
	1	NMVOC	Glass production
Ammonia production	1	CO, CO, NO_x, NMVOC , and SO_2	Ammonia production
Nitric acid production	1	NO_x	Nitric acid production
Adipic acid production	1	N_2O, NO_x, NMVOC , and CO	Adipic acid production
Silicon carbide and calcium carbide production	1	CO_2, CH_4, CO , and SO_2	Silicon carbide and calcium carbide production
Other chemical substance production	1	CH_4, N_2O, NO_x, NMVOC, CO, and SO_2	Other chemical production
Metal production	1	CO_2, NO_x, NMVOC, CO, and/or SO_2	Iron and steel production
	1	SO_2	Copper production
	--	No emission factors	Gold, lead, silver, zinc production
	1	--	Molybdenum production: emissions associated with production are included in calculations for the copper industry
Pulp and paper production	1	SO_2, NO_x, NMVOC, and CO	Kraft method: neutral sulfite and bisulfite
Food and beverage production	1	NMVOC	Emissions from the production of wine, beer, alcoholic beverages, malt whiskey, grain whiskey, and brandy, due to the fermentation of cereals and fruits
Food production	1	NMVOC	Heating, baking, fermentation, cooking, and/or drying processes
HFC, PFC, and SF_6 consumption	1	HFC, PFC, and SF_6	Secondary emissions in the production process or from fugitive emissions

While assessing emissions in this sector, special care was taken to avoid double-counting emissions in the energy and industrial processes sectors; the use of fuel coke for non-fuel purposes was discounted, for example, as was the usage of petroleum derivatives for non-fuel purposes.

3.4.3 Solvent and Other Product Use

General aspects

This sector does not generate emissions of gases with global warming potential. The only emissions registered are for non-methane volatile organic compounds (NMVOCs) in the categories of paint manufacture, paint use, adhesive use, and domestic solvent use. A breakdown of categories and subcategories is given in Table 14.

TABLE 14. Categories and subcategories for Solvents and Other Product Use, 2006

Sector	Category	Subcategory
Solvents and other product use	Paint manufacture	Water- and oil-based
	Paint use	Industrial and residential
	Adhesive use	Emissions from adhesive use
	Domestic solvent use	Emissions from domestic use

Methodology

For methodological reasons, this sector only accounts for NMVOC emissions from solvent use, using the inputs shown in Table 15.

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TABLE 15. Inputs for calculations of emissions from Solvent and Other Product Use

Category	Tier	Gases released	Input data
Paint production and use	1	NMVOC	Paint manufacture
	1	NMVOC	Paint use
Industrial adhesive use	1	NMVOC	Adhesive consumption
Domestic solvent use	1	NMVOC	Domestic solvent manufacture and use

3.4.4 Agriculture

General aspects

In the Agriculture sector, the IPCC 1996 guidelines include emissions of methane and nitrous oxide associated with livestock activities. Nitrous oxide is released from the surface of cultivated soil by direct and indirect mechanisms, methane is produced in rice cultivation, and methane, nitrous oxide, and precursor gases are generated by the on-site burning of plant biomass, dead or alive (burning of agricultural waste and periodic burning of savannahs). As Chile does not possess significant areas of savannah, the National Inventory does not include the periodic burning of savannahs. The categories and subcategories are shown in Table 16.

TABLE 16. Agriculture sector categories and subcategories

Sector	Category	Subcategory
Agriculture	Enteric fermentation	Cattle
		Other animals
	Manure management – methane emissions	Hogs
		Other animals
	Manure management – nitrous oxide emissions	Different manure management systems
	Rice cultivation	Irrigation, permanent or intermittent flooding
		Rainwater irrigation
		Elevation
	Agricultural land	Direct and indirect emissions, direct pasturing
	Burning of agricultural waste	Cereals, deciduous fruit trees

Figure 12, showing emissions from the Agriculture sector broken down by category, shows that emissions in the sector increased by 8% between 1990 and 2000, by 10% between 1990 and 2006, and by 18% for the period under study, 1984 to 2006. This increase is due mainly to increased emissions from the categories of cropland and enteric fermentation.

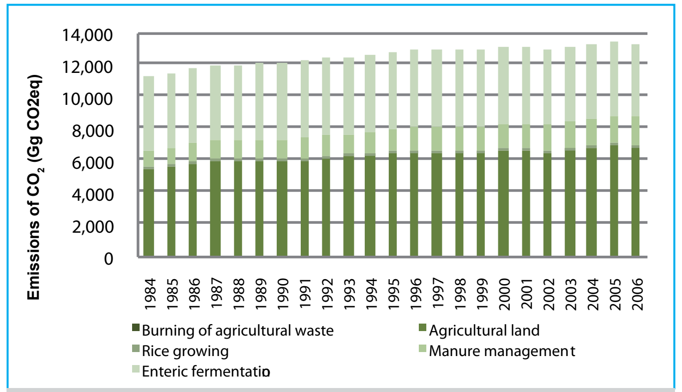

Figure 12. GHG emissions from the agriculture sector, by category, 1984-2006

Cropland represents the bulk of emissions in this sector, mainly due to nitrous oxide emissions generated by the application of mineral fertilizers. This agricultural category displays the highest growth in both absolute and relative terms (Figure 13). In 2006, 48% of emissions came from categories directly related to livestock activities (enteric fermentation, 34% and manure management 14%). The contribution of livestock activity increases substantially when nitrous oxide emissions from direct pasturing of animals are included.

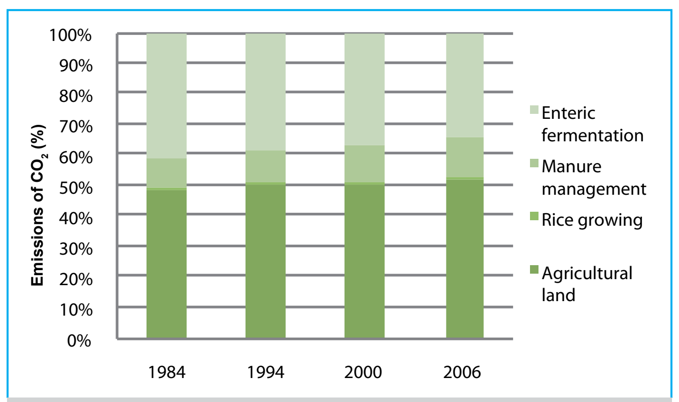

Figure 13. GHG Emissions in the agricultural sector, by source (%)

Figure 14 shows that direct emissions are the main source of nitrous oxide released from soils, displaying a rising trend that is less notable in relative than in absolute terms (from 32% in 1984 to 36% in 1994 and 39% in 2006). In this subcategory, the main emission source is mineral fertilizers, the use of which has increased over the time period (Table 17).

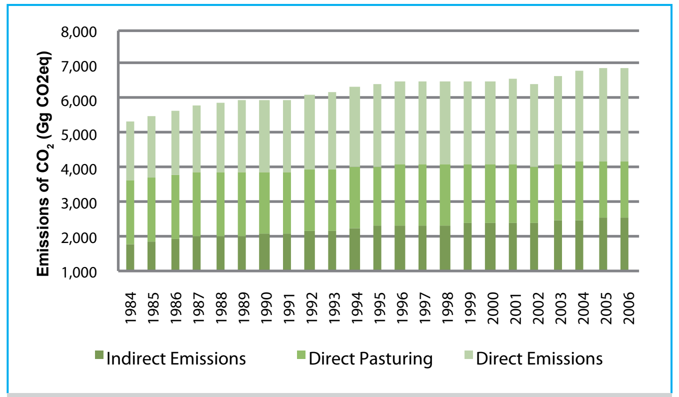

Figure 14. CH_4 emissions from the agricultural land category, by subcategory 1984-2006

TABLE 17. National nitrogen-based fertilizer consumption (tons N/year)

Country/year	1984	1994	2006
Total	95,378	201,667	273,079

Source: FAOSTAT, 2010.

In the category of enteric fermentation, Figure 15 shows that non-dairy cattle represent the main source of emissions, amounting to 60% in 2006, although this figure is lower than in 1998. The second most significant source is dairy cattle, representing 23% of emissions. The remaining 18% is contributed by all other animal species included in the inventory.

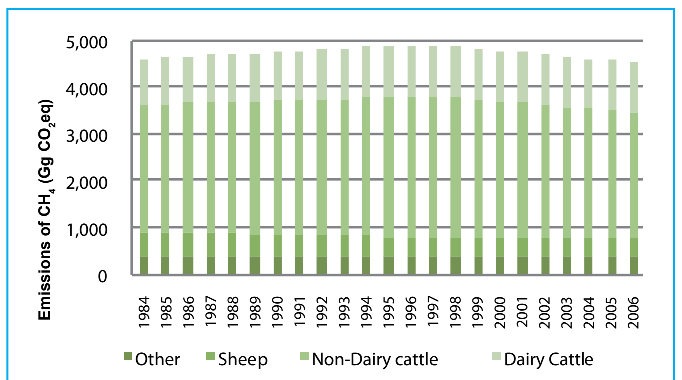

Figure 15. CH_4 emissions from the enteric fermentation category, by species, 1984-2006

Methane emissions from manure (Figure 16) come mainly from hog farming, which accounted for 66% of all emissions in the category in 2006, an increase over 45% in 1984 and 57% in 2000. This is unsurprising, as hog production has been on the rise in Chile since 1996. Meanwhile, emissions from cattle have dropped since 1998, alongside a reduction in the number of head of cattle and an increase in yields.

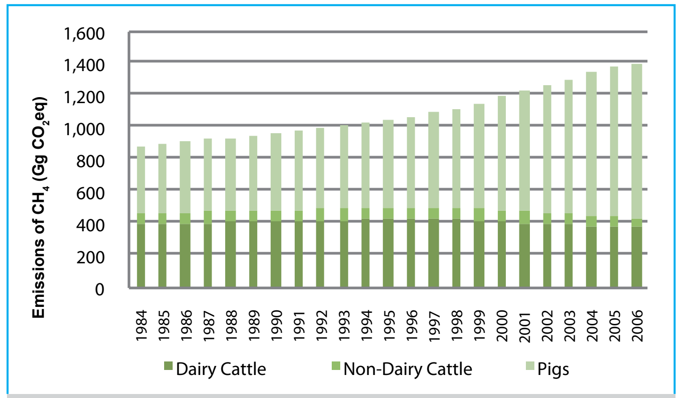

Figure 16. CH_4 emissions from the manure management category, by species, 1984-2006

The main animal sources of nitrous oxide are generated from droppings left in the fields during direct pasturing. Despite a downward trend over the time period analyzed, in 2006 these emissions still accounted for 82% of the total emissions from animal droppings, including animals kept in enclosed spaces as well as direct pasturing.

Nitrous oxide emissions from animal feces and urine come mainly from cattle and, to a much lesser degree, from other species raised in direct pasturing (goats, sheep, horses, South American camels, mules, and donkeys). It should be noted that nitrous oxide released by animals in direct pasturing is not included in this category, but rather under the agricultural land category.

Figure 17 also shows that emissions arising from the management system described as solid manure store and drylots contributes 17% of this gas, as of 2006.

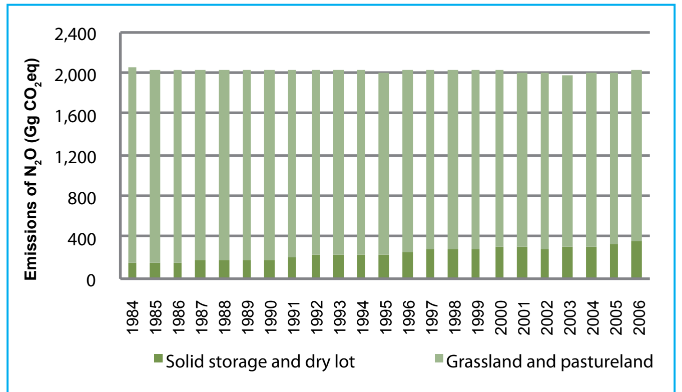

Figure 17. N_2O emissions from the manure management category, by management system, 1984-2006

Methodology

Most categories in this sector employed a Tier 1b methodology (owing to the regional disaggregation of activity data for the sector, explained above), with the exception of enteric fermentation and methane from manure management, for which Tier 2 methodologies were applied. Table 18 summarizes the inputs used to calculate emissions in the sector, by category.

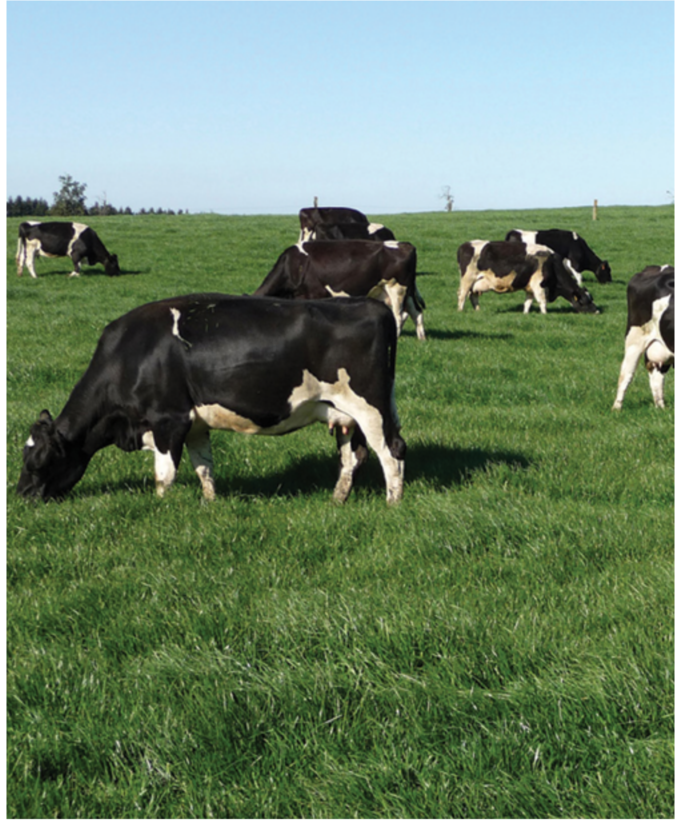

Photo: Ministry of Agriculture. Government of Chile

TABLE 18. Inputs used to calculate emissions for the Agriculture sector

Category	Dominant subcategory	Tier	Gases emitted	Input data
Cropland	Fertilizers	1b	N_2O	Area of arable land and orchards
Enteric fermentation	Cattle	2	CH_4	Animal population
Manure management - methane	Cattle and hogs	2	CH_4	Animal population
Manure management – nitrous oxide	None	2	N_2O	Different forms of manure management
Rice cultivation	None	1b	CH_4	Area under cultivation
Burning of agricultural waste	None	1b	CH_4, CO, N_2O, NO_x	Agricultural waste

The application of Tier 2 methodology for calculating emissions from enteric fermentation requires precise analysis of the animal population, including disaggregation into groups. Cattle were disaggregated as dairy cows, beef cows, heifers, calves, and young and adult beef cattle produced under different management systems. This data was used to generate emission factors using data provided by companies themselves and the expert judgment of Dr. F. Salazar of INIA; for hogs, the groups used were sows, boars, and piglets.

TABLE 19. Methane emission factors, Enteric Fermentation category

Animal Group	Method	Emission factors* kg CH_4 /head/ year		Source
		Pastured	Confined	
Cows-dairy	Tier 2	72.6	76.6	Specific values and expert opinions
Cows - beef	Tier 2	56.5	43.0	Specific values
Heifers	Tier 2	44.4	48.6	
Adults, beef	Tier 2	56.7	82.7	
Young animals, beef	Tier 2	36.7	30.7	
Calves	Tier 2	27.1	39.0	

* Default emission categories for dairy and non-dairy cattle:
- For Latin America, 57and 49, respectively
- For North America, 118 and 47, respectively

Table 19 presents the emission factors calculated for cattle, in accordance with procedures established by the IPCC Tier 2 methods. The table shows that applying this method generates 12 specific factors for a single species. In contrast, the Tier 1 method works with a single emission factor (57 for dairy cattle and 49 for non-dairy in Latin America, and 118 and 47, respectively for North America), showing that more precise results are obtained using the Tier 2 method.

For methane emissions released from cattle and hog manure management, where both species are significant, estimates were based on the Tier 2 method, with input obtained from expert Dr. F. Salazar of INIA (2009). Emission factors for methane emissions from cattle are broken down into 18 cases (3 per group of animals), shown in Table 20.

TABLE 20. Methane emission factors for Cattle Manure Management

Group of animals	Pasturing, temperate zone (regions I-VII)	Pasturing, cold-temperate zone (regions VIII-XII)	In confinement, nationwide
	kg CH_4 /head/ year		
Cows-dairy	2.01	1.34	108.9
Cows-beef	1.68	1.12	66.7
Heifers	1.23	0.82	69.1
Adults, beef	1.57	1.05	117.6
Young animals, beef	1.02	0.68	43.7
Calves	0.75	0.50	55.4

Country-specific emission factors for hogs were as follows:
- sows: 37.5 kg CH4 /head/year
- bulls: 46.9 kg CH4 /head/year
- juveniles: 12.5 kg CH4 /head/year

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3.4.5 Land Use, Land Use Change and Forestry (LULUCF)

General aspects

This sector accounts for carbon and nitrogen flows in managed woodlands, that is, those that display some human intervention. Unmanaged native woodland in areas set aside for wildlife conservation is excluded from the National Inventory, as the lack of human intervention implies a balance of photosynthesis and decay. This sector mainly records CO_2 emissions and capture through processes of forest biomass expansion (INIA, 2009). The categories and subcategories in the LULUCF sector included in the Chilean inventory are presented in Table 21 using the terminology employed by Chilean institutions in their regular statistics systems. The 2003 Good Practice Guidances for the LULUCF sector were used to obtain emissions for this sector, based on the categorization of land use and land use changes.

TABLE 21. LULUCF inventory categories and subcategories

Sector	Category	Subcategory
Land use, land use change	Forest lands	Forest lands with no land use change.
		Other land uses becoming forest lands.
	Grassland and scrubland	Grassland and scrubland with no land use change.
		Other land uses becoming grassland and scrubland.
	Cropland	Cropland with no land use change.
		Other land uses becoming cropland.
	Settlements	Settlements with no land use change.
		Other land uses becoming settlements.
	Wetlands	Wetlands with no land use change.
		Other land uses becoming wetlands.
	Other land	Other land with no land use change.
		Land becoming other land.

The balance of the LULUCF sector (Figure 18) shows steady growth in both greenhouse gas emissions and atmospheric carbon capture in Chile:

- In terms of emissions, 28,431 Gg of CO_2eq were released in 1984, rising to 49,968 Gg CO_2eq in 1994, 57,778 CO_2eq in 2000, and 73,843 Gg CO_2eq in 2006.
- In terms of sinks, 57,735 Gg CO_2eq were sequestered in 1984, rising to 74,600 Gg CO_2eq in 1994, 85,225 in 2000, and 93,229 Gg CO_2eq in 2006.

Overall, the balance has remained in favor of net carbon capture, but this trend is slowing down and may be reversed in the medium term: From a net carbon capture of 29,304 Gg CO_2eq in 1984, the balance dropped to 24,632 Gg in 1994, reaching 27,446 Gg in 2000 and 19,386 Gg CO_2eq in 2006, representing a 34% reduction over the entire period.

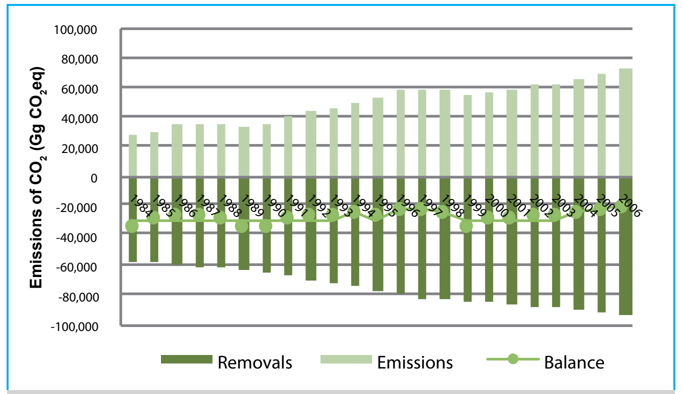

Figure 18. GHG emissions, removals, and balance from the LULUCF sector,1984-2006

Given the importance of the LULUCF sector, an analysis of its six categories is presented below, with greater detail provided for categories that account for a greater share of overall emissions, identified as key categories in the National Inventory.

It first must be underscored that the Chilean LULUCF sector is generally dominated by the 'forest land' category, and in particular by the subcategory 'forest land remaining forest land'. This subcategory makes up over 98% of emissions and removals in the category.

Figure 19 presents the emissions, sinks, and net balance for the forest land category, which, due to its major relative weight in the sector, is very similar to Figure 18. The figure shows that gross emissions in the category grew from 27,444 Gg CO_2eq in 1984 to 48,978 Gg CO_2eq by 1994, a 79% rise. In 2006, emissions of 72,799 Gg CO_2eq were registered, an increase of 165% over 1984 levels and 49% over those of 1994. In 2006, gross emissions in this category represented 99% of the sector's total.

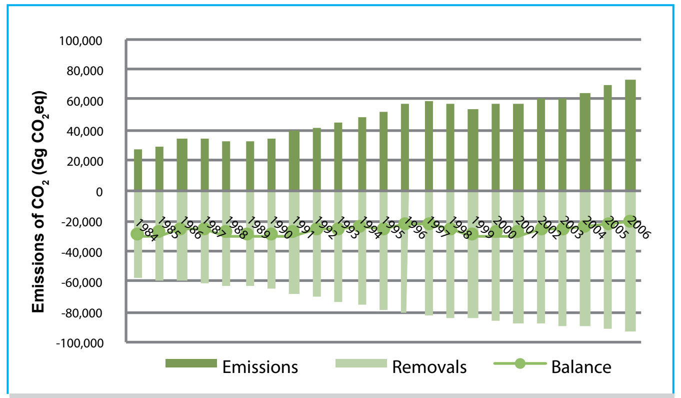

Figure 19. GHG emissions, removals, and balance from the forest land category,1984-2006

Figure 19 also shows that gross carbon sequestration has grown steadily, from 57,516 Gg CO_2eq in 1984 to 74,381 Gg CO_2eq in 1994 (a rise of 29%), reaching 93,010 Gg CO_2eq in 2006 (up 62% over 1984 and 25% over 1994). In 2006, sequestration in this category represented 99.8% of the sector's total capture.

Thus, the balance remains in favor of net sequestration, albeit with a net reduction from 30,079 Gg CO_2eq in 1984 to 25,403 Gg CO_2eq in 1994 and 20,211 Gg CO_2eq in 2006; this translates into an overall 16% drop for the 1984–1994 period and a 33% drop between 1984 and 2006.

Figure 20 shows that for the subcategory of 'forest land remaining forest land', the most significant items in regard to carbon capture are the increase in forest biomass (mainly from plantations of exotic forest trees) and second growth native woodland; for emissions, the most significant items are tree felling and forest fires.

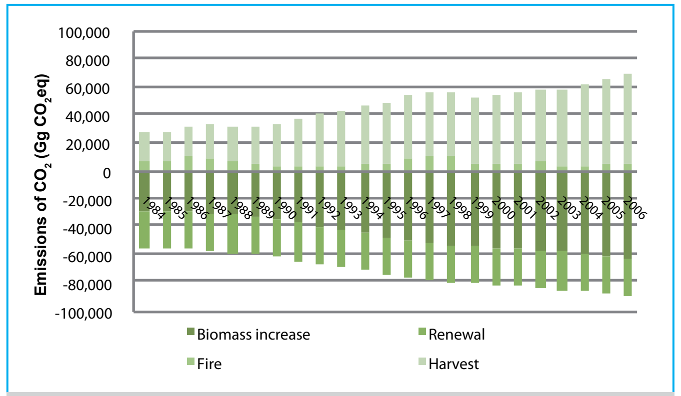

Figure 20. GHG emissions and removals from key headings under the subcategory forest land with no land use change, 1984-2006

Figure 21 shows that the species that has accounted most for the increase in forest biomass in Chile is *Pinus radiata*, which in 1994 was responsible for 78% of carbon capture in the subcategory, compared to 58% in 2006. The second most significant species is Eucalyptus, accounting for 19% of carbon capture in 1994, rising to 38% in 2006. The contribution of managed native woodland remains marginal, amounting to less than 1% of carbon captured in this subcategory. The relative weight of each species reflects the increase in area planted (Figure 21).

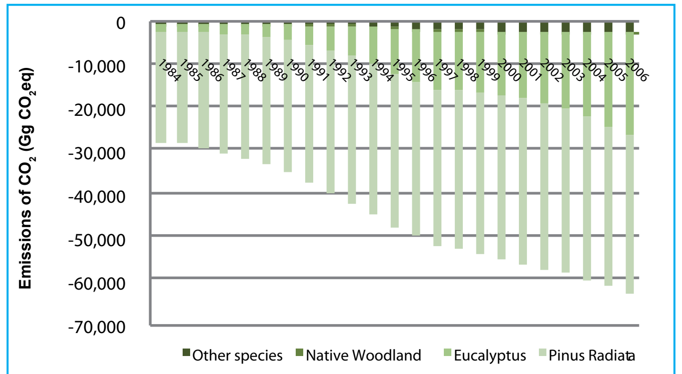

Figure 21. GHG removals by main forestry species contributing to increase in forest biomass, 1984-2006

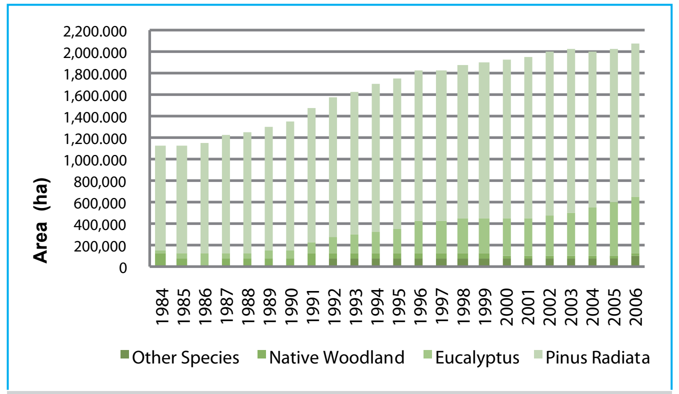

Figure 22. Cumulative area of Pinus radiata, eucalyptus, native woodland, and other forestry species, 1984-2006

It must be highlighted that logging activity in the country is displaying significant and sustained growth. This is reflected in the balance of the LULUCF sector, and shown in Figure 23, which shows that felling of forested tracts increased by 102% between 1984 and 1994, and by 53% between 1994 and 2006, for a total increase of 209% from the beginning to the end of the period. Firewood accounts for much of the wood harvested in the country. According to INFOR (2008) wood harvested for fuel comes from native species (63%), Eucalyptus (22%), and *Pinus radiata* (15%).

In terms of industrial logging and trees harvested for firewood, *Pinus radiata* is the main species felled, contributing 55% in 2006, followed by native species, with 29%, Eucalyptus at 12%, and other exotic species in the remaining 0.6%.

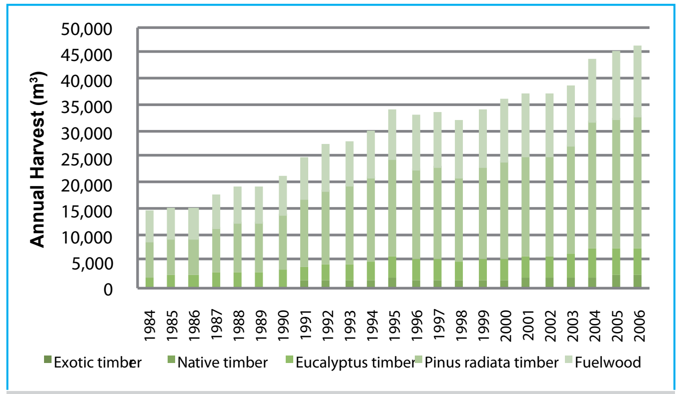

Figure 23. Annual logging of industrial timber and fuelwood, 1984-2006

The greater variability in the emissions curve for the category shown in Figure 19 is explained mainly by the inclusion of forest fires affecting wooded areas, whether native forest or forestry plantations. As Figure 24 shows, the amount of native forest and plantations lost to fire at each year has fluctuated, which explains the variations in gross emissions from this category from one year to the next.

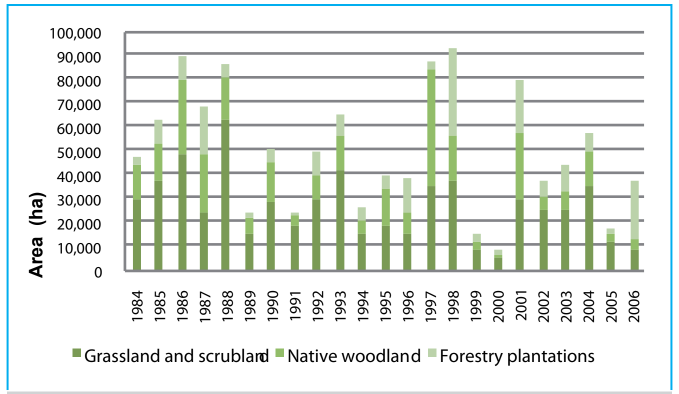

Figure 24. Area of native woodland, forestry plantations, and grassland burned, 1984-2006

Forestry plantations have a predominant impact in the category of 'forest land remaining forest land' and indeed in the LULUCF sector as a whole. In this regard it is important to note, as Figure 25 shows, that although the net balance of forestry plantations has consistently favored carbon capture, this trend has decreased since 2002 due to a sharp rise in logging activity beginning in that year.

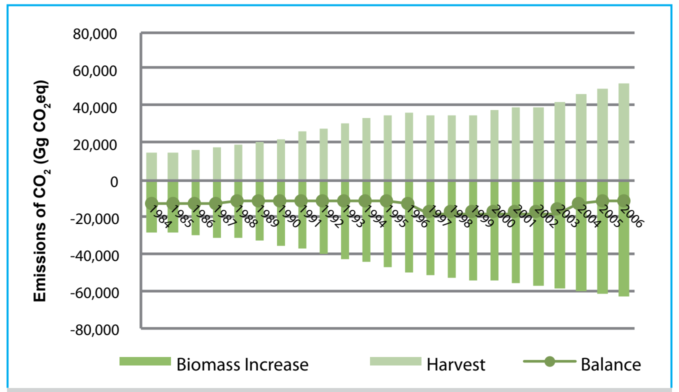

Figure 25. GHG emissions, removals, and balance from forestry plantations, 1984-2006

Figure 26 presents the balance of managed native woodland, in which capture has been constant owing to an increase in biomass, mainly from the inclusion of second-growth forested lands. Emissions from logging have risen steadily, however, bringing about a net reduction in the year-on-year GHG balance.

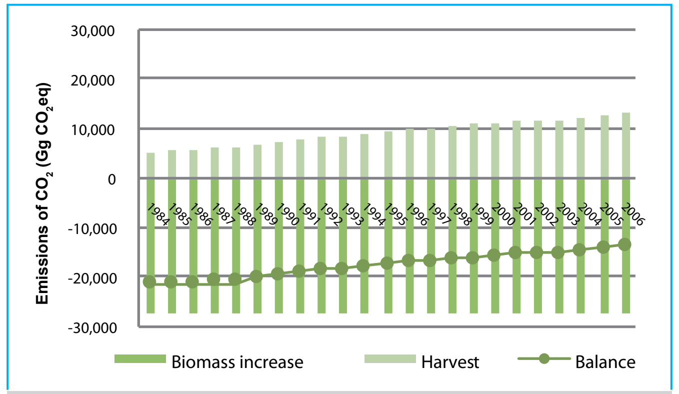

Figure 26. GHG emissions, removals, and balance from native woodland, 1984-2006

Meanwhile, in the subcategory of 'other land converted to forest land', changes in land use have included abandonment (grassland, cropland, settlements, wetlands, and other land converted to native woodland) and forestation (grassland/scrub land, cropland, settlements, wetlands, and other land converted to forestry plantations). The main prior uses of abandoned lands were grassland/scrub land and cropland. Figures for abandonment only account for sequestration of atmospheric carbon, with an annual capture of 428 Gg CO_2eq.

In the case of forestation, Table 22 shows the annual rate of land converted from other uses to forestry plantations, disaggregated at a regional level. The main prior uses of land repurposed for forestry were grassland/scrub land and cropland.

TABLE 22. Annual forestation (ha), by administrative region

Region	Grassland and Scrubland	Cropland	Settlements	Wetlands	Other land	Total
XV	n/a	n/a	n/a	n/a	n/a	n/a
I	n/a	n/a	n/a	n/a	n/a	n/a
II	n/a	n/a	n/a	n/a	n/a	n/a
III	n/a	n/a	n/a	n/a	n/a	n/a
IV	n/a	n/a	n/a	n/a	n/a	n/a
V	936	276	3	0	14	1,229
XIII	158	40	0	0	0	198
VI	913	795	0	2	5	1,716
VII	n/a	n/a	n/a	n/a	n/a	n/a
VIII	13,753	14,214	10	20	61	28,057
IX	5,892	8,310	1	28	22	14,252
XIV	5,030	105	1	59	147	5,341
X	1,964	3	0	6	4	1,978
XI	n/a	n/a	n/a	n/a	n/a	n/a
XII	0	0	0	0	0	0
Total	**28,646**	**23,743**	**14**	**115**	**253**	**52,771**

Source: CONAF

Gross annual capture from forestation was 713 Gg CO_2eq, while annual emissions amounted to 115 CO_2eq, giving a net annual balance of 598 Gg CO_2eq captured.

Figure 27 presents emissions, capture, and balances in CO_2eq for the grassland/scrubland category.

In 1994 these emissions represented 1.2% of the sector's total, and were produced by grassland and scrubland fires, land clearing and deforestation (plantations converted to grassland and scrubland). Sequestration in this category accounted for 0.2% of the sector total, owing to land clearing and regeneration.

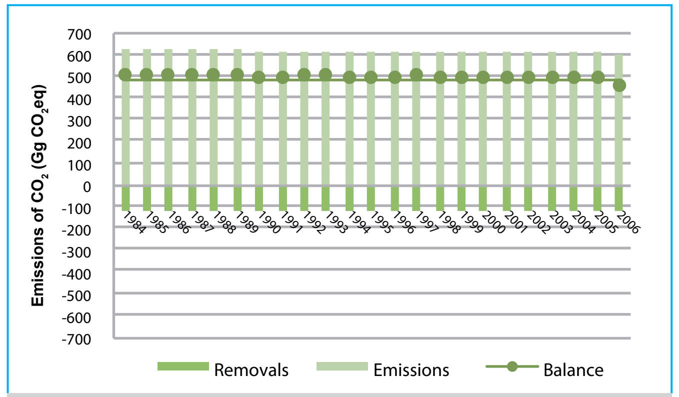

Figure 27. GHG emissions, removals, and balance from the scrubland and grassland category, 1984–2006.

In the subcategory of 'grassland/scrubland remaining grassland/scrubland', only the emission of gases other than carbon dioxide was included. Carbon dioxide is deemed to be in balance, as carbon captured through increases in the biomass is released during the same year either by fire or through the natural cycle of the grassland.

Figure 28 shows the area of grassland and scrubland and affected by fires. Given the nature of this phenomenon, the area affected has fluctuated significantly between years, peaking at a maximum of 62,862 hectares in 1988 and averaging 26,281 hectares over the period studied.

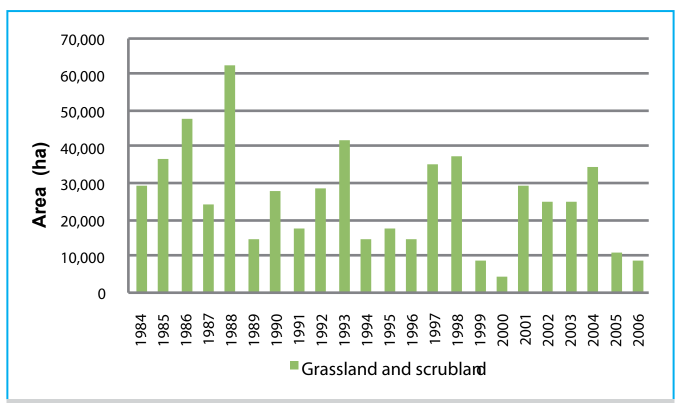

Figure 28. Area of grassland and scrubland burned, 1984-2006

Figure 29 shows emissions of gases other than carbon dioxide, mainly methane, produced by grassland and scrubland fires. Average emissions amount to 20 Gg CO_2eq, with a maximum of 34 Gg CO_2eq in 1987.

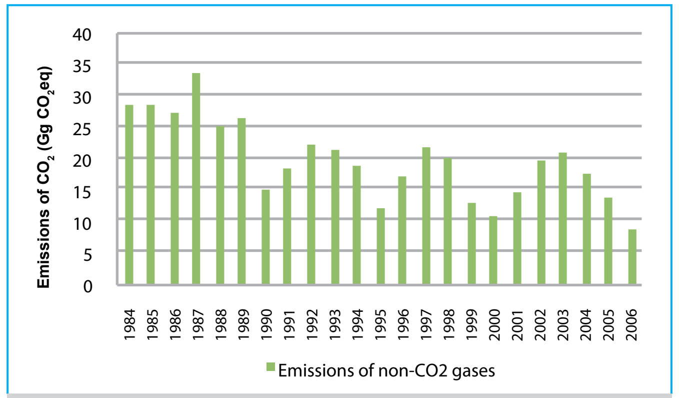

Figure 29. Emissions of non-CO_2 gasses from grassland and scrubland fires, 1984-2006

Finally, in the subcategory 'other land converted to grassland/scrubland', changes in land use arise through land clearing (native woodland converted to grassland and scrubland), felling (forestry plantations converted to grassland and scrubland) and regeneration (cropland, settlements, wetlands, and other land converted to grassland and scrubland).

Table 23 shows the annual area of other land types being converted to grassland and scrubland, disaggregated at a regional level. The main land uses undergoing regeneration are cropland and other land.

Photo: Chilean Forest Corporation (CONAF)

TABLE 23. Annual area of Other Land converted to Grassland/Scrubland (ha), by administrative region

Region	Land clearing	Felling	Regeneration				Total
	Native woodland n/a	Forestry plantations	Cropland	Settlements	Wetlands	Bare soil	
XV	n/a	n/a	n/a	n/a	n/a	n/a	n/a
I	n/a	n/a	n/a	n/a	n/a	n/a	n/a
II	n/a	n/a	n/a	n/a	n/a	n/a	n/a
III	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IV	n/a	n/a	n/a	n/a	n/a	n/a	n/a
V	69	12	101	0	0	2	184
XIII	31	0	32	0	3	0	66
VI	1,060	98	16	0	24	373	1,569
VII	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VIII	542	843	841	4	0	121	2,350
IX	1,190	652	149	1	31	53	2,077
XIV	319	38	2	0	3	93	456
X	589	62	4	0	0	161	815
XI	n/a	n/a	n/a	n/a	n/a	n/a	n/a
XII	135	0	0	0	0	0	135
Total	**3,935**	**1,704**	**1,144**	**5**	**62**	**802**	**7,651**

Source: INIA (2010)

The annual rate of sequestration in land clearing is 72 Gg CO_2eq, while annual emissions amount to 330 Gg CO_2eq, giving a net annual balance of 258 Gg CO_2eq released. For deforestation, annual rates are 242 Gg CO_2eq released and 31 Gg CO_2eq captured, giving a net balance of 211 Gg CO_2eq emitted. In the case of regeneration, annual capture amounts to 18 Gg CO_2eq and gross emissions are 12 Gg CO_2eq, for a net balance of 6 Gg CO_2eq sequestered.

Figure 30 presents the emissions, captures, and net balance in CO_2eq for the category 'cropland'. Emissions in this category represented 0.4% of the LULUCF sector total for 2000, generated from land clearing and removal of native woodland to create cropland. Carbon capture in this category represented just 0.1% of the total for the sector, arising from the clearing and re-clearing of lands (grassland/scrubland, settlements, wetlands, and other land converted to cropland). The main types of land being converted to settlements were cropland and grassland/scrubland.

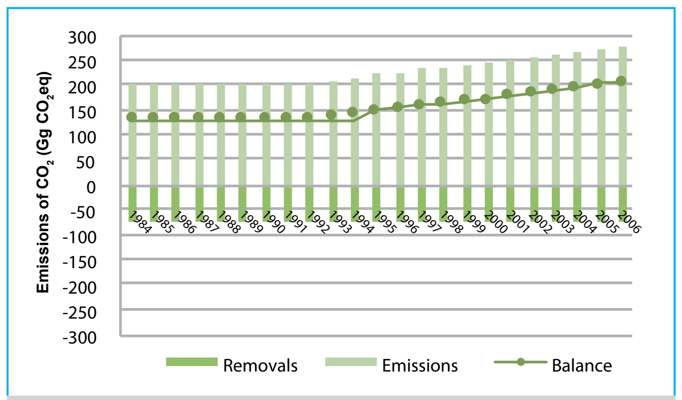

Figure 30. GHG emissions, removals and balance for the cropland category, 1984–2006

Land clearing associated with cropland accounts for annual carbon capture of 5 Gg CO_2eq, while annual emissions amount to 20 Gg CO_2eq, giving a net annual balance of 15 Gg CO_2eq released. For deforestation, annual rates are 97 Gg CO_2eq released, 13 Gg CO_2eq captured, and a net emission balance of 84 Gg CO_2eq. In the case of land re-converted to cropland, the annual rate of capture is 55 Gg CO_2eq, while gross emissions stand at 60 Gg CO_2eq and the net balance is 5 Gg CO_2eq released.

Emissions from the 'settlements' category represented 0.2% of the overall LULUCF total in 2000. Sequestration amounted to just 0.04% of the annual total, arising from the only item in this category – urban growth (urbanization), under the subcategory 'other land converted to settlements'. Annual carbon capture for this subcategory accounts for 23 Gg CO_2eq, while annual emissions amount to 109 Gg CO_2eq, with a net annual balance of 86 Gg CO_2eq released. The subcategory 'settlements remaining settlements' was not included due to a lack of information.

The final LULUCF category is 'other land', which includes all areas without vegetation owing to either natural or human causes. This land can only emit CO_2eq as vegetation decays and this activity amounted to 0.09% of emissions in the sector. Degradation of vegetation is a subcategory under 'land converted to other land'. The main land uses being converted to this use include grassland/scrubland and forest lands. Annual emissions in this subcategory amount to 45 Gg CO_2eq. The subcategory 'other land remaining other land' was not included due to a lack of information.

Methodology

The LULUCF sector has seen the most significant changes in methodology since the previous inventory because of the publication of the IPCC 2003 Good Practice Guidance, which introduced major revisions to the 1996 IPCC methodology used in the previous report.

Most importantly, although the country is making progress in improving data in this area, it still lacks the statistical and parametric information required for the complete application of the 2003 methodology. Therefore, out of the carbon pools recognized by the IPCC (above ground biomass and below ground biomass, litter, dead wood carbon, and soil organic carbon), only living above ground biomass is quantified.

In general, Tier 1b methodologies were applied, with regional disaggregation of activity data for the sector. An exception was items relating to increases in forest biomass and forestry logging/harvest, in the category 'forest land remaining forest land', for which Tier 2 methodology was used (including the application of default emission factors and country specific expansion rates). Table 24 summarizes the inputs used to quantify each subcategory.

TABLE 24. Inputs for calculations in the LULUCF sector

Category	Subcategory	Tier	Greenhouse gases released	Inputs
Forest land (FL)	Forest land remaining forest lands	1b,2	CO_2, CH_4, N_2O	Land use matrices (kha)
	Land converted to forest lands	1 b	CO_2, CH_4, N_2O	Land use change matrices (kha)
Grassland (GS)	Grassland remaining grassland	1 b	CH_4, N_2O	Land use matrices (kha)
	Land converted to grassland	1 b	CO_2, CH_4, N_2O	Land use change matrices (kha)
Cropland (AL)	Cropland remaining cropland	1b	CH_4, N_2O	Land use matrices (kha)
	Land converted to cropland	1 b	CO_2, CH_4, N_2O	Land use change matrices (kha)
Settlements (S)	Settlements remaining settlements	1 b	CH_4, N_2O	Land use matrices (kha)
	Land converted to settlements	1 b	CO_2, CH_4, N_2O	Land use change matrices (kha)
Wetlands (WL)	Wetlands remaining wetlands	---	CH_4, N_2O	Land use matrices (kha)
	Land converted to wetlands	1 b	CO_2, CH_4, N_2O	Land use change matrices (kha)
Other land (OL)	Other land remaining other land	---	CH_4, N_2O	Land use matrices (kha)
	Land converted to other land	1 b	CO_2, CH_4, N_2O	Land use change matrices (kha)

3.4.6 Waste

General aspects

This sector draws together emissions of methane and nitrous oxide resulting from microbiological processes that occur in the decay of organic matter under anaerobic conditions, mainly in solid waste disposal sites (managed and unmanaged), as well as emissions of nitrous oxide from the decomposition of human waste, and anaerobic treatment of domestic and industrial wastewater in liquid and solid phases (sludge). As in the case of agriculture, the IPCC methodology assumes that the CO_2 balance is zero, as emissions of this gas arise from a substrate produced by photosynthesis in annual cycles, or substrates derived from other organic substrates. Categories and subcategories in this sector are shown in Table 25.

TABLE 25. Categories and subcategories of anthropogenic waste

Sector	Category	Subcategory
Anthropogenic waste	Solid urban waste	Final disposal of solid urban waste
	Liquid waste	Domestic wastewater and sludge treatment
		Wastewater and sludge treatment
	Incineration of hospital waste	Incineration of human remains and cadavers, incineration of hospital waste
	Nitrous oxide released from human feces	Human feces produced by the urban population

Trends observed in subsector emissions in this category for the time series analyzed are highly linked to the availability of activity data, significant recent changes in certain economic activities in the country, and environmental improvements over the past decades in Chile in the areas of domestic solid and liquid waste management.

Total CO_2eq emissions in the sector (Figure 31) fall almost entirely within the category of solid urban waste, with a contribution that ranged from 88% to 94% of emissions over the time series. This category of waste management has also witnessed the most change in recent years in Chile. Looking at figures over the 1984–2006 period shows rising emissions from this sector, understandable since these depend on the quantity of solid urban waste generated, which is related in turn to urban development, which grew steadily over the period.

Emissions arising from the 'incineration of hospital waste' category account for the smallest proportion in this sector, mainly because the mass of material incinerated is very low. It should be noted, though, that this information is fragmented and coverage is probably not 100%.

Nitrous oxide emissions from the 'human waste' category are proportional to variations in urban population. Therefore, as the country's population has grown, nitrous oxide emissions in this category have increased.

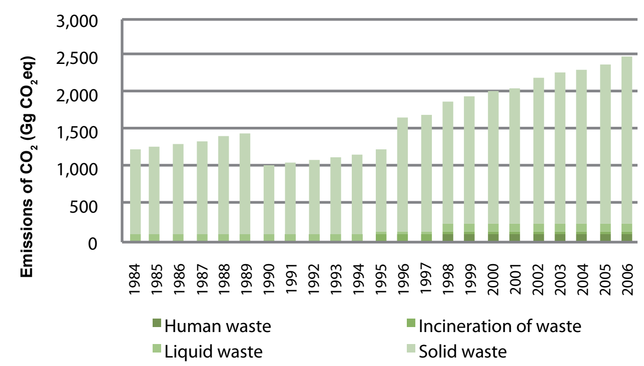

Figure 31. GHG emissions from the anthropogenic waste sector, by subcategory, 1984-2006

Regarding methane emissions from solid urban waste, the anomalous figures between 1990 and 1997 are a result of changes in the technology used for Chile's waste treatment systems:

- From 1984 to 1990, solid urban waste was not treated; or in more precise terms, treatment was through uncontrolled systems, with almost no methane recovery.
- From 1991 to 1996, dump sites (semi-anaerobic systems) with approximately 50% methane recovery, bringing about a significant drop in methane emissions.
- Since 1997 landfills have been installed, bringing about a rise in methane emissions as this technology uses fully anaerobic waste treatment that increases methane recovery (≈75%) but also increases emissions of this gas.

home

The liquid waste category accounts for a smaller share of emissions in the waste sector. As in the case of solid urban waste, significant changes in treatment technologies have been introduced, which is reflected over the period as changes in activity data sources, emission factors, and inputs associated with emission estimation systems, as the following timeline describes:

- 1984-1990: default IPCC factors used owing to a lack of information on treatment of wastewater and liquid industrial waste (LIW).
- 1991-1997: information on wastewater treatment submitted annually by the Superintendencia de Servicios Sanitarios (government body tasked with regulating companies providing wastewater treatment services).
- 1998 - 2004: liquid industrial waste data using information provided by the updated LIW inventory of the Superintendencia de Servicios Sanitarios in 1998, and updated information on liquid industrial waste in the Región Metropolitana (Greater Santiago) in 2004.

Emissions of liquid industrial waste were assumed to be constant between 1998 and 2004, entirely because no information exists on the treatment of liquid industrial waste, whereas information on domestic wastewater is available. Therefore, the rate of generation of liquid industrial waste and sludge is taken to be constant across the time period.

Methodology

In general, Tier 1b methodology was applied (since regional disaggregation of activity data for the sector was considered, as explained above). Table 26 shows a summary of the inputs used to calculate emissions for categories in the sector.

TABLE 26. Inputs for calculating waste emissions

Category	Tier	Gases released	Inputs
Solid urban waste	1b	CH_4	Solid urban waste deposited
Liquid waste	1b	CH_4	Volume of industrial and domestic wastewater treated at specific treatment plants
Incineration of hospital waste	1b	CO_2 CO, NMVOC NOx	Human remains and hospital waste incinerated
Other: emission of nitrous oxide from human waste	1 b	N_2O	N excreted by urban population connected to sewerage

Photo: Ministry of Agriculture. Government of Chile

4. GHG EMISSIONS MEMO ITEMS

In accordance with the GHG reporting methodology established by the UNFCCC, certain emissions should not be included in emission totals reported in national inventories, but should be reported as Memo Items separately from the rest of the country's emissions. Such emissions include greenhouse gas emissions generated through the consumption of fuel used in international transport (bunker fuels) and CO_2 emissions generated from the use of wood and biogas as energy sources.

4.1 MEMO ITEM: GHG EMISSIONS FROM BUNKER FUELS

The consumption of fuel in international transport, called bunker fuel, occurs in air transport (mainly jet fuel and aviation gasoline) and maritime transport (diesel and petroleum fuels).

In Chile, the current arrangement for compiling information on fuel consumption, undertaken in the context of the National Energy Balance, presents difficulties in assigning emissions from these fuels to domestic versus international air and sea transport, as statistics for fuel consumption in domestic and international transport are combined.

In building Chile's inventory, an effort was made to design a methodology that allowed the disaggregation of domestic and international fuel consumption, which would enable emissions associated with international transport to be identified as such (Sistemas Sustentables, 2010). Basically, records of fuel consumption by international transport companies were obtained from the Chilean Customs Service. These records are kept because international transport companies are eligible for reimbursement of value added tax on fuel sold in the country. Currently, companies must register information with the Customs Service, declaring the volume and type of fuel bought and attaching purchase receipts. This information is available for all years since 1991.

This information was used to disaggregate the fractions of fuel consumed in domestic transport from those used in international transport for both air and sea transport. The data obtained for international transport was used to build a time series for 1991-2006. Information for earlier years (1984-1990) was extrapolated by the consulting firm tasked with this project, arriving at the results shown in Figure 32.

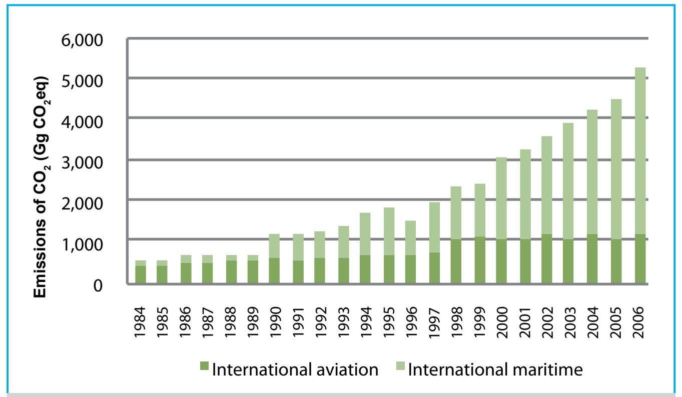

Figure 32. GHG emissions from international air and maritime transport, 1984-2006

Both classes of emissions rose during the period, with international maritime transport becoming predominant in this area during recent years. The result is in keeping with Chile's increasing insertion in international trade routes, as most of the country's exports are shipped by sea.

4.2 MEMO ITEM: EMISSIONS FROM CONSUMPTION OF WOOD FUEL AND BIOGAS

Emissions from the consumption of wood fuel and biogas included in the inventory arise from energy use. In the Chilean inventory, CO_2 emissions from these activities are presented as Memo Items. Meanwhile, emissions of greenhouse gases other than CO_2 are reported under the energy sector.

Information used in the compilation of the National Inventory is derived from the National Energy Balance, where the consumption of wood fuel comes under consumption in the energy sector and power plants. These figures show that wood fuel consumption is significant in Chile, most notably at the residential level and to a lesser degree in the industrial and commercial sectors. Taken as a whole, wood fuel and biogas consumption reported in 1984 accounted for 87,000 TJ (24% of the country's primary energy consumption in that year), reaching a maximum over the reporting period of 188,000 TJ in 2006 (corresponding to 18% of the country's primary energy consumption in that year). These values are equivalent to 8,600 Gg CO_2 for 1984 and 18,563 Gg CO_2 for 2006, the final year of the series – which is shown in full in Figure 33.

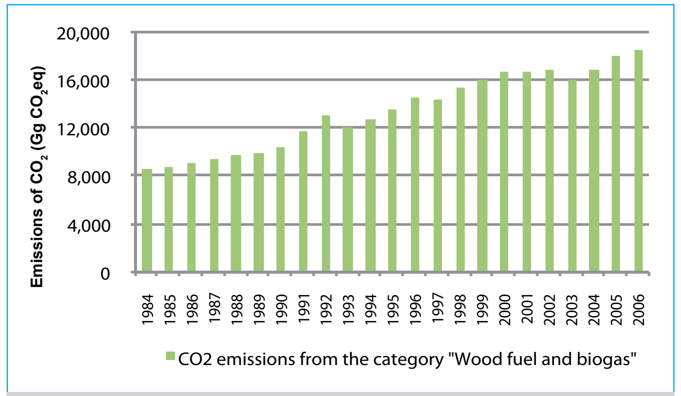

Figure 33. GHG emissions from the wood fuel and biogas sector, 1984-2006

5. UNCERTAINTY IN CHILE'S NATIONAL GHG INVENTORY

In Chile, the main entities that provide official activity data used to build the National Inventory do not generate sufficient annual information to complement the non-parametric data used in the Inventory, nor do they provide the statistics needed to gauge the uncertainty of the activity data they generate (INIA, 2010). As long as these bodies do not calculate the uncertainties associated with the data that they submit, it becomes impossible to determine comprehensively the uncertainty associated with emission calculations in the National Inventory. Because of the incomplete nature of this information, activity data based on estimations will have higher degrees of uncertainty; however, as official data on uncertainties associated with activity data are not available, uncertainty is taken to be zero, due to the lack of information.

The following section provides details about the absence of uncertainty estimates for activity data reported by different official sources (INIA, 2010):

- Instituto Nacional de Estadísticas (National Statistics Institute, INE): provides activity data on livestock populations by region, and at the national level, by species: cattle, hogs, horses, goats, sheep, camelids, and birds; cultivation of vegetables, fruit trees, annual crops, forage, and grassland; production of beer, alcoholic beverages, wines; sugars; margarine and solid fats; bread and animal fodder. This information is submitted on an annual basis, with no associated estimation of error or uncertainty.
- Food and Agriculture Organization of the United Nations (FAO): Provides information on the consumption of nitrogen-based fertilizers and activity data, similarly with no associated error or uncertainty data. These activity data are used in the Agriculture category of the inventory.
- Instituto Forestal (Forestry Institute – INFOR): Provides data on area of forested land, native species and forest fires, as well as pulp and paper. This information is submitted on an annual basis, but with no associated estimation of error or uncertainty.
- Corporacion Nacional Forestal (National Forestry Agency – CONAF): Provides data on land use, land use area, and land use change, and associated activity data; changes in levels of forest biomass and other wood resources, changes in the use of forest lands, abandonment of cropland. Neither INFOR nor CONAF offer information on errors in activity data and associated uncertainty percentages.
- Ministry of the Environment (formerly CONAMA): Compiles information on quantities of solid urban waste (SUW), quantity of SUW by final disposal and type of SUW (uncontrolled landfill, controlled landfill, biomass conversion). These activity data are used in the Inventory category of Waste and are not complete: SUW composition is not available for all years included in the inventory, for example. Additionally, information is not updated on an annual basis and activity data include no estimation of associated uncertainty or error. No current information is available, which represents a gap in activity data, as well as in associated errors or uncertainty percentages in this area.
- Superintendencia de Servicios Sanitarios (Sanitary Services Superintendency– SISS): Annual reports provide information on wastewater, wastewater treated, population connected to sewerage systems, and types of wastewater treatment plants by region. This information is published on an annual basis, and therefore the category of liquid waste – specifically the subcategory of domestic sludge and wastewater treatment – includes up to date activity data for all years since 1990. No information is published regarding associated error or uncertainty percentages. Activity data for liquid industrial waste, required for the subcategory of 'treatment of liquid industrial waste and sludge', are derived from the National Liquid Industrial Waste Inventory, published in 1998. No updated information for the country as a whole exists for more recent years, and this category therefore lacks annual activity data, as well as information on uncertainty or errors associated with these data.
- Instituto del Cemento y del Hormigón de Chile (Chilean Cement and Concrete Institute, ICH): Generates activity data related to cement, published on an annual basis, but without associated error or uncertainty information.
- Empresa Soprocal Calerias y Industria (lime production): activity data for lime production, submitted annually, but without associated error or uncertainty.
- Empresa Inacesa (Industria Nacional de Cementos S.A.): Generates activity data for lime, submitted annually, but without associated error or uncertainty data.
- Servicio Nacional de Aduanas (National Customs Service): Compiles activity data on sodium carbonate, since 1990, submitted annually, but without associated error or uncertainty.
- Ministerio de Obras Publicas (Ministry of Public Works, MOP): generates activity data for asphalt, submitted annually since 1998, but without associated error or uncertainty.
- La Asociacion de Industriales Químicos (Chemical Industry Association, ASIQUIM): Generates activity data for nitric acid, ethylene, formaldehyde, phthalic anhydride, polystyrene, polythene, and sulfuric acid, submitted annually since 1985, but without associated error or uncertainty values.
- Comision Nacional de Energía (National Energy Commission, CNE): Compiles activity data for methanol, submitted annually, but without associated error or uncertainty values.
- Empresa Compañía Minera del Pacífico (CAP): Generates activity data for steel, submitted annually, but without associated error or uncertaintyvalues.

Photo: Ministry of the Environment. Government of Chile

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CHAPTER 3

Chile's Vulnerability and Adaptation to Climate Change

PHOTO: MINISTRY OF THE ENVIRONMENT

HOME

1. INTRODUCTION

Chile is a country that is highly vulnerable to climate change because of its low-lying coastal areas, arid, semi-arid, and woodland areas, and susceptibility to natural disasters. Other factors that contribute to the country's vulnerability include the existence of areas prone to drought and desertification, its urban air pollution problems, and the mountain ecosystems of the Coastal and Andes ranges.

Studies conducted in Chile in recent years that address the impacts of and vulnerability to climate change have highlighted this situation while facilitating a better understanding of the phenomenon and its potential negative effects on the country's sustainable development plans.

This chapter presents information produced in Chile on the country's current vulnerability and the projected impacts of climate change. It also describes early adaptation efforts, including the formulation of short-, medium-, and long-term strategies that the country must implement if it is to successfully protect the country's social framework, economy, and natural systems from predicted changes.

Chile is already experiencing new climate trends, principally changes in precipitation and temperatures throughout the country. Studies of temperature changes over the 1979-2006 period show a downward trend in the ocean and coastal regions, but temperature increases have been observed in the Central Valley and particularly in the Andes Mountains, which is a key natural reservoir of water resources (Falvey and Garreaud, 2009; Carrasco et al, 2008).

In regard to temperature projections, two of the emissions scenarios forecast by the Intergovernmental Panel on Climate Change – A2 and B2 – have been found in the "Study on Climate Variations in Chile for the 21st Century" (U. de Chile/Geophysics Dept., 2006). These include temperature changes of between 1˚C and 3˚C (moderate scenario) and between 2˚C and 4˚C (severe scenario) throughout the country, with the most significant variations affecting Andean regions. The severity of these forecasts diminishes from north to south, and only in small areas of the far south of Chile is projected warming—under the moderate scenario—less than 1˚C. The study also indicates that, seasonally, projected temperature increases are greater during the summer, with warming of over 5˚C in certain high altitude areas of the Andes.

Precipitation projections show a significant difference between the two sides of the Andean watershed, with reductions on the western side (continental Chile), particularly at moderate latitudes and during the summer and autumn seasons. This contrast is most accentuated during the summer months under the severe scenario, with precipitation in certain parts of South-Central Chile being reduced to one-half or even one-quarter of current levels, while precipitation is projected to double immediately to the East of the Andean divide.

Practically all socioeconomic activities in Chile are linked to the climate. Some, such as agriculture and forestry, are directly dependent, as the climate is a key factor in the existence and health of these industries' primary resources. In other areas water resources play an extremely significant role, which means that any impact on water availability unleashes ripple effects on economic activities that rely on those resources. Other sectors of the economy are not directly related to the climate but are linked to sectors that are, and are therefore also susceptible to the impacts of climate change (ECLAC, 2009).

Water resources are an area of maximum priority, as projections point to a situation of great concern in the medium and long-term, with negative consequences most productive activities in Chile and additional pressures on the environment. In particular, reduced water availability is expected in many river systems, which will affect electricity generation, drinking water supply, agriculture, and industrial activities such as mining.

Glaciers are strategic reserves that contribute water to river systems during the winter and produce flows in arid regions. In Chile, most glaciers are retreating as a result of changes in historic climate variables. This factor will particularly affect the availability of water in river systems where melt water is significant, particularly in North-Central Chile.

The agriculture and forestry sector will also be affected by changes in patterns of precipitation and temperature, which will be reflected in yields, with variations by region and by species. The problem of reduced precipitation will be aggravated by a potential reduction in the availability of water for irrigation if climate change also affects groundwater resources and the replenishment of reservoirs. The changes in productivity forecast for the agriculture and forestry sector will also increase vulnerability associated with social and economic factors. This chapter includes an analysis of this vulnerability for municipalities throughout the country.

Chile possesses zones containing biodiversity of global significance due to the high level of endemism and the significant anthropogenic threats these species face. The two key areas are the Valdivia Mediterranean-rainforest hotspot (the largest area) and the tropical Andes hotspot (Altiplano zone). Climate change will affect the country's biodiversity; the terrestrial ecosystems most vulnerable to these changes are likely the Mediterranean ecosystems and the wetlands of the high Andes.

Scientific research shows that the great majority of species are expected to see their distribution ranges reduced, though only two extinctions are projected. This information has been adjusted for restrictions on species range brought about by inherent factors and/or by human impacts on habitat.

Figure 1 summarizes the impacts of climate change in Chile and their relation to climate projections. It should be noted that not all effects will be negative; some regions of the country will benefit from increased productivity in some economic sectors.

Photo: Ministry of the Environment. Government of Chile

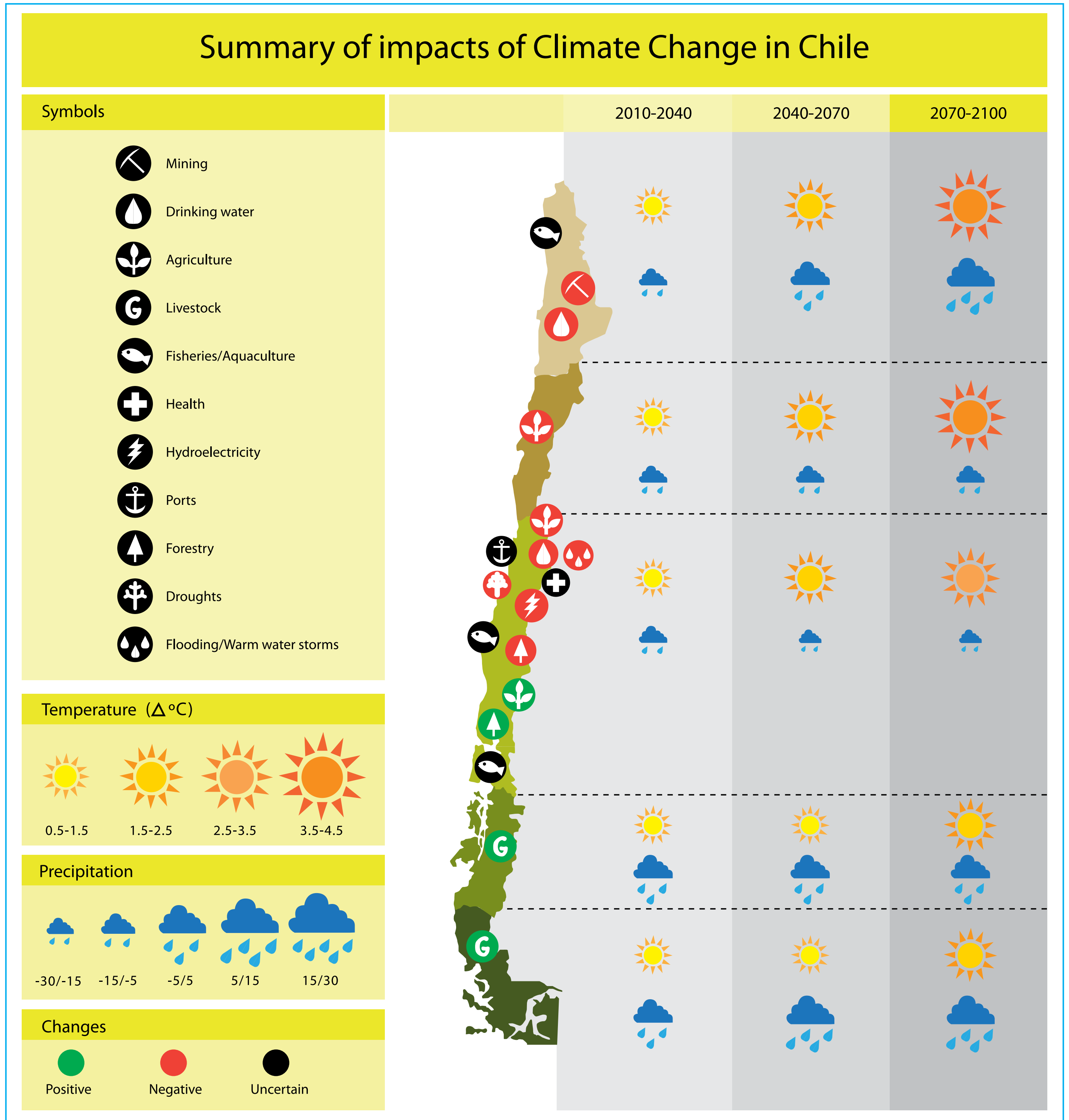

Figure 1. Schematic representation of the impacts of climate change and their relation to climate projections
Source: ECLAC, 2009

This information represents a significant advance for Chile and will inform decision making around climate change, a phenomenon that is riddled with uncertainty in terms of time, space, and magnitude. The information was generated primarily under the National Climate Change Action Plan (NCCAP) and in preparation for the Second National Communication, and will allow the country to begin the first stage of developing and implementing adaptation plans for each sector.

2. GENERAL BACKGROUND AND NATIONAL POLICIES

One of the main climate change challenges facing humankind is to adequately characterize and understand the vulnerability of natural and socioeconomic systems. By generating this knowledge, we can hope to implement adaptation policies and measures compatible with the goals of sustainable development. In order to be effective, adaptation processes must be economically efficient and designed to contribute to the well being of society. In this regard, adaptation policies and measures should be based on the framework of a country's sustainable development goals.

The concept of vulnerability is defined by the IPCC (2001) as: "[...] the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes." Vulnerability therefore is about the exposure of natural and socioeconomic systems and the sensitivity and adaptive capacity of those systems. A system's vulnerability and capacity for adaptation to climate change are thrown into sharp relief when extreme events associated with climatic variability occur. These events allow the evaluation of potential impacts or residual ones that arise after the application of adaptation measures to climate change or variation (Conde, 2003).

Chile is a country with a high level of vulnerability to extreme climatic events. Extreme hydrological and meteorological conditions have caused damage and disasters affecting broad socioeconomic segments. Characterizing the climate, climate variability, and climate change is therefore important for adequately designing climate change adaptation policies and measures (IDB-UN, 2007).

2.1 VULNERABILITY AND ADAPTATION IN THE NATIONAL CLIMATE CHANGE ACTION PLAN

In 2008 the main lines of action in matters relating to vulnerability and adaptation were set forth in the National Climate Change Action Plan (PANCC in Spanish), described in detail in the first chapter of this report, National Circumstances. It is worth noting that for the first three years of the Action Plan's implementation, the area of vulnerability and adaptation emphasizes conducting studies on climate change impacts and vulnerability as the first step towards proper adaptation policy planning. At the same time several environmental measures have been launched in the country to strengthen its socioeconomic and natural systems, even in areas in which developing climate change adaptation strategies is not the main objective.

Importantly, in addition to activities spearheaded under the PANCC, other studies relating to vulnerability and adaptation to climate change have been conducted that have contributed to the goals of the Action Plan. These include "Economía regional del cambio climático: Chile" (Regional Economics of Climate Change in Chile), a study coordinated by the Centro de Cambio Global at the Pontificia Universidad Católica de Chile under a joint initiative of ECLAC, the Inter-American Development Bank, the European Union, and the governments of the United Kingdom and Denmark. Within the framework of this project (ECLAC, 2009), in 2009 a series of sectoral studies were conducted in coordination with the same Chilean government bodies that are partners in the PANCC. These studies sought to assess the costs and benefits of climate change adaptation measures, and parts of them have been used in preparing this Second National Communication. Mining and sanitation services were also analyzed in the studies, mainly in terms of water usage and access to water resources. The studies also contributed to the economic assessment of impacts on the agriculture and forestry sector.

Photo: Ministry of the Environment. Government of Chile

3. CHILE'S VULNERABILITY TO CLIMATE CHANGE

3.1 CLIMATE TRENDS

As highlighted in Volume 1 of the 4th Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), significant climate change has been observed at a global level since the mid-19th century. This has been reflected in global average temperature data, sea levels, and snow coverage. Mountain glaciers and snow cover have experienced overall reductions in both hemispheres, and the melting of glaciers and ice caps has contributed to the rise in sea levels.

Changes have also been observed in Chile, principally in precipitation and temperatures, as these are the variables that are measured at the national level. Examining data for 1930 to 2000, the area of the country between Coquimbo and Temuco (30°S to 39°S) displayed a trend of reducing precipitation up until around 1970. Subsequent increases in the frequency of relatively rainy winters have contributed to a rise in precipitation since that time, reaching the highest levels between 1955 and 1985 (Universidad de Chile, Geophysics Dept., 2006). Rainfall in the South-Central and Southern regions showed a significant upward trend until the mid-1970s, then subsequently fell. Meanwhile, North-Central Chile (30°S - 34°S) has seen no significant variation in average annual precipitation, and more southerly areas have experienced a drop in these levels, particularly between 40°S and 44°S (Quintana & Aceituno, 2006).

Changes in precipitation in Chilean territory south of 30°S have been characterized by significant variability at the decadal level (i.e. variable time periods of the order of ten years). These have been linked to changes operating on the same time scale as the Southern Oscillation, as well as the El Niño and La Niña phenomena and the Pacific decadal Oscillation. The El Niño phenomenon is associated with an increase in precipitation throughout much of the country, and coincides with major hydrological and meteorological disasters (IDB-UN, 2007).

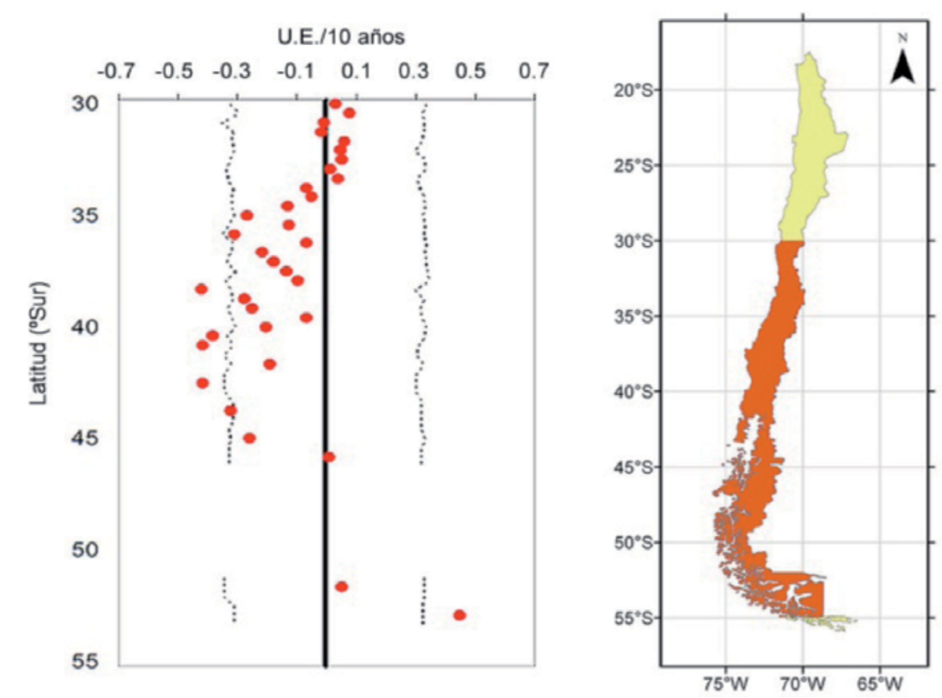

Figure 2. Linear trend in annual precipitation in Chile to the south of 30°S, 1970 – 2000
Source: Quintana & Aceituno, 2006

Figure 2 shows the magnitude of seasonal trends in Chile south of 30°S, between 1970 and 2000. Trends are expressed as changes in normalized values over each 10-year period. The dotted lines indicate the limits of positive and negative trend values at a p=0.05 level of statistical significance.

Temperatures in Chile generally vary slightly with latitude in coastal regions owing to the effects of the Pacific Ocean. On the coast, average annual temperatures range around 17°C in the North, 15°C in the Central region, and 6°C in the southernmost zone. In other areas, topography is the main factor influencing temperatures. Monthly variation is linked to seasonal variations in the solar azimuth. Average surface temperatures in non-tropical coastal areas of South America have shown little variation since 1940 or 1950, except for the south central region, where a drop in temperatures has been observed (Aceituno et al., 1992; Rosenbluth et al., 1997). This uniform trend was broken by a sharp rise in the mid 1970s known as the "climate shift" or *salto climático*.

More recent studies of temperature changes between 1979 and 2006 have observed a downward trend in the ocean and in coastal regions, but an upward trend in the Central Valley and even more so in the Andes Mountains (Falvey & Garreaud, 2009; Carrasco et al, 2008). Figure 3 shows a cross-section of Central Chile demonstrating the magnitude of these historic trends. Anomalies are calculated in terms of temperature variation from the average for the 1979-2006 period. The dotted lines show the linear trend for each dataset over the period. The rate of change over the period is also shown. The map on the right shows the locations where these temperature trends were measured.

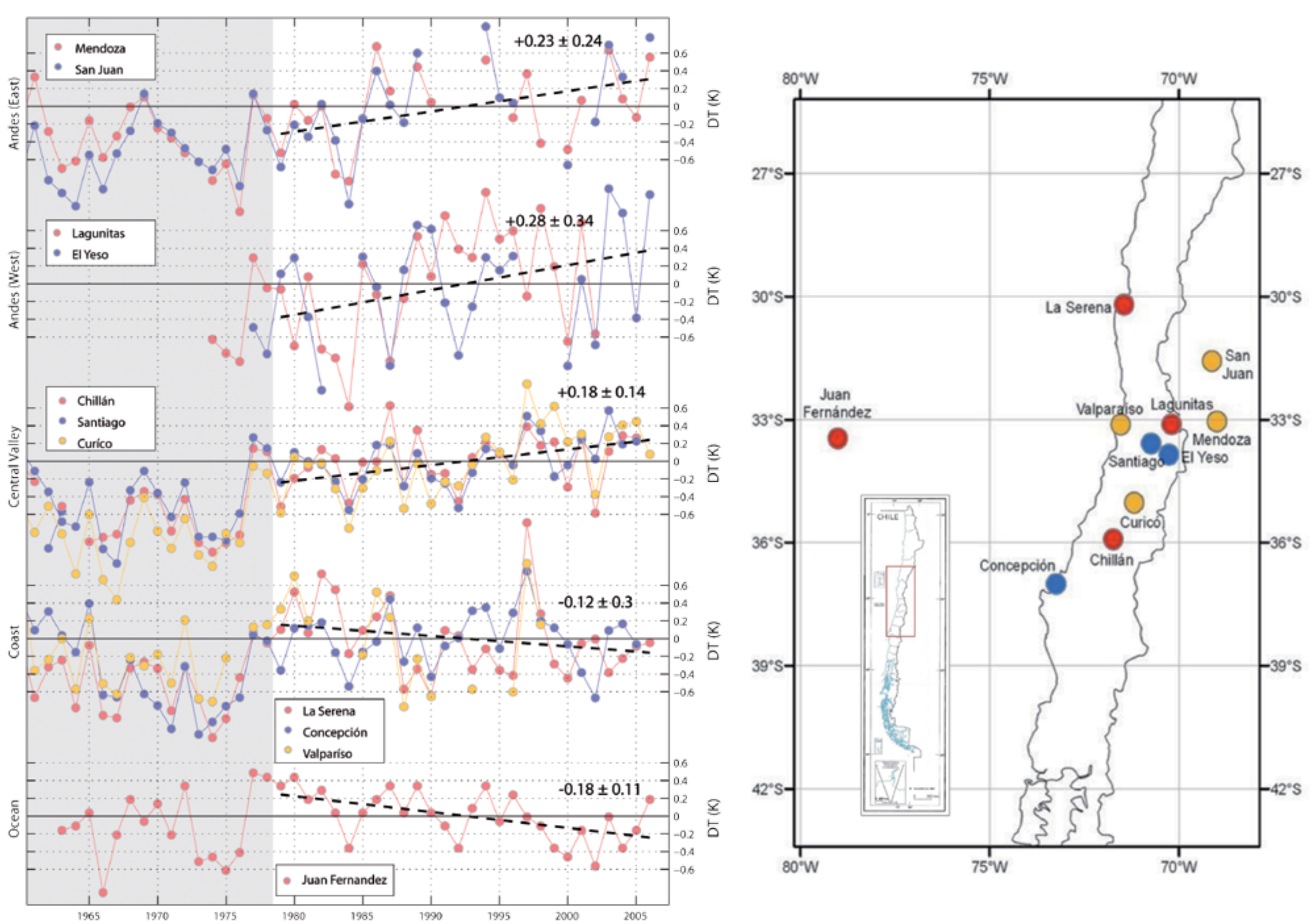

Figure 3. Time series of temperature anomalies in Central Chile (27.5° S – 37.5°S)
Source: Falvey & Garreaud, 2009

3.2 CLIMATE PROJECTIONS

Climate change projections can be obtained using global climate models that simulate the planet's climatic conditions and take into account different levels of GHG emissions and concentrations. The IPCC recognizes approximately 20 models suitable for generating such simulations. Potential GHG emission trends also can be obtained based on different projections for the economy, the global population, and degree of control of anthropogenic emissions. These are referred to as GHG emissions scenarios.

The many models and emissions scenarios used, coupled with our incomplete understanding of certain key aspects of long-term climate models and the chaotic nature of the system itself, mean that climate change projections for different regions of the planet always have some degree of uncertainty.

Greenhouse gas emissions scenarios

GHG emissions scenarios estimate potential future anthropogenic emissions and allow the analysis of how future GHG emissions may affect the climate. In late 2000, the IPCC published official emissions scenarios (IPCC, 2000), basing them on the publication of the IPCC Third Assessment Report, Climate Change 2001. These scenarios were developed in a process that began in 1992 and was updated in 1995 to include the analysis of "driving forces" (such as population increase, socioeconomic development, and technological change) that affect emissions, as well as the methodologies that gave rise to the scenarios proposed in the first report.

Each scenario represents a specific quantitative interpretation of four storylines (taken to be a specific combination of forcing factors), which leads to the organization of the scenarios into "families" (groups of scenarios with similar characteristics). The families of scenarios are as follows:

- The A1 scenario family comprises scenarios A1 F1, A1T and A1 B. The three A1 groups have different technological orientations: intensive usage of fossil fuels (A1F1); usage of non-fossil energy sources (A1T); and balanced use of all types of sources (A1B). The A1 storyline and scenario family describe a future world with rapid economic growth, the global population peaking around 2050 and then decreasing, and the rapid introduction of new, more efficient technologies.
- The A2 storyline and scenario family describe a more heterogeneous world; they are characterized by self-sufficiency and the preservation of local identities. Fertility rates across different regions converge very slowly, leading to continual growth in global population.
- The B1 storyline and scenario family describe a convergent world with a single global population reaching its maximum around 2050 and then decreasing, as in storyline A1, but with rapid changes in economic structures oriented towards service and information sectors, accompanied by less intensive use of raw materials and the introduction of clean technologies with efficient resource usage. This scenario family features many global solutions for economic, social, and environmental sustainability, as well as increased equality, but without additional initiatives related to the climate.
- The B2 storyline and scenario family describe a world based on local solutions to problems of economic, social, and environmental sustainability. This is a world in which the global population increases, albeit at a slower rate than under scenario A2, with moderate economic development levels and slower and less diverse technological change than under storylines B1 and A1. Although this scenario is also oriented towards the protection of the environment and towards social equality, these forces apply mainly at the local and regional levels.

Source: IPCC Working Group III Special Report

The main disadvantage of these global models is their low spatial resolution (hundreds of kilometers) – which may be insufficient for impact analysis. This is a significant limitation, particularly for countries that have coastal regions and complex topographies such as Chile, where the Coastal and Andean mountain ranges delimit a longitudinal narrowness that is on the same order of magnitude as the resolution of current global models.

In order to obtain information with a greater degree of spatial detail for Chilean territory, the Department of Geophysics at the Universidad de Chile was commissioned by CONAMA to prepare a "Study of Climate Variability in Chile for the 21st Century" (U. de Chile, Geophysics Dept., 2006), using the PRECIS regional climate change assessment model and the IPCC A2 and B2 greenhouse gas emissions scenarios. The study covered the national territory with a spatial resolution of 25x25 km^2. It was conducted by creating a regional model for the 2071-2100 period, and one for the 1961-1990 period, so that surface climate changes under emissions scenarios A2 and B2 could be contrasted with data from the recent historical period.

During 2009, preparations for the above mentioned document "The Economics of Climate Change in Chile" were complemented with climate projections prepared by the Geophysics Department of the Universidad de Chile in 2006, with data projected for three periods: an early period, running from 2010 to 2040; an intermediate period, running from 2040 to 2070; and a late period, running from 2070 to 2100 – once again using projections based on the HadCM3 global climate model. Figures 4 and 5 present temperature and precipitation projections associated with scenarios A2 and B2 for these periods, shown here by way of example.

3.2.1 Temperature

Projected temperature changes by the end of the century tend to be positive (warming) in all regions, and are greater under scenario A2. The average temperature change under scenario A2 measured against current temperatures in continental Chile range between 2°C and 4°C and are greater in Andean regions and decreasing from north to south. Only for the southernmost region and under scenario B2 are there some small where warming is less than 1°C (Figure 4). Comparing seasons, warming is greater during the summer – with projected differences of up to 5°C in some Andean highland regions. Projections for the early period (2010-2040) under both scenarios (A2 and B2) show increases throughout the country, but most notably in the Altiplano. Increases are greatest over this period under scenario B2. In the intermediate period (2040-2070), however, scenario A2 shows greater temperature increases in the Altiplano and South-Central areas (Figure 4).

Generation of climate change scenarios using the PRECIS model

PRECIS (Providing Regional Climates for Impact Studies) is a model that can be used to create climate projections at the regional level in order to determine possible impacts. It was developed by the Hadley Center (UK) and emerged in response to the need for a regional-scale climate projection model.

The model has a maximum resolution of 25 x 25 km^2. Although it can be used for many purposes, it is inapplicable in some situations (for example small islands or regions). The model can be applied to the four climate change scenarios proposed by the IPCC: A1FI, A2, B2, and B1, and can simulate specific time periods. Depending on the length of period selected and the power of the computer used, a single simulation can take between hours and months in calculating its projections.

The model takes into account meteorological variables such as atmospheric cycles, cloudiness, precipitation, and solar radiation, as well as the depth and temperature of oceans, and terrestrial topography.

Source: Jones et al., 2004.

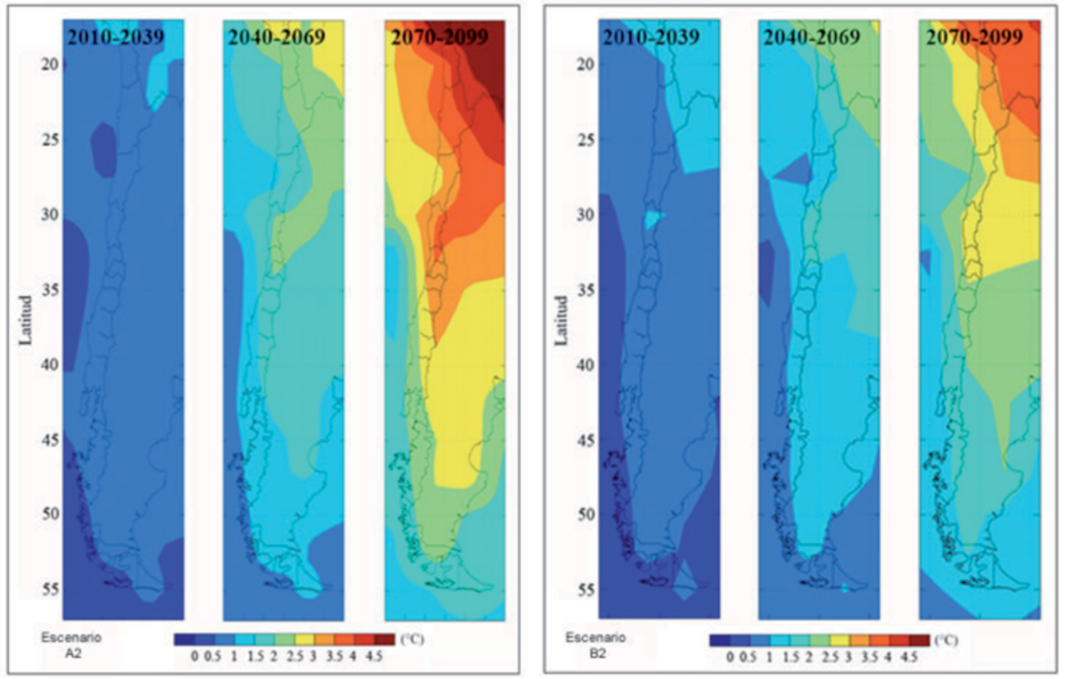

Figure 4. Temperature variation projections under scenarios A2 and B2
Source: ECLAC, 2009

3.2.2 Precipitation

Projections based on the model estimate that by the end of the 21st century precipitation in the highest areas of the Andes Mountains will present significant differences on either side of the continental divide: an increase projected on the eastern side (Argentine territory), and a decrease on the western side (continental Chile and adjacent Pacific Ocean). This effect is particularly marked at intermediate latitudes and during the summer and autumn seasons. The contrast is most notable for the summer season under scenario A2, with precipitation in some regions of South-Central Chile being reduced to one-half or even one-quarter of current values (Figure 5).

An analysis of the results obtained by latitude shows that:

- In the Altiplano, the model used projects an increase in precipitation during spring and summer, most notably for the spring season in the Region of Arica and Parinacota under scenario A2, and extending further, into the Region of Antofagasta, under scenario B2.
- In the north-central regions of Atacama and Coquimbo, the increase is more extensive under scenario B2, covering all Chilean territory between 20°S and 33°S during the autumn, but only the Altiplano during the winter.
- The model predicts a generalized reduction in precipitation in the central region under scenario A2 – a situation that is mirrored under scenario B2, except for in the winter, at latitudes below 33°S. The projected reduction is approximately 40% in low lying regions and becomes even more significant closer to the Andean foothills during the summer under both scenarios, but with a lower in magnitude in the autumn and winter seasons under scenario B2.
- The southern region is expected to experience little change from current patterns in terms of precipitation during autumn and winter. Precipitation does however decrease by approximately 40% during the summer and by around 25% in the springtime.
- The southernmost region is expected to see a 25% reduction in precipitation, but with little difference during the winter season and a slight increase possible in the extreme south, year-round.

Precipitation projections for the intermediate (Figure 5) and early (2010-2040) periods suggest a greater reduction under scenario B2 (10% to 20%) in the North-Central zone (regions of Atacama and Coquimbo) than under scenario A2. For the intermediate period, both scenarios predict precipitation increases in the Magallanes Region and reductions between the regions of Antofagasta and Los Lagos; however, these changes are more marked under scenario A2 (2040-2070).

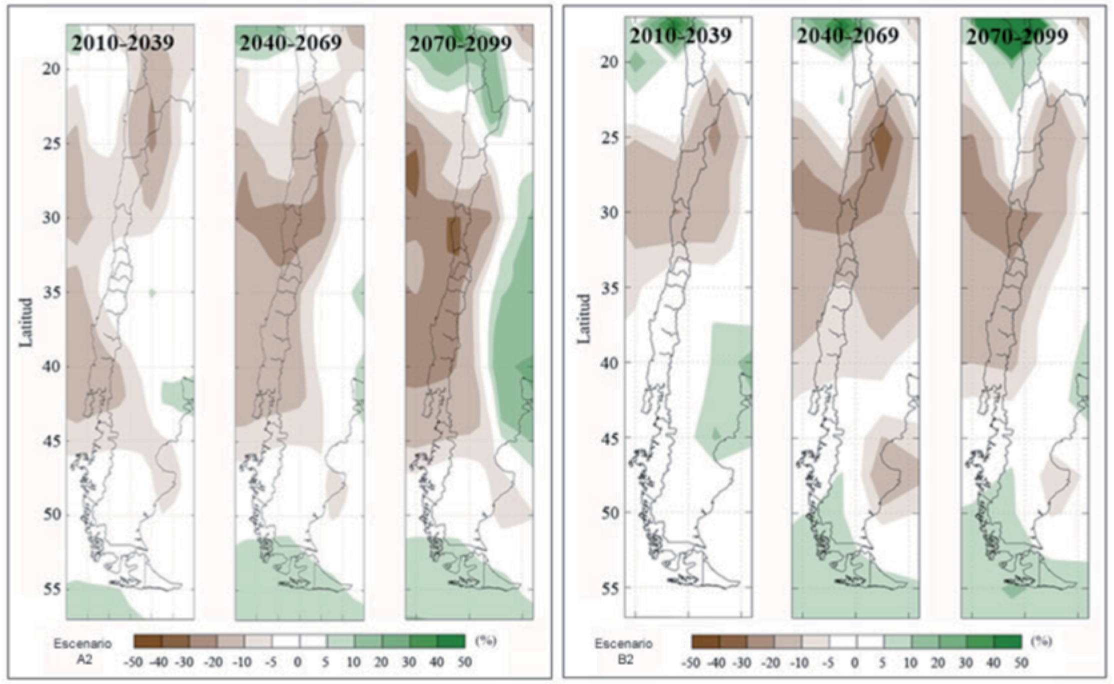

Figure 5. Precipitation projections under scenario A2 (% change against historic baseline)
Source: ECLAC, 2009

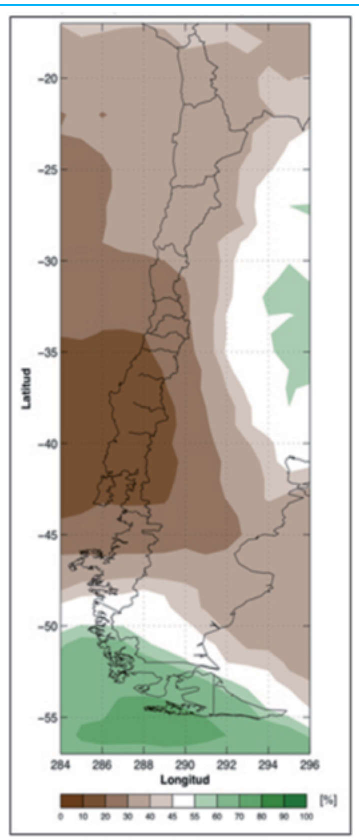

Figure 6. Percentage of models projecting precipitation increase for Chile for the 2010-2040 period
Source: ECLAC, 2009

An uncertainty analysis applied to precipitation projections (ECLAC, 2009) shows a high probability of reduction between the regions of Coquimbo and Los Lagos, with an expectation that clear effects of climate change will outweigh natural variability even in the near future. In the Magallanes Region (50°S to 55°S), a high degree of agreement exists among models that precipitation increases (by 5% to 10% over current values) would fall within the bounds of natural variability. In the Altiplano and North-Central regions (north of 27°S), significant differences exist between different projections. Figure 6 shows the percentage of models that project an increase in precipitation over the 2010-2040 period, including the level of agreement on precipitation reductions throughout virtually the entire country.

3.3 EXTREME CLIMATIC EVENTS AND PROJECTIONS

Although Chile lacks sufficient studies on the impact of extreme climatic events, research on climate disasters affecting the country's rural environment between 1541 and 2005 (Aldunce & González, 2009) shows a general trend towards more and more extremely dry years (Figure 7).

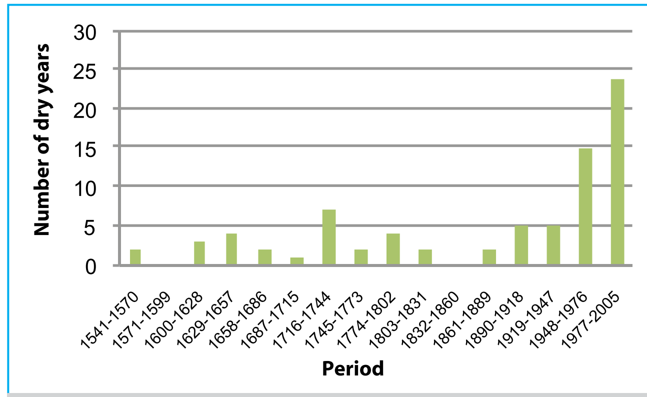

Figure 7. Number of dry years in historic periods (15th to 19th centuries) in Chile
Source: Aldunce & González, 2009

Projected climate changes are associated with changes in average atmospheric conditions, set against a baseline period of 30 years, however, the greatest climate-related socioeconomic impacts are for extreme events such as droughts or flooding, which are linked to climatic variability (IDB-ECLAC, 2007).

Based on the models taken into account in the uncertainty analysis (ECLAC, 2009), an analysis of projected climatic variability was conducted to gain a better understanding of potential impacts of extreme climate events. This analysis revealed a marked increase in the likelihood of drought events, especially in the intermediate and late timeframes. Drought is defined here as two consecutive years with annual precipitation below the 20th percentile of the baseline. In this analysis, 70% of the models projected that by the end of the 21st century drought events will occur more than 10 times in a 30-year period.

Conversely, although the number of extreme precipitation events is expected to decrease over much of the country, the occurrence of high precipitation events on days with unusually high temperatures appears to increase in comparison with the baseline situation.

This finding has significant implications, as the increase in the line of the zero isotherm in so-called warm storms has the effect of significantly increasing river flow rates, which can cause major catastrophes from flooding and also impact drinking water supply. Many of the extreme events currently affecting the country's climate patterns are related to the El Niño - Southern Oscillation phenomenon.

The El Niño - Southern Oscillation phenomenon (ENSO)

Like other parts of the planet, Chile experiences significant variations in climate patterns associated with El Niño and the Southern Oscillation. "El Niño" is a thermal anomaly in the ocean surface temperature in the central and eastern equatorial Pacific Ocean. It can be divided into three phases: a warm phase (El Niño), a cool phase (La Niña) and a normal phase (absence of anomalies). Meanwhile, the Southern Oscillation corresponds to an anomaly in the sea-level air pressure between the stations at Tahiti and Darwin. Although they describe two different processes, oceanic and atmospheric, the correlation between these two phenomena is so close that they are often referred to as the El Niño–Southern Oscillation phenomenon (ENSO).

In Central Chile, changes in precipitation patterns have been associated with the behavior of the Southern Oscillation, with unusually dry conditions occurring during the positive phase (La Niña) (Rubin, 1955; Pittock, 1980) and higher precipitation during "El Niño" years (Quinn & Neal, 1983; Kane, 1999). It can therefore be expected that changes in the relative frequency of ENSO caused by climate change may affect precipitation and the relative frequency of extreme events in the future. Although a scientific consensus has yet to form, some publications hypothesize an increase in the frequency of the ENSO, particularly in terms of El Niño events.

Timmerman et al. (1999) affirm that GHG increases and surface warming will increase the incidence of El Niño events in the Pacific Ocean system; this hypothesis is partially upheld by statistical observational studies conducted by Trenberth and Hoar (1997) that included a time series analysis covering the period from 1892 to 1995. However, recent events (since 2000) in which the El Niño phenomenon has not predominated but rather the opposite phase has been observed, may call these results into question, at least in terms of the magnitude of the trend. Conversely, paleo-climatological studies such as that of Moy et al. (2002) reveal a tendency towards the reduction in ENSO activity, across a timescale of millennia. In this context, the third report of the IPCC of 2001 states that changes in the frequency of ENSO events may occur, but that their magnitude and contribution to climate patterns may be highly dependent on the global circulation model chosen, and that this should therefore be considered an area with a considerable degree of uncertainty.

home

3.4 WATER RESOURCES

The availability of water resources in Chile is closely linked to climatic conditions, and it is therefore expected that water availability will be affected by changes in temperature and precipitation projected under the models used for forecasting the country's climate during the 21st century, particularly under the most severe scenario (A2).

The temperature increases associated with climate change that are expected in Chile will reduce the area of the Andes Mountains capable of providing a reservoir of snow from one year to the next; and considering that the 0°C isotherm will occur at higher altitudes (Carrasco et al, 2005), seasonal winter increases in flow rates in rivers flowing down from the Andes will become more pronounced due to increased flow rates in their tributaries. This will reduce the water reservoir stored as snow. For example, the Andean regions between 30°S and 40°S –the area with the most agricultural and forestry production, and the country's current main source of hydroelectric power– may suffer a highly significant loss of snow coverage during the first four months of the year.

The model applied also predicts a reduction in rainfall, except in the Altiplano during summer (for which case the model features a high level of uncertainty) and in the extreme south of Chile in winter. In the winter season precipitation will drop in areas between 30°S and 40°S. Decreases will also occur in the summer season in areas between 38°S and 50°S, most notably in the northern Andes. This will lead to a significant reduction in the flow rates of rivers that provide crucial water resources.

3.4.1 Glaciers

Glaciers are strategic reserves of water resources, as they not only contribute water to rivers during the summer, but are also the only source of water for rivers, lakes, and underground aquifers in arid regions during droughts. Chile has the highest concentration of continental glaciers in the southern hemisphere. A 2007 inventory identified 1,835 glaciers with a combined surface area of 15,500 km^2 of ice, and a further 4,700 km^2 of ice was not included in the inventory. The national total is believed to be over 20,000 km^2, of which more than 75% is located in the Northern and Southern Patagonian Ice Fields, in the regions of Aisén and Magallanes (DGA, 2009). The Southern Patagonian Ice Field is the planet's third largest body of ice, after Greenland and Antarctica.

Studies of glaciers in the country show that most are in retreat (see Figure 8). Out of 100 glaciers evaluated (Rivera et al., 2000), 87% showed reductions in size associated with changes in historic climatic patterns. It is believed that trends towards higher temperatures and more solar radiation in the Andean regions and lower precipitation will continue to have a negative impact on the surface area of glaciers in the Andes (Ohmura, 2006). This shall continue to affect the availability of water in river systems that receive significant inflow from glaciers, mainly those located between the Aconcagua and Cachapoal rivers, and certain other basins in the north of the country. This effect is most notable in the summer and autumn seasons, when inflow from precipitation and even snowmelt is reduced.

Despite the abundance of glaciers and ice fields in the country, little information exists on the current status of Chilean glaciers, with certain exceptions such as the Echaurren Norte glacier, which is a water source for Laguna Negra lake and the Yeso Reservoir, both of which provide drinking water to the Metropolitan Region. This glacier is monitored constantly, as a reduction in its size may have major effects on the availability of drinking water in Santiago. Another glacier that has been studied is Cipreses, which feeds water into the Cachapoal river basin, in the Region of O´Higgins. Over the past 50 years it has shrunk by an average of 27 meters, triple the rate observed since 1860 (Rivera et. al, 2007).

Photo: Ministry of the Environment. Government of Chile

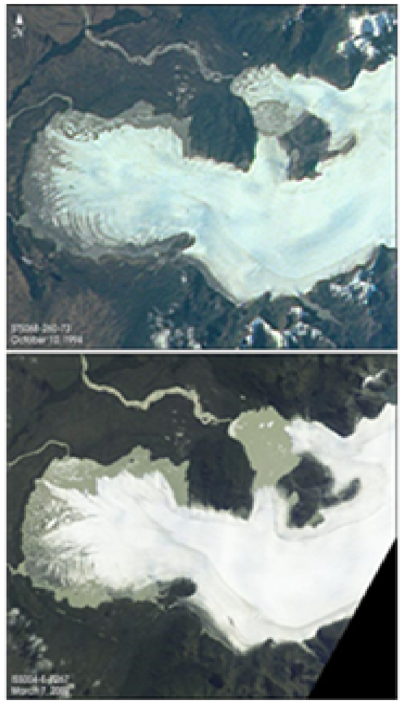

Figure 8. Changes in area covered by the San Quintín Glacier (located in the Southern Patagonian Ice Field, 47°S), from orbital photographs. The first image was taken in October 1994 by STS-068, and the second by the Increment 4 Crew of the International Space Station in February 2002.

3.4.2 Analysis of selected river basins

Several initiatives underway since 2008 are intended to generate or update information on Chile's vulnerability to changes in water resources arising from climatic variations. These studies (Agrimed, 2008; ECLAC, 2009; and U. de Chile, Civil Engineering Dept., 2010) provide the first quantitative data on expected impacts on water resources in eight basins between the regions of Coquimbo and Araucanía (see Figure 9) resulting from projected changes in temperature, evapo-transpiration rates, and precipitation corresponding to scenario A2. These basins were selected for their high level of human intervention and their importance in the regions analyzed. The figure shows the area of the sub-basin where the hydrological models were calibrated, the total area of the basin for each calibrated model, and dotted lines indicating the areas of basins with hydrological features similar to those studied.

Trends in equilibrium-line altitude (ELA) in the Andes

The advance and retreat of glaciers is related to climatic variations that generate changes in the rate of accumulation and ablation of glacial ice. Accumulation includes all processes that increase the mass of glaciers, mainly snowfall. Ablation includes processes that result in a decrease in mass, mainly sublimation and melting. The equilibrium-line altitude (ELA) marks the limit between these two areas, marking the point of equilibrium where the change in glacial mass is zero. This typically falls close to the snow line, the lower altitude limit of year-round snow.

The ELA may be determined using climatic variables such as temperature and precipitation. Effectively, it rises in altitude with increased temperature and/or reduced precipitation, and lowers in altitude with decreases in temperature and/or increases in precipitation. A study on ELA trends in the Andes mountains in Chile (Carrasco et al, 2008), indicates that:

- In the northern zone, ELA dropped until 1976 and then began to rise, showing an average positive trend of 68 ± 12m per decade over the period 1962-2003.
- In the central zone, it showed a negative trend, becoming positive during the 1970s, with an average rise of 11±3m per decade over the period 1958-2004.
- In the southern zone, the trend has been positive since 1970. ELA has shown an average rise of 34±2m per decade over the 1959-2004 period.
- In the extreme south, ELA has shown an average reduction of 8±2m per decade over the period 1975-2006. However, this finding does not correspond to studies of glaciers in the region, which show a clear frontal retreat and mass reduction.

* Further details of government bodies involved in the management of Chilean glaciers such as the General Water Department's Glaciology and Snow Unit at the Ministry of Public Works are provided in chapters 1 and 5 of this Second National Communication.

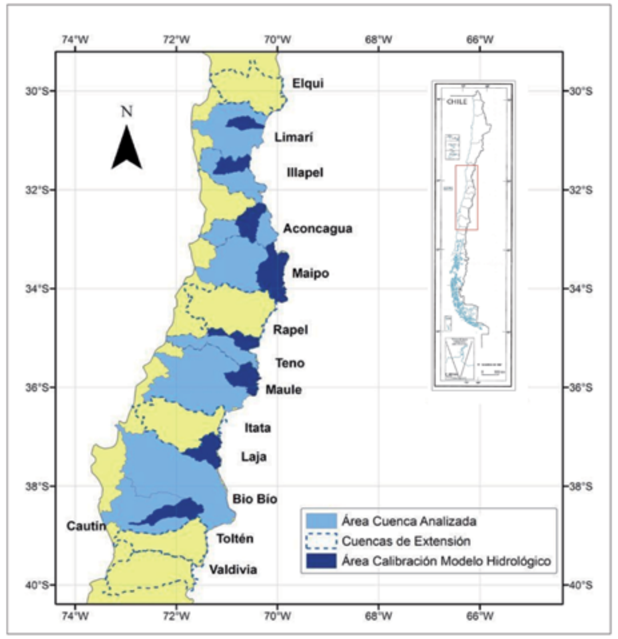

Figure 9. Map of river basins studied, hydrological model calibration area and related river systems
Source: U.de Chile, Depto.Ingeniería Civil, 2010

For each river basin, the flow simulation model based on the WEAP platform was calibrated using data gathered on a monthly basis. The flow rate projections were adjusted to smaller spatial scales, in a process known as downscaling, using specific data for each key meteorological station in these river systems, based on the HadCM3 A2 scenario. For some of these basins, impact analyses were conducted for specific productive sectors and are described in later sections of this document.

The results provided by flow simulation models (discharge rate changes over different time periods) are dependent on both the equations used to define the hydrological systems and the statistical data (time series) used as input for the models to generate the parameters used in these equations. It should therefore be borne in mind that the data used in these simulations are derived from statistics gathered over limited time periods, and the results are therefore subject to a certain level of uncertainty.

Figure 10 shows projected changes in average monthly flow rates for the five basins. Table 1 shows the changes projected under the climate change scenarios used, in accordance with different metrics. These correspond to annual flow rates, centroid location (or centre of gravity of the hydrograph, as a metric of hydrograph shape), and percentage of months showing a deficit (defined as months falling below the 90th percentile of historical statistical data for that month). For each metric, the simulation derived absolute values as well as a comparison between future scenarios and the baseline condition. A summary is presented in Table 1.

Photo: Ministry of the Environment. Government of Chile

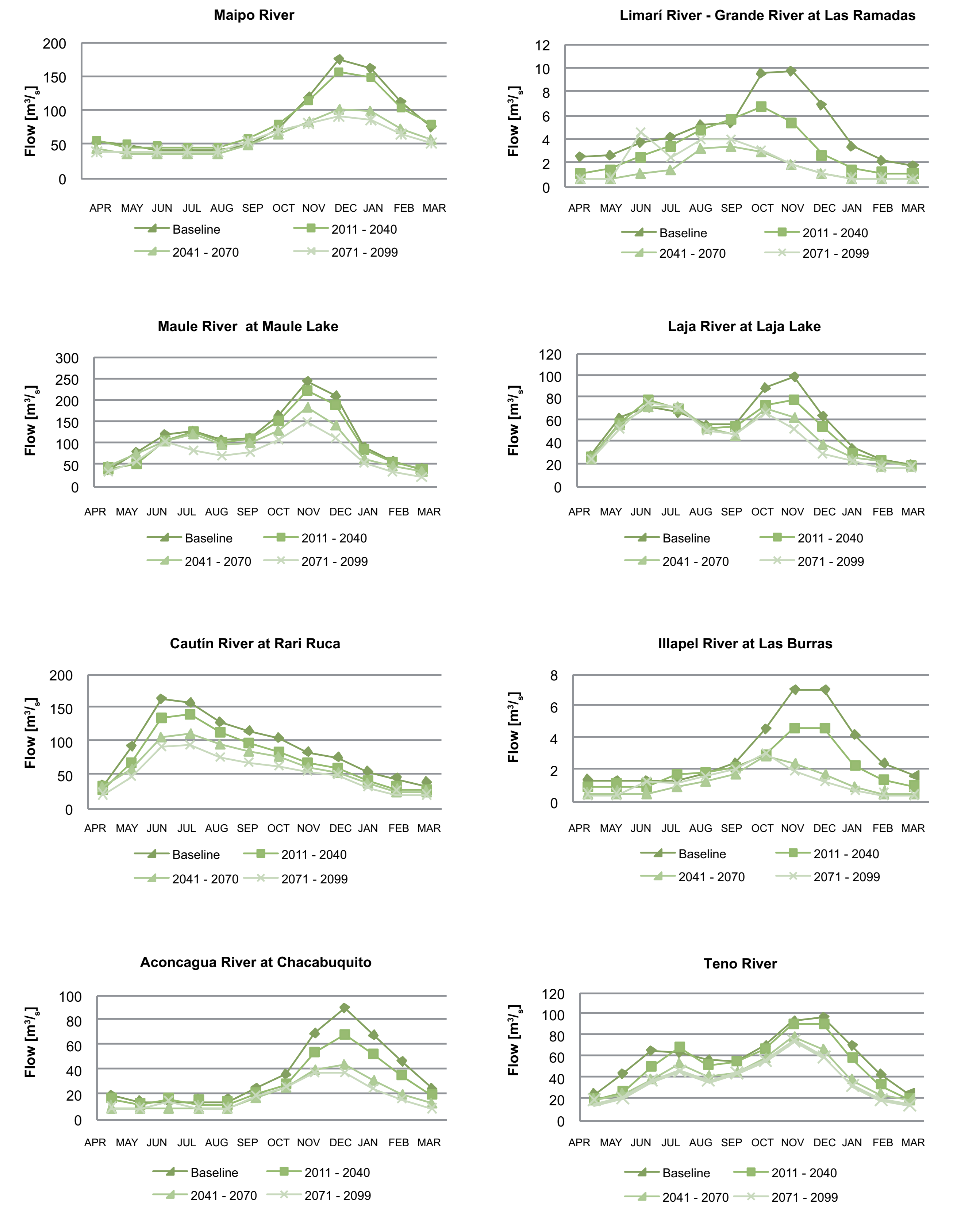

Figure 10. Average monthly hydrological conditions in the river basins studied. Historic baseline and three future periods under scenario HadCM3-A2
Source: U.de Chile, Depto.Ingeniería Civil, 2010

TABLE 1. Analysis of climate change impacts on different water resource metrics under scenario HadCM3-A2

Basin	Period Baseline	Average annual flow rate		Centroid		Number of months of deficit (%)	
		(m³/s) 4.8	Change against BL (%)	Date 31-Oct	Change against BL (day)	(%) 10%	Change against BL (number of times)
Limarí (Grande Las Ramadas)	Baseline	4.8		31-Oct		10%	
	2011 - 2040	3.2	66%	23-Oct	-8	21%	2.1
	2041 - 2070	1.5	32%	20-Oct	-11	73%	7.3
	2071 - 2099	2.1	44%	2-Oct	-29	67%	6.7
Maipo (Maipo San Alfonso)	Baseline	83.1		5-Dec		9%	
	2011 - 2040	82.7	99%	29-Nov	-6	7%	0.8
	2041 - 2070	60.0	72%	24-Nov	-11	23%	2.6
	2071 - 2099	58.3	70%	18-Nov	-17	34%	3.9
Maule (Maule at Laguna Maule)	Baseline	115.3		1-Nov		12%	
	2011 - 2040	106.4	92%	3-Nov	2	14%	1.1
	2041 - 2070	94.5	82%	23-Oct	-9	18%	1.5
	2071 - 2099	75.0	65%	22-Oct	-10	43%	3.5
Laja (Laja at Lago Laja)	Baseline	55.2		15-Oct		10%	
	2011 - 2040	51.4	93%	10-Oct	-5	24%	2.4
	2041 - 2070	46.2	84%	4-Oct	-11	42%	4.3
	2071 - 2099	43.5	79%	30-Sep	-15	56%	5.7
Cautín (Cautín at Rari Ruca)	Baseline	90.4		3-Oct		13%	
	2011 - 2040	75.4	83%	1-Oct	-2	38%	3.1
	2041 - 2070	63.9	71%	3-Oct	0	60%	4.8
	2071 - 2099	53.2	59%	5-Oct	2	76%	6.0
Illapel (Illapel at Las Burras)	Baseline	3.0		15-Nov		15%	
	2011 – 2040	2.6	84%	11-Nov	-4	18%	11.1
	2041 – 2070	1.3	42%	16-Oct	-30	44%	107.3
	2071 – 2099	1.3	41%	07-Oct	-39	53%	127.2
Aconcagua (Aconcagua at Chacabuquito)	Baseline	32.0		30-Nov		15%	
	2011 – 2040	29.0	93%	20-Nov	-10	13%	13.2
	2041 – 2070	20.0	63%	26-Nov	-4	40%	110.0
	2071 – 2099	18.0	58%	15-Nov	-15	47%	122.0
Río Teno (Teno confluence with Río Claro)	Baseline	55.1		29-Oct		15%	
	2011 – 2040	55.6	101%	29-Oct	0	17%	24.5
	2041 -2070	41.7	76%	15-Oct	-14	14%	51.1
	2071 – 2099	38.4	70%	16-Oct	-13	13%	74.1

Source: U.de Chile, Depto.Ingeniería Civil, 2010

In general terms, these modeling results for scenario HadCM3 A2 forecast significant impacts on water resources and reductions of available water flow rates in all cases (Figure 10 and Table 1, average annual flow rate). These reductions are greatest at the geographical extremes of the region analysed (Limarí and Cautín basins).

The hydrographs (graphs of flow rate over the year) change shape significantly in some river systems, with the maxima moving from the spring and summer months into the winter. This is a consequence of temperature increases, related to the build up and melting of snow.

These changes in water availability and flow seasonality lead to significant increases in the number of months of water deficit in almost all river systems, comparing projected flow rates with the stress level for each month over the historic data series. These water shortages will have significant consequences for the use of water resources by different productive sectors in Chile due to the marked increase in increase in low flow rate frequency. For example, in the Limarí River a flow rate of 2m³/s or less—lower than historic figures in 80% of years—is predicted to occur in 40% of years during the early period and 60% of years during the late period. With regard to flood risk, temperature increases will bring about increases in winter flow rates by increasing the altitude of the snowline, producing a consequent increase in water input from mountain regions.

An impact analysis has yet to be carried out to address the effects of these projected hydrological and climate changes on the delivery of the environment-sensitive services that are highly relevant in many of the country's river basins. Similarly, no analysis of the expected impact on water quality has been conducted. Currently, analyses are based on projected changes in resource availability, and their consequent effects on productive sectors in Chile.

3.4.3 Results by river basin

Limarí River

This river system will suffer a marked reduction in available flow, even in the earliest period modeled. By the end of the 21st Century a 55% loss in annual flow is expected. The analysis of the sub-basin of the Río Grande at Las Ramadas shows a significant change in flow seasonality, with a major reduction in the contribution of snowmelt, and movement towards a mixed pattern, with the centroid of the hydrograph moving forward by almost a month. This result is strongly dependent on the elevation of the river basin. It is expected that higher altitude sub-basins such as the Río Hurtado will retain a flow regime more strongly dependent on snow effects, while lower altitude sub-basins such as the Río Cogotí will suffer even greater loss of snow melt effects, becoming dependent almost entirely on rainfall by the end of the century.

This will have a significant impact on the agriculture sector—the main users of this river system—with losses in irrigation water coverage and consequent reductions in crop productivity, particularly for water users who lack mitigation infrastructure.

The same conclusions are applicable to the basins of rivers such as the Elqui, Illapel, and Aconcagua. In each case, differences will be linked to the elevation of the sub-basins and the types of water users. In the Illapel River, for example, copper mining activity accounts for more water usage.

Maipo River

This river system will suffer a marked reduction in available flow, beginning in the second period modeled. Flow rate reductions are low during the early period, but a loss of approximately 30% is projected by the end of the century. The sub-basin of the Maipo River shows a change in discharge seasonality, albeit to a lesser extent than the Limarí. The centroid of the hydrograph moves forward by more than 15 days, but snow-related effects remain significant. This is partly due to the elevation of this basin, which is located in one of the highest sectors of the Andes. Lower altitude sub-basins such as the Mapocho will lose their snow-related flow regimens, becoming almost entirely fed by rainfall by the end of the century, with consequent significant increases in winter flow rates.

These impacts will have a significant impact on this river's main water uses: agriculture, hydroelectric plants, and drinking water for Santiago and other settlements in the Metropolitan Region. Compared to the Limarí, the Maipo basin has a lower capacity to regulate flow rate and is more vulnerable to expected hydrological changes.

These conclusions can also be applied to nearby river systems such as the Aconcagua and the Cachapoal/Rapel, which will also be affected by a relative increase in water demand from the mining sector.

Maule and Laja Rivers

The basins of the Maule and Laja rivers will suffer a marked reduction in available flow, starting in the second period modeled. However, the Maule will suffer a significant drop in flow rate during the first period (approximately 10%). The projected reduction in average annual flow rate by the end of the century is approximately 30-35%. The sub-basins of the Maule River at Laguna Maule and of the Laja River at Lago Laja show a relative drop in flow rate during the spring and summer months, with no major changes during the winter. The centroid of the hydrograph moves forward by approximately 10 days, but the flow regime of these rivers remains mixed. This is due in part to their altitude (the Andes here are lower than in the Maipo basin region, for example) and greater water input during the winter.

Agriculture and hydroelectric power generation may suffer significant impacts, although agriculture in this basin often does not make use of irrigation. Given that much of the country's installed hydroelectric capacity is located on these rivers, it is expected that in future the relations among different users, who currently have no shortage of water resources, will become more complex. This effect may be exacerbated by the increasing loss of water availability that is expected to occur during the critical summer months.

These conclusions may also be applied to nearby river systems such as the Mataquito, Itata, and Biobío. Water resource usage is similar in these basins, with the exception of the Biobío, which faces demands not only from the agriculture and hydroelectric sectors but also from industrial and domestic users in the city of Concepción.

Cautín River

This river system will suffer a marked reduction in available flow, even in the earliest period modeled. By the end of the 21st Century a loss in annual flow of 40% is expected. The simulation shows no significant differences in the seasonality of flow rates, with the system retaining a rainfall-dependent regime that is characteristic of the southern regions of the country, where the Andes Mountains are much lower.

This change will have a significant impact on river systems' water users, particularly in the agriculture sector and the hydroelectric power industry, which is becoming more consolidated in this region and in the southern zones of Chile.

These conclusions may also be applied to nearby river systems such as the Toltén and even the Valdivia River. The hydroelectric industry is becoming more consolidated in these river systems also, and will be affected by reductions in available flow rates.

Illapel River

This river system will suffer a marked reduction in available flow, even in the earliest period modeled. By the end of the 21st Century a loss in annual flow of 59% is projected, showing extreme variations between years. The analysis modeled snow and ice melting earlier in the year, together with a reduction in maximum flow rates.

The area of land used by the agriculture sector extends beyond the river basin studied, but is much smaller than the unvegetated land that comprises up the basin's main land use.

Aconcagua River

This river system will suffer a marked reduction in available flow, starting in the earliest period modeled. By the end of the 21st Century a loss in annual flow of 42% is expected. During the 2010-2040 period, there is interesting effect in the rising limb of the hydrograph, with an increase in snowmelt discharge alongside a more severe recession limb, producing no major changes in total discharge volume. Flow during the rainy season generally diminishes, but the future simulations show a severe reduction in snowmelt flow, with the flow centroid moving forward into the month of November during the 2070-2099 period.

This represents a major reduction for a basin that supplies water to an agricultural valley that relies heavily on irrigation.

Teno River

This basin will suffer a reduction in flow rates beginning in the second period. By the end of the century, a reduction in the average annual flow rate of approximately 30% is expected. The analysis shows a reduction and displacement of peak flow, which moves forward by one month (into November).

The basin's land area along the banks of the Río Claro is used for pasture and cultivation on a rotating basis; however, most of the basin lacks plant coverage or consists of grasslands and glaciers.

3.4.4 Hydroelectric power sector

In order to assess the impact of climate change on the hydroelectric power sector, the effects of flow rate variations were estimated for two river systems that represent much of the country's hydroelectric capacity: Maule Alto and Laja. It should be pointed out that the results for these two river systems are not representative of the response for the entire national hydroelectrity sector, but the data produced are extremely relevant nonetheless. In any case, any analyses of these projections should consider that they were produced using simulations having some degree of uncertainty. This uncertainty is a result of both the simplifications inherent in the hydrological models applied and the time series used in the calibration of these models.

The results show a progressive drop in flow rates that reaches approximately 40% by the end of the 21st Century. Both river systems show a significant change in seasonality (an increase in the relative contribution of winter flow compared to summer flow) that can be explained by temperature increases.

The model was created in two phases: first, computational hydrological modeling was carried out using WEAP (Water Evaluation and Planning System); and subsequently, the relationships between hydrological conditions and power generation were determined. It was assumed that hydroelectric power generation is closely linked to the availability of water flow in the headwaters of the river basin. Thus, average annual flow rates and average power input into the Central Interconnected Electricity Grid were calculated for each river system.

Figure 11 presents a comparison of average monthly flow rates between the reference period (1970-2000) and three future periods, defined as 2010-2040, 2040-2070, and 2070-2100, under scenario A2.

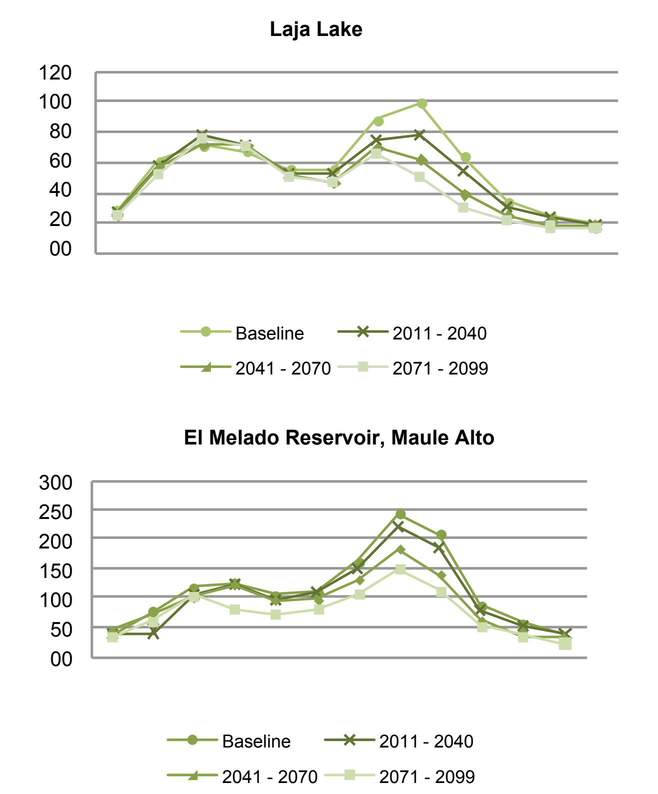

Figure 11. Hydrological conditions (flow rate in m^3/s) in the sub-basin draining into the El Melado reservoir in the Maule Alto system, and into Laguna Laja under scenario HadCM3-A2. Historic flow data for 1976-2000 are also shown

Source: ECLAC, 2009

Additionally, historic data on power generation were studied for all of the hydroelectric plants in the system, and the information was used to refine energy projections for the Maule and Laja basins. A specific relationship between flow rate and energy was also developed for the Maipo River.

The value for annual energy generation and discharge rates observed were used to build statistical relationships between the variables of interest. These variables were applied to the discharge rate variations for the Maipo, Maule and Laja systems to obtain projected generating capacity (Table 2).

TABLE 2. Projected hydroelectric power generation under scenarios HadCM3 A2 and B2 (in GWh)

	River system							
	Aconcagua	Maipú	Cachapoal	Biobío	Maule	Laja	Others in south	Total
Reference Period	1996-2008	1996-2008	1996-2008	2004-2008	1976-2008	1973-2000	1996-2008	NA
Base annual energy (GWh)	756	1,584	1,555	4,798	7,282	4,508	455	20,938
Scenario HadCM3-A2 (annual base energy percentage change)								
	Aconcagua	Maipú	Cachapoal	Biobío	Maule	Laja	Otras Sur	Total
2011-2040	-4%	-1%	-10%	-33%	-3%	-7%	-3%	-11%
2041-2070	-17%	-8%	-26%	-38%	-6%	-14%	-5%	-17%
2071-2099	-18%	-9%	-27%	-47%	-11%	-17%	-8%	-22%
Scenario HadCM3-B2 (annual base energy percentage change)								
2011-2040	-12%	-3%	-2%	-32%	-3%	-4%	-3%	-10%
2041-2070	-16%	-8%	-16%	-32%	-6%	-11%	-4%	-14%
2071 -2099	-10%	-9%	-9%	-40%	-8%	-12%	-6%	-16%

Source: ECLAC, 2009

Expected impacts on the hydroelectric power sector are significant, even during the earliest period modeled, in terms of both GHG emissions –which reach values close to 3000 Gg CO_2eq/year– and economic cost, which amounts to around 100 million dollars per year.

Variations in potential hydroelectric power generation for the SIC grid as a whole, in its current configuration, range from 11% in the early period up to 22% in the late period. This variation is in keeping with percentage changes estimated for river discharge rates. Among the individual river systems, the Biobío River appears to be the most sensitive. However, this analysis was an extrapolation of results obtained for the Maule and Laja rivers.

Economic impacts related to reductions in hydroelectric power generation assume that a reduction in hydro generation will lead to an increase in generation from coal-fired plants to compensate for the energy deficits arising, as an immediate adaptation measure.

TABLE 3. Impacts of Climate Change on Hydroelectric Power Generation

Period	Hydroelectric power generation		Impacts associated with increased use of thermoelectric power		
	GWh	Change (%)	Generation replacement (GWh)	GHG emissions (tCO_2eq/year)	Economic cost (millions of US$/year)
1976-2000	20,938				
Scenario A2					
2011-2040	18,129	-13%	2,809	2,626,488	101
2041-2070	17,653	-16%	3,285	3,071,434	118
2071 -2099	16,686	-20%	4,252	3,975,979	153
Scenario B2					
2011-2040	18,779	-10%	2,159	2,018,665	78
2041 -2070	17,934	-14%	3,004	2,808,740	108
2071-2099	17,539	-16%	3,399	3,178,065	122

Source: ECLAC, 2009

[1] The ECLAC (2009) study recognizes that this assumption oversimplifies the situation, as electricity generation in the country results from an economic optimization process that takes into account fuel prices and the cost of generating technologies.

3.4.5 Industrial and domestic water supply

At a national level, the industrial and domestic water supply depends directly on the availability of water resources, and in both cases the availability of water resources is the main threat affecting productivity. The domestic sector provides drinking water to the general population and to a subsector of industrial users, while the manufacturing industry sector requires a supply of raw water for its operations that it obtains from the domestic water supply network or from other sources such as wells or boreholes.

Changes in the hydrology of domestic water sources –i.e. water volume, seasonal changes, and/or water quality– may affect supply in the short or long term.

Studies centered on the Maipo River basin (ECLAC, 2009), which supplies the 40% of Chileans living in and around Santiago, estimate a reduction of around 50% during the summer season by the end of the century.

A financial estimate of the potential impacts of climate change on water supply activities in the Maipo River basin looked at whether the company that supplies almost all water in the region would have to purchase additional water rights. The study found that such purchases will be necessary in cases where the estimated supply does not meet projected demand. Prices were assessed based on water availability conditions considered feasible under a projected climate change scenario. Given that the availability of water in the Maipo basin will decrease by 3% against the baseline condition, it is estimated that there will be an approximate 3% increase in the price per share of water rights during the 2011-2040 period. The level of restriction will be higher during the 2041-2070 period, with a reduction of 19% under the baseline, increasing the price by 23%. Finally, for the 2071-2100 scenario, the drop in water availability will be 23%, and the price increase 30% (ECLAC, 2009).

The second phase of the simulation considered the number of water rights necessary. Table 4 summarizes an aggregate economic analysis of the potential impact of climate change on the water supply industry in greater Santiago. It shows costs of around two million dollars per year, leading to an increase of approximately two dollars per year in the average family's water bill. However, this value represents only the increase in costs to be paid by the company to ensure the water supply, and additional costs associated with changes in infrastructure will probably also arise.

TABLE 4. Climate change impacts on the water supply of the Metropolitan Region under scenarios A2 and B2

Period	Deficit (l/s)	Purchase Shares	Price (US$/share)	Cost (thousands US$)	Cost (thousands of US$/year)
Scenario A2					
2011-2040	100	634	52,233	33	1.1
2041-2070	1,700	951	62,313	59	2.0
2071-2099	1,800	441	67,353	30	1.0
Scenario B2					
2011-2040	1,300	1,121	52,233	59	2.0
2041 -2070	1,200	904	62,313	56	1.9
2071 -2099	1,200	6	67,353	0	0.0

Source: ECLAC, 2009

In the industrial sector, operations dependent on water will be affected in line with the water supply sector. Furthermore, operations dependent on water pumped from surface sources will also be affected by changes in patterns of replenishment of the basin's aquifer. However, little research has been conducted on these hydrological processes.

3.4.6 Mining sector

Climate change is expected to have a direct impact on the mining sector, as this industry is particularly sensitive to increasing variability in climatic conditions. Adverse effects that have been analyzed include operating delays, loss of revenue and increased production costs. Similarly, the trend towards processing lower-grade ores requires more energy and more water for the extraction and processing phases, and both of these resources are in short supply in Chile's mining zones.

At the national level, the mining sector accounts for a small proportion of total water consumption, around 4%. However, in the northern regions the sector accounts for 24% of water usage, making it one of the sectors that is most exposed to the impacts of climate change.

Mining activities are conducted throughout Chile, but are mainly concentrated to the north of 35ºS, the latitude of the El Teniente mine. Figure 12 shows a map of mining sites that were selected for the assessment of the impact of climate change on the mining sector in South America (EcoSecurities and CCG-UC, 2010).

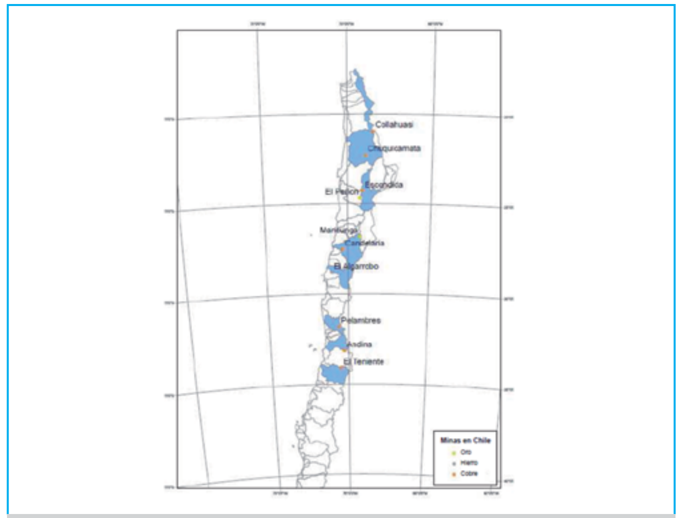

Figure 12. Location of mines assessed in Chile
Source: EcoSecurities and CCG-UC, 2010

Almost all of the river basins that sustain Chile's mining industry feature arid conditions, with the two most important exceptions being the Andina and El Teniente mines, located in the Aconcagua and Rapel basins, respectively (Table 5). All other mines are located in basins with less than 100mm/year of available water resources. From a hydrological perspective, water availability in most of these basins is zero, with evaporation being greater than or equal to precipitation in the basin.

Photo: Ministry of the Environment. Government of Chile

TABLE 5. Summary of hydrological conditions in river basins associated with selected mines

Mineral	Mine	Basin	Precipitation (mm/year)	Average T (°C)	Flow rate (mm/year) 1960 - 1990
Copper	Escondida	Endorheic basins, Salar Atacama	92	10.2	0.0
Copper	Pelambres	Río Choapa	326	14.4	54.2
Copper	El Teniente	Río Rapel (Río Cachapoal)	1,595	14.0	1,115
Copper	Andina	Río Aconcagua (Río Colorado)	720	14.2	373
Copper	Chuquicamata	Río Loa (San Pedro de Chonchi)	141	8.5	8.5
Copper	Collahuasi	Altiplano (Salar de Coposa)	169	4.0	0.0
Copper	Candelaria	Río Copiapó (Quebrada Paipote)	43	16.2	0.3
Iron	El Algarrobo	Río Huasco	175	14.5	5.5
Gold	Maricunga	Río Copiapó (Salar de Maricunga)	153	2.5	0.0
Gold	El Peñón	Endorheic basins, Salar Atacama	92	10.2	0.0

Source: ECLAC, 2009.

In order to estimate future water availability for this study, discharge rate changes were calculated using a simple hydrological balance, adjusted for temperature and precipitation anomalies for the 2010-2040 period projected under the global HadCM3 model for emissions scenario A2. Table 6 shows that water availability will decrease in all basins studied, with the most severe conditions arising in the near future in the mines to the north of El Teniente, to an extent that may compromise the productivity of the sector.

Photo: Xstrata Copper

TABLE 6. Results of modeling changes in water availability

Mine	Basin	Flow (mm/year) 2011-2040	Precip. Change (%)	Temp. Change (°C)	Flow Change (%)
Escondida	Endorheic basins , Salar Atacama – Pacific watershed	0.0	-13.0	0.7	-
Pelambres	Choapa River	43.6	-7.0	0.4	-19.5
El Teniente	Rapel River (Cachapoal River)	1,068.5	-5.5	0.4	-4.2
And ina	Aconcagua River (Colorado River)	356.0	-4.9	1.0	-4.6
Chuquicamata	Loa River (San Pedro de Chonchi)	4.8	-12.9	0.9	-44.0
Collahuasi	Altiplánicas (Salar de Coposa)	0.0	-11.2	0.9	-
Candelaria	Copiapó River (Quebrada Paipote)	0.0	-12.1	0.5	-100.0
El Algarrobo	Huasco River	0.7	-15.5	0.9	-88.2
Maricunga	Copiapó River (Salar de Maricunga)	0.0	-7.8	0.5	-
El Peñón	Endorheic basins, Salar Atacama – Pacific watershed	0.0	-13.0	0.7	-

Source: ECLAC, 2009

Finally, the study proposes that Chile's mining industry must develop early adaptation strategies that focus on obtaining the additional water resources necessary up to 2040, including improving water recycling efficiency and evaluating the use of seawater and desalination processes.

3.5 AGRICULTURE AND FORESTRY SECTOR

The agriculture and forestry sector is one of the socioeconomic systems that is most closely connected to climatic phenomena, and so impact and vulnerability studies have been a major national concern in recent years. Assessments have concentrated mainly on determining differences in the sector's production potential, using the Simproc simulation model.

This model was calibrated using information on current productivity, adjusted for climate variation projected by the HadCM3 model under emissions scenarios A2 and B2 for the 2046-2065 and 2070-2100 periods, including modeling of the impact of irrigation water availability (ECLAC, 2009). Yield results are presented for the A2 scenario during the 2070-2100 period, both with and without irrigation, for the cultivation of wheat, maize, potatoes, beans, and beets, for the optimal sowing date (Table 7). Summaries of impacts on productivity for grasslands (Table 8), fruit orchards (Table 9) and forest plantations (Table 10) are also provided.

TABLE 7. Projected yields for wheat, maize, potatoes, beans, and beets under scenario A2, for the 2070-2100 period

Crop	Irrigated	Not irrigated
Wheat	• Yield reduction expected, principally in foothills and coastal region, which will lose their current potential, becoming similar to the Central Valley.	• Yield reduction expected in northern and central areas of the country, due to increased frequency of droughts. Reductions of 10 to 20% in the central coast and central valley. • From the Andean foothills in the Region of Biobío southwards, in all regions, gradual yield increase of approximately 30%, and up to 100% in some parts of the Andean foothills in the regions of Los Ríos and Los Lagos.
Maize	• Between the regions of Coquimbo and Biobío, yield reduction expected throughout the central valley, by between 10 and 20%. • Yield increase of up to 50% in the coast and Andean foothills. • In the south, starting in the Region of Araucanía, yields expected to increase by 60% to 200%.	• Yields expected to remain marginal, reaching maximum potentials of less than 4 metric tons per hectare.
Potato	• In general, yield reductions by 10% to 20% expected in the north. • In the north-central zone and south to the Region of O'Higgins, yield reductions by up to 30%. • Between Talca and Temuco, reduced yields to extend from the north in the central valley, but yields in the coast and Andean foothills to increase by up to 50%. • From the Region of Araucanía southwards, yields to increase up to 150%, and 200% in the Region of Los Lagos.	• In general, and especially in the central zone, yields to remain marginal. Increases expected in the Region of Biobío and from the Region of Los Ríos to the Region of Aysén.
Beans	• No change in yields predicted for the northern, central, and south-central zones. From the Region of Araucanía southwards, productivity will increase by 10% to 20%, and up to 100% in the Region of Los Lagos. • In general, yields expected to remain very similar in the south-central and southern zones, around 4.5 metric tons per hectare per year.	• Low yields to remain steady in non-irrigated land. However, increases expected in the coastal areas of the south-central zone and from the Region of Los Ríos to the Region of Aysén. These increases will be of approximately 100%. • Sowing dates to remain steady in the southern zone. In some parts of the coast and Andean foothills of the southern zone, sowing dates will change from October to September.
Beets	• In the central valley, between the regions of Valparaíso and Maule, increases in yields by up to 50% in some districts. • Yields to reduce in the Andean foothills and coastal areas, to levels on a par with the central valley. • From the Region of Araucanía southwards, increases in winter temperatures will bring about increases in productivity.	• Under current climatic conditions, growing conditions for beets are better in coastal areas, with yields of up to 40 metric tons per hectare. • On the coast between the regions of Maule and Araucanía, yields are expected to drop by up to 50%. • In the central valley and Andean foothills, increases may occur in almost all districts from the Region of, Valparaíso southwards. • In the regions of Araucanía and Los Ríos, fall sowing dates will change, permitting increased yields in most districts.

Source: ECLAC, 2009

Photo: Ministry of the Environment. Government of Chile

TABLE 8. Grassland productivity under scenario A2 during the 2070-2100 period

Grassland	• Annual productivity is expected to decrease between the regions of Coquimbo and Los Lagos, associated with more severe dry periods • To the south, productivity is expected to increase by up to 20%. On the eastern slopes of the Andes, in the extreme south, productivity is expect to decrease by up to15% as a result of reductions in solar radiation. • In the Altiplano, productivity will increase as a consequence of higher rates of precipitation than those currently observed. • In the extreme south, productivity will increase on the western slopes of the Andes due to increased rainfall, temperatures, and solar radiation.

Source: ECLAC, 2009

TABLE 9. Fruit tree productivity under scenario A2 during the 2070-2100 period

Fruit tree	• Cultivation may be extended into the regions of Araucanía, Los Ríos, and Los Lagos. • Species that are highly dependent on the climate (for example, grapevines) may see the sensory properties of their products (aroma, flavor, color), affected, and thus the quality of production. • In general, it is expected that the increase in temperature will prolong the life cycle of certain major crop diseases, which may have serious consequences on fruit plant health. • In the case of diseases caused by fungi and bacteria, the projected climate conditions may favor increased proliferation. • Subtropical species such as the orange may improve their potential in almost all regions. • It is highly probable that climate conditions will improve the quality of fruit, as an increase in minimum temperatures may reduce their acidity. • In the north, production potential will increase significantly, especially in the valleys of the Region of Tarapacá. • In the Andean foothills of the central zone, climate conditions may permit an increase in the area of profitable cropland.

Source: ECLAC, 2009

Photo: Ministry of the Environment. Government of Chile

The Simproc Model

The Simproc crop model (Agrimed, 2008) integrates the eco-physical responses of crops faced with climatic stimuli over time. Growth is modeled between germination and harvest. Gross primary photosynthetic production is modeled based on solar radiation and leaf area. After subtracting respiratory losses, potential dry mass production is established, taking into account temperature and soil water availability.

The soil water balance is calculated to determine if a particular crop is receiving enough water, a factor that influences growth rate. The model simulates the crop's phenology based on accumulated degree days, and this factor is used to establish the crop's physiological age. This is then used to model the distribution of growth in different organs of the plant, as well as its sensitivity to catastrophic events such as frosts, thermal stress, or drought. The leaf area of the crop increases until the phenology triggers senescence, from which the area of leaves exposed to solar radiation decreases, bringing about a reduction in photosynthesis and drawing the cycle to a close.

The model requires climatic data and crop-specific eco-physiological parameters, which are used alongside information calculated within the model's simulation. Specifically, the required input fields are:

- Climate variables:
  maximum and minimum temperatures, weekly precipitation, solar radiation, evapotranspiration potential, relative humidity.

- Eco-physiological variables:
  Minimum, optimum, and maximum growth temperatures, degree-days for development and maturation, sensitivity to frost and water deficit for each phonological phase, root depth, photosynthetic efficiency, leaf area-weight ratio, respiration rates for maintenance and growth.

The model's output is summarized as:
- Production of dry mass
- Yield of grain, fruits, or part harvested
- Leaf area index
- Optimum sowing and harvesting dates
- Water consumption, irrigation productive efficiency
- Risk of frost, drought, and thermal stress at different times of the year

Source: Agrimed, 2008..

TABLE 10. Forestry productivity under scenario A2 between 2070-2100

	Pino radiata	Eucaliptus globulus
Forestry plantations	• Significant deterioration in production capacity expected in the north-central zone (between Coquimbo and the Metropolitan Region). This effect is less severe in the south, but may occur in the central zone (Metropolitan Region, Valparaíso, and O'Higgins), diminishing and disappearing in the Region of Araucanía, from where productivity will increase significantly, with marked increases between the Region of Los Ríos and the Island of Chiloé.	• Reduction in potential productivity expected in the Region of Coquimbo, resulting from reductions in precipitation. • In coastal areas of the central zone, productivity increases expected due to higher winter temperatures. Similar situation expected in the Andean foothills. • In the Region of Araucanía and to the south, significant increase in potential productivity, with a marked increase in regions of Los Ríos and Los Lagos.

Source: ECLAC, 2009

3.5.1 Impact on soil resources

Erosion has a significant effect on soil resources, and consequently on agricultural production. Erosion processes depend mainly on the intensity of precipitation, the gradient, and vegetation coverage. Both precipitation and vegetation can be directly and indirectly affected by climate change, which therefore has the capacity to accelerate erosion processes in a large proportion of Chile's agricultural areas. In this context, an assessment of the areas most susceptible to erosion processes by the year 2040 under climate change scenario A2 was conducted (Agrimed, 2008). The simulation adopted a grassland productivity model, and soil loss was estimated using the RUSLE model[2].

Given that the central zone of the country is the area likely to be most affected by climate change, the study analyzed the territory between the regions of Valparaíso and Los Lagos.

The majority of lands vulnerable to erosion in Chile are covered by herbaceous scrubland vegetation. The crossover between areas at higher risk of erosion and areas with a projected loss of natural plant coverage was used to estimate the areas that will be most vulnerable to severe soil loss processes. Areas of the Central Valley that are of high value due to their agricultural or forestry production (Figure 13) may be most severely affected by climate change as projected in this analysis. Soil loss through rain causing erosion is generally less significant in areas that are irrigated, as these areas tend to be flat or exhibit a mild gradient. In the Region of Coquimbo it was only possible to analyze risk in irrigated valleys, as there is a lack of sufficient soil information for estimating erosion risk in mountainous zones. According to this analysis, irrigated land in the south-central zone is expected to suffer soil loss from erosion of less than 5 metric tons per hectare per year. In coastal areas of the Region of Valparaíso and in the Andean foothills of the Metropolitan Region, potential soil loss may be as high as 100 metric tons per hectare per year, depending on gradient and land use.

The areas with the highest risk of rain erosion, both currently and under climate change scenarios, are located in the Coastal Mountain Range and in the foothills of the Andes. The most critical areas are located in the Region of Biobío, where strong pressures from agricultural and forestry land use have led to a marked degradation of soil resources. This zone may be susceptible to losses of 130 to 180 metric tons per hectare per year.

To the south of the Biobío Region, potential soil loss tends to drop, reaching very low levels in coastal areas of the Region of Los Lagos. In the Andean foothills, where soils are less protected by woodlands, the area of high potential soil loss extends into the Region of Los Lagos, suggesting that this may be a fragile zone.

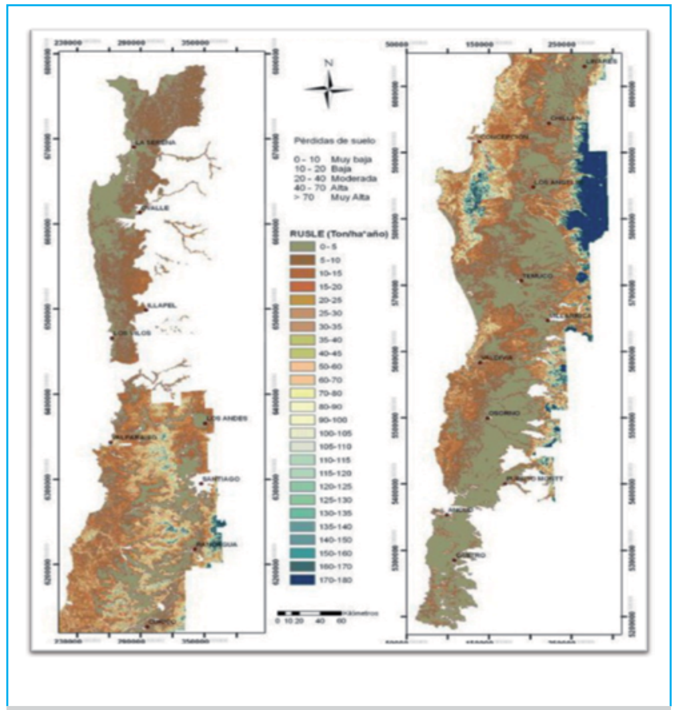

Figure 13. Potential soil loss (tons/hectare/year) from rain erosion estimated for 2040 based on estimated climatic conditions under the PRECIS-HadCM3 model and Scenario A2
Source: Agrimed, 2008

[2] The RUSLE model (Revised Universal Soil Loss Equation) is calibrated for areas with gradients of less than 22%, as it is designed to assess soil conservation practices in agricultural and forestry land. The model overestimates soil loss for steeper gradients, and must be recalibrated on a case by case basis. This study case therefore refers to potential soil loss.

3.5.2 Productive and socioeconomic vulnerability of the forestry and agriculture sector

The vulnerability analysis conducted for the agriculture and forestry sector (Agrimed, 2008) considers adaptation from three perspectives—productive, social, and economic. These are three key aspects of responses to the impact of climate change. From this perspective, a number of indices were developed to assess the sector's vulnerability and establish adaptation measures.

Agricultural vulnerability associated with the production component

This component reflects the vulnerability of the production system itself. The index is estimated based on information from the 7th National Agriculture and Forestry Census (2007), using information on trends in land area used for agriculture and forestry and the ratio between irrigated and non-irrigated land in each municipality.

The study indicates that the vulnerability of persons engaged in agriculture is lower for those who own smaller tracts of land. Although this allows them a measure of flexibility, it is often coupled with the fact that smallholders tend to have less access to capital to invest in technologies that could help them to adapt, and/or the liquidity necessary to face changes in productivity.

This index considers areas used for cereal crops, small agricultural plots, horticulture, forage, and fruit trees and excludes forestry and livestock activities as these production systems share few characteristics with agriculture, differing in terms of the area of land owned and the type of technologies used.

Figure 14 shows that levels of vulnerability are greater in areas with more cultivation of annual crops (valleys in Coquimbo Region and the Central Valley from the Region of Maule southwards). The higher level of vulnerability in the regions of Los Ríos and Los Lagos is explained by the lack of irrigation infrastructure. Central regions where fruit growing predominates show lower indices of vulnerability.

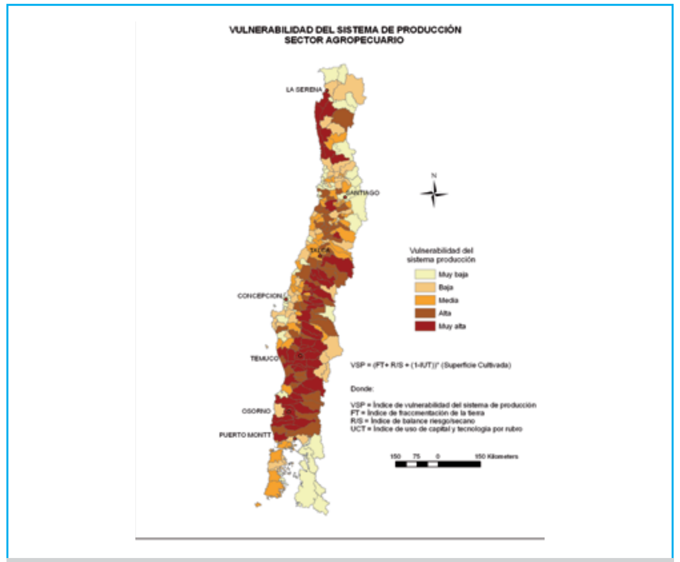

Figure 14. Agricultural vulnerability associated with production
Source: Agrimed, 2008

Agricultural vulnerability associated with the social component

This index reflects the population at risk of possible negative climate impacts on local agriculture. It considers the rural population and its human development level as well as the impact on local agriculture. The zones that are most vulnerable are those with high levels of agriculture and low human development indices. The most vulnerable areas are located in the regions of Coquimbo, Maule, and Araucanía (Figure 15).

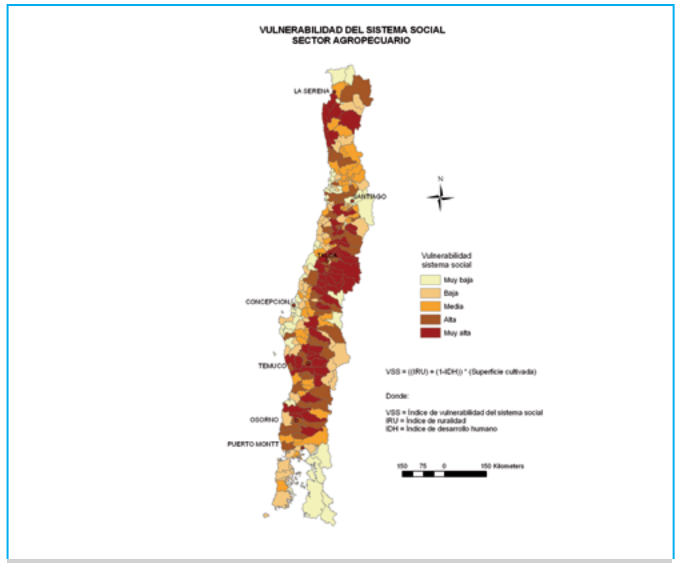

Figure 15. Agricultural vulnerability associated with the social component
Source: Agrimed, 2008

Agricultural vulnerability associated with the economic component

This index reflects the level of economic risk associated with the negative impact of climate change. It is calculated taking into account capital invested, supplies and technologies used in each field, and linkage with external markets. Thus, agriculture that uses higher degrees of technology and generates more profit is also more vulnerable in the economic component, as potential losses may be higher. This is pertinent to the export agriculture of Central Chile, which is technologically intensive and could potentially face the most significant economic losses in the country. These losses indirectly include reductions in foreign exchange associated with negative impacts on the agriculture and forestry sector.

Figure 16 shows that this index is highest in areas having a significant proportion of the country's fruit export orchards and crops, such as: grapes, apples, cherries, and nectarines.

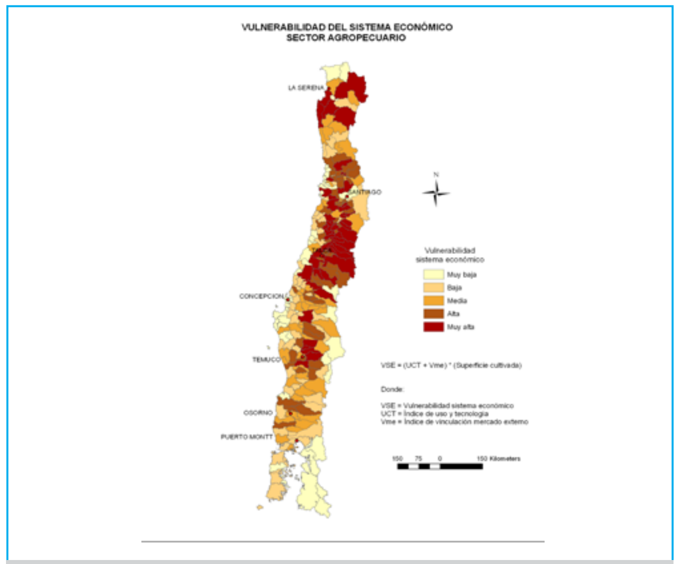

Figure 16. Agricultural vulnerability associated with the economic component
Source: Agrimed, 2008

3.5.3 Agriculture and forestry land use change: economic and labor impacts

Projected changes in the productivity of crops and plantations arising from changes in climatic conditions will impact economic profitability and therefore prompt changes in land use. This will in turn cause economic impacts (both positive and negative) and change the demand for labor.

Given that a close relationship exists between agricultural practices, land values, and climatic conditions, climate projections under the HadCM3 model may be integrated into a model capable of stimulating the expected responses of persons engaged in agriculture and effects on land values. A study into this effect was financed by the Ministry of Agriculture during this period (P. Universidad Católica de Chile, 2010).

Photo: Ministry of the Environment. Government of Chile

Socioeconomic impact methodology (Agrimed, 2008)

The socioeconomic impact of climate change on agriculture was estimated using the yield model proposed by Agrimed for 12 cultivar types (maize, wheat, potatoes, beans, beets, peach trees, apple trees, orange trees, grape vines, pasture, eucalyptus, and Pino radiata). The analysis takes into account intrinsic adaptation by persons engaged in agriculture in line with changes in climate patterns. The study was conducted on a municipal scale. To determine changes in land use and land value, at each phase of land assignation an econometric model was applied in which the proportional holdings – the areas used for the cultivation of a specific crop – were subject to a logistical model. Changes in land use were estimated using data from the 6th and 7th Agriculture Census (1997 and 2007). For both years, the total area used for agriculture was calculated, as was the area used to cultivate each species and the proportion of land used for agriculture in each municipality. Technical data sheets were used for each species to calculate yields and both fixed and variable costs, permitting net income per hectare to be estimated for each species in each municipality of the country.

Finally, for each climate change scenario estimates were generated for the assignation of land for each use, total revenue generated by the agriculture sector, and total labor requirements, by gender. The results of the analysis, for scenarios A2 and B2 during the 2070 -2100 period are summarized in the following variables: change in land use, change in net revenue, and change in labor requirements.

Change in land use

The area of cultivated land is projected to decrease under scenario A2-70 by approximately 1% of the baseline area (Figure 17). Similarly, areas used for fruit growing are projected to decrease by 2% under the most severe climate change scenario. The area used for pasturing and foraging (Figure 18) would decrease by approximately 1.5% over the current area. Conversely, the model predicts an increase in forestry plantations of approximately 5% over the baseline.

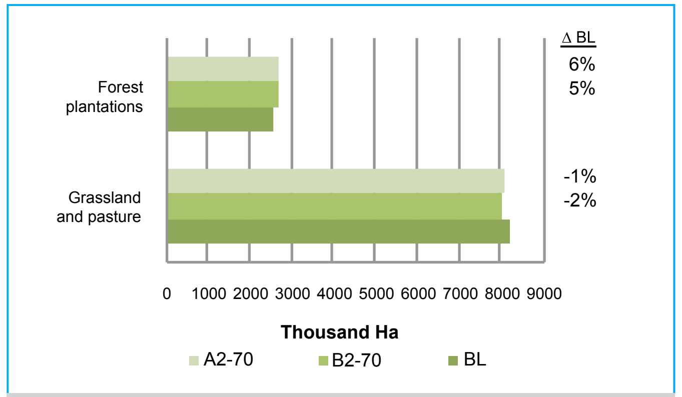

Figure 17. Area with fruit orchards and cultivated crops (baseline), and end-of-century estimations under scenarios A2 and B2
Source: ECLAC, 2009; P. Universidad Católica de Chile, 2010

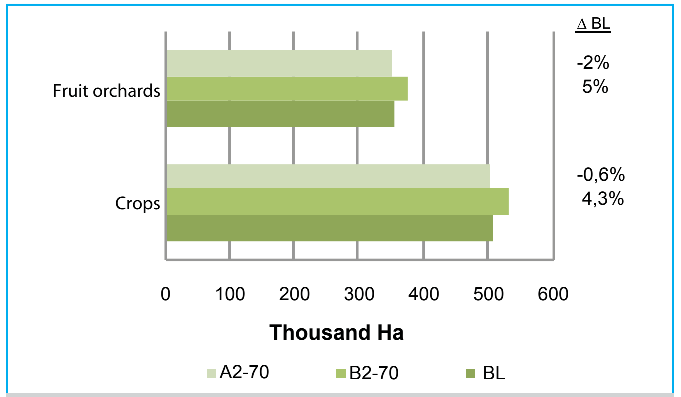

Figure 18. Area used as grassland, grazing land, and forestry plantations (Baseline) and end-of-century estimations under scenarios A2 and B2
Source: ECLAC, 2009; P. Universidad Católica de Chile, 2010

Changes in net agricultural income

At the national level, net revenue is projected to decrease by approximately 15% under the most severe climate change scenario (A 2).

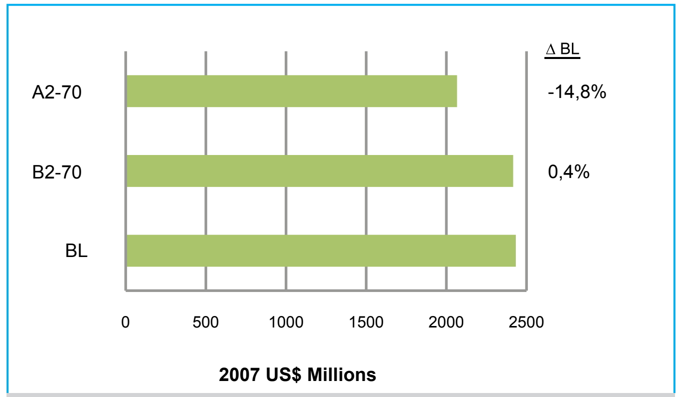

Figure 19. Net national agricultural revenue under the baseline scenario and projected climate change scenarios
Source: ECLAC, 2009; P. Universidad Católica de Chile, 2010

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It is also observed that net revenue in the south of the country increases under all scenarios in association with increased productivity in the sector. The north-central zone shows a decrease in revenue, associated mainly with productivity reductions arising from lower water availability for crops. In outlying cases the results of the simulation tend not to be plausible and they were therefore discarded.

Change in labor demand and possible impact on migration processes

Projected changes in agricultural productivity and changes in land use, particularly in the south-central and southern zones of the country, will cause variations in the demand for labor in rural areas. In general terms, migration to cities is expected to increase in the central zone, whereas in the south of Chile migration to rural areas is expected to increase due to higher demand for labor. In order to determine the magnitude of population movements, the model takes into account the reduction in labor demand associated with climate change phenomena. In the baseline situation, almost 5% of the national economically active population is engaged in agriculture. Under the climate change scenarios, labor demand will drop by 18% against the baseline (Table 11 and Figure 20).

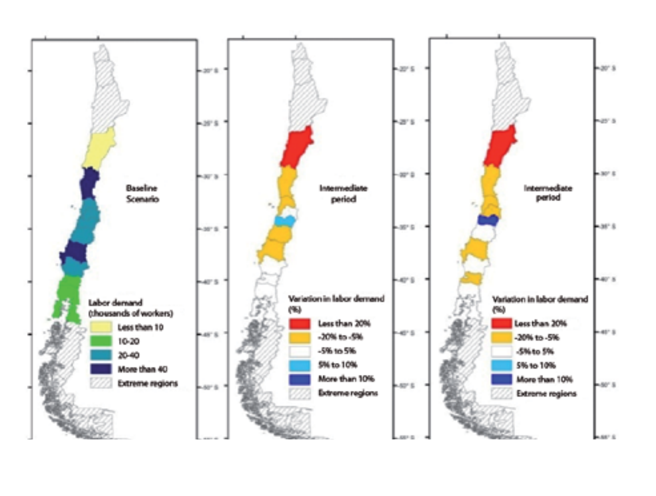

Figure 20. Changes in labor demand in the agriculture and forestry sector by 2100 under scenario A2
Source: ECLAC, 2009

TABLE 11. Labor demand (thousands of worker/year)

Region	Baseline	2010-2040	Scenario A2		Scenario B2	
			2040-2070	2070-2100	2040-2070	2070-2100
Atacama	7.00	6.21	3.72	2.43	4.43	3.53
Coquimbo	54.65	51.65	43.98	39.44	44.81	44.22
Valparaíso	27.36	24.81	19.08	17.50	20.60	20.62
Metropolitan	26.93	25.87	23.47	18.35	26.48	25.24
O'Higgins	39.20	39.37	42.28	40.87	41.78	44.23
Maule	30.94	30.16	28.06	28.72	28.28	29.20
Biobío	49.26	48.69	44.68	43.58	45.17	44.51
Araucanía	30.11	29.07	27.33	25.49	27.92	27.34
Los Ríos	12.43	11.79	10.29	9.07	10.62	9.71
Los Lagos	17.72	17.45	18.07	16.92	17.64	17.22
Total	**295.60**	**285.07**	**260.96**	**242.38**	**267.73**	**265.83**

Source: ECLAC, 2009; P. Universidad Católica de Chile, 2010

3.6 BIODIVERSITY

International studies on the impact of climate change on biodiversity conducted during recent years have shown that the recent increase in temperature observed on the planet has had a series of biological and ecological impacts on plants and animals, with a level of certainty regarding alterations in the limits of distribution ranges of species and their phenology (Parmesan, 2006).

The concept of biodiversity or biological diversity refers to the variability of living organisms found in all terrestrial and aquatic ecosystems, including diversity within a single species, between species, and between ecosystems. This factor plays a fundamental role in several processes that impact climatic equilibrium, water cycles, and soil development, as well as other ecosystem effects of importance to humans.

Chile's wide range of latitudes and altitudes produces very heterogeneous environmental conditions, which foster biological diversity. The climate patterns generated by these two geographical gradients have given Chile one of the planet's most arid regions and several zones with the highest number of precipitation days per year.

Conservation priority biodiversity hotspots are areas with a minimum of 1,500 species of endemic vascular plants, a high proportion of endemic vertebrates, and an original habitat that has suffered significant degradation due to anthropogenic activity. Chile has two biodiversity hotspots: the temperate Mediterranean climate zone and the Altiplano zone (Figure 21). The effects of human activity on the central zone of Chile have been observed for centuries. Since the 18th Century the Central Valley has seen the impacts of human expansion, including urban sprawl and the spread of livestock and agricultural activities. The current situation, seen throughout the Mediterranean regions of Chile's Central Valley, is a preponderance of livestock pastureland, cropland and plantations of exotic species (Neira et al., 2002). The most well-preserved habitat remnants, many of which are in public or private parks and reserves, are located in the coastal mountains and in the Andean foothills.

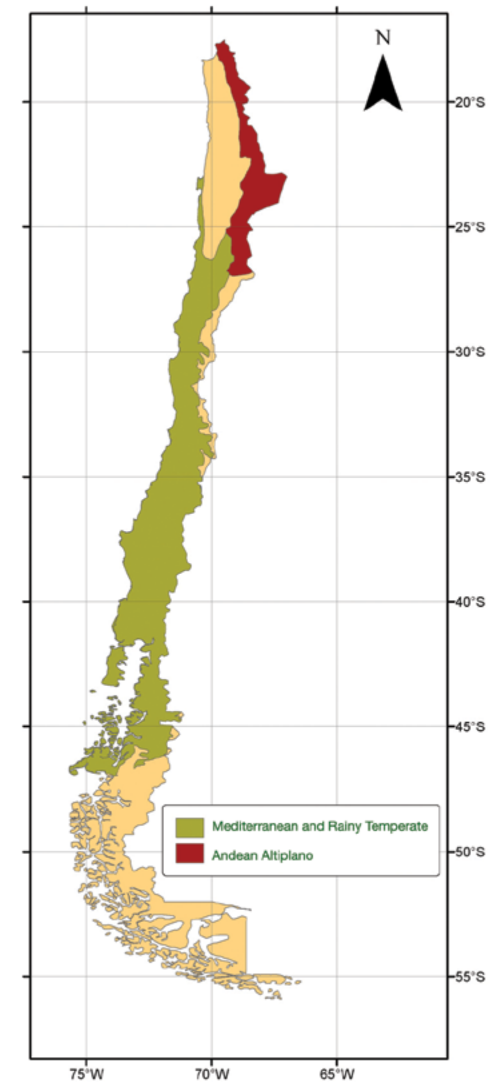

Figure 21. Map of biodiversity hotspots in Chile
Source: WWF, 2004

Considering the vulnerability of Chile's ecosystems, the vulnerability of the country's biodiversity in the face of climate change has been assessed at the level of species and ecosystems, in order to identify possible adaptation measures. A report prepared by IEB/Caseb and financed by CONAMA, entitled "Estudio de vulnerabilidad de la biodiversidad terrestre en la eco-región mediterránea, a nivel de ecosistemas and especies, y medidas de adaptación frente a escenarios de cambio climático" [Study of the vulnerability of terrestrial biodiversity in the Mediterranean eco-region, at the level of ecosystems and species, and adaptation measures under climate change scenarios] (IEB, 2010) compared the current distribution of species and ecosystems and the expected distribution under a climate change scenario, based on data from the PRECIS regional model. The model simulated potential changes in the distribution of 15 species of amphibians, 16 species of reptiles, 36 species of mammals, 1447 species of vascular terrestrial plants, and 36 ecosystems. Vulnerability was evaluated in the context of three protection scenarios, based on the limits of the current network of protected areas (scenario 1), including private protected areas (scenario 2), and excluding private protected woodland areas without official protection (scenario 3). Analysis at the level of species and ecosystems was complemented with an assessment of one key ecosystem representative of the high Andean wetlands and the Mediterranean ecosystem zone.

The methodology included an assessment of the current distribution of species and ecosystems based on climatic characteristics of the places where their presence is confirmed. Future projections of distributions were created using a statistical model based on the Maximum Entropy Principle (MaxEnt), generating the projected distributions for the 2070-2100 period.

In the case of high Andean wetlands, 8 locations were selected, corresponding to the river basins of the largest wetlands. A water balance was calculated for each basin, and modifications in the water cycle arising as a result of expected climate changes were then assessed.

3.6.1 Impacts on species

Modeling of potential ecological niches of the species studied showed that responses are highly dependent on the dispersion strategies input into the model. When it is assumed that the species are capable of dispersing rapidly during the time period modeled (late 21st century), more than half of the species studied appear to expand their distribution ranges; on the other hand, when it is assumed that the species are incapable of dispersion, most projections predict reductions in species' ranges. The projected impacts show that vulnerability is greater under emissions scenario A2 than under scenario B2.

An analysis of species' response to climate change shows that even under the limited dispersion model in which most species suffer reductions in their distributions, the number of extinctions is relatively low. In fact, the simulations featured only two extinctions, namely the *Festuca orthophylla* grass, in the limited dispersion model under scenario A2, and the *Nassauvia digitata* flowering plant in the unlimited dispersion model under scenario A2 and in the limited dispersion model under scenarios A2 and B2.

Festuca orthophylla

Nassauvia digitata

In terms of the level of coverage of species under the three protection scenarios, considered in the context of their current distribution and projected distributions under scenarios A2 and B2, all vertebrate species studied have some coverage under the protection scenarios. However, at least 10 of the plant species studied are not present in any of the national protected areas considered in certain scenarios.

3.6.2 Impacts on ecosystems

The impacts of climate change on the 36 ecosystems evaluated in the study mentioned above show a pattern of latitude variation in almost all ecosystem types present in the coastal and inland zone of north and central Chile. Additionally, ecosystems featuring schlerophyll and spiny vegetation exhibit the highest level of variation in their current distribution ranges.

The greatest change in vegetation ecosystems estimated for the end of the 21st Century occurs in the central zone of Chile, where ecosystems are most dynamic. For example, projection of ecosystems characteristic of Central Chile indicate that the area of inland Mediterranean thorny woodland under scenario A2 and semiarid Andean scrubland under scenario B2 would be significantly reduced. In this regard, the vegetation of the Mediterranean hotspot would be highly vulnerable to climate change.

Figure 22. Areas with greatest ecosystem variation resulting from climate change in Chile, under Scenario A2 for the 2070-2100 period
Source: IEB, 2010

The Andean Altiplano hotspot, characterized by wetland ecosystems that harbor significant biodiversity, was also found to be vulnerable. A water balance analysis of river basins in Northern Chile, closely linked to the wetland ecosystems of the zone, showed that by the end of the 21st Century most global climate models project a change in precipitation and increase in temperatures that would lead to a change in flow rates and surface runoff—the principal factors in maintaining the stability and functionality of the wetlands of the Chilean Altiplano.

3.7 COASTAL ZONES AND SEA LEVEL RISE

Average sea level changes resulting from variations in the total volume of the oceans are caused mainly by global temperature changes and by the melting of large ice masses. The level of the world's oceans has risen in recent decades, partially due to the effect of thermal expansion and the melting of glaciers, the ice caps, and polar ice coverage, as indicated in the IPCC 4th Assessment Report (IPCC, 2007).

In Chile, projections based on the HadCM3 model indicate rises in sea level of the order of 20cm on the northern coast of the country and 10cm on the southern coast (U. de Chile, Geophysics Dept., 2006).

The study "Evaluación de la vulnerabilidad y adaptación en zonas costeras y recursos pesqueros" [Assessment of vulnerability and adaptation in coastal zones and fishery resources] of the Centro EULA at the Universidad de Concepción (Centro EULA, 2001), financed by the First National Communication project, assessed the effects of sea level increases along the coast of the Gulf of Arauco on stocks of anchovy, common hake, and common sardine. The results suggest that a 1 meter sea level increase in the Gulf of Arauco would cause financial losses of between 23 and 54 billion Chilean pesos (1994 value) and threaten the livelihood of 1,200 to 1,800 individuals.

This study has not been replicated for other areas of the country or for other scenarios. However, a preliminary analysis of background information on sea level changes, seismic events, tsunamis, and variations in wave patterns along the coast of Chile has been conducted to identify trends and factors that should be taken into account in analyzing the future effects of climate change on the country's coastal regions (ECLAC, 2009).

In order to estimate the effects of changes in the maritime climate, a detailed study of oceanographic factors must be conducted, including sea level, prevailing and dominant wave patterns, tides and storm surges, and ENSO phenomena.

Climate change is one of many factors that contributes to the vulnerability of coastal regions, and may interact in synergy with other anthropogenic effects such as the installation of infrastructure in low-lying high-risk areas, the indiscriminate dredging of river beds, the stabilization of land subject to erosion, and urban sprawl into dune areas (ICOUV, 2010).

3.7.1 Sea level

Variations in sea level measured over a period of more than 40 years at Chile's oceanographic stations are not homogenous, and range between increases of up to +0.318 cm/year and decreases of up to -0.141 cm/year. Locations such as Arica and Antofagasta show an apparent drop in sea levels, while at Caldera and Talcahuano increases have been observed. At Puerto Williams a continuous reduction in sea level was observed through the 20th century, but this trend has reversed since 2000. The Easter Island station has also shown a greater increase in average sea level than the stations located on the continent.

Rates of variation observed in Chile are lower than those recorded at certain foreign stations where data have been gathered over a long period and increases and decreases of the order of centimeters per year have been observed, an order of magnitude greater than that recorded in Chile. However, variations are comparable to average values recorded at measurement stations in different parts of the world, which range between an increase of +0.59 cm/year and a decrease of -0.57 cm/year. By way of example, sea level time series recorded at Arica are presented (Figure 23) showing an increase of +0.14 cm/year, and at Talcahuano (Figure 24) showing a decrease of 0.14 cm/year.

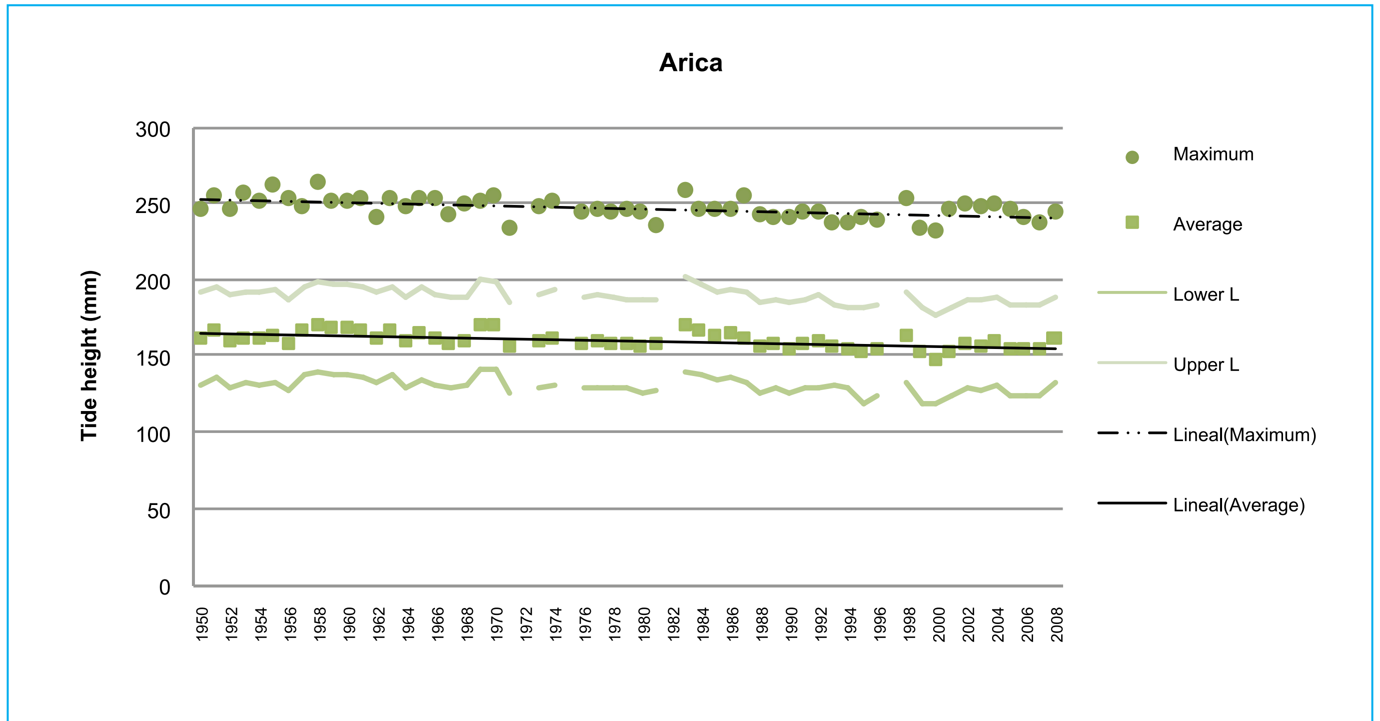

Figure 23. Variation in average annual sea level at Arica
Note: Not including tidal effects.
Source: ICOUV, 2010

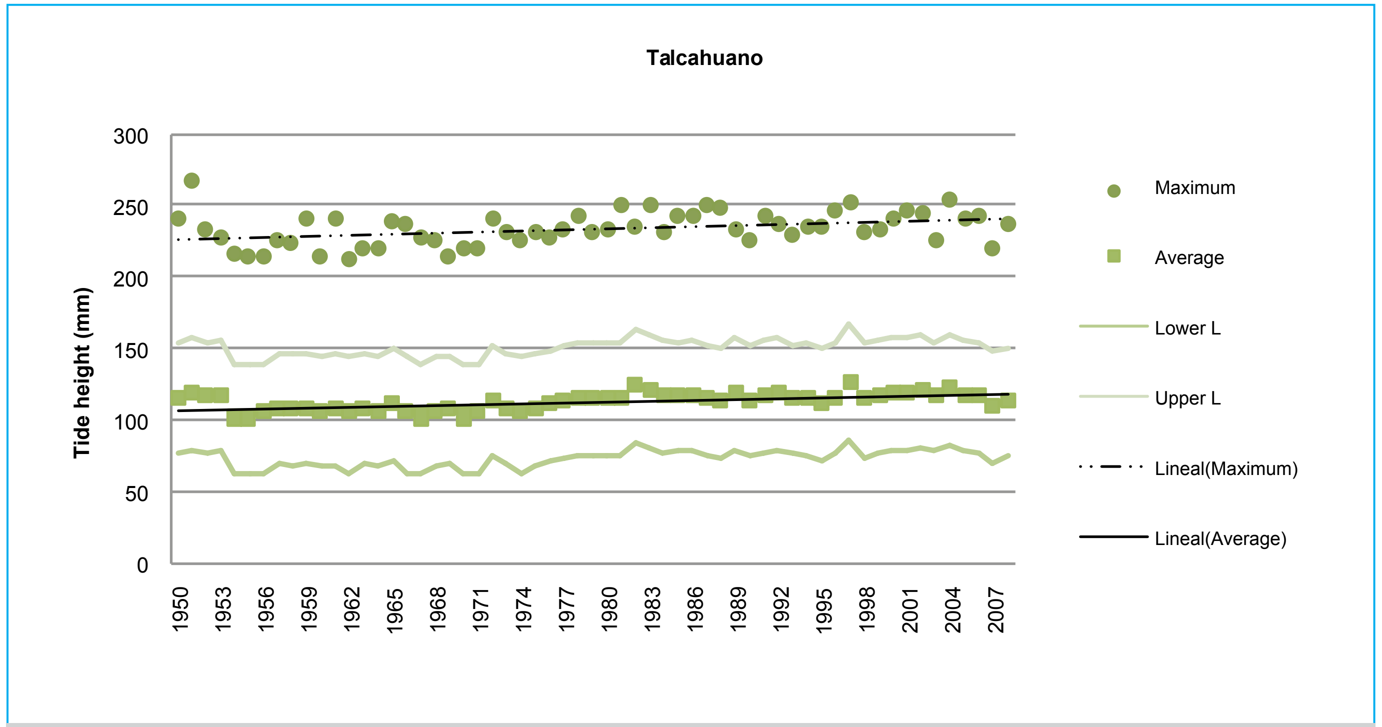

Figure 24. Variation in average annual sea level at Talcahuano
Note: Not including tidal effects.
Source: ICOUV, 2010

It is interesting to note that although sea levels on the coasts of Chile do not show major fluctuations over time, evidence exists for cyclical changes associated with ENOS phenomena. In El Niño years the sea level may rise by up to 0.3 meters over the general trend, and decreases of a similar magnitude are observed during La Niña years.

Due to Chile's high level of seismic activity, gradual changes in sea levels may be of little significance in the planning of adaptation measures. The best example of this can be seen in the impact of the earthquake and tsunami that affected the southern coast of Chile on February 27, 2010. The effect of this event on immediate sea level was at least an order of magnitude greater than the foreseeable impacts of sea level increases associated with climate change.

Nonetheless, it is interesting to analyze potential changes in climatologic and oceanographic conditions associated with climate change, as these effects may have a significant impact on the operation of port infrastructure today and in the future. Therefore, the following section presents a brief analysis of historical wave patterns on the coasts of Chile.

3.7.2 Wave patterns

The statistical analysis of prevailing wave patterns, not taking into account seasonal statistics, shows a change in the annual probability distribution of extreme events between the first years for which statistics are available (1985-1994) and more recent years (1995-2006). These variations suggest an increase in wave height over recent years, accompanied by longer periods and waves coming from ever more southerly directions. This increase in wave period and height implies an even more significant increase in wave power. Statistics on wave power show an increase in the probability of events with greater than average magnitude of up to 25%. An average increase of 0.4 Kw/year was recorded, as well as significant seasonal interannual variations. Wave power increases with increasing latitude.

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4. ADAPTATION TO CLIMATE CHANGE

4.1 WATER RESOURCES

4.1.1 Glacier Conservation and Protection Policy

In February 2009, CONAMA's Ministerial Council approved a National Glacier Conservation and Protection Policy. This policy was drafted because glaciers are fragile ecosystems that are valuable to humans for their climate regulation and water supply functions, as well as for their contribution to essential natural processes and activities such as tourism, scientific research, and sports. Because of this, glaciers need to be protected and conserved, in terms of specific regeneration processes, glacial fragility in the face of the new climate change scenarios emerging on the planet, temperature increases, geographic variations in precipitation patterns, increases in sea level and corresponding temperature variations that in turn bring about alterations in surrounding aquatic and terrestrial ecosystems.

The policy affirms the need to value Chile's glaciers and build knowledge about them in the national and international context by creating a national glacier registry, and by defining other research priorities. The policy calls for the registry to be drawn up by the General Water Department (DGA) at the Ministry of Public Works. It also calls for measures to preserve and conserve glaciers, to ensure the continuity of natural and productive processes that depend on them, and to generate essential environmental effects. It further identifies the need to establish glacier types and permitted uses, and to design institutional mechanisms and instruments for their implementation.

Government entities with purview over glacier-related issues were identified in 2010 as a first step toward operationalizing the glacier policy. The Centro de Estudios Científicos de Valdivia was commissioned by the DGA to draw up a national glacier strategy, presented in detail in Chapter 5.

Institutional climate change adaptation project: Adaptation case studies in Chile and Canada

Between 2004 and 2008 a project financed by the Major Collaborative Research Initiatives program of the Canadian Social Sciences and Humanities Research Council investigated the climate change adaptation capacity of areas with non-irrigated cropland (dryland). Two river basins were selected, the Elqui River Basin in the Region of Coquimbo in Chile and the South Saskatchewan River Basin in Western Canada. In Chile, the project was supported by CONAMA, the Center for Water in Arid and Semiarid Zones in Latin America and the Caribbean (CAZALAC) and the Institute for Political Ecology (IEP).

The project developed an overall systematic understanding of the regional institutional capacity to formulate and implement adaptation strategies for climate change and its predicted impacts on the supply and management of water resources in dryland environments.

The following activities were conducted during the project:

- assessment of the current vulnerabilities of a group of communities in each basin
- analysis of the role of institutions in resolving recent conflicts related to water scarcity
- historical study of institutional adaptation during periods of water scarcity
- analysis of environmental vulnerabilities identified by stakeholders
- assessment of government institutional capacity reduce the vulnerability of rural communities.
- assessment of future climate scenarios for each basin including their potential impacts, based on different climate models.

4.2 HYDROELECTRICITY SECTOR

In the energy sector, in 2010 the National Energy Commission (now the Ministry of Energy) funded a study to define hydrological scenarios, model the expansion of generating capacity, and design security risk indicators for the country's electricity supply. The results of this study, which was concluded during the first quarter of 2011, will contribute to public policy discussions about the most suitable approach to reducing risks associated with adverse hydrological scenarios in river systems with hydroelectric plants.

4.3 MINING SECTOR

In copper mining, water is used mainly in traditional floatation concentration processes, smelting, and electro-refining and hydro-metallurgical processes that include leaching, solvent extraction, and electro-winning (LX-SX-EW). However, each processor or mining project uses different amounts of water, always with a view to boost process efficiency.

The public-private national round table on water consumption in the mining sector selected COCHILCO to coordinate actions to be agreed and implemented by the DGA in conjunction with the mining sector. These activities included validating water consumption data provided by mining companies and defining the sector's usage conditions, requiring increased efforts in compiling, systematizing, disaggregating, and validating the applicable information.

In 2007 the DGA worked with the National Mining Society (SONAMI, a cluster of private mining firms) to compile and systematize information on water usage rights held by the mining sector, to establish the flow rate for water used by mining projects and determine freshwater consumption in copper mining processes. The results of these public-private efforts to increase information transparency are reflected in the study "Derechos, extracciones and tasas unitarias de consumo de agua del sector minero. Regiones centro-norte de Chile" [Water rights, extraction, and unit consumption in the mining sector. North-central regions of Chile], published in 2008 by Proust Consultores for the DGA's Planning and Studies Division. This study was also the first step in determining water consumption by the mining sector in the country and provided information on the progress the sector had made to use water more efficiently.

Based on these achievements, COCHILCO decided to work on the compilation, systematization, and analysis of information on water consumption in mining projects, to provide quality information on the current situation in regard to copper mining and water resources. The organization launched a database to show changes in the sector's water consumption and demand over time. The results were published in the study "Consumo de agua en la minería del cobre 2009" [Water consumption in copper mining 2009] (COCHILCO, 2010). According to this study, average annual water extraction reported by copper mining companies for 2009 amounted to 11.97m^3/s. It should be pointed out that this figure does not include sea water or water extracted from wells at the mining sites. In percentage terms, the Region of Antofagasta represents 48% of total extraction of fresh water in the country. The Region of O´Higgins is in second place with 14% of total extraction, followed by the Region of Copiapó, with 12%, the Region of Tarapacá with 10%, and finally, the Region of Valparaíso with 7%, the Metropolitan Region with 5%, and the Region of Coquimbo, which represents 4% of total fresh water extracted in Chile during 2009. Unit fresh water consumption for the production of mineral concentrates was 0.72 m^3/ton, and 0.13 m^3/ton of ore processed for cathodes. In general terms, unit fresh water consumption was similar for both concentration and processing and hydro-metallurgy over the period analyzed (2006-2009), indicating that progress in water efficiency achieved over the past decade by copper mining companies has been maintained.

Rational and efficient water usage is currently considered to be of fundamental importance in the mining industry, where companies are taking action to optimize their consumption by implementing best practices and/or the introducing better technologies that reduce demand, freeing up limited water resources. These include water recirculation, desalination and direct use of seawater (depending on the characteristics of the ore), using more concentrated suspensions in production (reducing water percentage) in large scale industrial production, and site selection to enhance control of leakage.

4.4 FORESTRY AND AGRICULTURE SECTOR

Chile is highly vulnerable to climatic conditions, but opportunities to apply adaptation measures exist. First, there is still time to design and implement economically and socially affordable adaptation policies, and the sooner adaptation actions are implemented, the more opportunities there will be in relation to climate change in the country's main productive sectors—agriculture, forestry, and technological development (Aldunce, 2010).

The sector of the Chilean economy that has developed the largest number of adaptation actions has been the agriculture and forestry sector, in which a number of studies have been funded by ODEPA and FIA, and in some cases with the support of CONAMA (now the Ministry of the Environment), out of these institutions' own budgets. These studies have generated information on vulnerability as a contribution to the design of concrete policies for the medium and long term. In 2008, CONAMA commissioned the Universidad de Chile to conduct the study "Análisis de vulnerabilidad del sector silvoagropecuario y de los recursos hídricos y edáficos de Chile frente a escenarios de cambio climático" [Analysis of the vulnerability of the agriculture and forestry sector and the water and soil resources of Chile to climate change scenarios], which provided background information for the design of future adaptation measures. Similarly, in 2009 the Ministry of Agriculture's Institute of Agricultural Research (INIA) and the Universidad de Concepción conducted the "Estudio sobre impacto, vulnerabilidad y adaptación al cambio climático en el sector silvoagropecuario de Chile" [Study on impact, vulnerability, and adaptation to climate change in the agriculture and forestry sector in Chile]. Additionally, in 2010 the Pontificia Universidad Católica de Chile was commissioned by the Ministry of Agriculture's Office of Agricultural Studies and Policies to conduct the study "Estimación del impacto socioeconómico del cambio climático en el sector silvoagropecuario de Chile" [Estimation of the socioeconomic impact of climate change on the agriculture and forestry sector in Chile], which provides important background information for the assessment of adaptation actions that should be designed for the country in future.

The results of another study commissioned by the Ministry of the Environment and conducted by the consultant firm Asagrin are also available in Chile. The study, entitled "Portafolio de propuestas para el programa de adaptación del sector silvoagropecuario al cambio climático en Chile" [Portfolio of proposals for the adaptation program of the agriculture and forestry sector to climate change in Chile], presents a suite of adaptation measures designed for different agro-ecological zones, and is intended as input for a sectoral adaptation plan. Similarly, INIA conducted a multi-year project called "Adaptación de sistemas productivos de papa and trigo al cambio climático" [Adaptation of systems for the production of potatoes and wheat to climate change], in collaboration with researchers from Chile, Uruguay, and Peru. The study focused on the genetic improvement of these species as an adaptation to thermal and water stress and against attack by new diseases, pests, and weeds. The project is funded by the Regional Fund for Agriculture Technology (Fontagro) and the Inter-American Development Bank.

4.4.1 Water efficiency in the agriculture and forestry sector

Adaptation measures identified in these studies often emphasize water efficiency. In this regard, the Ministry of Agriculture's Law Nº 18,450, commonly known as the Irrigation Law, should be highlighted since the expansion of efficiency measures is certainly a priority issue in the agriculture and forestry sector.

Since this law was passed in 1985, its aim has been to increase the area of the country that is irrigated, to improve water supply to regions suffering a shortage for irrigation, to create incentives for water efficiency, and to increase the area of land used in agriculture and livestock activities by improving drainage or facilitating the installation of irrigation. The law authorizes the state to manage a program for small scale irrigation and drainage projects that operates through a system of public tenders, allowing small scale growers to access a state subsidy. The law provides grants to irrigation projects costing no more than UF12,000 (approximately US$500,000) when undertaken by individuals, or UF30,000 (approximately US$1,250,000) when presented by irrigation associations. The grant subsidizes up to 90% of the total cost.

It also should be noted that the law benefits irrigation user organizations and directs resources towards the recovery of irrigation water quality where water is contaminated, and towards the support of sustainable agriculture.

4.4.2 Management of agricultural emergencies

The Ministry of Agriculture formed the National Agricultural Emergency Commission, which includes instruments such as the national agricultural sector emergency and insurance system. This system is managed by the Agricultural Insurance Committee (COMSA) and operated through private insurance companies. It permits persons engaged in agriculture to transfer the risk of economic loss resulting from damage to an insured crop as a result of climatic phenomena. This allows the producer to recover the direct costs of production, which increases income security and protection for his or her family. To facilitate access to the program, the beneficiary of the policy (the person engaged in agricultural activities) receives a public subsidy for payment of premiums. This initiative is currently available in the agricultural districts of Coquimbo and Los Lagos regions and there are plans to expand it to other regions of the country.

The risks covered are drought in dryland agriculture, excessive or unseasonal rainfall, frost, hail, snow, and wind damage. This type of insurance covers most cereal, horticultural, legume, and industrial crops. A plan exists to extend it to crops in greenhouses or plant nurseries, fruit crops, and flowers, in order to provide more coverage for the country's agricultural sector.

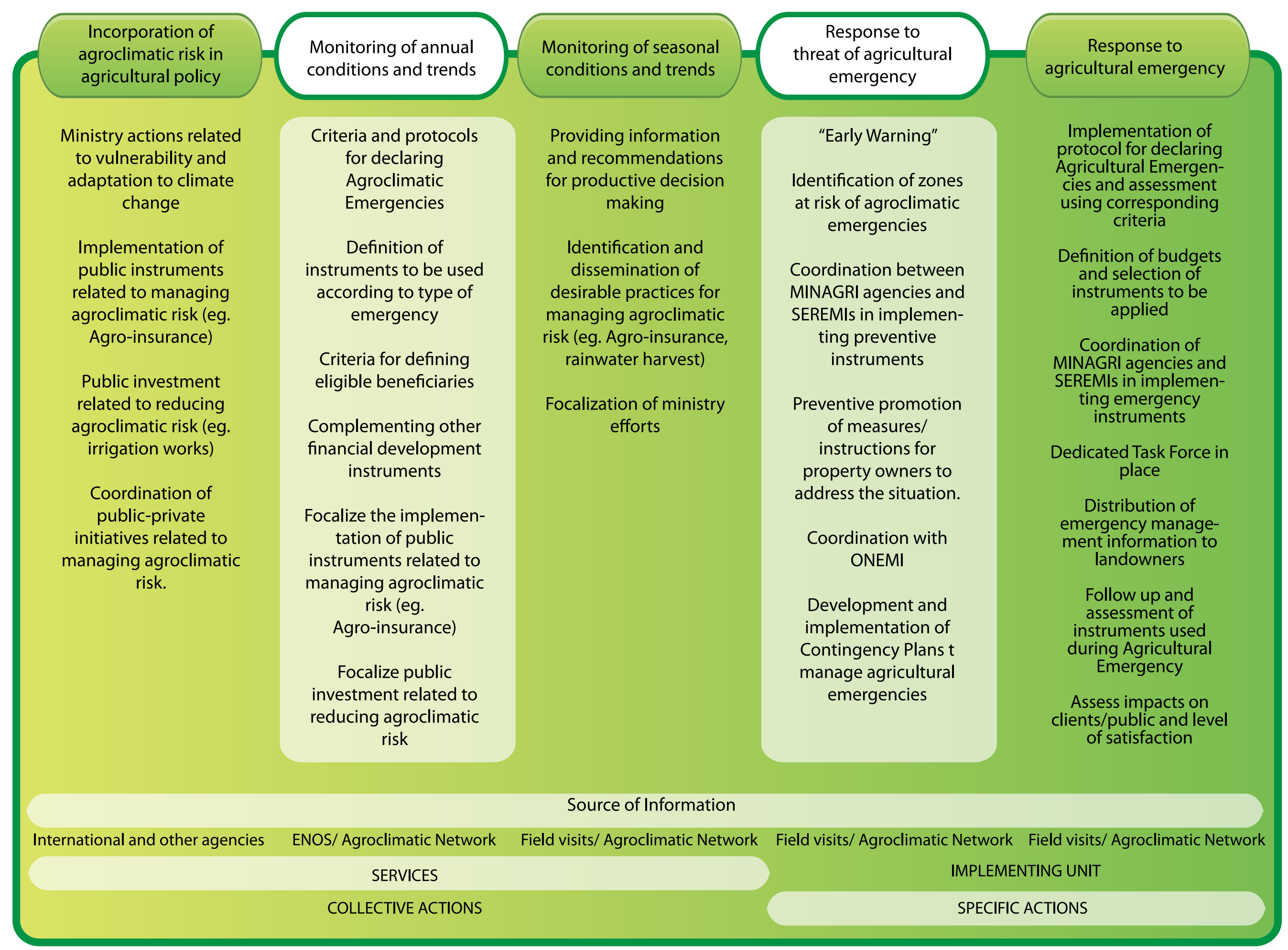

Figure 25. National Management System for Agricultural Emergencies and Agro-Climatic Risk
Source: INIA, 2010

4.4.3 Genetic improvement

The Ministry of Agriculture has established a platform for genetic improvement in response to climate change that is being managed by INIA and will be the launchpad for the preparation of crop, forage, and fruit varieties that are better adapted to the conditions generated under climate change. This initiative should be promoted strongly in the coming years.

To date, research projects in this area have sought to build resistance to major crop diseases and introduce on a trial basis new varieties of grape, stonefruit, cherry, raspberry, and apple, in order to diversify supply. Additionally, the Consorcio Tecnológico de la Fruta S.A. is currently engaged in a number of projects that are aimed at the genetic and productive improvement of grapes, stonefruit, cherries, raspberries, and apples. This organization–a partnership of exporters, the Asociación de Exportadores de Chile (Asoex) and the Universidad Católica–is subsidized by the Ministry of Agriculture through the Agricultural Innovation Foundation.

Study on impact, vulnerability, and adaptation to climate change in the agriculture and forestry sector in two agro-climatic zones in Chile

This study, funded by the Ministry of Agriculture and completed in late 2009, helped generate initiatives to improve the competitiveness of the agriculture and forestry sector by rigorously analyzing the requirements of adaptation, validation, and/or incorporation of new technologies in the reduction of the impact of climate change. The "Estudio sobre impacto, vulnerabilidad y adaptación al cambio climático en el sector silvoagropecuario en dos zonas agroclimáticas de Chile" (FIA-INIA, 2009) was conducted by the INIA Quilamapu Regional Research Center with the collaboration of the Faculty of Agriculture of the Universidad de Concepción. The Center for Agriculture and the Environment (Agrimed) at the Universidad de Chile also played a major role in generating relevant information on climate and production.

The study is an economic projection of the impact on production in areas of interest in two agro-climatic zones involved mainly in export and livestock/crops, respectively, under scenario A2 for the years 2020 and 2040, focusing on small and medium scale agricultural production.

The zones studied are the irrigated Central Valley zone and the south-central Andean foothill zone. These comprise agricultural lands with significant low-income family farming activity in the O`Higgins and Biobío regions. One of the reasons for selecting the irrigated Central Valley zone was its large fruit production and export production, while in the south-central foothill zone the predominant agricultural activities involve crops and livestock. These zones possess a Rengo temperate Mediterranean climate and an Andean foothill temperate Mediterranean climate, respectively.

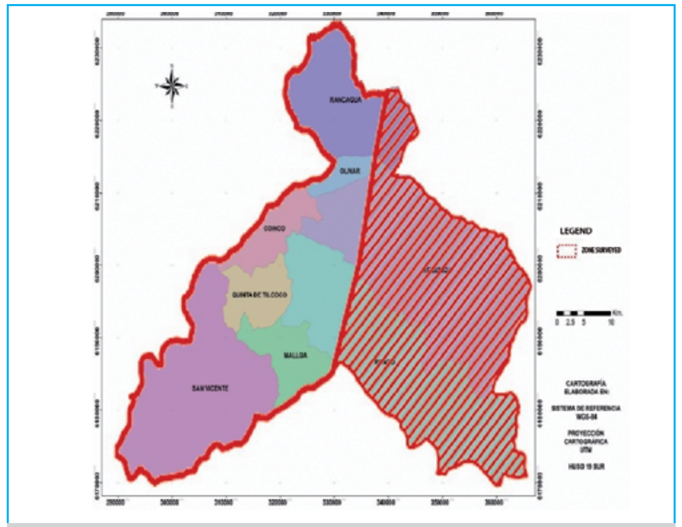

Figure 26. Libertador Bernardo O'Higgins Region. Irrigated Central Valley agro-climatic zone
Note: Inside the thick red line: municipalities included in the zone; crosshatched: not part of the study area.

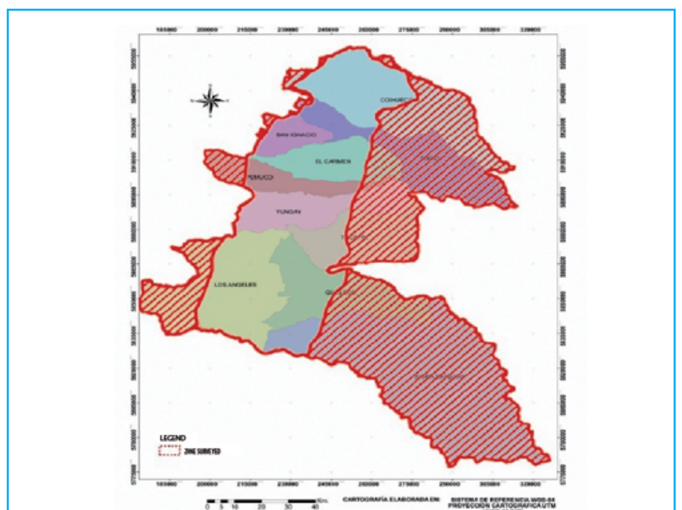

Figure 27. Biobío Region. South-central Andean foothill agro-climatic zone
Note: Inside the thick red line: municipalities included in the zone; crosshatched: not part of the study area.

Impact on productivity

In terms of productivity, it was found that in the irrigated Central Valley zone, annual crops using artificial irrigation display moderate reductions in future yields, but current levels of productivity will not alter significantly, in general. However, the optimum sowing season for maize and wheat must be brought forward in order to maintain this level, with wheat becoming a winter crop. Given that potato crops will experience a drop in yield and an increase in water requirements, it seems likely that the potato shall cease to be a viable option in this area. The general trend projected for fruit species, as was found in other studies, is towards a drop in yield that becomes significant under scenario A2 by 2040. Of special concern is that yields of blueberry and apple crops are expected to drop by 40% to 50% under scenario A2 in 2040. Conversely, projected future reductions in cherry and raspberry yields are moderate. Grapes for direct consumption and for winemaking present relatively similar and stable dynamics over time. Forestry plantations will experience a reduction in future yields in line with other results, suggesting a geographical displacement of optimum forestry land towards the country's south-central and southern areas. Pasture productivity remains unchanged under this simulation.

Productivity projections for the south-central Andean foothill zone show increased yields for irrigated maize and potato crops, albeit with a change in sowing season. Irrigated wheat productivity remains stable, and dryland wheat yields increase by 20%, with wheat becoming a winter crop. No general trend in projected future yields of fruit species was identified for this region, although yield increases were observed under scenario A2 in 2020 and decreases under scenario A2 in 2040 that nonetheless remained greater than current values. Plum productivity increased, as did the productivity of grapes for direct consumption, which presents a new challenge, as this crop is barely present in the area today. All fruit species analyzed exhibited major increases in water requirements, regardless of whether yields increased or decreased. Productivity of forestry plantations remained steady or increased slightly, adding weight to the theory that this region shows good potential for forestry. Pasture yields remained stable in the projections, with a slight increase in alfalfa crops, but water requirements rose markedly, which will present challenges in this area.

Economic impact

Economic impact was more significant in the irrigated Central Valley zone, in terms of negative effects, mainly in the scenario–A2 in 2040. The crops with the greatest economic deterioration under scenarios A2 in 2020 and A2 in 2040 are fruit species. However, it is noteworthy that there is a positive economic impact on cherry, blueberry, and raspberry cultivation in the south-central foothill zone. No significant impact was detected for pastureland, which showed stable economic performance even in scenarios A2 in 2020 and A2 in 2040, particularly in the south-central foothills. White clover may present an interesting irrigation alternative in the irrigated Central Valley. In the forestry sector, *Pino radiata* remained a viable option in both zones, with due attention to avoiding occupation of agricultural land. Eucalyptus becomes less economically viable under scenarios A2 in 2020 and A2 in 2040 in the Central Valley zone, but may gain a foothold in the south-central zone. Overall impact under scenario A2 in 2020 in the irrigated Central Valley amounts to a loss of more than CLP$4.7 billion, with a CLP$4.2 billion loss attributed to fruit species and a CLP$560 million loss from annual crops. The economic impact under scenario A2 in 2040 is even greater (CLP$26 billion). Meanwhile, the economic impact in the south-central foothill zone is positive, amounting to a gain under A2 in 2020 of CLP$11 billion, with a strong contribution from annual crops such as wheat. Under scenario A2 in 2040 the impact increases to CLP$13 billion. Certain crop types, such as raspberry, blueberry, cherry, and apple require further analysis, as the predicted yields and economic margins suggest significant reductions in business feasibility, even under scenario A2 in 2020. Adaptation measures based solely on agriculture and irrigation cannot compensate for deteriorations in the sector.

Adaptation measures

Adaption measures that were highly recommended in the study include the use and substitution of plant varieties; improvement and adjustment of irrigation systems; changes in irrigation systems; and sustainable management of groundwater. Others include tree planting; increasing water availability; more efficient and effective fertilizer usage; creation and application of composting; usage and incorporation of agricultural waste; usage of fire (not general burning); livestock herd-irrigation-pasture management; and livestock infrastructure.

Specifically, immediately valuable short term land adaptations in the irrigated Central Valley zone are mainly related to water resources, temperature and soil fertility; in large and small scale fruit production, key measures are linked to water resources; in vineyards, they are linked to water resources, temperature and fertility of soils; and in pastures and forestry plantations, they are linked to water resources. In the south-central Andean foothills, the same general trends apply in immediately valuable short term land adaptations. However, cropland and pasture adaptations show more variability in the key measures suitable for different plant species.

Tables 12 to 18 summarize key information from the study on specific adaptation measures.

TABLE 12. Land adaptation measures associated with the category "Water resources and temperature" in the agriculture and forestry areas

Varieties • Adjustment and/or change in sowing season. • Incorporation of a certified variety and/or suitable strain. • Change to a certified variety and/or suitable strain.
Current irrigation • Technical/economic assessment of the current efficiency of the irrigation system and design of improvements. • Implementation of improvements in the current irrigation system. • Improved maintenance of irrigation systems.
Change in irrigation system • Selection and design of a more efficient irrigation system. • Implementation of the irrigation method.
Sustainable management of groundwater • Addition of primary tillage activities. • Reduction in primary tillage activities. • Activities and/or applications that streamline and improve weed control. • Implementation of soil water monitoring. • Incorporation of land waste into the profile. • Implementation of catch crops, cover crops, and green manure crops.
Tree planting • Implementation of new planting techniques for improved retention of ground moisture. • Adjustment of planting date. • Use of drought resistant understory plants (acquisition).
Water availability • Cleaning of water canals. • Construction activities to increase water retention capacity. • Study and design of new water accumulation systems. • Construction of new water accumulation systems. • Maintenance of water accumulation systems. • Lining of water canals. • Incorporation of other construction activities and accumulation systems.

Source: FIA-INIA, 2009

TABLE 13. Adaptation measures associated with the category "Soil fertility" in the agriculture and forestry areas

Fertilization • Contracting of soil analysis services. • Contracting of canopy analysis services. • Prioritize acquisition of greater quantities of fertilizers. • Reduced fertilizer acquisition. • Field application of additional fertilizer(s).
Composting • Composting techniques. • Compost content analysis services. • Application and incorporation of compost.

Source: FIA-INIA, 2009

TABLE 14. Land adaptation measures associated with the category "Soil recovery and conservation" in agriculture and forestry areas

Agricultural waste • Waste incorporation techniques. • Collection of waste onsite and offsite. • Strategic fertilizer application to balance element ratios (C/N).
Fire • Creation and/or maintenance of firebreaks. • Grassland control (stubble, straw, etc.). • Elimination of material generated in crop thinning and pruning.

Source: FIA-INIA, 2009

TABLE 15. Land adaptation measures associated with the category "Water resources and temperature" in the fruit tree area

Varieties • Adjustment and/or change in sowing season. • Incorporation of a certified variety and/or suitable strain. • Change to a certified variety and/or suitable strain.
Current irrigation • Technical/economic assessment of the current efficiency of the irrigation system and design of improvements. • Implementation of improvements in the current irrigation system. • Improved maintenance of irrigation systems.
Change in irrigation system • Selection and design of a more efficient irrigation system. • Implementation of the irrigation method.

Source: FIA-INIA, 2009

Sustainable management of groundwater
- Addition of primary tillage activities.
- Reduction in primary tillage activities.
- Activities and/or applications that streamline and improve weed control.
- Implementation of soil water monitoring.
- Incorporation of land waste into the profile.
- Implementation of catch crops, cover crops, and green manure.

Tree planting
- Implementation of new planting techniques for improved retention of ground moisture.
- Adjustment of planting date.
- Use of drought resistant understory plants (acquisition).

Water availability
- Cleaning of water canals.
- Constructions to increase water retention capacity.
- Study and design of new water accumulation systems.
- Construction of new water accumulation systems.
- Maintenance of water accumulation systems.
- Llining of water channels.
- Incorporation of other construction activities and accumulation systems.

Source: FIA-INIA, 2009

TABLE 16. Adaptation measures associated with the category "Soil fertility" in the fruit tree area

Fertilization
- Contracting of soil analysis services.
- Contracting of plant matter analysis services.
- Prioritizing acquisition of greater quantities of fertilizers.
- Reduced fertilizer acquisitions.
- Field application of additional fertilizers.

Composting
- Composting techniques.
- Compost content analysis services.
- Application and incorporation of compost.

Source: FIA-INIA, 2009

TABLE 17. Land adaptation measures associated with the category "Soil recovery and conservation" in the fruit tree area

Agricultural waste
- Waste incorporation techniques.
- Collection of waste onsite and offsite.
- Strategic fertilizer application in order to balance element ratios (C/N).

Fire
- Creation and/or maintenance of firebreaks.
- Grassland control (stubble, straw, etc.).
- Elimination of material generated in crop thinning and pruning.

Source: FIA-INIA, 2009

TABLE 18. Adaptation measures associated with the category "Cattle raising" in the dairy and meat area

Herd, water, and pasture management
- Contracting of soil analysis services.
- Prioritizing the acquisition of greater quantities of fertilizers.
- Reduced fertilizer acquisitions.
- Selection and design of a more efficient irrigation system.
- Implementation of the new irrigation method.
- Changes in pasture usage and/or collection of forage from pastureland.
- Acquisition, design, and installation of electric fences.
- Improvements to permanent pastureland.
- Change permanent forage crop varieties.
- Incorporation of supplementary forage crops.
- Change of permanent forage crop species.
- Change in management of animal feeding and nutritional supplementation (+ or – cost).
- Change in reproductive or sanitary management (+ or – cost).
- Change of animal breed (importation and/or and hybridization).

Infrastructure
- Adjustment and/or expansion of infrastructure (conservation of pasture, storage, drinking water, repairs, shade, births, other).
- Pasture conservation services.
- Progressive implementation of infrastructure, equipment, and management practices for the management of slurry and waste.

Source: FIA-INIA, 2009

The study found that the adaptations that cause the greatest perception of risk or fear among persons engaged in agriculture are bank credit, change of species or crop type, change of crop rotation, increased mechanization, changes in animal breeds, and changes in annual crop area grown. Conversely, the types of adaptation that are considered lowest risk are training; adoption of new forms of marketing; and changes in management, in irrigation systems, and in water capture and collection infrastructure. It was also observed that a relationship exists between adaptation, risk, and vulnerability. Thus, producers who consider themselves more economically vulnerable were willing to take on only a lower level of risk, indicating that those most vulnerable to climate change are not necessarily the ones most willing to adapt.

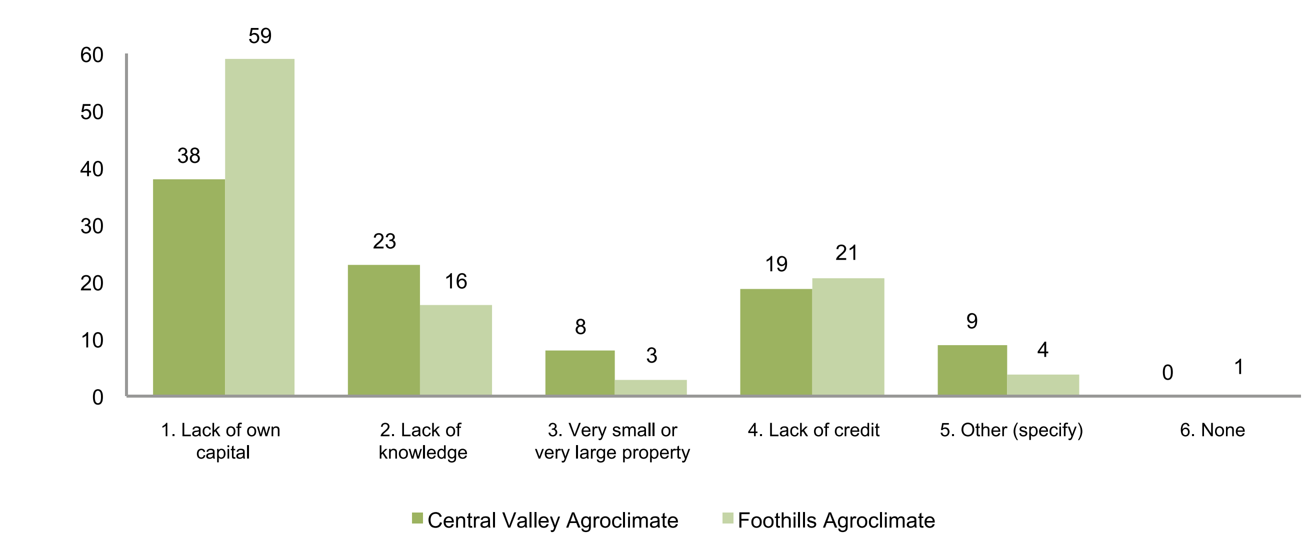

Figure 28. Survey of Main Issues facing Landholders in Adapting to Climatic Variation
Source: FIA-INIA, 2009

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Adaptation costs

As mentioned, the study derived approximate figures for the impact of adaptations and generated proposals for their implementation. Some principal results are as follows:

- Under scenario A2 in 2020, the impact of the principal adaptations is negative in both zones studied. Meanwhile, under scenario A2 in 2040, the impact in the irrigated Central Valley zone is positive and amounts to CLP$9.5 billion, mainly because fruit trees offer a higher margin for adaptation. In the south-central foothill zone the positive impact amounts to CLP$1.3 billion, again attributable to fruit species.
- As a general strategy, adaptation decisions should be made sooner rather than later, but with a view to future investment. However, not all measures are economically viable, and certain sub-sectors fail to meet the necessary conditions for some initiatives. In the irrigated Central Valley under scenario A2 2020, field crops will be less profitable if the adaptations are implemented, but the cultivation of apples, cherries, plums, blueberries, and raspberries will benefit from higher profit margins if adaptation measures are adopted. Pasture and forestry plantations also lack the economic conditions to support adaptation. Similarly, in the south-central foothills under scenario A2 in 2040, fruit species improve with the implementation of adaptations, and yields and profit margins fall dramatically without adaptation and respond better to adaptations for recovering yield. In the south-central foothills under scenario A2 in 2020, the profit margins of annual crops are also lower without adaptation than with it. The same situation applies to fruit species, although plums, raspberries, and grapes respond well to adaptations in terms of production, which may justify their implementation. Pastures and forestry plantations cannot support the cost of implementing adaptations. Under scenario A2 in 2040, adaptations may be implemented for annual crops as long as the species concerned responds strongly. Apples, cherries, blueberries, and raspberries have a strong net favorable response to adaptation. Plums and grapes are neutral.
- For the irrigated Central Valley, the study proposes implementation of adaptation measures for apples, cherries, plums, blueberries, raspberries, and grapes for direct consumption, as the margin generated with adaptations is greater than without adaptations. In wine vineyards, the advisability of adaptations depends on the probability of obtaining or recovering high yields, and on price variables. Such measures may allow these crops to remain economically attractive and help future decisions related to the geographical displacement of horticulture towards the south. For alfalfa, white clover, and natural pasture there is no need to incorporate explicit adaptations, and the same is recommended for forestry plantations. Meanwhile, in the south-central foothill zone the study proposes implementing adaptations for irrigated maize, potato, and wheat crops, depending on the likelihood of a high yield response and price. For dryland wheat, the only justifiable adaptation is a change in cultivar/strain. Among fruit species, the study proposes implementing adaptations for apples, cherries, blueberries, and raspberries. No climate change adaptation measures are proposed for pasture or forestry plantations, as adaptation promises no increase in margin for these land uses.
- As an orientation for policy and subsidy instruments, the average annual cost for economically justifiable land adaptations amounts to CLP$6.625 billion (US$12.5 million) in the irrigated Central Valley zone and CLP$3.5 billion (US$6.6 million) in the south-central foothill zone.

Proposed policies to support adaptation

Finally, the study offer more detailed proposals to improve policies and incentives, analyzing them from the perspective of institutions and policies, research, training and education, and stimulus instruments.

In regard to institutions and policies, the main points are: to avoid focusing on conceptual redefinitions and existing advisory and technical activities, and instead to work toward more effective coordination of entities and activities; to foster coherence in decision making and actions on climate change that target major sectors of the national economy; to specify institutional responsibilities and hierarchies; and to assess and measure funding dimensions continually and adequately fund key activities through the passage of a legal decree. It should be borne in mind impacts will be local, and therefore strategies for applying current and future regulations and policies must be implemented with careful attention to the target agro-climatological zone, the predominant production system, and the type and characteristics of producers and production associations.

In terms of stimulus and support instruments, the study points out that while none of these systems were put in place specifically to address climate change, they still are useful for supporting measures for adaptation or reduction of vulnerability. Furthermore, as with strategies and policies, stimulus instruments also must be implemented with careful attention to the target agro-climatological zone, the predominant production system, and the type and characteristics of each producer and production associations.

With regard to the stimulus instruments currently being operated by the different public entities mentioned in the study, some of these are identified as being particularly relevant for climate change adaptations and could be adjusted or made even more flexible.

4.5 BIODIVERSITY

In 2010 the Institute of Ecology and Biodiversity (IEB) conducted a study entitled "Vulnerabilidad de la biodiversidad terrestre en la eco-región mediterránea, a nivel de ecosistemas y especies, y medidas de adaptación frente a escenarios de cambio climático" [Vulnerability of terrestrial biodiversity in the Mediterranean eco-region at the level of ecosystems and species, and adaptation measures for climate change scenarios]. The study was funded by CONAMA and it analyzed the vulnerability of biodiversity in Chile in a climate change context by comparing the current distribution of species and ecosystems against their expected distribution in climate change scenarios (see section 3.6 of this chapter).

The study also provides valuable information in outlining possible climate change adaptation measures from a biodiversity perspective. Its recommendations include:

Strengthening the network of protected areas

Chile has made significant investments to safeguard the integrity of its national biodiversity resources. This approach is reflected in the country's extensive National System of State-Protected Wilderness Areas (SNASPE), which–together with private initiatives and conservation areas set aside under international agreements and land use restrictions–cover approximately 20% of continental Chile. Although percentage is high compared to many other countries, most of these areas are in the far north and south of the country in zones that are highly susceptible to climate change and have a high projected degree of species and ecosystem dynamism.

Monitoring program for species, habitats, and behavior of critical ecosystems

In addition to launching a national network for global monitoring, it is also necessary to monitor species and habitats that are expected to experience major changes in distribution.

Ongoing assessment of the effects of climate change on biodiversity

Effective assessment of the responses of critical species, ecosystems, and habitats is heavily dependent on the availability of data and the methodological approach used. In this regard, assessments must be updated when new data come to light, including agreed projections for Chile.

Create or strengthen institutional mechanisms that respond to climate change challenges for biodiversity in the context of global changes caused by humans

The challenges of climate change are by nature interdisciplinary and require the participation of a wide range of scientific disciplines and pertinent public institutions. Such efforts must be coordinated by a decentralized body capable of making fast and informed decisions.

4.6 OTHER SECTORS

In 2011, a seminar was organized jointly by the Ministry of the Environment and the Under-secretariat of Fishing to promote the actions set forth in the National Climate Change Action Plan for the Fishing sector. These actions include disseminating and reviewing the latest knowledge about climate change and its impacts on the fishing and aquaculture sector and on marine biodiversity at the national and international level; identifying studies and research needs in order to generate the information needed to define the best adaptation mechanisms for the country; and to coordinate the efforts of different stakeholders.

In the health sector, an information-gathering project began in 2010 on the effects of climate change in public health in other countries and actions that have been taken to address these, for the purpose of drafting an initial proposal for a sectoral adaptation plan. Activities have also been implemented in partnership with civil society organizations such as the Chilean Red Cross to support of the creation of such a plan.

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CHAPTER 4

Mitigation of Greenhouse Gases

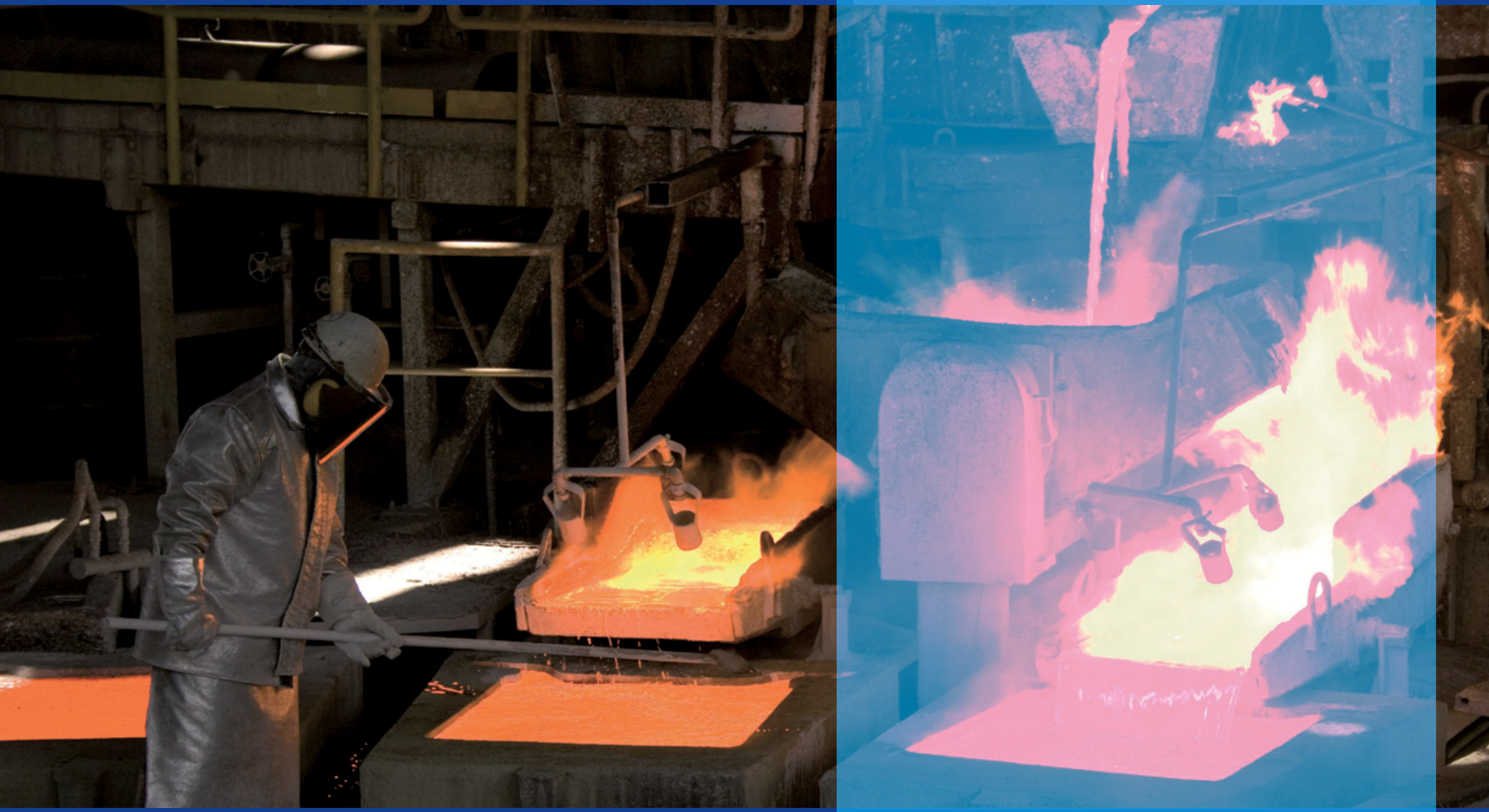

PHOTO: XSTRATA COPPER

HOME

1. INTRODUCTION

1.1 GREENHOUSE GAS MITIGATION IN CHILE

Chile recognizes the need to stabilize atmospheric emissions of greenhouse gases at a level that prevents hazardous anthropogenic interference in the global climate system, reduces total emissions, and protects and improves carbon sinks and greenhouse gas deposits through appropriate mitigation measures. The country's contribution to international efforts in this area is underpinned by the principle of "common but differentiated responsibility" and is intended to support the aim of the United Nations Framework Convention on Climate Change (UNFCCC) while obtaining potential environmental and social cobenefits for Chile.

Box 13.7 of the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), which shows the extent of GHGs to be mitigated, offers important information for Convention signatories as they may determine how to apply the principle of common but differentiated responsibilities in their mitigation actions. In effect, achieving a stabilization scenario of 450 ppm CO_2eq will involve differentiated commitments by the Parties, which translates into absolute emission reductions for Annex-1 countries and substantial reductions in emission growth rates for non-Annex 1 countries, including Chile, that must be achieved by 2020 and beyond.

Chile's emissions are low on the global scale, accounting for just 0.2% of all GHGs released, and this level has remained relatively stable according to statistics from the International Energy Agency (IEA) and the World Resources Institute (WRI). It is important to note, however, that emissions are on the rise, both in Chile and around the world.

This chapter presents initiatives that could be implemented in Chile as part of the country's commitment to slow its emissions, as well as early actions that are already underway to achieve this objective and foster the country's sustainable development.

1.2 MITIGATION IN THE NATIONAL CLIMATE CHANGE ACTION PLAN

In December 2008, the Government of Chile approved the country's National Climate Change Action Plan, establishing "Mitigation of Emissions" as one of its three strategic lines of action. The general objective associated with this line of action is to "work toward becoming a low-carbon economy as a means of promoting sustainable development in Chile as well as a means of contributing to global efforts to reduce GHG emissions."

This line of action includes identification of the country's GHG mitigation potential to help limit emissions growth and focused work on sectors with the highest emissions and/or removals, namely energy generation, transportation, mining, and agriculture and forestry activities. Details of emissions and removals by these sectors are presented in Chapter 2 of this National Communication, on the National Greenhouse Gas Inventory.

During the period covered by this report, Chile has undertaken a series of actions to mitigate its emissions, the impacts of which will be verified in the medium and long term. These early mitigation actions represent a pioneering contribution that goes above and beyond Chile's commitments as a non-Annex 1 country under the Convention and reaffirm our country's pledge to support its main objectives.

The Plan of Action identifies the following priorities for GHG mitigation:

- Updating of the emissions inventory
- Evaluation of the country's potential to mitigate the impacts of GHGs
- Generation of mitigation scenarios
- Formulation of a national mitigation plan for GHG emissions and the corresponding sector-specific plans.

Over the last 10 years a series of measures has been implemented to fulfill the objectives defined in the Plan of Action. These measures are outlined later in this chapter.

1.3 GHG MITIGATION IN CHILE

It is recognized in Chile that to stabilize GHG emissions, countries around the globe must respond collectively and adequately to the challenges of climate change. However, industrialized countries must take the lead in these efforts by agreeing to clear, ambitious and quantifiable emission reduction goals. Without such goals, it will be difficult for the international community to take the needed action to confront climate change head-on. If industrialized countries do not demonstrate leadership in resolving the problem that they caused—and for which they have an historic responsibility—it will be difficult for developing countries to carry out relevant mitigation actions.

Although Chile's emissions are relatively low on the global scale, we recognize that if our economy continues to display the high growth of recent decades, emissions will rise accordingly. Because of this, there is significant political will in Chile to limit the growth of GHG emissions by funding and implementing actions to mitigate GHGs with the technical and financial support of Annex 1 countries.

Along this line, by 2020 current emission levels in the developing world should have been reasonably reduced through nationally appropriate mitigation actions (NAMAs) implemented in a context of sustainable development and subject to measurement, reporting and verification processes. Chile shall be responsible for implementing unilateral NAMAs as well as NAMAs supported by Annex 1 countries through technology transfer, funding and capacity building, all of which should also be subject to strict measurement, reporting and verification processes.

In Chile's view, it is important to expand the use of market-based mechanisms in developing countries in order to cap emission increases. In this regard, both unilateral and internationally financed NAMAs should be allowed to generate carbon credits.

Chile intends to participate actively in defining rules for the use of incentives that seek to reduce emissions from deforestation and degradation of both tropical and native forests, and even forest plantations. Indeed, a major part of the country's mitigation efforts could come from this sector.

These strategic approaches will continue to be central to Chile's position in international climate change negotiations and the country will therefore work to ensure that its concerns are reflected in a legally binding, long-term cooperation agreement.

Chile and the Copenhagen Accord

- Chile subscribed to the Copenhagen Accord on January 29, 2010.
- On August 26, 2010, Chile presented information for inclusion in Appendix II of the Accord: *Chile will take nationally appropriate mitigation actions to achieve a 20% deviation below the "Business as Usual" emissions growth trajectory by 2020, as projected from year 2007. To accomplish this objective Chile will need a relevant level of international support. Energy efficiency, renewable energy, and Land Use and Land Use Change and Forestry measures will be the main focus of Chile's nationally appropriate mitigation actions.*

Chile believes in the need to make and concrete advances towards a lower carbon economy based on its commitments under the Convention (Inset 1: Chile and the Copenhagen Accord). To this end, since 2010 the Government of Chile has introduced several instruments that will generate information to support decision making on mitigation, so that in the coming years efforts can be focused on designing and implementing an emissions mitigation strategy.

The concrete advances expected from these efforts include:

- Strengthening the preparation of emissions inventories by establishing a national office for GHG emissions inventories (more details on this are presented in Chapter 6 of this National Communication).
- Integrating the various sector-specific efforts to project emissions for the coming years, in order to establish a baseline that has been agreed-upon by the Government as a whole. This will enable ministries to engage in emissions projection exercises that complement each other and are based on a common foundation.
- Generating information that will enable Chile to produce NAMAs in the short term, especially for the energy and LULUCF sectors.

In 2011, the Government of Chile plans to embark on an extended exercise to prepare long-term emissions mitigation scenarios based on a methodology developed in South Africa prior to COP 15. Under this methodology, social actors are involved in identifying potential climate change mitigation actions and estimating their costs, social implications, and barriers to implementation. This exercise will take place over the medium-term (two or three years) and is expected to generate the best information possible for formulating public policies in this area for the remainder of the decade.

For the present, as this chapter will demonstrate, initiatives are also being carried out in different sectors through a variety of ministries. These efforts have produced preliminary information regarding sector-specific mitigation options. They do not claim to offer exhaustive analyses but are more indicative at present. A means of prioritizing them must be established in the short term.

1.4 RESULTS OF THE GHG EMISSIONS INVENTORY AND IDENTIFICATION OF RELEVANT EMISSION SOURCES AND SINKS

Figure 1 represents the global growth of CO_2 equivalent (CO_2eq) emissions for the 1984–2006 period for the five inventory sectors, as well as the balance of emissions and removals, which is positive for the entire period analyzed. From 1990 (UNFCCC base year) to 2006 (the last available year), Chile's emissions increased overall by 232%, with a 37% increase from 2000 to 2006 alone. If the LULUCF sector is not counted, GHG emissions by Chile increased by 68% from 1990 to 2006 and by 12% between 2000 and 2006.

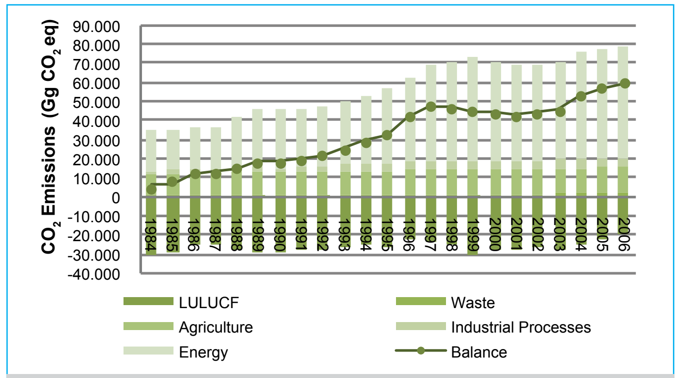

Figure 1. GHG emissions, removal, and balance by sector, 1984–2006

Source: Ministerio del Medio Ambiente, based on INIA (2010), Sistemas Sustentables (2010), and POCH (2008)

At the sectoral level, the importance of the LULUCF sector in CO_2 removal in Chile is recognized, although the net capture by this sector decreased gradually between 1984 and 2006. In absolute terms, the Energy sector contributes a growing and significant proportion of national emissions; its emissions increased by 85% between 1990 and 2006. The Agriculture sector is the second largest net emitter, although its emissions have grown the least in recent years, just 10% from 1990 to 2006. In contrast, the Waste sector is responsible for the largest emissions increase in the period –142%– although in absolute terms this sector's emissions are still quite low.

As Figure 2 shows, the Energy sector is responsible for most of the sharp rise in net national emission levels, with a 168% increase between 1984 and 2006.The remaining sectors also display increased emissions, but because of their lower absolute emission levels they do not have a significant impact on the national GHG balance. Figure 2 also clearly shows how carbon capture by the LULUCF sector has dropped steadily.

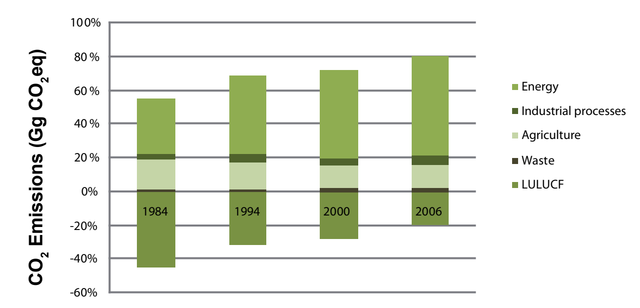

Figure 2. GHG Emissions and Removals, percentage contribution by sector of the Chilean GHG Inventory
Source: Ministerio del Medio Ambiente, based on INIA (2010); Sistemas Sustentables (2010); POCH (2008)

Photo: Ministry of the Environment. Government of Chile

2. SECTOR SPECIFIC ANALYSES

2.1 ENERGY SECTOR

The energy sector includes the exploration, development, generation, transmission, transportation, storage, distribution, consumption, efficient use, import, and export of energy, as well as any other activities related to electricity, gas, petroleum and its derivatives, nuclear energy, geothermal and solar energy, and other energy sources.

Chile's energy policy is founded upon the legal and regulatory role played by the State through the Ministry of Energy and the institutions under its purview, while the private energy sector is responsible for investments in the sector. This arrangement means that Chile's energy policies will have a major impact on limiting the growth of GHG emissions. Some central aspects of the energy policy of President Sebastian Piñera Echenique's administration are as follows:

- Increase energy availability to satisfy demand, assuming an average economic growth rate of 6% annually up to 2020.
- Increase the security of the country's short, medium and long term energy supply, encouraging energy generation projects that reduce failure risks and strengthening fuel supply logistics to enable prompt and effective responses to events and contingencies.
- Promote the development of competitive and sustainable investments.
- Work towards the goal of having 20% of Chile's installed capacity for electricity generation come from non-conventional renewable energies by 2020. These energy sources are both locally and globally environmentally sustainable and are available within the country itself.
- Strengthen energy independence and the participation of private investors in hydrocarbon exploration and development.
- Enhance existing regulations for accessing energy resources in order to increase investment in renewable energies available in the country.
- Conduct studies and consolidate the institutional structure to permit the development of any cost-efficient energy source in the future.
- Promote research programs in the area of energy and educate new generations of citizens on the importance of energy savings and efficiency.
- Improve the information available on the country's energy resources to support the formulation of a policy to promote energy efficiency and energy savings projects.
- Enhance existing energy efficiency standards and certification programs for residential construction, household appliances, lighting and transport vehicles.

2.1.1 Regulatory framework related to mitigation

Incentive for the Use of Non-Conventional Renewable Energies (NCREs)

In 1982, the enactment of the General Electrical Services Law (LGSE) laid the foundation for a competitive electricity system and positioned Chile as an international pioneer in this area.

This legal framework was based on a "technology neutral" principle that makes no distinction between non-conventional renewable energies and other forms of energy. It is important to note that in Chile, Non-Conventional Renewable Energies (NCREs) are defined as wind energy, small scale hydroelectric hydro power (plants up to 20 MW), biomass, biogas, geothermal energy, solar and tidal energy. To support the incorporation of NCREs, in March 2004 Law 19.940 reformed the LGSE, changing several aspects of the energy generation market in Chile that affected all forms of energy generation, but included special provisions for NCREs. The reform opened up the spot market and guaranteed the right to be connected to the country's power grids to small generating plants, many of which fall into the NCRE category. This move increased commercial and generating opportunities for these small producers.

In addition, the reform exempted projects using NCREs from paying transmission fees, using a differentiated scale–one for plants generating up to 9 MW and another for those generating between 9 MW and 20 MW. In addition to benefitting those sources, this exemption serves to recognize a positive externality, given their low impact on transmission grids and on investments associated with their expansion.

Law of Non-Conventional Renewable Energies (Law 20.257)

On April 1, 2008 Law 20.257 entered into force, mandating that a certain percentage of power sold by electricity companies operating in systems with an installed capacity greater than 200 MW come from NCREs.

This law and its regulations have translated into price signals and business models for decision makers in the electricity market, manifested in the steady development of NCRE projects associated with energy grids in Chile. The main features of the Law, which is applicable only to new projects implemented by electricity companies that remove energy from power grids by selling it to distributors or end users, include the following:

- From 2010 to 2014, all energy contracts signed on or after 2007 shall be required to supply at least 5% of their energy from non-conventional renewable sources.
- As of 2015, this percentage will increase by 0.5% per year until reaching 10% in 2024.
- This gradual increase will be applied in the following way: 5.5% of all energy removed from the system shall be subject to this mandate in 2015, 6% in 2016, and so on, until reaching the goal of 10% by 2024.

Law of Geothermal Energy (Law 19.657)

The exploration and development of geothermal energy in Chile is governed by Law 19.657 on Geothermal Energy Concessions, published in January 2000, and its regulation, published in October 2004. This law establishes a special system for granting concessions for the exploration and development of geothermal energy. In 2009, under this legal framework, an invitation to tender offers on 16 geothermal concession areas was issued, worth an estimated investment of US$ 85 Million.

Tax Exemption for solar thermal systems (Law 20.365)

The main objective of this instrument is to foster the development of solar hot water systems (solar thermal systems, STS) by means of a fiscal policy instrument that encourages demand. The instrument addresses barriers such as the high startup costs for STS, the long capital recovery timeframe in the housing sector, and the low relative demand, which hinders the emergence of associated services and the large-scale adoption of this technology.

The tax exemption established in Law 20.365 entered into force in August 2010 and targets construction companies that are willing to use solar systems in new housing developments, allowing them to discount the cost of solar collectors they install from their taxes on a sliding scale indexed to the value of each home. This measure seeks to promote the use of solar technology and extend its benefits to houses and buildings across the country by offering up to 100% of the installed cost of these hot water systems for new houses eligible by the tax exemption. The exemption covers 100% of the tax on solar thermal systems for houses priced at approximately US$87,000[1] and up to 20% of the tax for houses worth approximately US$195,000.

The Law also includes a consumer protection provision that mandates a five-year guarantee against failures in the solar thermal system and a free inspection within the first year of home ownership.

2.1.2 Regulatory framework for energy efficiency

Energy efficiency labeling

Since 2008, Chile has been phasing in mandatory energy efficiency labeling for electrical appliances and electronic devices. The initiative began with incandescent and compact fluorescent bulbs, refrigerators and freezers, electric induction motors, and stand-by systems for ovens, microwave ovens and air conditioners. Additional electrical and electronic devices will be added to these in the coming years.

This labeling scheme is being implemented under Chilean standards that comply with ISO 15502 and IEC 60000 standards.

For street lighting, in the years leading up to 2010, information was gathered and rules formulated for road lighting that include energy efficiency criteria. In this area, the Chilean Energy Efficiency Agency, in collaboration with the Inter-American Development Bank (IDB) and the United Nations Development Program (UNDP), has been conducting a pilot program in the south of Chile that runs from 2008 to 2012.

[1] Estimated using US dollar exchange rate against the UF (Unidad de Fomento) in mid-2010.

Thermal regulations for housing

These regulations were incorporated into the General Construction and Urbanism Bylaw (OGUC, Article 4.1.10) and have been in force and operating in Chile since 2000. The first stage, which began in March of that year, established minimum R-values for housing roof systems that improved resistance to heat flow significantly in that part of the building shell. This dramatically reduced heat loss, especially during winter, to the great benefit of occupants of public housing complexes.

The second stage came into force in early 2007 and complemented the first one. This stage set out requirements for limiting heat loss through walls, floors, and ventilated floors and windows, limiting size according to R-values.

Minimum energy performance standards (MEPS)

Chile is currently formulating a strategy to establish Minimum Energy Performance Standards, based on the Ministry of Energy's newly granted authority to enact MEPS, which was established in the recently passed law that also created that institution. The first phase was implemented in 2010 and involved MEPS for lighting.

2.1.3 Institutional aspects of the energy sector related to mitigation

Center for Renewable Energies (CER)

In 2009 the Center for Renewable Energies was created under the purview of the Chilean Economic Development Agency (CORFO) and the direction of the Ministry of Energy with the aim of creating a technology antenna for the development of renewable energies in Chile.

The Center was set up as a platform for capturing knowledge on renewable energies from around the world and analyzing potential applications in Chile, especially in the private sphere. CER's work is focused in three main areas:

- Information Center: CER responds quickly and effectively to inquiries from anyone involved in the renewable energy sector.
- Accompanying NCRE investment projects and pilot projects: CER accompanies investment and pilot projects focused on NCREs during the development stage, facilitating institutional relations to bring these projects into being. In this line of action, CER supports official approval processes, offers venture fund "matchmaking," guides investors in the use of development instruments, establishes networks of human capital and offers technical guidance in general.
- Promoting and disseminating NCREs: CER promotes NCREs in different contexts at the national level through courses, workshops, seminars, training, encounters, activities and working groups.

National Energy Efficiency Program (PPEE)

In 2005, the Government of Chile, through the Ministry of Economy, set up the National Energy Efficiency Program, inviting a wide variety of stakeholders from the public and private sectors to participate. The Program was created in response to the Environmental Performance Review conducted by the Organization for Economic Cooperation and Development (OECD), which recommended, among other things, that Chile incorporate Energy Efficiency into its national development.

The PPEE, which became the responsibility of the National Energy Commission in January 2008, has contributed to the development of sustainable energy in Chile by promoting, along with other public and private institutions, advances in Energy Efficiency. Two such advances were reducing energy demand in the Central Interconnected System (SIC) energy grid by 2.6% between March 2008 and March 2009, in comparison with the previous year and establishing Energy Efficiency as a central pillar of Chile's national energy policy.

The importance of Energy Efficiency to energy sector development is reflected in the significant increase in the budget allocated to the National Energy Efficiency Program by the National Energy Commission, which rose from US$ 1Million in 2006 to US$3.5 million in 2007, US$13 million in 2008 and close to US$40 million in 2009.

Chilean Energy Efficiency Agency (ACHEE)

The authority granted to the newly created Ministry of Energy under Law 20.402 led to the creation of the Chilean Energy Efficiency Agency in 2010. This entity was the successor to the PPEE and includes the participation of representatives of the ministries of Transportation and Telecommunications, Housing and Urbanism, and Energy, as well as the academic and business sectors. This new Agency has an updated mandate that replaces the lines of action of the PPEE with the role of designing and establishing public policies for Energy Efficiency in the respective divisions of the Ministry of Energy.

The Agency's central objective is to study, assess, promote, inform and develop a wide range of initiatives focused on energy diversification, energy savings and energy efficiency. Its mission is to implement public energy efficiency policies outlined by the Ministry and serve as a bridge among different groups of end-users in relation to those policies.

2.1.4 Sectoral programs 2000-2010

In recent years, the Government of Chile has developed a policy to support competitive electricity generation based on non-conventional renewable energies (NCREs) by identifying barriers that hinder or limit the implementation of these energy forms and taking action to remove these barriers. Major barriers and actions taken to remove them in recent years are described briefly below.

Lack of information

One factor that seriously limits investment in this area is the lack of information available to new investors and even to well established energy sector companies. This lack of information leads to great uncertainty in the issuing of permits for these new technologies, in the trustworthiness of the technologies themselves, in the availability of resources, and other factors. For this reason, Government agencies have produced a clearinghouse of information for investors that includes:

- Assessment of forestry and agricultural biomass resources
- Information on wind, solar and geothermal power
- Inventory of hydraulic projects associated with irrigation works
- Technical-economic assessment models for projects
- Guides for environmental assessment and for CDM projects

Precarious infrastructure

Another issue that hinders the development of NCREs is the lack of infrastructure to support the development of these technologies, especially regarding transmission and access to main transmission lines on power grids. To remedy this, the Government has launched an initiative to encourage projects with shared transmission lines, and conducted exploratory studies to determine how to transmission networks can be adapted to accommodate NCREs.

Uncertainty about new technologies and limited access to credit

NCRE projects have encountered difficulties in accessing credit because of the uncertainty that exists about these new technologies in financial markets. To revert this trend, the State enhanced the regulatory framework by facilitating long term contracts with NCREs under Law 20.257 and by encouraging investment by introducing three instruments:

- Subsidies for pre-investment studies and detailed engineering studies
- Preferred lines of credit
- National and international promotion of projects

Geothermal energy: high exploration costs

The development of geothermal energy sources deserves special mention because of the high potential of this technology in Chile and, conversely, the high cost of its development. In response to this situation, the Government of Chile has created the following instruments:

- A contingent subsidy to mitigate the risk of exploration
- Generation of geological information linked to geothermal energy
- National Petroleum Company (ENAP) partnerships with private investors for geothermal energy exploration

Advances

In four years, Chile doubled its installed capacity for electricity generation with NCREs, from 286 MW, or 2.4% of the country's total installed capacity at the end of 2005 to 600 MW, equal to 4% of the total in late 2009, and this figure has continued to rise (see Figure 3). It is interesting to note that from 2004 to the end of 2009, NCRE projects submitted to the Environmental Impact Assessment System (SEIA) represented a total of 2553 MW, 2000 MW of which were for wind energy.

Another significant advance has been the creation of complementary services to support the development of NCRE projects, such as geothermal and drilling services, manufacturing of pressure lines for small hydro plants and windmill manufacturing plants.

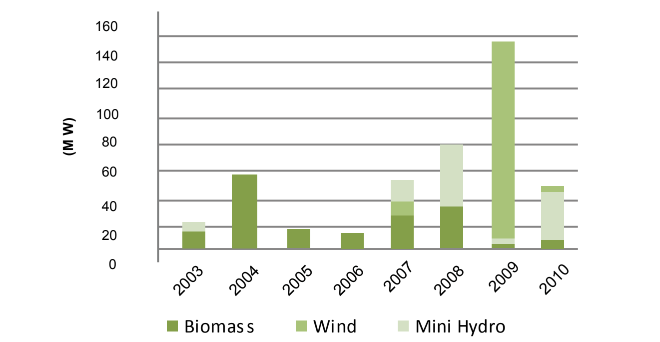

Figure 3: Evolution of NCRE Projects (MW)
Source: Ministerio de Energía (2011)

Non-competitive NCREs

In addition to competitive energy generation technologies from NCREs, there are others that have an excellent potential in Chile but require more development to become competitive. The Government of Chile supports the development of two of these energy sources: second generation biofuels and solar and tidal energy for electricity generation. Two lines of action have been established to promote the further development of these as yet-uncompetitive two forms of NCREs:

Anticipate potential barriers and eliminate them

In the case of biofuels, the following programs have been implemented under this line of action:

- Market development through imports
- Pilot projects for blending imported biofuels with traditional fuels
- Authorization of blends of fuels with diesel and gasoline for vehicle use
- Specific tax exemption for vehicle fuels

For electricity generation from solar and wave energy, two studies were conducted and the standards updated to facilitate entry of these technologies into the market:

- Measurement of solar radiation in northern Chile
- Preliminary Site Selection for Chilean Marine Energy Resources.

Capacity Building

The second line of action to support non-competitive NCREs is capacity building. Four projects that are intended to create and strengthen existing technical capacities in this area have been implemented in Chile:

- Between 2006 and 2008, the National Commission for Scientific and Technological Investigation (CONICYT) supported 53 new energy research projects, representing a real investment of CLP$ 5.1 billion.
- Since 2005, CORFO's Innovation and Business Development Program (InnovaChile) has approved 68 projects related to the energy sector, especially in biofuels, energy efficiency and NCREs, collectively valued at more than CLP$ 6.9 billion.
- Since 2005 CORFO's InvestChile program has co-financed pre-investment studies for 205 projects with a total value of CLP$ 2.478 billion.

Looking forward

In order to facilitate technology transfer and development, the Government of Chile has created consortia for second-generation biofuel technologies and solar pilot projects for electricity generation. The former consist of two consortia, one for lignocellulose biofuel research and the other for algae and microalgae biofuel research. These consortia are funded by a research program focused on lignocellulose, rapeseed, jatropha, microalgae and forage turnip.

For the solar-generated electricity pilot projects, support will be provided to the country's first projects, which consist of a 500 KW photovoltaic project for a small electricity grid and a thermoelectric solar plant of approximately 10 MW connected to one of the largest electricity grids in the country.

Energy efficiency

Chile has channeled its efforts to promote energy efficiency primarily through its National Energy Efficiency Program and the Chilean Energy Efficiency Agency, a public-private foundation charged with promoting, strengthening and consolidating the efficient use of energy by coordinating and implementing national and international public-private initiatives in different energy consumption sectors to foster the country's sustainable development (for more details, see Chapter 1 of this Communication, on National Circumstances). This institutional arrangement has enabled the development, since 2009, of the following sectoral programs:

• Energy Efficiency Preinvestment Program

This program offers a subsidy to optimize energy consumption and reduce energy-related costs, enabling small and medium sized enterprises (SMEs) to identify investment alternatives and assess them from a technical, economic and financial standpoint. The program subsidizes energy efficiency audits, implementation plans for energy efficiency measures, and the preparation of investment projects for presentation to potential funding sources. The subsidy covers up to 70% of the total cost of the project up to a maximum of around US$12,000.

• CORFO Energy Efficiency Loan

This is a long term loan or bank leasing scheme that allows companies to make the investments they need to implement energy optimization projects and reduce the costs associated with energy use. The loan is intended to support investment in machines and equipment, buildings and installations or engineering works, engineering and installation services, and similar goods and services that companies may require to operate an energy efficient business, including the working capital associated with those investments.

• Advances in the residential, commercial and institutional sector

A series of programs have been established in the recent years, most notably:

o A program to switch from incandescent to compact fluorescent lighting involving approximately 2.5 million bulbs for the 40% most vulnerable families in the country.

o An incentive program for thermal retrofitting of existing housing that has benefited 9,000 households.

o A Pilot Program to Improve Standards for New Public Housing involving 400 residential units.

o An Energy Efficiency Improvement Program for Public Buildings, including 25 diagnostics and a comprehensive energy efficiency program for La Moneda presidential palace.

o Mass media campaigns for energy efficiency, to raise public awareness on good energy use and promote the use of practical energy efficiency measures.

o To complement this program, in the first half of 2010 the campaign "Levantemos Chile con buena energia" (Let's Raise Chile Up with Good Energy) was implemented in the areas most affected by the earthquake that struck the country in February 27, 2010. The campaign included visits to 32 localities and 61 schools to deliver the message.

• Advances in the industrial sector:

o An instrument was developed and implemented for pre-investment in energy efficiency measures jointly with CORFO. This instrument offers co-financing of up to 70% of the cost of energy audits.

o Preferred lines of credit for energy efficiency projects, launched in 2008 with CORFO with funding from the German Development Bank, KfW.

o Technical Assistance program for industrial motor systems to boost energy savings by optimizing systems using energy efficient motors.

The National Energy Efficiency Program has also been involved in implementing energy efficiency programs in the transportation and mining sectors, including the technical assistance program for energy efficiency for shipping companies and the truck replacement program. More details of these activities are found in the transportation and copper mining sections of this chapter.

In November 2010, the first Energy Efficiency Expo in Latin America was held in Santiago, Chile. The event was held to promote energy efficiency technologies and mechanisms and to disseminate best practices. About 5,000 people attended the event, along with 120 institutions from Chile and abroad. Information about the event can be viewed online at: http://www.expoeficienciaenergetica.cl

2.1.5 Studies of sector-specific mitigation options and their main results

In the past ten years a series of studies have been conducted that, directly or indirectly, indicate the most suitable and highest yielding options for mitigating GHG emissions in Chile's energy sector. The Government of Chile, especially the Ministry of Energy and the National Energy Commission, have financed many of these studies; their results, however, have not been translated automatically into official domestic policies or positions for international negotiations and multilateral agreements. The most significant studies conducted in this area are listed below:

- Poch Ambiental for CNE (2009). Proyección de la evolución de las emisiones de gases de efecto invernadero en el sector energía. Años 2000-2025 (Projected Evolution of Greenhouse Gas Emissions in the Energy Sector, 2000-2025)
- POCH Ambiental for CORFO (2009). Estrategia y potenciales de transferencia tecnológica para el cambio climático (Strategy and potential technology transfers for climate change).
- PROGEA (2009). Consumo de energía y emisiones de gases de efecto invernadero en Chile 2007-2030 y opciones de mitigación (Energy consumption and greenhouse gas emissions in Chile 2007-2030 and mitigation options).
- PRIEN (2008). Estimación del potencial de ahorro de energía, mediante mejoramientos de la eficiencia energética de los distintos sectores (Estimating the potential energy savings from improvements to energy efficiency in different sectors).
- PROGEA (2008). Diseño de un modelo de proyección de demanda energética global nacional de largo plazo (Design of a model for projecting long term national energy demand).
- PROGEA (2008). Emisiones de gases de efecto invernadero en Chile: antecedentes para el desarrollo de un marco regulatorio y evaluación de instrumentos de reducción (Greenhouse gas emissions in Chile: information for developing a regulatory and assessment framework for instruments to reduce GHGs).
- De Miguel, C., O´Ryan, R., Pereira, M. and Carriquiri, B. Energy shocks fiscal policy and CO_2 emissions in Chile.
- PRIEN (2008b). Estimación preliminar del potencial de la eficiencia en el uso de la energía eléctrica al abastecimiento del SIC (Preliminary estimation of the potential of efficient electricity use in the SIC grid).
- PRIEN / NEIM (2008). Aporte potencial de energías renovables no convencionales y eficiencia energética a la matriz eléctrica, 2008-2025 (Potential contribution of non-conventional renewable energies and energy efficiency to the electricity grid, 2008-2025).
- PRIEN / NEIM (2008a). Estimación del aporte potencial de las energías renovables no convencionales y del uso eficiente de la energía eléctrica al sistema interconectado central (SIC) en el periodo 2008-2025 (Estimating the potential contribution of non-conventional renewable energies and the efficient use of electrical energy for the Central interconnected Grid (SIC) for the 2008-2025 period).
- Eficiencia Energética: Diseño de incentivos económicos a la compra de refrigeradores energéticamente Eficientes (Energy Efficiency: Design of economic incentives for energy efficient refrigerator purchases).
- GAMMA Ingenieros-CNE (2004). Evaluación del desempeño operacional y comercial de centrales de cogeneración y estudio del potencial de cogeneración en Chile (Evaluation of operational and commercial performance of cogenerating plants and study of the potential for cogeneration in Chile).
- PRIEN / CONAMA (1999). Mitigación de gases de efecto invernadero. Chile 1994-2020 (Mitigation of greenhouse gases in Chile, 1994-2020).

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2.1.6 Strengthening sectoral mitigation capacities with international financing

The most significant internationally-funded initiative for mitigating GHG emissions in Chile is that carried out by GTZ, the German International Cooperation Agency, which implements projects that are funded by the agency itself and by other German government institutions such as the Federal Ministry for Economic Cooperation and Development (BMZ) and the Federal Ministry of the Environment, Environmental Protection and Nuclear Security (BMU). This cooperation initiative is focused on two specific areas—non-conventional renewable energies and energy efficiency.

The United Nations Development Program (UNDP) has also contributed financing and implemented projects in Chile that are intended to promote a sustainable energy policy.

Non-conventional renewable energies: BMZ/GTZ project. Supporting the implementation of a sustainable energy policy for Chile: diagnostic and recommendations

Since 2004, GTZ has supported Chile with a technical cooperation project in the NCRE area. The project promoted activities carried out by the Government of Chile in this area and included complementary activities co-financed by GTZ. The aim was to produce recommendations for the Government's sustainable energy policy after a participatory analysis with representatives of civil society and the private, academic and public sectors. The process included work sessions and seminars in which recommendations were presented and reformulated. The aim was to achieve a set of agreed-upon policy instruments that would improve the sustainability of the country's energy supply and were coherent with the objectives of economic growth, social equity and environmental protection. The project involved universities, Chilean and international organizations, and electricity market investors, companies and experts. The 7-year project began in August 2004 and has a total budget of €4,245,000.

Public lands for energy generating projects using renewable energies: BMU/GTZ project

The objective of this project is to identify, appraise and promote the use of State owned land in Chile's Norte Grande region for energy generation projects using NCREs. This 3-year initiative began in November 2008 with a total budget of €1.2 million. The project involves studying the potential for wind and solar power at different localities of the Norte Grande, followed by pre-feasibility and other studies for wind farms generating 100 to 200 MW. The results will be published and the concessions deemed most suitable for wind and solar power generation will be offered for public tender.

Strategy for expanding the use of renewable energies in Chile's electricity grids: BMU/GTZ project

This project is intended to develop a strategy for the medium and long term to expand the use of NCREs in Chile's electricity grids in a way that is compatible with Chile's energy policy. The 4- year project, which also includes formulating regulatory proposals for implementing the strategy, began in October 2009 and has a budget of €3,000,000.

Other geothermal and NCRE refinancing projects: KfW and GTZ projects

German international cooperation, through the German Development Bank (KfW), contributed €80,000,000 to refinance investments in NCREs in Chile. The KfW also contributed €5,100,000 to Chile's National Geological and Mining Service (SERNAGEOMIN) to acquire laboratory equipment and support the exploration of geothermal sites. In addition, approximately €400,000 was earmarked for technical assistance and training of SERNAGEOMIN staff. The implementation of these activities was overseen by the Federal Institute of Geoscience and Natural Resources (BGR).

Energy Efficiency: BMZ/GTZ project

The German Federal Ministry of Economic Cooperation and Development (BMZ) commissioned GTZ to promote energy efficiency in Chile, working with the National Energy Commission through the National Energy Efficiency Program. The 4-year project began in October 2006 and was intended to improve the technical and institutional capacities of public and private entities to implement energy efficiency measures in industry and buildings. At the same time some goals were set, such as reducing energy demand by 30% in five pilot projects involving new and renovated housing; organizing training programs for energy service companies (ESCOs) operating in the housing and industrial sectors, and formulating internal energy efficiency policies in 3 kinds of industrial plants and implementing quantitative goals for reducing energy consumption in their internal processes.

Project for Energy Efficiency and Cogeneration in Public Hospitals: BMU-GTZ project

This initiative is financed by Germany's Federal Ministry of the Environment, Environmental Protection and Nuclear Security and focuses on energy efficiency, cogeneration, sustainable innovation and the development of NAMAs in the context of Chilean-German bilateral cooperation. It consists of a pilot program to introduce and implement replicable energy efficiency measures and cogeneration in public hospitals. The project also seeks to introduce an ESCO energy management model as well as micro- and small-scale energy generating plants in public hospitals. The project is being implemented by GTZ under the National Energy efficiency Plan (PPEE) with a total budget of €1,050,000. The pilot project includes a cogenerating plant in the Cañete Hospital.

Other projects co-financed by the Global Environment Facility

In September 2001 the UNDP signed agreement CHI/00/G32 with the CNE and the Ministry of Foreign Relations, under which GEF would co-finance the project "Removal of Barriers to Rural Electrification using Renewable Energies," with a total GEF contribution of US$ 6,067,300. Chile's contribution was estimated at US$ 26.3 million, mainly from investments in rural electrification using renewable energies obtained from State subsidies, private sector contributions and beneficiaries themselves. In 2010, two additional GEF-financed projects were being implemented under the PPEE for a non-refundable amount of US $ 5 million. The Inter-American Development Bank is the implementing agency for these projects, which are: Promotion and strengthening of the energy efficiency market in Chile's industrial sector (GEF/SEC 3599) and Incentives for establishing and consolidating an energy services market in Chile (GEF/SEC 4176).

2.1.7 Private sector developments for mitigation

The country's private energy sector has been especially active in recent years in identifying mitigation measures eligible to participate in the Kyoto Protocol's Clean Development Mechanism (CDM). Details of projects in this sector and an associated analysis is included in this chapter, in the section "Cross-sector Actions" and in the section on "Technology Transfer" in Chapter 5, whose title is "Additional Information related to the Convention's Objectives."

2.1.8 Potential sector-specific mitigation options for developing NAMAs

The country's energy sector has great potential for mitigating greenhouse gas emissions in both energy generation and consumption. But there is also some uncertainty about the degree of penetration of mitigation technologies and the technical capacity needed to take advantage of this potential. Some factors that contribute to this uncertainty are future prices of energy generating and consumption technologies, future international fossil fuel prices, and national economic growth rates, among others.

Chile intends to introduce nationally appropriate mitigation actions, or NAMAs, and to this end has been conducting a series of studies in recent years to determine the precise potential for mitigating GHG emissions in the country and the costs associated with that potential.

Thus, based on the information obtained from previous studies, in 2011 the study "Co-beneficios de la Mitigacion de Gases de Efecto Invernadero" (Co-benefits of Greenhouse Gas Mitigation) was conducted by the Environmental Division (GreenLab UC) of the Scientific and Technological Research Office of the Pontificia Universidad Catolica de Chile (DICTUC). This study assesses, among other things, the expected costs of GHG reductions that are estimated for a series of measures, in order to determine the potential for GHG abatement at different levels per ton of CO_2eq. The study also develops an abatement cost curve. The following section will discuss energy sector measures derived from this curve.

TABLE 1. Potential mitigation measures in the energy sector

Sector	Subsector	Measure
Energy	Electricity generation	Geothermal, SING
		Mini hydro, SIC
		Nuclear, SIC
		Geothermal, SIC
		Wind, SING
		Wind, SIC
		Solar SING
		Biomass, SIC
Industry	General	Accelerate changeover to efficient motors
		Cogeneration
Commercial, public, and residential (CPR)	Residential	Efficient showers
		Efficient residential lighting
		Standby loss reduction
		Efficient residential refrigeration
		Home insulation
		Solar collectors
	Commercial	Efficient commercial refrigeration

Source: Greenlab UC-DICTUC, (2011)
Note: SING: Norte Grande Interconnected Grid
SIC: Central Interconnected Grid

Table 1 presents a summary of mitigation measures, classified as: electricity generation, industry, residential and commercial consumption[2].

This study considers three mitigation scenarios, explained by the level of penetration of the emissions reduction measures, namely Weak, Medium and Strong. The technology penetration levels for each of these measures are necessarily different and to a certain degree not comparable, given the great differences in the cost of investment, the maturity of the technologies themselves, and other variables that are not related to this analysis. For this reason, the scenarios created for this exercise (Weak, Medium and Strong) were designed for these measures and take into account the maximum ranges of penetration of each technology.

Table 2 below offers a brief description of each of the three penetration scenarios (Weak, Medium and Strong), for each of the measures evaluated for the Commercial, Public and Residential (CPR) sector.

Photo: Ministry of the Environment. Government of Chile

[2] The studies mentioned also include the transportation, mining, and agriculture/forestry sectors, which were omitted from this chapter to focus on the energy sector.

TABLE 2. Penetration scenarios used for the energy sector mitigation measures considered

Measure	Scenario	Description
Thermal insulation for homes	Weak	Increase home insulation, provided it is the most economically viable option in relation to reductions in heating fuel consumption.
	Medium	Integrate maximum economically viable improvement in insulation, even when not the most economically viable option.
	Strong	Incorporate maximum improvement in insulation (out of options evaluated) regardless of cost.
Solar collectors	Weak	Consider one half of the homes covered in the medium option.
	Medium	Take into account the solar thermal system promotion law for new homes for the 2010-2013 period, and, given that the law expires after that time, presuming a stable rate of implementation at 35% of new homes for the 2014 – 2025 period.
	Strong	Assume that all new homes include solar thermal systems.
Efficient showers	Weak	Assume that 30% of existing homes change to efficient shower heads, and 50% of new homes incorporate them.
	Medium	50% of existing homes and 70% of new homes.
	Strong	100% of existing homes and 100% of new homes.
Standby loss reduction	Weak	30% reduction in standby loss by 2030. Penetration to grow in a linear fashion from 2010.
	Medium	50% reduction in standby loss by 2030. Penetration to grow in a linear fashion from 2010.
	Strong	100% reduction in standby loss by 2030. Penetration to grow in a linear fashion from 2010.
Efficient commercial refrigeration	Weak	Replacement of 70% of refrigeration systems used in supermarkets.
	Medium	Replacement of 90% of refrigeration systems used in supermarkets.
	Strong	Replacement of 100% of refrigeration systems used in supermarkets.
Cogeneration	Weak	80MW in 2015 and an additional 100MW in 2020.
	Medium	120MW in 2015, an additional 160MW in 2020, and an additional 180MW in 2025.
	Strong	120MW in 2015, an additional 160MW in 2020, and an additional 180MW in 2025.
Efficient motors	Weak	Replacement of motors at 10%. 100% of new motors are efficient.
	Medium	Replacement of motors at 30%. 100% of new motors are efficient.
	Strong	Replacement of motors at 100%. 100% of new motors are efficient.
Efficient residential lighting	Weak	5% annual changeover in installed capacity switching incandescent lighting for low energy bulbs (CFL or LED), starting in 2010. Replacement mainly with CFL for the first 5 years, and with LED thereafter.
	Medium	As above, but with 10% annual changeover.
	Strong	Ending of sale of incandescent bulbs in 2012, with subsequent differentiation of CFL and LED. Mainly CFL up to 2015, mainly LED thereafter.

Source: Greenlab UC-DICTUC, (2011)

For the generation sector, the three assessment scenarios (Weak, Medium and Strong) were determined according to the installed capacity (in MW) of each of the generating technologies up to the year 2030.

Table 3 displays the installed capacity of different generating technologies in the country's two largest interconnected grids, the Central Interconnected System (SIC) and the Norte Grande (SING).

TABLE 3. Projected installed capacity of electricity generation technology (2030) for Weak, Medium, and Strong scenarios (MW)

System	Technology	Weak	Medium	Strong
SIC	Biomass	201	281	402
	Wind	1072	1500	2143
	Geothermal	594	832	1188
	Tidal	50	70	100
	Mini hydro	319	447	638
	Nuclear	1000	1400	2000
SING	Wind	280	392	560
	Geothermal	180	252	560
	Solar	55	77	110

Source: Greenlab UC-DICTUC, (2011)

Table 4 summarizes the mean cost of each of the mitigation measures identified for the mitigation scenarios analyzed, and is intended to show the potential mitigation range that exists for the different scenarios. The time period considered for these measures is 2010 to 2030, and the average cost is calculated as the total investment over the period (in US$) divided by aggregate emission reductions for that 20-year period (in millions of tons of CO_2eq).

TABLE 4. Average cost (US$/ton CO_2eq) and emission reductions (Mton CO_2eq) from mitigation measures under the scenarios analyzed (Weak – Medium – Strong)

Measure	Average cost (US$/ton CO_2eq) [Weak/Medium/Strong]			GHG Reduction (Mton CO_2eq) [Weak/Medium/Strong]		
Efficient showers	[-253	/-255/	-259]	[7.3	/11.4/	20.7]
Efficient residential lighting	[-76	/-79/	-89]	[10.5	/15/	20.2]
Motor replacement acceleration	[-87	/-74/	-59]	[0.3	/0.8/	2.8]
Efficient commercial refrigeration	[-73	/-71/	-75]	[0.3	/0.4/	0.4]
Standby loss reduction	[-71	/-70/	-74]	[5.2	/8.2/	10.7]
New efficient motors	[-59	/-56/	-57]	[10.4	/12.9/	13.7]
Efficient residential refrigeration	[-42	/-26/	-18]	[1.6	/1.9/	2.1]
SING Geothermal	[-13	/-13/	-13]	[21	/29.2/	41.8]
SIC Mini hydro	[-13	/-13/	-13]	[14.5	/19.1/	25.1]
Home insulation	[-18	/-9/	1452]	[9.9	/10.5/	15.4]
SIC Nuclear	[-8	/-8/	-8]	[27.9	/35.9/	45.8]
SIC Geothermal	[-6	/-5/	-5]	[27.7	/36.3/	47.8]
SING Wind	[-2	/-2/	-2]	[4.3	/6.1/	8.7]
SING Solar	[5	/5/	6]	[0.4	/0.6/	0.8]
SIC Wind	[5	/6/	7]	[17.5	/23.2/	31]
Cogeneration	[-5	/8/	8]	[7.9	/14.8/	13.1]
Biomass SIC	[47	/54/	62]	[5.2	/6.1/	6.7]
Solar collectors	[178	/178/	175]	[1.9	/3.7/	9.8]

Source: Greenlab UC-DICTUC, (2011)

2.1.9 GHG abatement cost curve for the Energy sector in Chile

Figure 4 in this section presents, by way of example, a GHG abatement cost curve for selected measures in the Chilean energy sector for the 2010–2030 period, and is based on the previous table. The mining and transportation subsectors were also excluded as they are addressed in the respective sections of this Communication.

In order to achieve a conservative estimate, this abatement cost curve was based on the "Weak" scenario described in the previous table, i.e. with a minimum level of penetration of the chosen technologies. At the same time it is important to clarify that, despite the fact that most of these measures present negative costs in the average cost analysis, there are other barriers to their implementation, both economic and non-economic. Incorporating and adequately quantifying barriers is a challenge for any analysis that examines the cost of implementing GHG reduction measures. Included among these barriers are additional charges for the State and a lack of understanding in the financial sector, which limits potential investment in projects that requite strong financing and involve relatively long-term return on investment and generally atomized benefits—such as those obtained from the large scale use of energy efficient technologies in the residential sector. It is also worth mentioning that the cost-benefit ratio associated with GHG emission reductions does not reflect the many direct and easily measurable co-benefits involved, such as savings on fuel, and other indirect ones that are more difficult to correlate, such as reductions in local pollution levels and the resulting impact on human health.

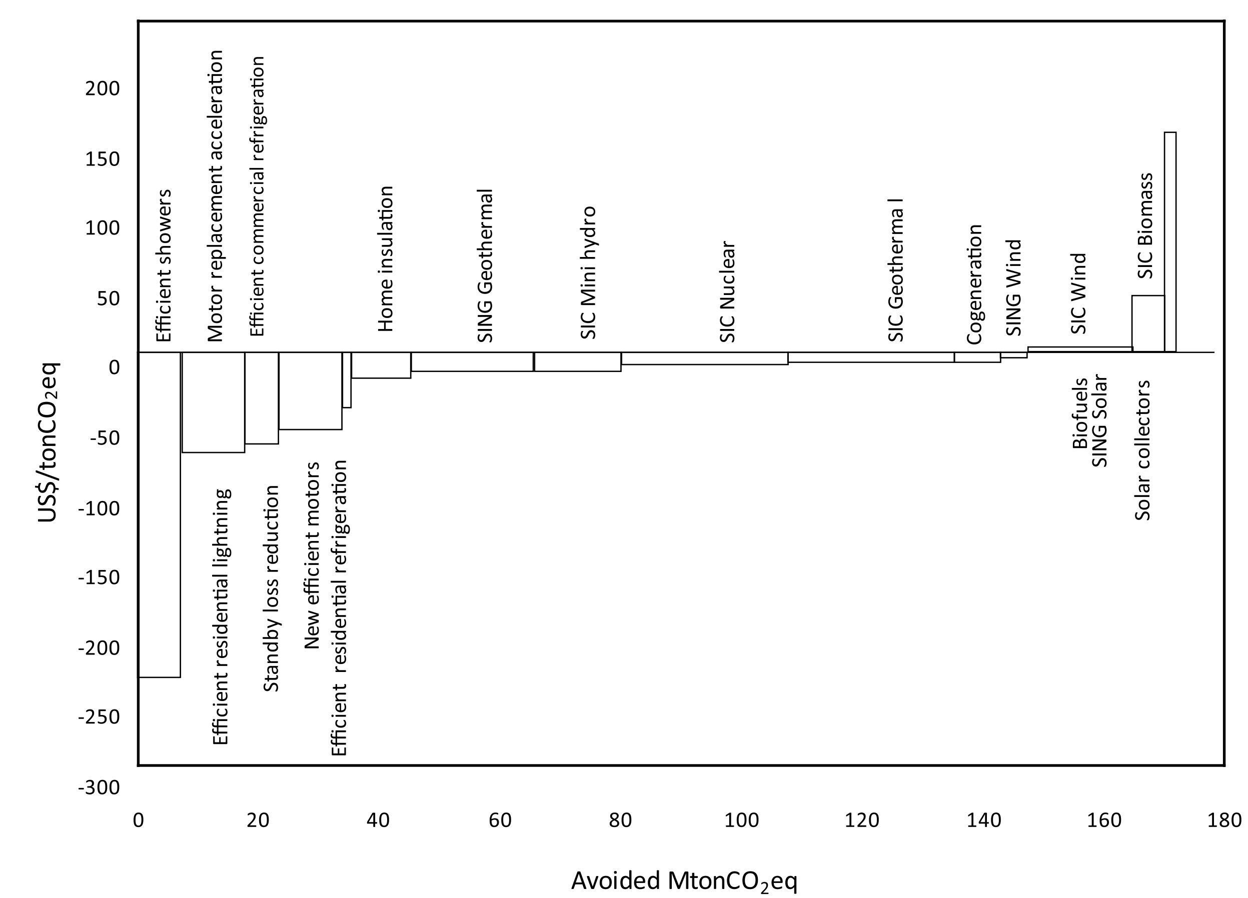

Figure 4. Mean cost of mitigation measures, Weak scenario (US$/ton CO_2eq)
Source: GreenLab UC-DICTUC, 2011

The GHG abatement cost curves provide quantitative information for representing which actions would be the most effective in reducing emissions, and the cost of each of them. The curve displays the range of actions that can be implemented using the technologies studied. The abatement cost in this case is defined, along with additional costs for replacing a given technology with an alternative that reduces GHG emissions. The vertical axis shows the abatement cost, measured in US dollars per ton of CO_2 equivalent, and the horizontal axis shows potential emission reductions, measured in tons of CO_2 equivalent. The width of each bar represents the potential GHG reduction. The height of each bar represents the average cost reducing a ton of CO_2 equivalent in 2030 by means of that action. As observed in the abatement cost curve, the more CO_2 equivalent that the combined technologies reduce, the higher the cost per ton of CO_2 abated.

Measures with negative costs, for their part, are mainly those that take advantage of the high potential for energy efficiency existing in Chile's different productive sectors, such as industry and commercial, public and residential sectors. In the majority of cases, the cost of implementing these measures is very low (promotion, regulation, certification, small technological improvements, etc.) and the benefits in terms of fuel savings are significant.

In regard to their reduction potential, energy efficiency measures are the most effective at reducing GHGs and therefore represent a great potential for negative or very low cost-reductions.

The analysis also includes measures for the generation subsector that were incorporated despite their positive costs. These tend to be areas that Chile has decided to promote above and beyond the country's interest in limiting the growth of GHGs, because of their strategic value to the country's energy security.

2.2 AGRICULTURE, LIVESTOCK AND FORESTRY SECTOR

Chile's agriculture, livestock and forestry sector is recognized as being carbon neutral. This means that the emissions reported in GHG inventories that are generated by the activities of the agriculture and livestock sector are equal (in tons of carbon equivalent) to the amount removed through forestry activities (FIA, 2010).

The Ministry of Agriculture considers that GHG emissions associated with this sector's activities can be reduced by increasing energy and productive efficiency, improving agricultural practices, in terms of both production and environmental aspects, and decreasing forest fires.

It is also deemed possible to compensate for the sector's emissions by actions that capture carbon, such as reforestation and/or managing native forests, or through the use of "emission neutral" renewable energies. To take advantage of this potential contribution to mitigating climate change, MINAGRI has implemented a series of activities in the framework of the National Climate Change Action Plan.

2.2.1 Regulatory framework impacting mitigation

In MINAGRI's regulatory framework and incentive instruments there are no provisions oriented directly towards climate change. However, the Ministry has made several instruments available to the sector for addressing GHG emission mitigation in different spheres of action.

Decree Law 701 and its modifications

In 1974, Decree Law 701 (DL 701) was enacted to establishing the country's forest capital and meet the growing demand of the national forestry industry through subsidies to private parties undertaking forestation. From 1974 to 1995, subsidies were paid out for some 800,000 hectares of suitable, eligible land, with a total investment of nearly US$136 million (nominal). This state-sponsored effort also generated major positive externalities such as erosion control, carbon capture and rural employment (ODEPA, 2009).

In 1998, Law 19.561 modifying DL 701 was enacted, extending several subsidies to 2010, with a different focus—the protection and recovery of degraded soils in Chile and forestation activities carried out by small landowners, the latter including a group of additional benefits. From the enactment of the DL 701 modification up to 2008, the Government of Chile approved US$ 284 million (nominal value) in subsidies for forestation and soil protection, financing the forestation of 475,000 hectares and soil recovery on another 175,000 hectares (ODEPA, 2009), as shown in Figure 5.

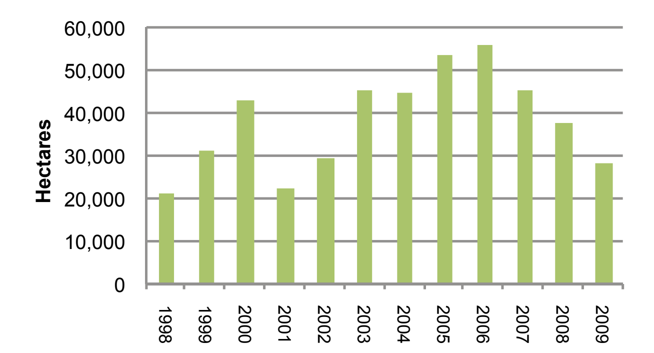

Figure 5. Land area (Ha) subsidized under DL 701 and amendments, 1998–2009
Source: ODEPA, with data from CONAF.

This program includes:

- Subsidies granted to small landowners for forestation and management of forests planted in land suitable for forestry. The aim was to give small landowners a subsidy equal to 90% of the net cost of plantation for the first 15 hectares, and 75% of the rest.
- Subsidies to undertake forestation, soil recovery and stabilization activities in dunes, on fragile soils, volcanic soils and those in process of desertification, in degraded soils or degraded soils on slopes with a grade greater than 100%. The subsidy provides an amount equal to 75% of the net cost of each activity.

To define the costs of forestation and soil recovery on land eligible for the subsidy in each season, each year CONAF sets a table with the costs of forestation, recovery of degraded soils, dune stabilization, pruning and thinning per hectare, as well as for each kilometer of wind barrier.

Native Forest Law

Law 20.283 on the Chilean Native Forest was enacted in July 2008 and is intended to protect, recover and improve the country's native forest species, ensuring their sustainability through management and preservation plans. The law defines small landowners as those with title to total property of no more than 200 hectares. This limit is larger for landowners living in the far south of Chile, particularly in regions XI and XII, who may own up to 800 hectares, provided that their assets are valued at less than US$150,000 and their income derives mainly from agricultural or forestry activities.

The law mandates detailed rules and definitions for the application of this instrument, including subsidies to promote the conservation, recovery and sustainable development of native species, among other things.

The Native Forest Law also defines a series of incentives, most notable among which are those for preserving environmental services in native forests and xerophytic formations, forestry activities oriented towards obtaining non-wood forestry products, and the management and recovery of native forests for wood production.

Since the date of its publication, two competitive subsidies have been offered: In the small landowner category, 1063 applications were approved for a total of approximately US$2.5 million in subsidies, which represents 54% of the total amount earmarked for this type of property owner; meanwhile, in the "other landowner" category, 340 applications were approved valued at approximately US$4.3 million, which corresponds to 93% of the amount earmarked for this group in the budget.

Incentive System for the Recovery of Degraded Soils (SIRSD)

The SIRSD officially came to an end on 15 November 2009. This program was implemented by ministerial mandate from 1996 to 1998 and through Law 19.604 and DFL 235 from 1999 to 2009. Efforts are currently focused on improving and updating the system.

The development instrument was established by the Ministry of Agriculture to authorize subsidies to Chilean farmers and livestock producers that agreed to undertake actions to preserve and improve soil quality on their land. The subsidy promoted certain practices and instruments to stop or reverse soil degradation processes and recover soil productivity, thereby allowing these landowners to better participate in productive processes. The subsidy originated with Chile's participation in the Mercosur. In 1995, MINAGRI established a set of measures to support farmers in the south-central part of the country (Maule to Los Lagos regions) who had lost revenue because of foreign competition and the importation of foreign products (mainly wheat, oilseed, meat and milk). One of these measures was the Program to Establish Grasslands, implemented in the regions of Biobio, Araucania and Los Lagos-Los Rios.

In 1997, sub-programs for phosphate fertilization and soil liming were added to combat the lack of phosphorus and excess acidity in the soils of these regions, under the Soil Productivity Recovery Plan. In 1999, with the creation of a legal framework, this Program was officially named the SIRSD, and two new sub-programs were added, for soil conservation and soil rehabilitation.

The Program's incentives were available to all farmers in the country and were granted by the Institute for Agricultural Development (INDAP) to small farmers as they are defined in a Law, and by the Agriculture and Livestock Service (SAG) to all other growers and livestock producers, including private legal entities and private individuals who were not eligible under INDAP (small, medium and large producers).

All growers were required to present a management plan formulated by an accredited operator to SAG or INDAP for the respective agency's approval. Each applicant could access a maximum subsidy of US$12,000 per year. Private sector participants in this Program were agricultural operators, professionals, and technicians who designed management plans and took soil samples, accredited laboratories that analyzed the samples and farmers themselves, who were the direct beneficiaries. Other experts also participated in specific activities of the SIRSD. Public sector participants included the Office of the Undersecretary of Agriculture, ODEPA, SAG, INDAP, and regional representatives of the agricultural ministry.

Irrigation Law

Chile's Irrigation Law 18.450 of 1985 allows the private sector to obtain subsidies of up to 90% to install infrastructure and technical irrigation systems to modernize their growing techniques and make them more competitive. There is consensus in the Chilean agriculture sector that irrigation is one of their main development instruments. For this reason, the funds available under the Law of Development (Ley de Fomento) have increased significantly in recent years, from CHL$11 billion to 29 billion.

In recent years, the distribution of these funds has been focused on small and medium sized growers. The law establishes subsidies for individual irrigation projects that cost less than US$500,000, or US$ 1.25 million in the case of projects presented by irrigation associations. The maximum amount of subsidy is between 70 and 90% of the total cost of the project, according to the new beneficiary classification system, which also extends the program to 2022.

In effect, this law allows the Government of Chile to fund minor irrigation and drainage works through a competitive, public subsidy program that gives growers access to state development funds to increase the efficiency of their water use.

2.2.2 Sector-specific programs, 2000-2009

Over the period indicated, MINAGRI has focused intensely on the management, conservation and sustainable use of natural resources and the protection of Chile's natural heritage. In this context, climate change mitigation in the agriculture, livestock and forestry sector is founded upon the conviction that GHG emissions generated by this sector can be reduced by the more efficient use of fossil fuels, increases in energy efficiency, the production of raw materials for bioenergy generation in the form of biofuels, and the application of best agricultural, livestock and forestry practices.

Feasible opportunities for sectoral emission compensations have also been identified and include carbon capture activities such as forestation, sustainable forestry management, and forest conservation.

Actions in this sector include:

- Development of the National Greenhouse Gas Inventory for Chile's non-energy sector from 1984 to 2007. This analysis was conducted by the Institute of Agricultural Research for CONAMA in 2010.
- Promoting the application of good agriculture, livestock and forestry practices, with emphasis on more efficient use of irrigation water and nitrogenous fertilizers.
- Incorporation of good agricultural practices and promotion of agricultural and livestock exports to consolidate the country's image in this market.
- Search for opportunities related to certified GHG emission reductions under the Kyoto Protocol's Clean Development Mechanism. This is being pursued through a study of the bioenergetic potential of agricultural, livestock and forestry waste for individual landowners and by associations of producers in this sector.
- Program to develop hydroelectric plants associated with irrigation works, implemented by the National Irrigation Commission in collaboration with the CNE, to deliver electrical energy to the central interconnected grid (SIC).
- Launching of the subsidy program for sustainable forestry management and native forest conservation established under the Law for the Recovery of the Native Forest and Forestry Development.
- Broad-based, participatory discussion process involving the public and private sectors for the extension of Decree Law 701 to promote forestation development, and the subsequent drafting of a new forestation law that includes promotion of forest plantations for energy uses. These forests act as carbon sinks while the trees are growing, and their harvest provides raw material to replace the use of fossil fuels, as they are burned directly to produce electricity or are transformed into biofuels such as ethanol and biodiesel.
- Formalizing the sale of fuelwood, to ensure that sellers obtain their supply from sustainably managed forests and that the wood offered has low moisture content. It is important in this regard that clean production agreements be negotiated and signed with fuelwood sellers.
- In recent years some studies have also been conducted that directly or indirectly point to options and potential opportunities available in Chile for mitigating GHG emissions in the forestry sector. Although the Government of Chile, specifically through the Ministry of Agriculture and the National Environmental Commission, has funded some of these studies, their results have not necessarily been translated into official positions in either international negotiations or multilateral agreements. Some of the most relevant studies and documents prepared by the Ministry in this area are mentioned below:

- Estimación del carbono capturado en las plantaciones de pino radiata y eucaliptos, relacionadas con el DL 701 (Estimations of carbon captured by plantations of Pinus Radiata and Eucalyptus related to DL 701). Department of Forestry Sciences. Universidad Catolica de Chile, 2007.
- Impacto socioeconómico del cambio climático en el sector silvoagropecuario (Socioeconomic impact of climate change on the agriculture, livestock and forestry sector). Department of Agrarian Economics, Universidad Catolica de Chile, 2009.
- Estrategia comunicacional sobre la huella de carbono de los productos agropecuarios (Communications strategy for the carbon footprint of agricultural, livestock and forestry producers). Prochile – ODEPA, 2009.
- Medidas sectoriales de mitigación del cambio climático (Sector-specific measures for mitigating climate change). Consejo de Cambio Climatico y Agricultura, 2009.
- Posición del Ministerio de Agricultura en REDD+ (Ministry of Agriculture Position in REDD+), 2009.
- Negotiations in the Climate Change Convention, ODEPA, 2009.
- Respuesta Institucional de Chile al Cambio Climático (Chile's Institutional Response to Climate Change), FIA, 2010.
- Estudio Determinación de la huella de carbono de los principales productos agropecuarios de exportacion (Study to Determine the Carbon Footprint of the Principal Agricultural and Livestock Export Products), INIA, 2010.
- Diagnóstico del aporte de emisiones de carbono en manzanas rojas y verdes, asociadas a las etapas de produccion y transporte hasta el mercado de destino (Analysis of the carbon emissions of red and green apples associated with stages of production and transportation to destination market). Fundacion de Desarrollo Fruticola –ASOEX– Prochile.
- Estado de situación de los compromisos del Minagri en el Plan Nacional de Accion de Cambio Climatico (Status Report on MINAGRI's commitments under the National Climate Change Action Plan), Consejo de Cambio Climatico y Agricultura, 2010.

Climate change in the agriculture, livestock, and forestry sector in Chile

This publication was prepared by the Ministry of Agriculture's Fundación para la Innovación Agraria (FIA) in order to gauge the Chilean agriculture, livestock, and forestry sector's vulnerability to climate change and to determine principal expected impacts during the coming decades. The text covers scientific advances in the understanding of the phenomenon, projections, and institutional responses such as agreements and commitments to facing the coming challenges.

The book represents an effort to systematize the accumulated experience of the FIA, which since 1998 has participated in UNFCC discussions and negotiations as the Ministry of Agriculture's representative on issues relating to land use, land use change, and forestry. The role has allowed the foundation to accumulate a storehouse of knowledge from primary sources.

The report is broken down into four chapters: the climate change situation and definitions; international response to the problem of climate change; climate change in the Chilean agriculture, livestock, and forestry sector; and Chile's institutional response to climate change. The third of these chapters sets forth issues such as impact on water availability, agro-meteorological risks, agricultural vulnerability, expected effects on key Chilean crops (wheat, maize, potatoes, beets, apples, stone fruit, grapes, forestry plantations, etc.) and on temperature and hydrology patterns. It also covers other topics, including measures for adaptation and prevention of the adverse effects of climate change.

Source: FIA, 2010

2.2.3 Sector-specific potential mitigation options

Mitigation associated with sector development

The information presented here is from the study "Analisis de opciones futuras de mitigacion de GEI para Chile asociadas a programas de fomento del sector silvoagropecuario" (Analysis of future GHG mitigation options for Chile associated with programs for agriculture, livestock and forestry development) (CGC-UC, 2011) commissioned by the Ministry of the Environment. The general aim was to estimate the potential impact and cost of mitigation associated with development programs in the agriculture, livestock and forestry sector in relation to their contribution to carbon capture, GHG emission reductions in productive activities, and replacement of fuels with renewable energies. The impact of each program was assessed, taking into account short (2020), medium (2030) and long-term horizons (2050) under different scenarios defined, in terms of the level of public investment, activities included and the geographic distribution of its incentives.

The mitigation analysis was undertaken for the four subsectors that make up the agriculture and forestry sector (livestock, crops, degraded soil and forests). A significant part of the information used to configure future mitigation scenarios was collected in validation workshops that included discussions and analyses of relevant factors (including timeframes, amounts and rate of adoption of the instrument). From this, a baseline of emissions and mitigation scenarios was constructed and mitigation proposals and instruments associated with the proposed measures were validated. Table 5 summarizes the information from all subsectors analyzed for the measures considered. While the values in this table cannot be simply added up, as they represent mitigation potentials of different measures in different sectors, they do show that all subsectors have the potential for mitigating GHGs.

According to the results of the study, the forestry subsector has the greatest mitigation potential, with annual averages between 5–10 times higher than the others. This potential will involve forestation of 650,000 hectares in total by the year 2050, with the effects distributed over an extensive geographic area, meaning that the impact per hectare will be relatively low. The livestock and crops subsectors, for their part, have interesting mitigation potentials that are concentrated in specific productive segments and in smaller areas than in the forestry subsector. The soils subsector also displays interesting mitigation potentials that are higher than those estimated for livestock-related measures and involve an area of close to 103,000 hectares for all years reported.

An overall analysis of national mitigation potentials under the expected scenarios and with the implementation of several measures—a forestation program, a degraded soil recovery program, optimized fertilization regimes and the use of ionophores—leads to an annual mitigation potential of 3,180 Gg CO_2eq by 2020, 2,760 Gg CO_2eq by the year 2030, and 1,890 Gg CO_2eq by the year 2050, which translates into total mitigation amounts of 31,800 Gg CO_2eq by the year 2020, 55,2000 Gg CO_2eq by 2030 and 75,400 Gg CO_2eq by the year 2050 (annual average times number of years).

TABLE 5 GHG emission projections for selected agriculture, livestock, and forestry subsectors resulting from development programs

Subsector	2020	2030	2050
	(Gg CO_2eq/year)	(Gg CO_2eq/year)	(Gg CO_2eq/year)
Forestry	2,874.3	2,449.3	1,555.3
Degraded soil	0	33.1	32.6
Annual and perennial crops	267.4	278.6	297.8
Livestock	46.4	6.4	6.3

Source: CCG UC, 2011.

Mitigation associated with native forest protection in Chile

In 2009, the National Forestry Institute (INFOR) was commissioned by the Ministry of Agriculture's Office of Agrarian Studies and Policies (ODEPA) to conduct the study –Potencial de mitigacion del cambio climatico asociado a la Ley N°20.283 sobre Recuperacion del Bosque Nativo y Fomento Forestal" (Climate change mitigation potential associated with Law 20.283 on the Recovery of Native Forest and Forestry Development) (INFOR, 2009). Its main objective was to determine potential GHG emissions captured or displaced by actions resulting from the law, mainly through government subsidies for native forest management.

Based on assumptions about forestry management, ten scenarios were established, oriented towards obtaining bioenergy from pruning of forest biomass and recovering the native forest through enrichment actions and livestock exclusion to increase carbon capture. These management schemes were subject to five types of annual budget allocations with a minimum of 30% and maximum of 70% for each mitigation mechanism. The area covered in the study included native forests but excluded those that were officially preserved and protected and located between the Maule and Magallanes regions. The assessment horizon was 20 years.

As a result, an area was identified with a productive potential of 4.3 million hectares of native forest and an available area subject to legal intervention of 1.1 million hectares. Of the area available, in the 20-year horizon between 523,000 and 733,000 hectares will be placed under management and the potential GHG capture will range from 34,000–52,000 Gg CO_2eq in total over the 20-year period, respectively.

With a longer horizon of 30 years, using the same assumptions as the previous scenario, the capture of GHGs will range from 68,000–141,000 Gg CO_2eq, respectively, while for a 40-year horizon, the potential GHG capture will range from 97,000 to 234,000 Gg CO_2eq.

2.2.4 Private-sector developments oriented to mitigation

In the past 30 years, developments in the agriculture and forestry sector have included a significant focus on access to export markets, especially the United States and European Union. As a point of reference, 50% of Chile's exports are sent to markets that are establishing environmental regulations in this area (FIA, 2010).

In this regard, leading industries in this sector have implemented multiple actions to mitigate GHG emissions, as follows:

Wine Industry

- Quantification of GHG emissions in all direct and indirect operations and carbon audits by accredited third parties.
- Emissions compensation schemes for CO_2eq generated by transportation, through forest restoration projects, renewable energy use, and purchasing of carbon credits.
- Decreasing bottle weight and other energy efficiency measures.

Forestry Sector

- Measurement of emissions and carbon footprint of several forestry companies, from direct to third-party emissions arising from their operations.
- Adoption of self-supply electricity policies with thermoelectric generation using biomass and cellulose by-products.

Agro-industry Sector

- Strategies to reduce the sector's carbon footprint by 1 million tons of CO_2eq per year.
- Measurement and reduction of GHG emissions of several exporting companies through the implementation of energy efficiency measures and optimization of transport.

Fruit Sector

- Analysis of carbon emissions from red and green apple production for different stages of production and transport to final markets.

2.2.5 Cross-sectoral actions in the agriculture, livestock and forestry sector

This sector has begun measuring the carbon footprint of its major export products. This very relevant example shows how international climate change measures can impact activities in Chile's agriculture, livestock and forestry industries, as the most demanding markets are now requiring carbon footprint labeling on imports, and this requirements appears to be more and more common.

As a result of this work, at the suggestion of the Council for Climate Change and Agriculture a Cooperation Agreement was signed with the National Standards Institute (INN) for the establishment of a Local Committee. This body would be the official source for information on the ISO's advances in formulating a carbon footprint standard and would facilitate the INN's participation in that process by gathering and communicating the opinions of Chilean stakeholders on that issue.

One important task in estimating carbon footprints is to define a common communication strategy that would allow different stakeholders to convey results in a similar format. To achieve this, the Council recommended that the process by which the carbon footprint was determined should be publicized for companies and products, before any absolute values were made available.

2.2.6 Future GHG emissions scenarios and projections

There are no sector-specific estimates of emissions projections for the agriculture, livestock and forestry sector. The projections found in this Communication were based on the results of the study "Analisis de opciones futuras de mitigacion de GEI para Chile asociadas a programas de fomento en el sector silvoagropecuario" (Analysis of future GHG mitigation options for Chile associated with programs for agriculture, livestock and forestry development) (CGC-UC, 2011), which include projected emissions for some sub-sectors.

It is important to emphasize that GHG emissions estimates for the livestock, crops and degraded soil subsectors considered in the study correspond to emissions from the respective year, but the figures for the forestry subsector correspond to CO_2eq removals that were accumulated by all standing plantations up to the year of reference, divided over the respective period; in other words, the final value represents the cumulative effect from 2011 to the respective year, expressed as an annual average.

Livestock subsector

To estimate projected GHG emissions, CO_2eq estimates per ton of meat and milk produced were calculated for the years 2011, 2020, 2030 and 2050. This was arrived at by projecting the number of heads of cattle and yield per head for bovine cattle, using secondary data sources (livestock surveys; annual statistics reports from the National Statistics Institute (INE); production of meat on the bone and reception of milk from ODEPA). For hogs, the number of heads was obtained using a logistical regression model and meat production was based on productivity information (kg of meat on the bone) per live animal between 1984 and 2008 (linear regression) and population projections for each region.

Methane and nitrous oxide emissions estimations included the use of Tier 1 methods for managing hog manure (methane and nitrous oxide), Tier 1 methods for nitrous oxide emissions from bovine manure, and Tier 2 method for methane emissions from enteric fermentation and management of bovine manure. Lastly, emissions estimations per unit produced were obtained by dividing projected emissions by projected production. Estimates calculated in this way are displayed in Table 6.

TABLE 6. GHG emission projections for the livestock subsector resulting from development programs (Gg CO_2eq/year)

Year	Livestock type	Total emissions (Gg CO_2eq/year)
2011	Beef cattle	3,013
	Dairy cattle	901
	Hogs	1,204
	Total	**5,119**
2020	Beef cattle	2,962
	Dairy cattle	964
	Hogs	1,609
	Total	**5,534**
2030	Beef cattle	2,949
	Dairy cattle	1,050
	Hogs	1,800
	Total	**5,800**
2050	Beef cattle	3,113
	Dairy cattle	1,259
	Hogs	1,894
	Total	**6,267**

Source: CCG UC, 2011

Annual and perennial crops subsector

To establish GHG emissions for this subsector, CO_2eq emissions were estimated based on the amount of nitrogen applied, as determined by the recommended dosage of nitrogen fertilizer and the projected area seeded and/or planted. As with livestock estimates, data was obtained from Agriculture and Livestock censuses, the INE's annual agricultural reports, and agricultural production data from ODEPA. Estimations were calculated for 2011, 2020, 2030 and 2050. Projected areas planted with annual and perennial crops were arrived at by using historical data available for the past ten years and the opinion of an expert panel. This enabled the market trends for each individual crop analyzed to be taken into account in the calculations.

GHG emissions in this subsector correspond mainly to nitrous oxide (N2O) from the application of nitrogen to soils via nitrogen-based fertilizers. These were estimated using projected area under cultivation. The total GHG emissions estimated for annual and perennial crops are displayed in Table 7.

TABLE 7. GHG emissions projections for the annual and perennial crop subsector resulting from development programs (Gg CO_2eq/year)

Year	Crop	Gg CO_2eq
2011	Annual and perennial	1,289
2020	Annual and perennial	1,371
2030	Annual and perennial	1,429
2050	Annual and perennial	1,527

Source: CCG UC, 2011

Degraded soils subsector

To determine emission projections for degraded soils, activities eligible for the subsidy program in this area (SIRSD) were systematized, including subsidized activities and labor registered in the database provided by SAG (Ministry of Agriculture agency) for the 2000–2009 period, and subsidized activities registered by INDAP for the 2007–2009 period. Activities that mitigated GHG emissions—according to the study's background literature and the judgment of experts—were selected from these databases.

The projected emissions were estimated up to 2022, as the current law provides budgets up to that year. To calculate projected GHG emissions/removals, the area projected for each group of activities was multiplied by the emissions factors identified for that group of activities. This information was used to produce Table 8, which summarizes the frequency of GHG mitigation activities for the years 2011 and 2020, without considering the years 2030 or 2050.

TABLE 8. Projected GHG emissions for the degraded soil subsector resulting from development instruments (Gg CO_2eq/year)

Year	Activity	Emissions Gg CO_2eq/year
2011	Organic compost	-25.4
	Soil liming	7.9
	Zero tillage	-4.8
	Agricultural development	7.4
	Grassland	-29.9
2011 Total		**-44.8**
2020	Organic compost	-10.6
	Soil liming	10.4
	Zero tillage	-1.9
	Agricultural development	3.1
	Grassland	-34.7
2020 Total		**-33.8**

Source: CCG UC, 2011

Photo: Ministry of the Environment. Government of Chile

Forestry subsector

The GHG emissions estimates for the forestry sector that are presented in the study mentioned are linked to subsidized tree plantations and assume a scenario in which Law 19.561 of 1998 (which modified DL 701 of 1974) would not be extended beyond 2011. The analysis takes into account that DL 701, in its current form, includes subsidies to small landowners for forestation, soil recovery activities, and dune stabilization in soils considered fragile or in the process of desertification. It also includes degraded soils with slopes with a grade greater than 100%, regardless of the type of landowner, under the assumption that these lands are forested without any subsidy, but less and less frequently.

According to the IPCC definition, the land use, land use change and forestry subsector (LULUCF) accounts for GHG emissions, mainly carbon dioxide (CO_2) and carbon capture. For plantations, CO_2 capture is taken into account only in the category "carbon balance from changes in forest and other woody biomass stocks," which involves a balance between the expansion of biomass in forested lands and annual harvests of forest products (basically timber and firewood). To calculate this value, the CONAF database of areas and amounts of subsidized forests for the 1976–2009 period were used, along with forestry statistics from INFOR. Other technical parameters considered include biomass composition, the ratio of below ground and above ground biomass, the density of stemwood, carbon content by component, regional productivity by species and productive management per species.

Projected CO_2 emissions estimations were arrived at by estimating the annual forestation area for different species, which, combined with yield tables, produces a volume of m^3 per hectare for two species—eucalyptus and pines. This number is then multiplied by the species' anhydrous density to obtain the tons of dry matter per hectare, and ultimately the total number of tons of dry matter per hectare using an expansion factor that takes into account the proportion of total dry matter. The total dry material is transformed into tons of CO_2, assuming 50% carbon content in the total dry matter and an expansion factor of 44/12 from carbon to CO_2. These calculations considered different species that are grown extensively in sites with low productivity.

The two components of the DL 701 subsidy program had a participation rate of around 50% for the 2000–2009 period. Nevertheless, in calculating the average for the 2005–2009 period, a decrease in the forestation component and an increase in the degraded soil recovery component were observed, with an average participation of 68%. As the component is independent of the type of landowner, it is assumed that less land would be forested even in the absence of this instrument. Expert opinions were obtained from institutions such as the Chilean Forestry Association (CORMA) and ODEPA to calculate the rate of forestation in hectares projected to 2050. Without a direct incentive for forestation, this rate shows an instant decrease in 2011 of up to 10% of the average historic value for the 2005–2009 period.

The calculations made in the study also assumed that all carbon contained in living biomass is released when the forest is harvested, which is consistent with the current use of residual harvested biomass and adds a conservative criteria to estimations of carbon capture by these plantations (Table 9). The projected area in hectares for the years 2020, 2030 and 2050, coupled with estimated yields per hectare for each species and region, enable estimations of carbon captured by the root biomass and surface area of forest plantations. In these cases it is assumed that the forest is managed in a plantation-harvest cycle up to the years indicated.

Photo: Ministry of the Environment. Government of Chile

TABLE 9. Projected GHG emissions for the forestry subsector resulting from development instruments (Gg CO_2eq/year)

Year	TOTAL (Gg CO_2eq/year)
2011	-5,5
2020	-150,0
2030	-149,4
2050	-96,1

Source: CCG UC, 2011

Table 10 shows total GHG emissions (Gg CO_2eq) per year for the agriculture and forestry subsectors identified as the most relevant in this study. The tendency in all subsectors, according to the study, is toward increased emissions (or decreased carbon capture in the case of forests) as a direct result of increased production (for crops and livestock) and the likely shift in emphasis in the SIRSD program towards productive activities. For forest plantations, annual sequestration decreases mainly because the amount of area forested is diminishing year by year. Capture drops gradually from 2020 to 2050, when the number of new hectares being added reaches zero.

The increased production that is forecast for the livestock and crops subsectors accounts for most emissions, as these subsectors' net captures (from soils and forest) are not enough to neutralize their emissions. This is also significant in the forest subsector, where the absence of a forestation incentive program stabilizes the number of hectares being forested and therefore also the rates of CO_2 capture. The new orientation of the SIRSD program will result in more emissions (or less carbon captured) in the long term, owing to increased fertilization and soil liming and decreased or stabilized area devoted to grassland.

TABLE 10 GHG emissions projections for selected agriculture, livestock, and forestry subsectors resulting from development programs

Subsector	2020	2030	2050
	(Gg CO_2eq/year)	(Gg CO_2eq/year)	(Gg CO_2eq/year)
Forestry	-150.0	-149.4	-96.1
Degraded soil	-33.8	0	0
Annual and perennial crops	1,371.1	1,428.5	1,527.2
Livestock	5,534.4	5,800.3	6,266.6
Total	**6,721.8**	**7,079.4**	**7,697.7**

Source: CCG UC, 2011

Photo: Ministry of Agriculture. Government of Chile

2.3 TRANSPORTATION SECTOR

The transportation sector in Chile, like that in most countries of the world, accounts for a high percentage of national GHG emissions owing to the high consumption of fossil fuels. According to figures from the 2006 GHG Inventory, transportation sector emissions of CO_2eq in Chile, included in Table 11 with 2006 values, are caused mainly by road transport (92.3%), followed by domestic air transport (5.1%), domestic maritime transport (2.2%) and finally rail transport (0.4%)

TABLE 11. Distribution of CO_2 equivalent emissions (CO_2eq) from the transport sector in Chile, 2006

Transport sector subcategories	2006 (Gg CO_2eq)
Road	15,750
Rail	58
Domestic maritime	381
Domestic air	874
Total	17,063

Source: Chile National Emissions Inventory, INGEI

In those Chilean cities with high levels of air pollution, and especially the country's largest cities of Santiago, Concepcion, Valparaiso-Viña del Mar, much of this contamination comes from road transport (CENMA, 2005). Controlling emissions, mainly of particulate matter and its precursors, is the main focus of regulation and enforcement by local and national environmental and transportation authorities. Efforts to mitigate GHG emissions associated with on-road transportation appear to be a direct co-benefit for the country and are coherent with environmental efforts already in place.

2.3.1 Regulatory framework for mitigation

In the reporting period, the Ministry of Transportation and Telecommunications (MTT) has been the public institution charged with formulating policies, provisions and standards for the development of safe, efficient, environmentally friendly transportation systems and providing equitable access to different modes of transport to guarantee the rights of users. Enforcement actions to control vehicles in the country's transportation system fall under the purview of this Ministry and include the control of vehicle emissions of both local and global air pollutants.

Alongside the MTT and the Ministry of Planning's National Investment System, the Office of Transportation Planning (SECTRA) is the technical entity responsible for the comprehensive planning and social assessment of investments, infrastructure and management of the country's transportation systems at the national, regional and local levels. Its overarching purpose is to improving the quality of life of transport system users. With this mission, the Office develops methodologies, information and modeling instruments and provides expert advice and technical support to other agencies in this area. It also prepares pre-investment studies, analyses and technical proposals. Since 2001, the Office has been conducting studies to assess urban transportation emissions, including local contaminants and greenhouse gases, as well as fuel consumption.

In 2007, the country's energy efficiency program (PPEE) also began to assess to reduce energy consumption in the on-road transportation sector and thereby reduce GHG emissions.

In the decade following 2000, the transportation regulatory framework focused on abating emissions associated with local contaminants rather than on mitigating greenhouse gas emissions, and its structure emphasized designing and applying reporting instruments and economic incentives.

Two examples of this approach were the financial incentive to introduce hybrid vehicles in private fleets and the national truck renewal program. In the former case, in March 2008 the Government of Chile introduced a new tax credit in the private transportation sector for companies purchasing new hybrid vehicles. The financial incentive consisted of a refund of the annual vehicle license fee for a period of four years. It is estimated that this incentive resulted in the increase in sales of this kind of vehicle from 61 units in 2006 to 190 in 2008. By 2010, around 450 hybrid vehicles were on the road in Chile (Geasur, 2010). The national truck renewal program (*Cambia tu camion* initiative), organized by the CNE and the PPEE, was launched in September 2009 in order to encourage owners of the oldest trucks on the road to purchase new models, thereby modernizing on-road cargo transport vehicles and improving energy efficiency and environmental protection[5]. This program encourages owners of trucks 25 years old or more to scrap and replace them with new ones by providing an economic incentive. In Chile these vehicles are usually owned by small transport companies that are willing to renew their vehicles but cannot afford to purchase newer and more efficient trucks. The Government grants differentiated incentives to the program's beneficiaries, depending on the features and size of the new vehicle purchased; the difference in cost between the incentive provided and the price of the new vehicle must be financed by the owner him- or herself by a bank loan.

The regulatory framework that was in place during this period focused on controlling emissions of local pollutants (mainly particulate matter) by vehicle fleets in the Metropolitan Region, where Chile's capital city of Santiago is located. Since 1996, this region has been in non-compliance with primary air quality standards for particulate matter (PM_{10}), ozone (O_3) and carbon monoxide (CO). Because of this situation, since 1998 a pollution control plan has been operating in the city that includes specific measures for controlling local emissions in the transportation sector.

During the same period, vehicle emissions of local pollutants were monitored at the national level through "technical inspection" stations operating under the purview of the MTT.

2.3.2 Sector-specific programs 2000-2010

The national on-road transportation sector has been especially active in seeking out more environmentally-friendly alternatives, some of which contribute to mitigating GHG emissions. Some of the measures implemented are:

- Promoting the penetration of low-carbon vehicle technologies
- Restructuring the urban transit system
- Renewing vehicle fleets with more modern vehicles
- Promoting alternate modes of transportation
- Implementing energy efficiency measures in high priority fleets.

The National Climate Change Action Plan also includes several initiatives of this kind in its priority lines of action. The line "Mitigation of GHG Emissions" identifies the need for infrastructure and safety measures to achieve the large-scale, regular use of bicycles as a mode of transport. Other initiatives are mentioned in the lines of action "Capacity Building" and "Adaptation to the Impacts of Climate Change," which focuses on the design and development of instruments to encourage the transfer and adoption of mitigation and adaptation technologies. This line includes two specific actions related to the transportation sector: one is a labeling scheme that was launched in 2010 to inform consumers of the energy usage and emission levels of contaminating gases released by new vehicles, including CO_2 emissions; the other involves incentives for the use of more energy efficient vehicles, such as zero emission or very low emission vehicles.

Promoting the penetration of low-carbon vehicle technologies

Other public sector actions that promote low-carbon technologies include eco-labeling of vehicles, a measure that the MTT pledged to carry out under the Climate change action plan, and the legislative bill presented to the National Congress in late 2009 to give low emission vehicles (hybrids, electrical vehicles, those that use alternate fuels such as dedicated natural gas or hydrogen) their own official class in Chile. Both initiatives are expected to obtain Congressional approval in 2011.

Restructuring the urban public transit system

In the past decade, the MTT and SECTRA collaborated with regional governments on projects to restructure public transit in Chile's largest cities, with the aim of reducing the overall number of passenger trips taken. The largest project implemented was Transantiago, in the Metropolitan Region, which was launched in February 2007 as part of Santiago's urban transit plan for 2000-2010. Transantiago marked the beginning of a new stage for public transit in Chile's capital, as it installed an integrated public transit system that combines subway lines with feeder bus lines in different sectors of the city. The system also included a "smartcard" for payment of fares. The implementation of Transantiago has not been free of problems, some of which have still not been resolved two years after the system's introduction. Still, the system organized and reduced the number of buses circulating on the streets of Santiago (Universidad de Chile, 2010).

During the same period, a decree was passed to freeze the number of taxis operating in the Metropolitan Region for five years. The initiative was launched in 2005. In 2009 there were 41,408 taxis on the roads (regular, collective and tourist taxis) according to registers of the MTT and the INE.

Vehicle renewal

In 2009, the National Energy Commission, through the National Energy Efficiency Program, implemented the program "Cambia tu Camion" (Trade in your truck), in which 196 trucks that were 25 years old or more were scrapped and replaced by vehicles with up to date technology and excellent energy and environmental performance ratings.

Also in 2010, the MTT evaluated a project to scrap old passenger buses in Chile's regions and replace them with modern vehicles. The impact on regional cities is expected to be greater than that in the Metropolitan Region as the buses on these roads are generally older.

In the past decade the MTT has also encouraged the conversion of taxis and collective taxis to natural gas fuel, mainly through retrofitting of existing vehicles. According to the MTT, by 2009, 3% of regular taxis and 10% of collective taxis operating in the Metropolitan Region had been converted to natural gas.

Promotion of alternate modes of transportation

In regard to the Santiago subway system, advances were made in 2000 (extension of line 5), 2004 (extension of line 2), 2005 (line 4) and 2006 (line 4A). These gradually expanded a subway network that by December 2009 had 94 kilometers of rail and 101 stations in five interconnected subway lines that served 2.3 million passengers daily. Other changes to urban transit systems this decade include the inauguration of the Valparaiso subway (Merval) in 2005, with a rail network of 43 kilometers and 20 stations, and the greater Concepcion commuter train (Biovias), also inaugurated in 2005 with 17 stations in two rail lines.

In regard to non-motorized modes of transportation in Chile's cities, in the past decade the MTT, SECTRA, and MINVU worked intensively with regional authorities, mainly on the creation and maintenance of bicycle networks. By 2009, eleven Chilean cities had bike lanes operating. The barriers to introducing and maintaining these kinds of initiatives—such as cultural and educational mindsets and safety concerns related to accidents—should also be mentioned, however.

Implementation of energy efficiency measures in high priority vehicle fleets

Also worth noting is that the MTT has been studying measures to increase the efficiency of inter-urban cargo transport since 2005, and in 2007 the Ministry joined the PPEE in implementing pilot projects in this area. As this transport sector has both high fuel consumption and GHG emissions, there is a need to analyze its technological efficiency and formulate and apply standards, even though regulating this sector presents some challenges. One initiative that bears mention is a pilot project that provides efficient driver training to drivers working for small companies engaged in inter-city on-road shipping. This project was implemented under the National Energy Efficiency Program and the Chilean Energy Efficiency Agency in 2009 and 2010 as "Mueve tu camion con buena energia" (Move your truck with good energy). The project also included a module on fleet management and another on technical and mechanical vehicle inspection, and achieved fuel savings of around 10% among participating companies (AChEE, personal communication).

2.3.3 Potential sector-specific mitigation options

This section presents the results of two major, publically funded studies on mitigation of GHG emissions for the transportation sector. The studies were concluded in the first half of 2010.

[5] In 2008 the cargo vehicles in Chile numbered 140,000 (115,000 regular trucks and 25,000 tractor-trailers), many of which were quite old (averaging 13 and 10 years old, respectively). Small companies tended to own older trucks, a common feature of atomized markets (73% of on-road shipping companies had just one truck, the average age of which was 15 years).

The study "Analisis de opciones futuras de mitigacion de gases de efecto invernadero para Chile en el sector energia" (Analysis of future options for mitigating greenhouse gases in Chile's energy sector) (Poch Ambiental, 2010) was financed by the Ministry of Energy and CONAMA. The study used the LEAP program and modeled the country's energy grids independently, taking into account different projected generating capacities. For the fuel sector, consumption was projected using a top-down model and econometric analysis. Results were produced for three timeframes: 2010, 2020 and 2030.

In regard to the transportation sector, the study only worked with measures for on-road transport subsector because its contribution to GHG emissions is much greater than that of other modes of transportation. Most of the study's proposals are for increasing energy efficiency in vehicles, although there are also proposals to change transportation modes, technologies, and fuels, as Table 12 shows. A description was prepared for each suggested measure that considers the potential for penetration and mitigation, estimated costs, and data and assumptions that were taken into account.

TABLE 12. Summary of greenhouse gas mitigation measures/technologies identified for on-road transportation

Activity	Category	Technology/Measure	Description
General	Technology and/or fuel change	Biofuel usage	Use of a percentage of biofuel (biodiesel) as a diesel replacement.
General	Energy efficiency	Efficient driving (Eco-driving)	Training for drivers of light vehicles, buses, shared taxis, and trucks in better driving practices (Eco-driving), reducing fuel consumption and associated CO_2 emissions.
Light vehicles	Modal change	Modal change through expansion of the Metro subway system	Construction of further subway lines/expansion of existing lines. Emissions reductions are related to the transfer of users from gasoline-powered light vehicles to the subway network, increasing numbers of passengers per journey.
Inter-urban goods vehicles	Energy efficiency	Aerodynamic improvements	Implementation of aerodynamic devices to improve fuel efficiency (diesel) in inter-urban cargo vehicles.
Inter-urban goods vehicles	Energy efficiency	Renewal of cargo truck fleet	Replacement of trucks older than 25 years with new, more efficient trucks to reduce diesel consumption and associated GHG emissions.
Light vehicles	Energy efficiency	Renewal of light vehicle fleet.	Replacement of vehicles older than 25 years with new, more efficient vehicles to reduce fleet GHG emissions.
Light vehicles	Technology and/or fuel change	Hybrid vehicles in fleet renewal	Replacement of conventional (gasoline) vehicles with hybrid vehicles. GHG emission reductions are linked to the improved efficiency of hybrid cars.

Source: Poch, 2010

According to the summarized results (see Table 13), the most favored measures are those with both positive and negative costs, but with net savings. In terms of reducing emissions, the two most effective measures for the 2010-2030 period, relative to the baseline, are associated with biofuels (gradually increasing the penetration of biofuel consumption in on-road transport in Chile from 2% in 2015 to 15% in 2030) and the introduction of aerodynamic improvements in the current truck and tractor-trailer fleet in Chile until 40% of the fleet has been improved (not including those vehicles that come factory-equipped with this kind of improvement).


Photo: Transantiago. Government of Chile

TABLE 13. Summary of results for the transport sector under the 2010-2030 reference scenario.

Sector	Measures	PV sector costs (Millions of US$)	PV total costs (Millions of US$)	Accumulated GHG reduction (Millions of tons CO_2eq)	Average sector costs (US$/ton CO_2eq)	Average total cost (US$/ ton CO_2eq)
Transport	Biofuels	1,043	1,043	23	45	45
	Efficient driving	-229	-229	3	-69	-69
	Expansion of subway lines	133	134	1	182	182
	Aerodynamic improvements	-2,088	-2,088	13	-163	-163
	Renewal of cargo truck fleet	72	72	0.10	743	743
	Renewal of light vehicle fleet	11	11	0.004	3,042	3,042
	Hybrid vehicles	-77	-77	3	-30	-30
	Total	-1,134	-1,134	43	-26	-26

Source: Poch, 2010

The second study is entitled "Analisis y desarrollo de una metodologia de estimacion de consumos energeticos y emisiones para el transporte" (Analysis and development of a methodology for estimating energy consumption and emissions in transportation) (Sistemas Sustentables, 2010). This study was financed by SECTRA and oriented specifically towards the transportation sector. Econometric models were used to estimate projected energy consumption by region for different modes of transportation for the 2010–2025 period. With this information, associated emissions were calculated for local and global air pollutants.

The following five measures were evaluated in regard to their potential for reducing fuel consumption:

- Efficient driving for private vehicles, allowing savings of 10% on fuel consumption for 10% of vehicles circulating in three regions of the country.
- Efficient driving of cargo trucks, allowing a savings of 10% on fuel consumption for 20% of trucks circulating beginning in 2015, in three regions of the country.
- Technology renewal for private vehicles, allowing the entry of gasoline-hybrid, plug-in hybrid and electric vehicles (3% in all) and the removal of vehicles with Euro I technology in the same proportion in the region of Valparaiso.
- Technology update of regular and collective taxis in the Metropolitan Region, replacing 3% of gas-powered vehicles with Euro III technology and 15% of gas-powered Euro I vehicles with the same total quantity of new vehicles with gas, plug-in or electric hybrid technologies.
- Change in transport mode from road to rail, by decreasing the number of medium and heavy trucks by 10% in Region VIII and replacing these with rail transport.

Table 14 shows the estimated reductions in fuel consumption expected from applying these measures up to 2015.

TABLE 14 Reductions in fuel consumption from the application of road transport measures for 2015

Measure	Vehicles affected	Reduction in fuel consumption, 2015
#1	Private vehicles	8,707.6 m^3 diesel; 24,055.1 m^3 gasoline
#2	Trucks	9,326.54 m^3 diesel
#3	Private vehicles	12,413.84 m^3 gasoline
#4	Taxis and collective taxis	19,097.50 m^3 gasoline
#5	a) Trucks	19,516 m^3 diesel
	b) Trains	- 5,561 m^3 diesel (*)
(*) additional consumption through increased demand for rail transport		

Source: Sistemas Sustentables, 2010

As a complement to the study, the consultant built an application in Access that evaluates the GHG mitigation potential at both the regional and national levels, according to the user's preference.

2.3.4 Private sector developments oriented towards mitigation

This section presents two initiatives implemented by the private sector. In 2007, the Confederation of Production and Commerce (CPC), a national association of companies in Chile, awarded the Energy Efficiency Award to the intercity shipping company LitCargo for its actions to improve energy efficiency in its vehicle fleet. To date, LitCargo is the only transportation sector company to have received this honor. Additionally, since 2009 the local government and transportation companies in Punta Arenas have been implementing a program to phase-in buses fueled by CNG. As of early 2010, four transit routes in this southern Chilean city were using this locally produced fuel.

It is also worth noting that small courier companies operating in downtown Santiago now use vehicles powered by electricity, LPG and compressed natural gas.

2.3.5 Projected GHG emissions in the sector

Based on projections of fuel consumption in the transportation sector for the 2010–2025 period, as estimated in the study "Analisis y desarrollo de una metodologia de estimacion de consumos energeticos y emisiones para el transporte" (Analysis and development of a method for estimating energy consumption and emissions for transportation), GHG emissions were calculated for this period.

Figure 6 shows that the contribution of on-road, air, maritime and rail emissions of CO_2eq to the national total are expected to rise between 2010 and 2025. The figures are broken down by mode of transportation examined in the study mentioned. The portion of on-road emissions in the projections remains virtually the same for the period under study, as Table 15 shows.

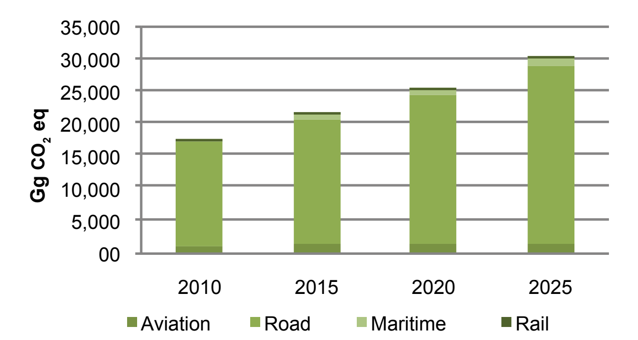

Figure 6. Projected CO_2 emissions from the Chilean transport sector, 2010–2025
Source: Ministerio del Medio Ambiente, based on data from Sistemas Sustentables, 2010.

TABLE 15. Distribution of CO_2eq projected emissions in the transport sector by mode of transportation, 2010-2025 (%)

Mode	2010	2015	2020	2025
Air	5.3%	5.2%	4.6%	4.4%
Road	91.4%	90.5%	90.5%	90.2%
Maritime	3.0%	4.0%	4.6%	5.2%
Rail	0.3%	0.3%	0.3%	0.2%

Source: Ministry of the Environment, based on data from Sistemas Sustentables (2010)

Considering the importance of GHG emissions from on-road transport, more detailed projections are presented for this sector only. Four aspects in particular were addressed: the contribution of families of vehicles used for on-road transportation; fuels that are consumed in this sector primarily; regions of Chile that account for the most fuel consumed in this sector; and technologies for improving emission levels (mainly of local pollutants) and their impact on emissions from private vehicles on the road in Chile.

The study grouped on-road vehicles in the country into four families: private vehicles, taxis, buses and trucks. As can be seen in Figure 7, GHG emissions by private vehicles produce the most GHG emissions from on-road transportation, growing from 54% per year in 2010 to 56% in 2025 as a proportion of the total value calculated for all families of vehicles on the road.

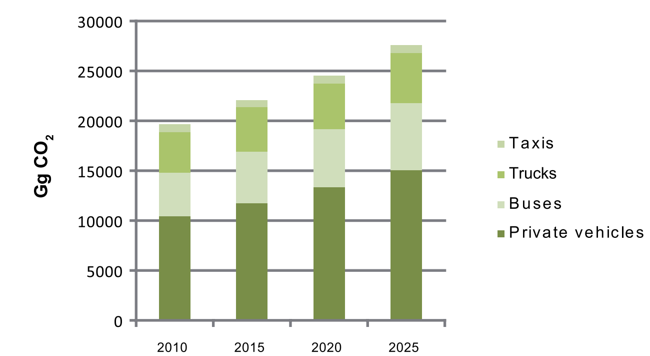

Figure 7. Projected CO_2 emissions from the road transport sector by vehicle type, 2010–2025
Source: Ministerio del Medio Ambiente, based on data from Sistemas Sustentables, 2010.

In terms of fuel consumption for the on-road transportation mode, it is estimated that the percentage of diesel consumed will grow in relation to that of gasoline, the other commonly used vehicle fuel in Chile, mainly as a result of the expected increase in imported diesel-powered private vehicles. Thus, CO_2eq emissions associated with the use of diesel fuel are estimated to rise from 53% in 2010 to 69% in 2025.

In regard to the geographic distribution of GHG emissions in the country's 15 regions, the Metropolitan region is the by far the largest consumer of fuels for on-road transportation, accounting for 37% of all national emissions in this category. Nevertheless, the study predicts that this share will drop to 33% by 2020 and 32% by 2030.

Lastly, in regard to the gradual phase-in of private vehicles with lower emission technologies (Euro vehicles, in this case Euro1 to Euro5), Figure 8 shows the gradual disappearance of the more polluting vehicle technologies and the increasing role of more modern technologies such as Euro 5 in GHG emissions from vehicles on the road in Chile. In fact, by 2020 vehicles equipped with Euro 5 technology will be the largest group. However, the emission reductions that are achieved through the increased use of vehicles equipped with Euro technologies are much greater for local pollutants than for GHGs, and thus technological renewal will not in itself be able to revert the trend towards rising GHG emissions in this sector.

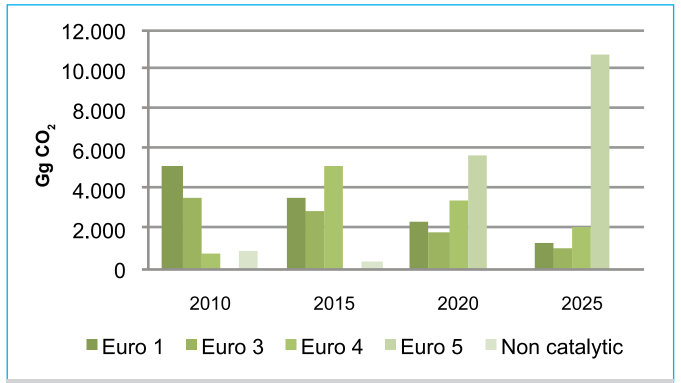

Figure 8. Projected CO_2 emissions by private vehicles in Chile, by emission control technology, 2010–2025
Source: Ministerio del Medio Ambiente, based on data from Sistemas Sustentables (2010)

2.4 COPPER MINING SECTOR

Chile is the largest copper producer in the world, accounting for 34% of all copper produced on the planet. The country's main copper exports are cathodes obtained by electrowinning (39%), copper concentrate (33%) and cathodes obtained by electrorefining (20%) according to official figures from 2010 (COCHILCO, 2011).

Copper mining is of vital importance to the Chilean economy, accounting for 17.4% of the country's GDP in 2010 (Banco Central, 2011).

The copper industry is also a major consumer of energy, both fuel and electricity. In 2009 the sector consumed 17% of all net electricity generated by the SIC and 84% of that produced in the SING ("Consumo de energia y emisiones de gases de efecto invernadero asociadas de la mineria del cobre de Chile para 2009", COCHILCO, 2010). Copper development and production in Chile involves a series of processes, from ore extraction (from open pit or underground mines), to concentration and refining of sulfated minerals (pyrometallurgy), or leaching, solvent extraction and electrodeposition for minerals that can be leached (hydrometallurgy), all of which consume different amounts of energy. In recent years it has become an industry priority to increase energy efficiency in copper production processes. In this regard, the Informe Ambiental y Social 2009 (2009 Environmental and Social Report) published by the Mining Council of Chile (2010) identifies the challenge of mining companies in the country to use energy efficiently, mainly through operating initiatives. Through such measures, mitigation of GHG emissions associated with mining activities becomes a direct cobenefit for the country and is coherent with the sector's development goals.

Nevertheless, major challenges must still be addressed in the coming years, such as providing incentives in the area of copper production, given that the high price of copper on the international market and the positive economic outlook in the medium term make it more and more profitable to extract the lowest grade ore, which will require more energy and therefore produce more GHG emissions per unit produced. Additionally, copper mining projects launched over the past decade are also experiencing a gradual reduction in the grade of ore extracted, which will also require more energy to process, owing to the hardness of the ore and longer distances over which it must be transported. This process, known as "mine aging," will increase in the present decade (COCHILCO, personal communication).

Lastly, it is important to note that copper metal is one of the best conductors of electrical energy and is widely used in equipment designed to increase efficiency in electricity consumption: high efficiency motors, transformers, wind turbines, solar panels, air conditioning and refrigeration equipment all use this metal (Procobre Chile: www.procobre.org). Copper is therefore a major ally in global efforts to shift towards more energy efficient economies.

2.4.1 Mitigation in the regulatory framework

In the 2000–2009 period, two public sector institutions led the way in generating information on GHG emissions that can be used to assess mitigation measures: the Chilean Copper Commission (COCHILCO), part of the Ministry of Mining, and the National Energy Efficiency Program, under the purview of the Chilean Energy Efficiency Agency.

COCHILCO has inventoried and compiled information on GHG emissions released by the country's copper mining companies. This work was been publicized in regular public reports drafted by the agency's Office of Studies and Public Policies, such as: *Coeficientes unitarios de consumo de energia de la mineria del cobre 1995–2006* (Unitary coefficients in energy consumption in copper mining, 1995–2006) (2007); *Coeficientes unitarios de consumo de energia de la mineria del cobre 2001–2007* (Unitary coefficients of energy consumption in copper mining, 2001–2007) (2008); *Emisiones de gases de efecto invernadero de la mineria del cobre de Chile 1995–2006* (Greenhouse gas emissions in copper mining in Chile, 1995–2006) (2008); *Emisiones de gases de efecto invernadero de la mineria del cobre de Chile 2001–2007* (Greenhouse gas emissions in copper mining in Chile, 2001–2007) (2008) and the comprehensive updates of *Consumo de energia y emisiones de gases de efecto invernadero de la mineria del cobre de Chile año 2008* (Energy consumption and greenhouse gas emissions in copper mining in Chile in 2008) (2009) and *Consumo de energia y emisiones de gases de efecto invernadero asociadas a la mineria del cobre de Chile año 2009* (Energy consumption and greenhouse gas emissions associated with copper mining in Chile in 2009) (2010).

In regard to the PPEE, one of its main lines of action since the beginning has been the identification of potential energy efficiency applications for Chile's mining industry. In 2006, a working group was established to promote energy efficiency in the industry. Its structure and activities are described in this section.

To date, no regulatory framework has been formulated for mitigating GHG emissions in the copper mining sector and companies have focused primarily on voluntary, experimental implementation of energy efficiency measures in their productive processes.

As for copper production inputs, despite the importance of having an electricity supply to produce the many commercial copper products made in Chile, in recent years the mining sector has been gradually separating its energy generation operations (regulated by the Ministry of Energy and the National Energy Commission) from its main line of business by selling off its interests in the energy market.

2.4.2 Potential mitigation options and GHG projections for the mining sector

During the period covered, COCHILCO has generated information on the relationship between copper production and GHG emissions in Chile. Figure 9 shows the growing trend in energy consumption against copper production in the country between 1995 and 2009, while Figure 10 presents estimated emissions for the copper mining sector for the same period, for each of the two electricity grids that supply power to Chile's copper producing regions (SIC and SING).

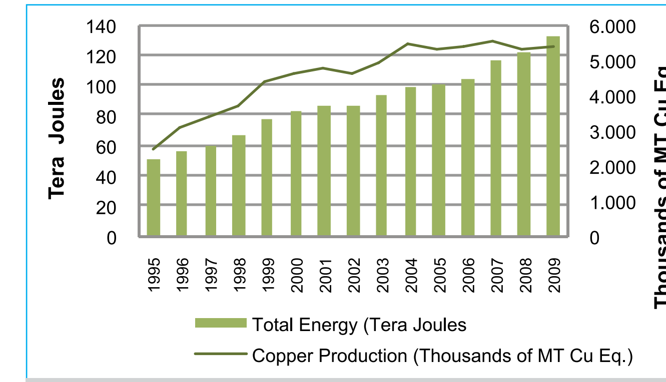

Figure 9. Evolution of energy consumption and copper production, 1995–2009
Source: Comisión Chilena del Cobre, COCHILCO (2010)

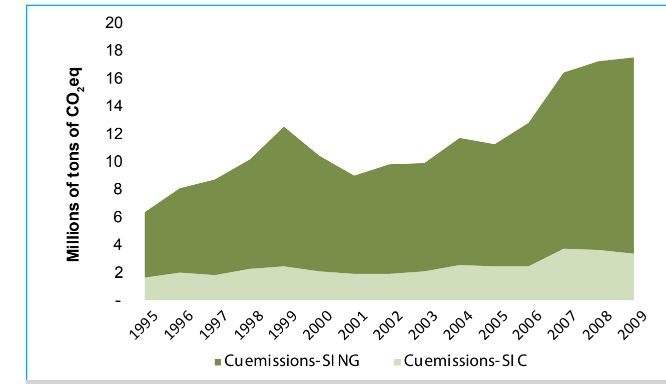

Figure 10. Evolution of CO_2 emissions from copper mining in Chile by energy grid, 1995–2009
Source: Operating statistics of CDEC, SING and SIC. Comisión Chilena del Cobre (2010)

The difference in the total emissions released by the two electricity grids supplying copper mining operations is partly due to the fact that 2/3 of all copper production occurs in the geographic region covered by the SING, which means that more electricity is consumed; however, the main reason for the discrepancy is that the SING grid is 99.6% thermoelectric, while the SIC (in 2009) obtained 58.5% of its energy from hydroelectric power. More details on the Energy sector are provided in this chapter.

To analyze potential mitigation options, in 2009 COCHILCO prepared the first GHG emissions projections for the copper mining industry, based on information available that year both for national energy demand and mining sector growth for the 2009–2020 period (COCHILCO, 2009). This was a concrete contribution of the mining sector to the mitigation line of action in the National Climate Change

Action Plan and was intended to help guide decision making by mining sector companies wishing to undertake energy efficiency and mitigation actions. It also served as input for decision making on energy matters in the public sector.

The study looked at CNE projections for Chile's energy generation systems supplying power to copper mining operations, as well as production forecasts for the copper industry. The latter were prepared using information about mining projects underway and planned for the 2009–2020 period. In all cases studied, the expected increase in GHG emissions (from fossil fuel consumption and electricity generation) was greater than the expected growth in copper production (Figure 11). A preliminary assessment was also undertaken of the impacts of energy efficiency measures on mitigation (Figure 12) that found that even if very aggressive measures were implemented at certain stages of production, the emission reductions achieved would be very limited. Instead, the exercise found that other kinds of mitigation actions would be more efficient in decreasing the growth in GHG emissions in this sector.

In all of the cases studied, indirect emissions from copper production—those generated by the electricity used in mining operations—account for more than 73% of the sector's emissions (Figure 11). This is due mainly to the projected configuration of the country's electricity generation systems, mainly the SIG, that supply Chile's principal mining operations.

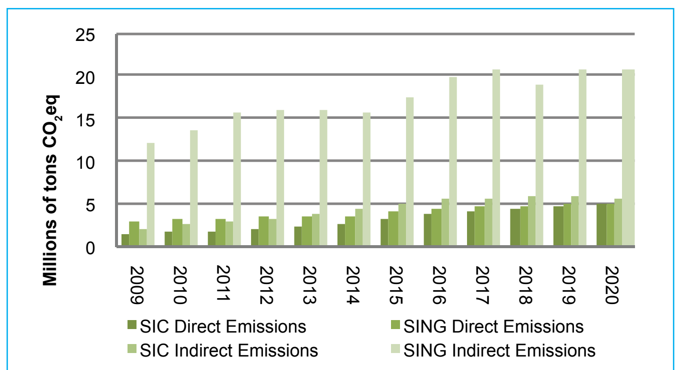

Figure 11. Projected direct and indirect GHG emissions by the copper mining sector in Chile, by electricity grid
Source: Comisión Chilena del Cobre, COCHILCO (2009)

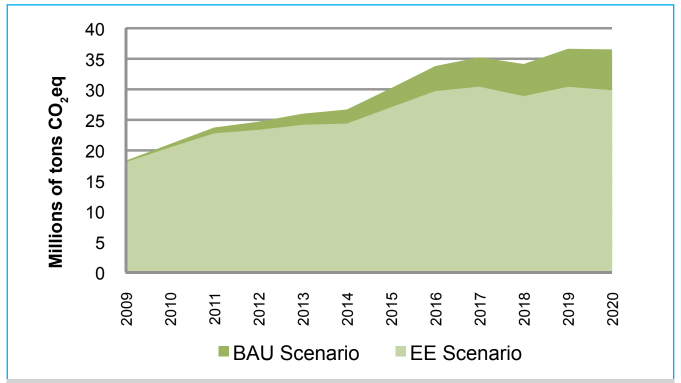

Figure 12. Impact of energy efficiency measures on projected emissions from the copper mining sector in Chile.
Source: Comisión Chilena del Cobre, COCHILCO (2009)

2.4.3 Private sector developments oriented towards mitigation

Efforts to mitigate emissions in Chile's copper mining sector have focused primarily on exploring opportunities to increase energy efficiency in industrial copper processing operations.

Energy efficiency has been an important tool for the mining sector in terms of lowering production costs and increasing competitiveness, and the sector has therefore become a national leader in energy efficiency applications. These advances have been noted by Chile's industrial sector, most notably in an energy efficiency award granted to the mining sector by the Confederation of Production and Commerce (CPC) and the National Mining Society (SONAMI) (CNC, 2009). The high price of copper in the international market since 2007 also has contributed to energy efficiency by making funds available for pilot projects and other measures such as the introduction of energy efficient electrical motors. Implementing these measures on a large scale is a challenge, however, so their effects are not likely to be felt in the immediate future.

Unlike the state-owned CODELCO, the leading copper producer in the world, several of the largest private copper companies in the sector are subsidiaries of multinationals with head offices in Australia, Switzerland, Canada, the United States and the United Kingdom. Many of these have been very proactive in ensuring their local subsidiaries are environmentally responsible. Indeed, Chile's leading copper mining companies, their trade associations, the Mining Council and SONAMI, are all members of the International Council on Mining and Metals, an entity that has analyzed the implications of climate change for the mining industry and has prepared and disseminated a Climate Change Policy for the sector (www.icmm.com) that was signed in 2009 by several mining companies operating in Chile.

2.4.4 Sector-specific programs implemented from 2000 to 2009

The longest running energy efficiency initiative in Chile's mining industry is the "Mesa Minera de Eficiencia Energetica" (Energy Efficiency on Mining Working Group), which has been operating since 2006. The group includes large mining companies and non-metal mining companies operating in Chile, public entities and industry associations (such as the Mining Council, SONAMI Acenor), all of which work together to promote the efficient use of energy in Chilean mining. The Group encourages voluntary public and private participation and promotes research, innovation and the exchange of good practices, making the mining sector an agent of cultural change in favor of sustainable development and a promoter of competitiveness for both the sector and Chile (Mesa minera de eficiencia energetica, 2008). Through its implementation of partnered innovation projects (primarily demonstration projects) and cooperation initiatives to exchange experiences, management and technology, the Mining Working Group has become a source of information and leadership for energy efficiency in the Chilean mining industry. For example, in 2007 it backed the implementation of a pilot project to replace electric motors with energy efficient motors in copper mining companies, working with suppliers and industrial clients. Other projects in this sector over the period covered have been oriented towards controlling intense electricity consumption in industrial processes at peak operating hours and achieving energy reduction goals in specific industries (Mesa minera de eficiencia energetica, 2008).

Today, the Mining Working Group is implementing a work plan for the 2010–2012 period that includes designing and implementing energy management systems based on the future ISO 50001 standard, disseminating its achievements and activities in a communication plan, and coordinating energy efficiency actions among groups involved in the mining industry (L. Ellis, President of the Mesa Minera en Eficiencia Energetica, personal communication).

Another valuable initiative in the sector is the Framework Clean Production Agreement for Large-scale Mining, signed between the Government of Chile and private sector entities in 2000. This document establishes the efficient use of energy as one of its areas of action.

3. CROSS-SECTORAL ACTIONS

3.1 ECONOMIC INSTRUMENTS ORIENTED TOWARDS MITIGATION

3.1.1 The Clean Development Mechanism in Chile

Since the Kyoto Protocol was ratified by Chile in 1997, the country has been both active and proactive in promoting and implementing projects under the Protocol's Clean Development Mechanism (CDM), becoming a leader in Latin America and around the globe in terms of CDM projects registered and methodologies approved.

Chile also participated in the negotiation and approval process for the Marrakesh Accord (2001), proposing an interim CDM stage in 1998 that enabled a preparatory process for CDM project management. This process followed the Marrakesh definitions and involved the establishment of an Executive Board, methodology panels and accreditation panels for Designated Operational Entities even before the Protocol entered into force. This step allowed CDM projects to be registered with the Executive Board.

In line with its desire to make use of the CDM promptly, in 2003 Chile established its Designated National Authority (DNA), an entity required under the Protocol for CDM emission reduction projects and for participating in the carbon market. To date, Chile has had 73 projects approved by the DNA, thanks to the promotion of the CDM nationally and internationally, the DNA's review of projects, and the signing of cooperation agreements with industrialized countries on matters related to the CDM. By late 2010, the CDM Executive Board had registered 42 of these projects. Taken together, the Chilean projects registered are expected to generate a reduction of 4,957,224 tons of CO_2eq (UNFCCC, 2010).

However, the number of projects in Chile being submitted to the CDM for approval has been decreasing since 2007, with just four projects approved in 2009. This downward trend seemed to turn around in 2010, however, when 20 projects were submitted for approval (see Table 16).

TABLE 16. CDM projects approved by the Designated National Authority (DNA)

Year	Projects approved by DNA each year
2003	7
2004	3
2005	7
2006	14
2007	10
2008	8
2009	4
2010	20
Total	73

Source: Chile DNA, December 2010

The most common type of CDM project in Chile (Figure 13) is hydroelectricity generation, followed by methane capture in sanitary landfills and in industrial farming activities.

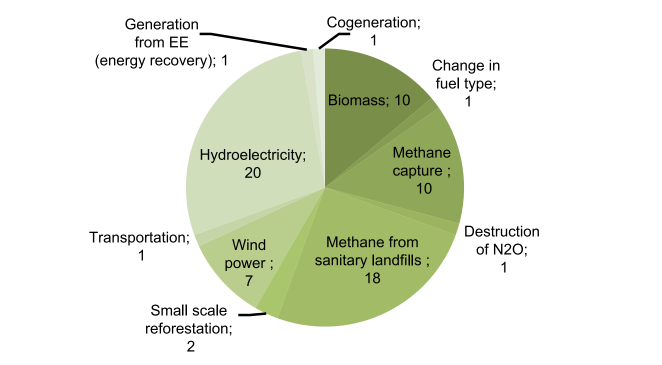

Figure 13. Types of CDM projects approved by the Chilean DNA
Source: Chile's Designated National Authority, December 2010

Operation of the CDM in Chile

• Designated National Authority

In Chile, the DNA has an Executive Committee that is chaired by the Minister of the Environment and coordinated by the Ministry itself. The Committee includes a representative of each of the following institutions: the ministries of Foreign Affairs, Energy, and Agriculture, and the National Clean Production Council. The Committee is responsible for ensuring that CDM projects in Chile are voluntary and contribute to sustainable development.

Projects are presented to the Ministry of the Environment, which reviews the information and contacts the corresponding regional Environmental Assessment Service (SEA) to confirm that the project conforms to the Environmental Framework Law, which is used as a measure of sustainability for issuing national approval for the project. If there are any observations on the proposal or on the information presented, these are submitted to the project proponent, which must resolve them. Once any outstanding observations have been resolved, the project is brought before the Committee, where the final letter of approval is granted (or not).

• Chilean Economic Development Agency (CORFO)

CORFO is a public economic development agency that promotes domestic production, including non-conventional renewable energies through the Clean Development Mechanism. In 2006, CORFO organized the First International Meeting on Renewable Energy Investments and the CDM. This meeting was held subsequently every year from 2007 to 2010, bringing together key stakeholders in the renewable energy market and carbon market and attracting hundreds of foreign and Chilean investors, consulting firms, equipment suppliers and project developers to explore new business opportunities offered in the energy sector.

CORFO currently is supporting the implementation of a portfolio of projects in the area of non-conventional renewable energies (NCREs). In 2009, the portfolio included 51 projects worth a total of US$ 1.6 billion and representing a total generating capacity of 823 MW.

• PROCHILE

The Chilean Export Promotion Bureau, PROCHILE, is part of the Ministry of Foreign Relations and is charged mainly with promoting CDM-eligible Chilean projects abroad (Prochile, 2010).

CDM within Chile

CORFO's Enterprise and Innovation Office operates the Executive Office of InnovaChile, which promotes CORFO's actions in the areas of innovation and technology transfer. As such, one of Innova's areas of interest is clean

production, which improves companies' environmental performance and makes them more competitive. In this context, two entities were created in Chile that demonstrate the importance of promoting carbon markets within Chile and encouraging Chilean companies to use them. The main objectives of these entities are to disseminate carbon markets, identify projects and guide potential developers as they strategically sell GHG reduction credits. These entities are:

- Chile-CO_2: A project developed by the Universidad de Chile's Foundation for Technology Transfer (UNTEC).
- CGF-MDL: Center for promoting and strengthening clean development in Chile, established by the Pontificia Universidad Catolica de Valparaiso.

In 2010, the Chilean Energy Efficiency Agency identified emission factors for the SIC and SING electricity grids for use with CDM projects and based on United Nations' protocols.

3.1.2 Voluntary carbon markets

Voluntary carbon markets are different from regulated carbon markets (CDM) mainly because the former do not require national approval of the host country and the validation and verification process depends on the standard used, which means that they are simpler, at least in theory. Nevertheless, the criteria for approving projects in the voluntary market are similar to those used for the CDM and are intended to ensure that emissions reductions are real, long-term and comply with environmental standards without being counted twice.

The registries for this market have improved in recent years, however, moving from very diffuse reporting to web portals in which details of Verified Emissions Reductions (VERs) can be identified for specific projects.

In general, information on voluntary markets comes from surveys and reports prepared by participating companies and organizations. One of the most important of these is the Annual State of the Voluntary Carbon Market, a report published by Ecosystem Marketplace and New Energy Finance. This document reports that since its creation, the volume and value of transactions carried out in voluntary markets in Latin America represent only a miniscule portion of the global carbon market. In 2009, for example, voluntary markets represented 1% of the volume of global markets, and just 0.3% of the value of emissions traded on the global carbon market, according to the World Bank. A study by both entities on the state of the voluntary market in 2009 reported that Latin America produced 16% of all voluntary carbon credits. This is due in part to the prices of carbon credits in Latin America, which are the lowest of all regions of the world. In contrast, in 2009 Latin America was responsible for less than 2% of the global demand for voluntary carbon credits.

State of the voluntary carbon market in Chile

Despite the lack of public information on the advancement of the voluntary carbon market in Chile, in 2008 CORFO commissioned a study (Deuman, 2008) to compile information on Chilean suppliers of VERs. The agency consulted with First Climate and One Carbon, both suppliers and purchasers of VERs from different types of projects, including two implemented by the companies Masisa and Codelco. The case studies described these two projects, which participate in the voluntary carbon market in Chile, as follows:

Masisa – Masisa joined the Chicago Climate Exchange, pledging to reduce its greenhouse gas emissions by 6% by 2010 (using the years 1998–2001 as a baseline).

The reductions represented 400,000 tons of CO_2 in 2010. The pledge included annual reports on emissions and removals.

CODELCO – In 2003, CODELCO chose to certify its emission reduction in the Chicago Climate Exchange. In 2007, this voluntary market certified emission reductions for a project that the company presented, which consisted in changing the fuels used in the Chuquicamata and Caletones smelters from petroleum to natural gas. This measure reduced CO_2 emissions by around 220,000 tons between 2003 and 2006.

Santiago Climate Exchange

The Santiago Climate Exchange (SCX) is the first completely private climate exchange in the Southern Hemisphere and plans to incorporate derivative instruments and futures, like more developed markets. The SCX is a joint initiative of Celfin Capital and Fundacion Chile. Celfin is a financial company with experience in developing open,

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competitive and diversified trading exchanges. Fundacion Chile is a private non-profit corporation with the expertise for developing emission reduction methodologies and has worked with different actors in the area in emission mitigation.

SCX allows any interested citizen to implement CO_2 reduction projects eligible for carbon credits. The traders participating in the exchange do not need to be shareholders (Santiago Climate Exchange, 2010).

3.2 OTHER INSTRUMENTS FOR MITIGATING GHG

Carbon footprint

In recent years, several entities have emerged in Chile to enable companies and individuals to calculate their carbon footprint. Using simple information, these companies calculate the amount of GHG emissions that a person or company releases from burning fossil fuels and consuming energy in their daily activities. The footprint tool also offers recommendations for lowering individual and corporate carbon consumption, i.e. reducing the carbon footprint, and most of them allow the interested party to compensate for their emissions by supporting clean development projects. Some entities offering carbon footprint instruments in Chile are listed below:

- Carbón Zero, Fundación Chile
- Fundación Reduce tu Huella
- CO_2 Neutral
- Cero CO_2, Instituto de Ecologia Politica
- Green Solutions
- Chile-CO_2.

As part of the effort to mitigate GHG emissions in the agriculture and forestry sector, in 2009 MINAGRI commissioned an analysis of the carbon footprint of Chilean export products in this sector to help maintain their competitiveness in international markets. Through the use of the UK standard (PAS 2050: 2008 BSI, based on ISO 14067) the life cycles of fruit, vegetable and grain species, along with dairy and meat products, were evaluated. In general, the main source of GHG emissions from these products is the energy and inputs used to produce them and, for meat and dairy products, the animals themselves. The relative contribution of long distance international transport to GHG emissions appears minor in the carbon footprint of Chilean products.

For its part, in 2010 the Ministry of the Environment commissioned a study to determine its own GHG emissions and design a plan to reduce its carbon footprint, which will make it the first ministry in Chile to do so.

3.3 ADDITIONAL PROPOSALS FOR MITIGATING GREENHOUSE GASES IN CHILE

"Mitigating climate change: How much does it cost? Efficient and effective proposals"

This initiative emerged as part of a strategic partnership and joint action with the Fundacion Chile, Fundacion AVINA, Fundacion Futuro Latinoamericano, the Centro de Cambio Global at the Pontificia Universidad Catolica de Chile and the Universidad Alberto Hurtado, and Empresas Electricas A.G. It was launched in May 2010 to gather useful information and generate proposals for public-private decision making on mitigating greenhouse gases in Chile through dialogue and consensus building among key stakeholders.

The objectives of this initiative are:

- To analyze and discuss different mitigation alternatives, including the no mitigation option
- To apply agreed upon criteria to analyses (economic, social, environmental)
- To use the agreed upon criteria to identify measures with the greatest mitigation potential and the best potential results
- To propose specific instruments and actions for mitigation that can developed into public policies.

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CHAPTER 5

Other Information Relevant to the Achievement of the Convention's Objective

PHOTO: MINISTRY OF THE ENVIRONMENT

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1. INTRODUCTION

This chapter examines Chile's efforts in the areas of technology, research, education and capacity building, illustrating the importance of climate change within the national agenda and the concrete actions that are being undertaken to address this phenomenon in the country. The chapter also identifies a series of challenges, gaps, and needs related to climate change in Chile that will have to be addressed in a coordinated manner, with due attention to the properties of the systems involved and both individual and collective responsibilities.

The chapter describes measures and activities that were implemented over the last ten years to incorporate the issue of climate change into national sustainable development strategies. The reporting period spans the time between the First and Second National Communication, with particular attention paid to the last five years because of the many initiatives that have been implemented during that time in the public, private, academic and civil spheres. The issues addressed are relevant both generally and for Chile specifically, and include the following:

- Technology transfer in the area of climate change
- Systematic observation of climate change
- Information on climate change research programs
- Public education, training, and awareness raising about climate change
- Strengthening of national and local capacities in regard to climate change
- Financial, technical and local capacity-building needs and barriers.

This section examines the technology transfer and innovation system in Chile and assesses the country's technological needs in high priority sectors of the national economy. It also describes technology transfer activities in the public and private spheres carried out under the institutional framework governing innovation in Chile. Lastly, it emphasizes the importance of earmarking national resources to encourage the development of local knowledge, technologies and social and institutional processes for mitigating and adapting to climate change.

In order to develop, exchange and disseminate information about Chile's vulnerability to climate change, and incorporate new and appropriate mitigation and adaptation technologies, it is necessary to obtain knowledge and understanding of climate in the country . In Chile, systematic observation of climate change has been carried out through national climate change observation programmes that monitor atmospheric weather, oceanographic conditions and glaciers, among other variables. Chile's institutions also have been active participants and even leaders in global climate change observation and the identification of technological and institutional gaps that need to be addressed.

Climate change research programs in Chile have evolved significantly over the last ten years. Several programmes are operated by universities and other research centers in Chile, and the National Commission for Scientific and Technological Investigation (CONICYT) has made a relevant contribution to scientific developments related to climate change. The importance of international research networks is also worth noting. Lastly, existing research networks also need to be strengthened in some key areas.

Given their inherent complexity and the need to involve stakeholders from many different sectors, national climate change mitigation and adaptation efforts require the active and informed participation of citizens and decision makers. In this regard, recent activities in Chile have included education and awareness raising campaigns and on institutional. Legal provisions for developing educational and awareness raising programs remain unresolved.

The creation and development of national and local capacities is one of the three main lines of action in Chile's National Climate Change Action Plan (PANCC). This line enables public sector actions to incorporate Chile's vulnerability and adaptation to climate change into the country's medium- and long-term national policies. Capacity building has also been important in the work of non-governmental organizations representing civil society and the private sector.

2. TECHNOLOGY TRANSFER

In the area of climate change, technology transfer consists of disseminating low emission technologies and those that enable adaptation to the effects of climate change. For those involved in the transfer and use of these new technologies, the economic benefits are those perceived by the whole society (decreasing the cost of climate change, better use of natural resources in the economic process, etc.) and by companies (Ockwell et al, 2007).

2.1 CHILE'S TECHNOLOGY TRANSFER AND INNOVATION SYSTEM

In Chile, policies and programs to support innovation are promoted by public and private agencies that make up the country's technology transfer system. This system has a multi-scale approach that involves a variety of institutional arrangements and includes:

- General coordination entities
- Implementing entities
- Sector-specific and regional entities
- Institutions dedicated to research and technology promotion.

The interrelation of institutions working on technology transfer and innovation in Chile are presented in Figure 1. While not all functions and processes involved in this scheme target technology transfer for climate change specifically, the diagram offers a visual view of relationships and interconnections at different levels, from the policy framework and overall coordination of this area to local instances that carry out innovation and technology transfer.

This organizational and operational system was developed through a process of political and institutional learning and adaptation that began in the 1990s. The first stage of the process involved the creation of institutions that supported the implementation of R+D projects in the private sector, but lacked sector specific priorities (horizontal funding). Stage two began in 1996 and involved support for prospective technology studies and the creation of the Technological Innovation Program, which was implemented jointly with the Ministry of Economy (MINECON), the Chilean Economic Development Agency (CORFO) and the Ministry of Agriculture (MINAGRI) (MINECON, 1997). During this stage, attention was focused on specific sectors, clean production, and other strategic issues. In 2000 a differentiated policy was introduced for institutional technology transfer and innovation, focusing on a series of strategic areas and on the development of clusters.[1] In 2001 the Innovation and Business Development Program (Innova Chile) was launched to promote generic technologies in the areas of biotechnology, clean production, renewable energies, energy efficiency and quality management, among others (MINECON, 2009; Poch Ambiental, 2009). The most recent stage began in 2005 with the creation of the National Council for Innovation and Competitiveness (CNIC) and, in 2007, the Ministerial Council for Innovation, whose members include representatives from the ministries of Finance, Foreign Relations, Education, Public Works, Agriculture, Economy, Defense and Transportation and Telecommunications. The Council's mandate is to coordinate public sector actions on innovation and

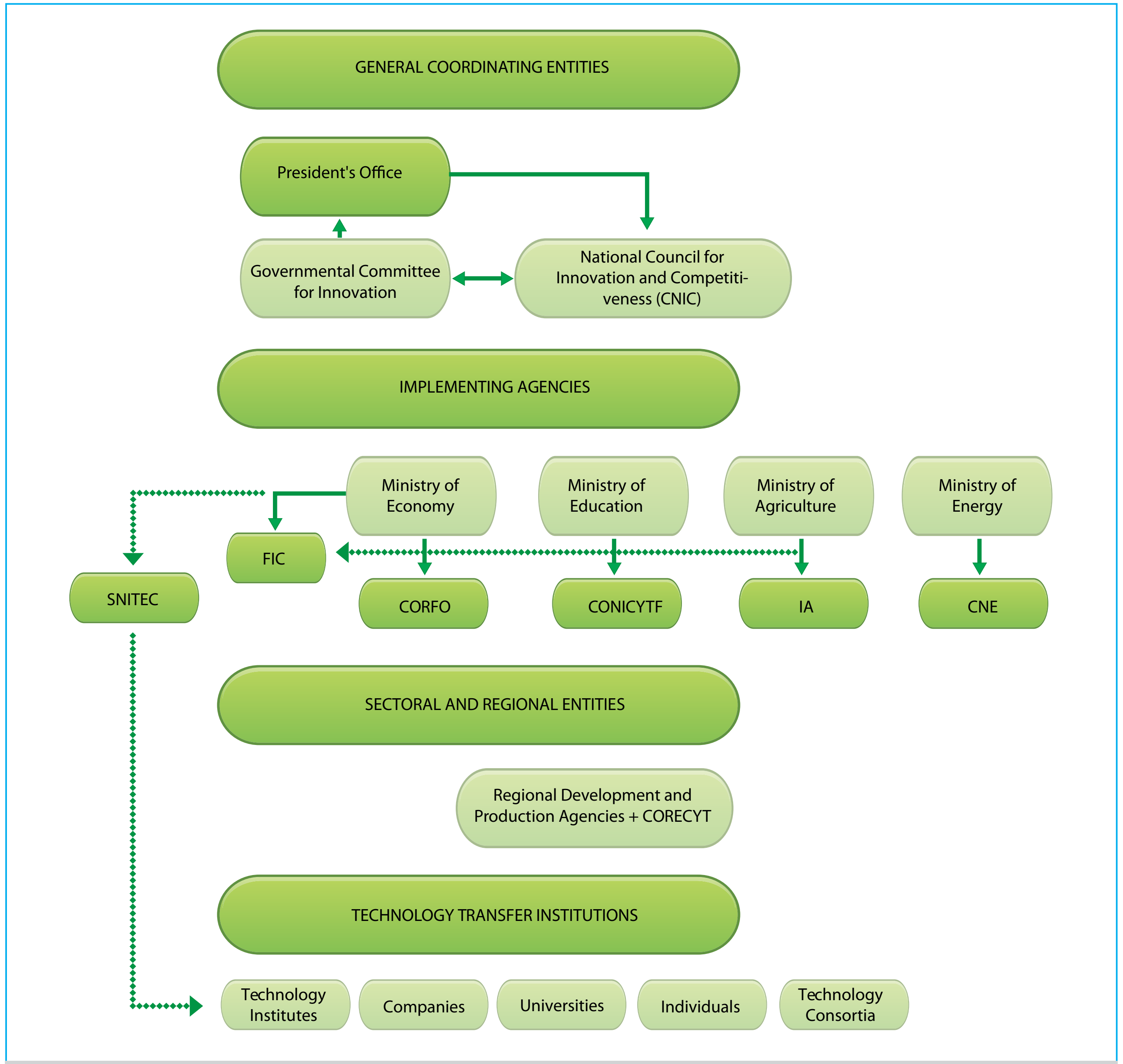

Figure 1. Institutional Framework for Innovation and Technology Transfer in Chile
Source: Poch Ambiental, 2009

[1] In this document, the term "cluster" is understood as a network of individuals, companies and institutions linked together through a shared desire to develop a product, service or a relatively well-defined geographic zone. The expertise and targeted focus of such a group gives it competitive advantages. It is important to note that the Government of Chile's 2010–2014 Innovation Program no longer uses the concept of cluster development for innovation.

determine the authorities responsible for implementing the National Innovation Strategy.

One implementing agency involved in this framework is the Agrarian Innovation Foundation (FIA), a Ministry of Agriculture agency that promotes agrarian innovation. The Foundation promotes the development of innovation culture and processes in the sector by supporting initiatives, formulating strategies, and disseminating the information and results of innovative projects and programs in the country's agriculture and livestock sector.

While this strategy takes a general approach to innovation, its lines of action have included climate change and the analysis of both adaptation needs and mitigation challenges.

In addition, although technology development and transfer have not been geared specifically towards climate change, institutional arrangements and instruments currently in place to promote technological innovation offer a platform for technology transfer oriented towards climate change. This new political strategy has a long-term outlook and a firm interest in developing clean, environmentally sustainable production.

It can be concluded that policies formulated over the past decade, and especially since 2005, have pursued development via the transformation of the productive system, especially through technological innovation and development. The advances made have led to a culture of innovation, in which R+D and private sector participation are encouraged in the development of innovative technologies.

According to the 6th Survey on Innovation, the 3rd R+D Survey and the 1st Census of Public Spending on R+D (MINECON, 2009), Chile spent 0.4% of its annual GDP on R+D in 2008, much lower than the 2.3% of GPD spent on R+D among OECD countries that same year. That year the private sector financed 43.7% of all R+D, with projects being implemented mainly within universities (40.8%) and by companies themselves (40.4%).

In the area of climate change, Chile's innovation system and institutional technology transfer framework face the challenge of complementing and coordinating innovation strategies with climate change efforts. This means generating ways and means for the institutions in each sphere to work together to focalize research and development efforts and to create and expand markets for mitigation and adaptation technologies. Furthermore, efforts to build capacities in technological and other high skills areas will help with the construction of Chile's own technological foundation. This foundation should promote the adoption of technologies, prioritizing those for climate change mitigation and adaptation.

2.2 TECHNOLOGY NEEDS ASSESSMENT

Technological needs must be assessed to support and guide the design of policies and programs aimed specifically at developing and transferring appropriate climate change technologies and fostering collaboration among key stakeholders.

With this need in mind, Chile carried out its first Technology Needs Assessment (TNA) in 2003 to address the commitments acquired under the United Nations Framework Convention on Climate Change (UNFCCC). This first assessment was conducted by a consulting firm (Deuman Ingenieros, 2003) and focused on the transportation, industry and electricity generation sectors. It identified technological options for mitigation in terms of both features and type. It also included a description of projects and activities linked to mitigation in the abovementioned sectors, highlighting the use of gas (natural and LPG) in transportation, cogeneration in industry, and the use of wind energy, mini-hydropower, biomass and solar electricity generation. All of the projects were small-scale, in the very early stages of development, and identified as promising alternatives at that time.

In 2009, with greater knowledge and awareness in the country about the need to adopt technologies to address climate change, CORFO commissioned a study to establish criteria and priorities for a national technology transfer strategy oriented towards climate change adaptation and mitigation. The study laid the foundation for a national discussion of sector-specific alternatives in this area (Poch Ambiental, 2009).

The study examined five key economic sectors in Chile: copper mining, the food industry (including fruit and other produce and processed foods), construction, transportation and aquaculture. It did not take into account the energy sector, which was to be assessed separately because of its great importance. Productive processes of each sector were analyzed in order to prioritize subsectors, activities and processes and to identify and categorize technological needs. The information was used to estimate the costs, benefits and mitigation potential (or contribution to adaptation, where applicable) of a range of technologies. One technology for mitigation and another for adaptation were chosen for each sector, to focalize efforts around a specific technology development and transfer strategy (Table 1).

TABLE 1. Summary of mitigation and adaptation technologies identified for Chile in the study "Technology Transfer Strategy and Possibilities for addressing Climate Change"

Sector	Mitigation Technology	Adaptation Technology
Copper Mining	Solar thermal concentration for heating copper electro-winning solutions	Surface reservoirs for overflows
Construction	Pellet (biomass) residential heating systems	Rainwater harvest and usage systems
Transportation	Aerodynamic improvements for heavy vehicles (trucks)	Training for infrastructure design (roads and bridges)
Food	Precision agriculture	Development of genetically resistant varieties
Aquaculture	Biodigestion of organic waste	Integrated water recirculation systems

Source: Poch Ambiental, 2009

Sectors were selected according to some general variables (relative macroeconomic importance, centrality to productive networks, environmentally friendly), their mitigation potential and the climatic vulnerability in geographic zones in which they would operate. The selection of a specific technology in each sector took into account its contribution to mitigation, adaptation, and sustainable development, as well as the level of investment required. As the context of each sector was unique, with different variables and internal processes, the summary did not compare the results of different sectors. This was done to avoid reducing interest in certain sectors or technologies that contributed less to mitigation (or those that seem less vulnerable in terms of adaptation) despite being highly relevant within the sector itself or for the country as a whole.

The same study offered recommendations for integrating climate change policies and strategies with those for technological innovation and development, as some key sectors have not yet internalized opportunities for technology transfer. The study also highlighted the need for private sector involvement, arguing that private investment will enable the transformation of the global production and energy system and allow innovation systems oriented towards climate change to be effectively implemented in developing countries. Lastly, the importance of public investment was also recognized, although it was suggested that public investment alone will not move Chile sufficiently towards a low emission economy (Poch Ambiental, 2009; Stern, 2006).

Regarding the participation of stakeholders in the technology transfer process, the new technology needs assessment concludes that there is a lack of effective coordination among the different agents that should be helping to generate, implement and disseminate technologies for climate change (scientists, academics, private sector and public sector, among others). It also recognizes the need for local, innovative capacity building for the creation, development and emergence of knowledge and technologies adapted specifically for the Chilean context (Table 2).

Photo: Ministry of the Environment Government of Chile

TABLE 2. Main findings of the strategic technology transfer study "Technology Transfer Strategy and Possibilities for addressing Climate Change"

Area of analysis	Conclusions
National context and policy frameworks	Technology transfer for climate change has not been internalized by key sectors in the country. At the policy level, for example, the National Climate Change Strategy and the National Climate Change Action Plan (PANCC) barely mentioned technology transfer and its role in mitigating emissions and adapting to the effects of climate change.
	The Center for Renewable Energies (CER) promotes and facilitates the development of the NCRE industry in Chile. It assesses existing technology requirements, which should be an ongoing reflexive activity that will allow these needs to be revised and adapted over time. These assessments should become the first step in the process of building road maps, followed by plans of action for low emission technologies. In addition, the National Energy Efficiency Program has the mission of consolidating energy efficiency in Chile in order to contribute to sustainable energy development in the country (CER, n.d.).
Strategies to strengthen technology transfer in Chile	A technology transfer strategy for climate change in Chile should be based on a policy with long-term objectives that also considers importing technologies (equipment and knowledge) and building technological capacities internally, both to enable technologies to be adapted to local realities and to produce internationally competitive technologies.
	Private resources must be leveraged and the private sector must be encouraged to become more involved in technology development.
	Technology transfer measures and policies must be aligned with the country's innovation strategies and systems.
In regard to key aspects for negotiating future international agreements	Suitable mechanisms must be created to build capacities throughout the chain of research, development, demonstration and launching. International collaboration is crucial, as it will provide access to tacit knowledge and other pertinent aspects that will promote capacity building for local innovation.
	Promoting technology transfer will require addressing the issue of intellectual property. Nevertheless, access to technology is not enough to promote local innovation capacities; more emphasis must be placed on the transfer of tacit knowledge.
	It is not acceptable that countries with disparate economic, social and environmental realities be required to implement the same measures.

Source: Poch Ambiental, 2009

2.3 PILOT PROGRAMS AND OTHER TECHNOLOGY TRANSFER EXPERIENCES IN CHILE ORIENTED TOWARDS CLIMATE CHANGE

The last decade was a period of technological experimentation, with the identification of better opportunities for facing climate change, the development of specific technological knowledge, participation in emerging international markets and generation of a legal, regulatory and technical regime for supporting technology transfer.

The most relevant public and private initiatives in this area are presented below. Research and development activities associated with technology transfer processes are not included here as they were addressed under the "Technology Needs Assessment" section of this chapter.

2.3.1 Activities in the public sector

CORFO implements the policies of the Government of Chile in the areas of business development and innovation. It operates through tools and instruments that are coherent with a market economy, creating the conditions for building a society of opportunity. Linked to the promotion of environmental technologies (including those for mitigating and adapting to climate change) and in line with the policy of innovation pursued over the past decade, CORFO has created a series of development instruments and incentives for the adoption of non-conventional renewable energies (NCREs) and the promotion of Energy Efficiency (EE) among different groups of GHG sources in Chile.

The section below describes CORFO's co-financing instruments available in 2009 for projects related to climate change mitigation and adaptation. These are divided into instruments that support pre-investment stages of NCRE projects (Table 3), instruments that support investment in NCRE projects (Table 4) and other CORFO instruments that support innovation, financing and investment. Details of the number and type of projects, as well as amount invested (including CORFO funding) are also included.

Support instruments for the pre-investment stage of NCRE projects

- Todochile: Co-financing pre-investment stage of electricity generation and biofuel projects in Chile's regions.
- Pre-investment NCRE RM: Co-financing pre-investment stage of electricity generation project for the Metropolitan Region (RM).
- Advanced stage co-financing: Co-financing of basic and detailed engineering studies for electricity generation projects, electricity connection and environmental impact assessment studies or declarations, among other activities.

TABLE 3. NCRE projects supported by CORFO in the pre-investment stage

Main indicators of projects supported in the pre-investment stage				
	Number of	Power	Investment*	CORFO contribution
	Projects	MW	Millions of US$	Millions of US$
Operation	**5**	**32.9**	**51.65**	**0.18**
Hydraulic	4	30.6	45.9	0.13
Wind	1	2.3	5.75	0.04
Construction	**16**	**129.5**	**256.8**	**0.89**
Hydraulic	13	102.5	204.2	0.67
Wind	1	10.5	21	0.02
Biomass	2	16.5	31.6	0.2
TOTAL	21	162.4	308.45	1.07

Source: CORFO, 2010
* Estimated in millions of US$.

a) Support instruments for investment in NCRE projects

- CORFO Environmental Credit Program: Credit scheme financed with Chilean funds and German cooperation (KfW) and operated by the national banking system with preferential terms for investment projects, including NCREs.
- CORFO NCRE Credit Program: Loans financed by CORFO and administrated by the banking system with preferential terms for investments in electricity generation and transmission using NCREs (wind, biomass, and small-scale hydropower).

TABLE 4. Projects receiving CORFO NCRE funding

	Number of	Power	Investment
Base	Projects	MW	Millions of US$
Water	11	75.5	0.188
Solar	1	1	0.007
Biomass	2	16	0.017
Transmission	1	-	0.007
TOTAL	15	92.5	0.22

Source: CORFO, 2010

b) Other CORFO instruments supporting innovation, financing and investment

Innovation:

- Business development subsidy: Supports the design and drafting of new, competitive high performance business projects, their organization and startup.
- Subsidy for business innovation: Supports initiatives for technological innovation and development under individual business management schemes and partnerships to boost company competitiveness by incorporating new and improved processes, products and/or services.
- Public interest and pre-competitive subsidy: Boosts competitive capacity of productive sectors by resolving complex production issues and improving operating conditions in markets and productive sectors.
- Technology transfer subsidy: Supports initiatives that improve knowledge of and access to management and production technologies of use to Chilean companies.

Financing:

- Risk capital: Designed to promote the risk capital sector in Chile and private investment in investment funds, to encourage private investment in small and medium sized enterprises.

Investment:

- High technology subsidy: Covers part of the cost of establishing foreign high tech companies in our country. Support is offered for drafting a business plan, startup management, human resources development, investment in fixed assets and advanced skills training, among other aspects.

Over the period covered in this Communication, the National Energy Commission (CNE), now the Ministry of Energy, was another key actor in the implementation of technology transfer initiatives. One of its most notable projects operated within the Rural Electrification Program (PER), which was established in 1994 and now falls under the Ministry of Energy's energy access and equity division.

Additionally, the Ministry of Energy's non-conventional renewable energy division and the sustainable development division (which used to be part of the "environment and non-conventional renewable energies" area of the CNE) have carried out studies and other initiatives to increase the level of knowledge and information about climate change mitigation technologies linked to the energy sector. For example, collaborative projects with bilateral funding (from GTZ) were carried out to produce guides for environmentally assessing NCRE projects in the areas of wind energy (2006) and biomass energy (2007), and for designing CDM projects for the energy sector (also published in 2007).

In recent years, the CNE also has helped to improve information about the availability and potential of renewable natural resources in energy generation. For example, a study of wind energy potential was conducted with the support of the Global Environment Facility (GEF). This study has helped open a market for this kind of technology in Chile. On the use of biomass, in 2007 the energy generation potential of waste from the primary wood industry was studied, and in 2008, the energy generating potential of this kind of waste from forest management in Chile was also studied. Regarding small-scale hydropower projects, CNE worked with the National Irrigation Commission to produce an inventory of hydraulic projects associated with irrigation works. Studies to identify and classify the types of biomass available in Chile were also conducted with the support of GTZ and INFOR.

2.3.2 Private sector activities

The National Climate Change Action Plan (PANCC) and National Climate Change Strategy place special emphasis on the private sector's economic role in enabling Chile's shift to low carbon economic growth. In this context, in addition to the public sector's design of sector-specific policies and support activities, market instruments are considered crucial and have played a central role in encouraging investment in low emission technology transfers over the past decade.

Chile has participated very actively in implementing the Kyoto Protocol's Clean Development Mechanism (CDM) and has become a leader in terms of the number of projects implemented in relation to the size of its economy.

Although the CDM was examined in Chapter 4 of this report on Mitigation of Greenhouse Gases, it is worth looking at here also, as it is considered the most effective mechanism for transferring technology from developed to developing countries under the framework of the Kyoto Protocol. However, no clear conclusions can be drawn about the CDM's effectiveness in transferring technology to Chile, as the projects implemented involve different processes, stakeholders, technologies and institutional frameworks.

Among the CDM projects in Chile, the most popular ways to reduce GHG emissions include biogas recovery technologies, used in sanitary landfills and in manure management (mainly with hogs), and energy generating technologies such as hydroelectric and biomass. As most of these projects have imported their technologies, little equipment has been developed within Chile, a situation that some experts ascribe to the small size of the domestic market. However, the reasons for this lack of development are more complex, having to do with intellectual property laws, risk aversion to technological developments based on reverse engineering, and other aspects that are closely tied to the incipient nature of Chile's innovation system, which has not yet yielded the results that such long-term processes require.

Experts consulted consider technologies such as anaerobic biodigestion (recovery of methane for use as an energy source) to be the most promising. These local experts affirm that the complementary technology (equipment and knowledge) needed to design and implement such projects has been developed, meaning that all basic and detailed engineering work, mechanical components, piping and civil works for CDM projects are being carried out in Chile with local technological capacities. In addition, technological know how has been exchanged on the operation, maintenance and use of these technologies. This expertise includes management and decision making to select the most suitable technologies, adapt them to local conditions and make use of them to obtain optimum yields. According to the experts consulted, these capacities already exist in Chile and are increasingly robust.

As highlighted in the PANCC (CONAMA, 2008), along with the development of technology projects, innovation in the financial and business sector is crucial for materializing investment in climate change mitigation projects and the flows associated with the sale of certified emission reductions. One example of this in Chile is the emerging collaboration between local private banks and CORFO in granting loans to NCRE projects, as described earlier in this chapter.

2.4 TECHNOLOGY TRANSFER ACTIVITIES AND NATIONAL PLANNING

The interrelation of learning and knowledge building processes, coupled with advances in the production of technological equipment and the socio-institutional contexts in which technology is produced, adopted and used, demonstrate that the link between technology and sustainable development cannot be explained by a simple concept such as technological determinism.

For example, in the energy sector, modifications of the General Electrical Services Law in 2004 and 2005 directly affected the system for technology development and knowledge transfer, including emissions mitigation equipment, while accelerating the introduction of NCREs.

Although these legal reforms are not directly tied to the technology transfer process for climate change, the long

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term objectives they established have created an environment favorable to the development of technological knowledge and have enabled the transfer and adoption of low emission electricity generating technologies. The legislative changes alone reflect a learning process and a policy shift towards a more reflexive perspective, promoting greater socio-cultural and economic transformations that have enabled such advances as the rapid emergence of the wind energy industry in Chile.

In conclusion, while the integration of climate change—and technology transfer specifically—into Chile's political arena has advanced in the past decade, there is still much to be done to install the issue at the top of the political agenda, to remove it from the strictly environmental sphere and position it within the sphere of innovation and national social and economic development.

Knowledge transfer, the development of local abilities and technologies, and technology transfer from abroad all need to be strengthened. This can be accomplished by introducing new mechanisms and new roles for the individuals and institutions involved in the process, by incorporating new stakeholders, and by adapting legal, institutional and socioeconomic processes. Effective technology transfer depends on the success of other processes such as research, access to information, capacity building and public awareness, which are addressed in more detail in other sections of this Second National Communication.

3. SYSTEMATIC OBSERVATION OF CLIMATE VARIABILITY AND CLIMATE CHANGE

Systematic observation of the climate and its variability is carried out in Chile through monitoring of relevant meteorological, atmospheric, oceanographic and terrestrial parameters. The process involves the use of modern equipment, automatic reporting mechanisms, and self-sustaining operating and processing systems for the information that is generated.

This section describes and analyzes programs operated in Chile for the systematic observation of climate variability and climate change, and the research activities associated with the decade-long study of climate variability in Chile, which was conducted from 2000 to 2010. Three major themes will be addressed:

- The status of national-level systematic climate observation programs, with emphasis on the role of research organizations and associated government institutions.
- The participation and role of Chilean institutions in international climate investigation and observation systems
- The gaps identified in the investigation and observation of meteorological, atmospheric and oceanographic phenomena, with special emphasis on areas that require additional knowledge and information to increase understanding of the national and regional climate system.

3.1 NATIONAL CLIMATE OBSERVATION PROGRAMS

Programs to systematically observe key climate variables examine meteorological and oceanographic data of Chile's different climate zones. These programs are usually associated with agriculture, maritime and air transport and weather in general, rather than being focused on the systematic study of climate change itself.

Over the last decade these programs have provided the country with valuable information, statistical data obtained from regular monitoring with modern technology and in time series that are useful for studying climate trends with horizons on the order of several decades.

These programs also make use of atmospheric weather monitoring conducted by the Chilean Meteorological Directorate (DMC), oceanographic and glacier monitoring, and inter-institutional cooperation for establishing an agricultural weather network in Chile.

3.1.1 Monitoring of atmospheric weather and climate variables by the Chilean Meteorological Directorate

The Chilean Meteorological Directorate (DMC, www.meteochile.cl) is a government institution under the purview of the General Civil Aviation Directorate. The entity observes atmospheric weather and currently has a system of weather stations that monitors several key variables hourly through synoptic observation (atmospheric temperature and pressure, precipitation, wind direction and intensity, cloud cover and height, visibility and relative humidity). The DMC operates 25 weather stations according to international standards, from Arica (in the North) to Base Frei in Chile's Antarctic Territory. It also operates a network of five radiosondes that enable vertical atmospheric monitoring of variables such as temperature, pressure, humidity and wind. This network has been generating data since 1958, which makes it a pioneering example of systematic observation among countries in the region. Thirty DMC stations are also part of the global atmospheric monitoring program operated by the World Meteorological Organization (WMO). The DMC also maintains an 18-station network for monitoring UV radiation in Chile.

The information generated has enabled the study and implementation of climate models in Chile, which has produced important national information for climate change research. The DMC also records and interprets meteorological variables related to the El Niño/Southern Oscillation (ENSO) phenomenon.

3.1.2 Sea level monitoring, oceanographic observation and associated climate phenomena

The Chilean Navy's Hydrographic and Oceanographic Service (SHOA) is another public institution that monitors variables linked to climate. SHOA's main mission is to provide information and technical assistance to enable safe navigation in territorial waters, lakes, riverways, inland seas and on the high seas adjacent to Chile's shoreline (www.shoa.cl). This service conducts regular monitoring of the sea level, water surface temperature, air temperature and atmospheric pressure through a series of coastal stations located throughout the Chilean mainland and offshore islands, as well as in the Chilean Antarctic Territory.

SHOA began collecting data around 1945, with automated tide gauge. In 1999, with 17 stations operating in the country's main ports and other strategic points, the agency began updating its instruments. Today it boasts a digital instrument network that transmits real-time data via satellite from 24 localities and three self-contained digital stations (two in the Chilean Antarctic Territory and the third on Isla San Pedro in the Golfo de Penas). The tidal gauge network is currently being updated to improve the quantity and quality of monitoring provided, and by the end of 2011 the network was expected to include 33 operative stations.

The data generated make it possible to conduct studies of climate variability. Currently, time series data is available on the order of decades for the port cities of Antofagasta, Valparaíso, Talcahuano, Puerto Montt and Punta Arenas. However, as the measurements of sea level were taken in port facilities, they provide values relative to tectonic plates. Without geodesic measurements of the movements of these plates, it is impossible to uncouple these relative measurements to obtain conclusive results regarding systematic variations in sea level (Shoa, 2010).

Since 1999, SHOA also has been monitoring the El Niño/Southern Oscillation (ENSO) phenomenon through oceanographic cruises. Initially, only the central coast adjacent to the port of Valparaíso was covered, but since 2002 the agency has conducted joint monitoring with Peru, and more recently, Ecuador, although in the latter case these measurement campaigns were not synchronized with those in Chile and Peru.

From 1999 to 2009, monitoring of ENSO was conducted twice per year in a research cruise in which data was collected on temperature, salinity and dissolved oxygen in the water column from 0 to 1,000 meters of depth, and up to 200 nautical miles offshore. The cruise covered the area from the far north of the country to the central Chilean coast.

3.1.3 Glacier monitoring

Chile's General Water Directorate (DGA, www.dga.cl), part of the Ministry of Public Works, produced a National Glacier Strategy in 2009. The strategy envisions an implementation horizon of 10 to 20 years and its lines of action seek to improve current knowledge about the condition of Chile's glaciers, enable forecasts of glacial changes, and determine the potential impacts of those changes on Chilean society and the country's natural heritage, especially in regard to the associated water resources.

As part of this strategy, the DGA's Glaciology and Snow Unit (described in Chapter 1 of this Communication on National Circumstances) directs the government's glacier monitoring efforts, which include the collection and systematization of information for a National Glacier Registry that is expected to be complete in 2011. Particularly, the DGA installed two refuges that enable samples to be obtained throughout the year in glacier-influenced zones of the Northern and Southern Patagonian Ice Fields. These have been operating since 2009. The agency also installed two high altitude hydrometeorological stations, one in Mapocho Alto and the other in Maipo Alto. The unit has also studied the surface topography of glaciers through detailed airborne surveys using laser technology (LIDAR). Using measurements derived from land-based radar, the agency has also estimated the volume of four glaciers (Jotabeche, Juncal Norte, San Francisco and Echaurren). In regard to white glaciers, in 2008 the agency inventoried the Cordillera de Darwin range, where it delimited 2,606 km^2 of ice. In 2009, the same exercise was conducted in the basins adjacent to Chiloé Island, where the inventoried glaciers occupy an area of 737 km^2. Lastly, in 2010, 3,265 glaciers were inventoried in four water basins between the Palena and Pascua rivers, representing a total area of 1,042 km^2. Additional efforts in this area have included a survey of covered or rocky glaciers in the Copiapó, Elqui, Limarí, Choapa and Aconcagua river basins, which is now available as a general inventory.

The challenges set out in Chile's glacier strategy are to increase the country's installed capacity for investigating glaciers, to systematize glacier monitoring efforts, to build accessible databases, generate modeling capacities to replicate processes that have occurred, and project glacial responses based on different future climate scenarios.

3.1.4 Agrometeorological Network of Chile

In 2009 a system was launched that collects and analyzes meteorological data from 114 automated monitoring stations distributed around the country (www.agroclima.cl). This new network operates mainly in the irrigated agricultural valleys located between the Elqui River in Coquimbo Region and the Biobío River in the region of the same name. It complements the meteorological monitoring stations that have provided data to the agriculture sector over the past 30 years, providing updated equipment and enabling public and private institutions to collaborate on decision making in this sector.

The system represents the combined effort of the Fundación para el Desarrollo Frutícola (Foundation for Fruit Production), whose members include the Asociación de Exportadores de Chile A.G., the Ministry of Agriculture's Agricultural Research Institute and the DMC. It is funded by the Fund for Innovation for Competitiveness. The Foundation for Fruit Production operates the network of 114 stations, receiving and disseminating their data. The other stations in this network continue to operate individually.

This network provides real-time information that gives early warning to the agriculture sector, particularly for preventing pests, drought, flooding and other extreme climate events. It is also used to manage the use of phytosanitary products (SimFRUIT, 2009). The network was installed to improve the country's agricultural system by providing information on temperature, precipitation, wind, solar radiation, atmospheric humidity and other parameters relevant to the climate.

The information it generates enables more applied research into climate change across the country.

3.2 PARTICIPATION OF CHILEAN INSTITUTIONS IN INTERNATIONAL CLIMATE OBSERVATION

Chile participates in different international climate observation initiatives. For example, SHOA, DMC, the Fisheries Development Institute (IFOP) and the Fisheries Office all have representatives on the Permanent Commission for the South Pacific, along with their counterparts in Colombia, Ecuador and Peru. This body coordinates observation and investigation activities and prepares a monthly Climate Alert Bulletin on El Niño/Southern Oscillation (ENOS) that reports on ocean surface temperatures and sea level. Monitoring conducted at specific stations is also reported to data centers of the Global Sea Level Observing System (GLOSS), a program coordinated by the Intergovernmental Oceanographic Commission.

Chile also contributes data from 17 of its monitoring stations to the Global Climate Observing System (GCOS) operated by the United Nations' World Meteorological Organization (WMO), which studies the global environment. The DMC contributes data from 25 surface and 5 radiosonde stations to the WMO's World Weather Watch, which observes atmospheric weather. The WMO itself selected the Chilean stations based on spatial geographic criteria and historic data from the stations themselves. Chile participates in this network by providing atmospheric, oceanographic and terrestrial observations.

Chile and Peru have shared skills and cooperated in other ways via professional exchanges between SHOA and the Peruvian Hydrographic and Navigation Directorate. These activities have focused on the functionality and operation of instruments and advanced software programs for ocean monitoring. In 2010 and 2011, Ecuador has joined this monitoring effort alongside Chile and Peru.

3.3 GAPS IN CLIMATE OBSERVATION

In recent years the country installed modern equipment and institutions engaged in climate monitoring have obtained the technical and professional resources to perform their duties with excellence. Nevertheless, at present climate observation activities are performed for other purposes, whether for production, communication, transportation, or other ends. For this reason, systematic climate change observation must be incorporated into the mission and duties of the many institutions conducting this work in Chile and their work –including basic observation activities, research and analyses–must be better coordinated.

Such inter-institutional coordination efforts should also identify observation priorities and establish linkages and mechanisms to foster research within government institutions and encourage cooperation with the academic and scientific communities.

Another limitation related to the gaps is the geographic distribution of Chile's monitoring stations. More coverage is required in southern Chile (Patagonia) and in high mountain zones (above 2,500 m), mainly for the study of variables associated with changes in the cryosphere and southern ecosystems.

Lastly, there is a need for more observation of variables related to biodiversity and other aspects of the country's ecosystems, as climate changes are related to other global environmental phenomena such as biodiversity loss, water acidification, changes in the global nitrogen cycle, and desertification, to name just a few. In this regard, a further limiting factor is the lack of digitally available systematized information.

Photo: Ministry of the Environment Government of Chile

4. CLIMATE CHANGE RESEARCH PROGRAMS

This section contains a description and analysis of different climate change research programs in Chile in areas such as climate change science, vulnerability and adaptation, emissions mitigation and, still in the early stages, the development of emission factors.

Specific activities have been carried out within the following areas:

- Existing climate change research programs in Chile
- Local participation in research with bilateral and multilateral institutions
- Identification of specific needs and priorities to strengthen research programs.

4.1 RESEARCH PROGRAMS

4.1.1 Major projects implemented in the area of climate variability over the 2000–2010 period

The main research program conducted during the period covered in this Second National Communication was a downscaling exercise or study of climate variability at the local level (U. de Chile/ Depto. Geofísica, 2007). This study proposed a future scenario for Chile for changes associated with the changing climate and identified changes already occurring. The study's impact in Chile was similar to that produced by the results presented to the world in early 2007 in the IPCC's Fourth Assessment Report. The Chilean study was the first to recognize that climate change is an issue of great importance to the general population and should be incorporated into the country's public policies.

The study was conducted using the regional PRECIS (Providing Regional Climates for Impact Studies) model developed by the United Kingdom's MetOffice. While the study represents a major advance in climate change research in Chile, its conclusions should be understood as a projection only, as the model used is not entirely suitable for high altitude climates (above 2,500 m a.s.l.).

Another important project, entitled "Variabilldad climática en Chile: evaluación, interpretación y proyecciones" (Climate Variability in Chile: Evaluation, interpretation and projections), was implemented by researchers at the Universidad de Chile, the Universidad de Concepción and the DMC from 2006 to 2008 and financed by CONICYT and the World Bank. This project had three objectives:

- To assess the variability of the regional climate system in recent decades over different timeframes, in comparison to global climate fluctuations.
- To conduct diagnostic studies to identify physical mechanisms that explain unknown aspects of regional climate variability
- To assess the most likely regional climate conditions in a future scenario with a greater greenhouse effect.

The project has served to train researchers in atmospheric and oceanographic sciences, strengthening national scientific capacities by funding graduate theses and postdoctoral studies. It has also strengthened international collaboration and generated numerous publications (www.dgf.uchile.cl/ACT19).

4.1.2 CONICYT and climate change research in Chile

Chile's National Commission for Scientific and Technological Investigation (CONICYT) has two overarching objectives: to promote the development of human capital and strengthen science and technology in Chile. These two pillars are supported by the transversal actions of two areas, scientific information and international relations. With this structure, CONICYT seeks to fulfill its overall mission of contributing to Chile's economic, social and cultural advancement. It accomplishes this through its programs, which promote development in different areas and address a variety of national challenges. The Commission is the nation's leading public funder of scientific and technological research.

Table 5 displays selected CONICYT-funded projects implemented over the 2000–2010 decade in the area of climate change.

TABLA 5. Selected climate change projects funded by CONICYT, 2000–2010

Area	Title of project or study	CONICYT Grant Fund	Institution responsible
Climate science	System for estimating extreme rainfall events for the prevention and mitigation of flooding and overflows in the context of climate variability and change (2008).	XVI FONDEF R+D Competition 2008	Universidad de Talca
	Regional Modeling of future climate and its impact on natural resources (2006)	Grant competition for collaborative networks focused on multidisciplinary research projects and millennium science initiatives	Universidad de Chile
	Climate variability in Chile: Assessment, interpretation and Projections (2004)	First national competitive grant program for multidisciplinary research projects in science and technology (2004) and I Competition for excellence in international cooperation (2006)	Universidad de Chile
	Climate change in Southern Chile Andes over the past 1000 years (41°–51°S) (2000)	FONDECYT regular grant competition	Universidad Austral de Chile
Vulnerability and adaptation	Evidence of climate change in Chile's urban centers: implications for natural risks and adaptive capacity (2010)	FONDECYT regular grant competition	Pontificia Universidad Católica de Chile
	Effects of land use change and climate change on water resources. New factors in integrated water basin management (2009)	FONDECYT regular grant competition	Universidad Austral de Chile, Universidad de Concepción
	Impact of climate change on scientific literacy and sustainable awareness among Chile's elite population (2009)	FONDECYT regular grant competition	Universidad de Santiago de Chile
	Social sciences multidisciplinary initiative SOC28: social and environmental impacts of global climate change in the BioBio Region: Challenges for sustainability in the 21st Century (2008)	International linking support for collaborative research centers and groups	Universidad de Concepción
	Observation and spatial modeling in Chilean vineyards in the context of climate change (2008)	ECOS-CONICYT scientific cooperation program	Pontificia Universidad Católica de Valparaíso
	Social and environmental impacts of global climate change in the BioBio region: challenges for the 21st Century (2007)	II Open Competition for social science multidisciplinary studies, with a focus on public policy innovation	Universidad de Concepción
	Global climate change in high mountain zones: consequences of temperature rise on recruitment, photosynthetic performance and importance of positive interactions in the Andes(2006)	FONDECYT-International cooperation incentive	Universidad de Concepción

Area	Title of project or study	CONICYT Grant Fund	Institution responsible
Vulnerability and adaptation	Stability and recent behavior of glaciers on the Antarctic Peninsula – Interactions with ice platforms) (2006)	Second multidisciplinary research competition in Antarctic Science	Centro de Estudios Científicos
	Glaciology and climate change) (2006)	I Competition for excellence in international cooperation	Centro de Estudios Científicos
	Environmental heterogeneity in Mediterranean ecosystems and susceptibility of plant species droughts resulting from climate change) (2005)	Grant Competition under the CSIC-CONICYT Scientific Cooperation Program	Consejo Superior de Investigaciones Científicas, Universidad de Concepción
Mitigation	Characterization of the carbon balance: the case of Chile's export fruit industry and possibilities for mitigating emissions) (2007)	XV Research and Development Competition	Universidad Santo Tomas
	Modeling the current and potential distribution of tree species in Chile's temperate forests in relation to climate change) (2007/2008)	FONDECYT-International cooperation incentive	Pontificia Universidad Católica de Chile
	Modeling the current and potential distribution of tree species in Chile's temperate forests in relation to climate change) (2006)	FONDECYT-Regular grant for initial research projects	Pontificia Universidad Católica de Chile
	Establishing a unit for carbon offset projects and transactions)(2001)	Program for Technology Transfer projects–Phase one	Instituto Forestal, Universidad Austral de Chile

Source: CONICYT, 2010, institutional webpage.

CONICYT's Program for Funding Research Centers of Excellence (FONDAP) was established in 1997 as a scientific development instrument to coordinate the efforts of groups of researchers with a demonstrated track record and advance expert knowledge in areas of scientific importance to the country that are already highly developed. Since its creation, FONDAP has financed 9 centers of excellence. In 2010, the program had two projects under implementation that were investigating matters related to climate change: the Center for Advanced Studies in Ecology and Biodiversity (CASEB), housed in the Pontificia Universidad Católica de Chile, and the Center for Oceanographic Research in the Southeastern Pacific (COPAS), operating in the Universidad de Concepción.

One of CONICYT's main initiatives for supporting research is its regional program, inaugurated in 2000 to promote the establishment of regional centers for scientific and technological development throughout the country and develop high level research capabilities in basic and applied science. This program brings together regional stakeholders from government, universities, and business. Although the research carried out by these centers does not focus specifically on climate change, their work has contributed to national efforts in this area. Especially worth noting in this regard is the work undertaken by the Center for Advanced Studies of Arid Zones (CEAZA), operated by the universities of La Serena and Católica del Norte, and the Institute of Agricultural Research for the Region of Coquimbo (INIA-Intahuasi), which focuses mainly on studying the impact of climatic oscillations on the water cycle and on biological production in north-central zones of Chile. Other centers that were established over the past decade include the Center for Quaternary Studies of Fuego-Patagonia and Antarctica (CEQUA), located in the Magallanes and Chilean Antarctic region and operating through the collaboration of the Universidad de Magallanes, the Chilean Antarctic Institute and the Fisheries Development Institute. There are also 12 other regional research centers located across the country today.

TABLE 6. Chilean centers receiving funding from CONICYT for climate change research 2000–2010

Center	CONICYT Program
Centro de Estudios Avanzados en Zonas Áridas (CEAZA) (2007)	I Competition for equipping regional science and technology development centers
Centro de Estudios Científicos (CECS) (2006)	Second multidisciplinary research competition in Antarctic Science
Centro de Estudios del Cuaternario de Fuego-Patagonia y Antártica (CEQUA) (2007)	I Competition for Projects focused on developing advanced human capital to strengthen regional centers
Centro del Desierto de Atacama (CDA) (2006)	I Competition for excellence in international cooperation
Centro de Investigación de Ecosistemas de la Patagonia (CIEP) (2004)	III Competition for the creation of regional cooperative R+D consortia in the framework of the Bicentennial science and technology program

Source: CONICYT, 2010

4.2 CHILE'S PARTICIPATION IN RESEARCH ACTIVITIES WITH INTERNATIONAL MULTILATERAL AND BILATERAL INSTITUTIONS

Over the 2000–2010 decade, Chilean researchers have participated continually in a variety of research networks focused on environmental sustainability and global change, both within Latin America and globally. Four examples of this collaboration are presented below.

4.2.1 Regional Fund for Agriculture and Livestock Technology (FONTAGRO)

FONTAGRO is a consortium of Iberian-American countries that was created to finance research and innovation in science and technology in the agriculture and livestock sector to help reduce poverty, increase the competitiveness of food production chains and enhance sustainable management of the region's natural resources. Argentina, Bolivia, Chile, Colombia, Costa Rica, Ecuador, Spain, Honduras, Nicaragua, Panama, Paraguay, Peru, the Dominican Republic, Uruguay and Venezuela are members of FONTAGRO. The Fund conducts research of regional interest on the following topics, among others: water and soil management; improving productive efficiency (viable, small scale agriculture, value chain sustainability); characterization, improvement and optimization of genetic resources; technology in agro-food chains; product and food health and safety; and sector-specific policies, activities and institutional strengthening (FONTAGRO, n.d.).

Since it was founded in 1998, Chilean institutions and researchers have participated in FONTAGRO research projects related to the country's adaptation to climate change. A summary of these is presented in Table 7.

TABLE 7. Climate change-related projects funded by FONTAGRO that have included Chilean institutions and researchers

Project	Objective	Implementation period	Chilean participant
Evaluación de los cambios en la productividad del agua frente a diferentes escenarios climáticos en distintas regiones del Cono Sur (Assessment of changes in water productivity under different climate change scenarios in Southern Cone regions)	Contribute to the development of productive strategies that enable increased water productivity.	2009 - 2012	INIA
Variabilidad y cambio climático en la expansión de la frontera agrícola en el Cono Sur: estrategias tecnológicas y de políticas para reducir vulnerabilidades (Climate variability and change in the expansion of the agricultural zone in the Southern Cone: technological and political strategies for reducing vulnerability)	Contribute to climate change adaptation of existing agricultural production systems in the context of regional expansion by identifying vulnerabilities and adaptation measures.	2009 - 2012	INIA
Aumento de la competitividad de los sistemas productivos de papa y trigo en Sudamérica ante el cambio climático (Increasing the competitiveness of potato and wheat production systems in South America in the context of climate change)	Increase the competitiveness of South American potato and wheat production systems under climate change by selecting and developing genotypes that are more tolerant to drought and higher temperatures.	2009 - 2012	INIA

Source: http://www.fontagro.org/.

home

4.2.2 Inter-American Institute for Global Change Research (IAI)

Chile is a member of the IAI and is represented on its executive board by CONICYT. This intergovernmental organization seeks to promote scientific excellence, international cooperation and the free exchange of scientific information for the purpose of increasing our understanding of global change and its socioeconomic impacts (IAI n.d.).

In pursuit of its mission, the IAI promotes exchanges among scientists and political officials to increase scientific capacities in the region and provide useful and timely information for formulating effective policies. Its primary objective is to encourage investigation beyond the scope of national research programs by conducting comparative studies on issues that are relevant to the region as a whole (IAI n.d.). Table 8 shows IAI funded projects relevant to Chile

TABLE 8. Lists IAI-funded projects in which Chilean researchers and/or institutions have participated.

Project	Objective	Implementation period	Chilean participant
Hacia la evaluación de prácticas de adaptación ante la variabilidad y el cambio climático (Assessing adaptation practices for climate variability and climate change)	Develop an index for assessing adaptation practices for climate variability and change, the Index of Usefulness of Adaptation Practices (UIPA).	2006-2007	Universidad de Chile
Adaptación a los impactos de la contaminación del aire y los extremos climáticos en la salud en ciudades latinoamericanas (Adaptations for the impacts of air pollution and extreme climate on public health in Latin American cities)	Investigate the individual and combined effects of exposure to meteorological conditions related to stress and air pollution, and human vulnerability to health conditions in south Latin American cities (Buenos Aires, Bogotá, Mexico City and Santiago, Chile).	2007-2009	Universidad de Chile
Emisiones, mega-ciudades y clima de América del Sur. (Emissions, mega-cities and climate in South America)	Generate regional emissions data and panoramas for climate change in South America, with emphasis on the impacts of and on mega-cities; establish the baseline for chemical-meteorological operative forecasting for South American mega-cities, and consolidate and expand the local network for active research and capacity building in the Americas for modeling the terrestrial system.	2006-2010	Universidad de Chile; Centro de Modelamiento Matemático (CMM); Universidad de Santiago de Chile; Universidad Nacional Andrés Bello; Universidad de Valparaíso
Documentación, comprensión y proyección de cambios en el ciclo hidrológico de la cordillera Americana (Documentation, understanding and projections of changes in the hydrological cycle of the Cordillera Americana)	Examine hydrological cycles in different water basins of Bolivia, Chile and Argentina, as well as the western mountains of North America.	2006-2010	Universidad Austral de Chile
Consorcio internacional para el estudio de los cambios climáticos y globales relacionados con los océanos en América del Sur (International consortium for the study of global climate changes related to South American oceans)	Assess the role of thermohaline fronts in biological enrichment, identify physical mechanisms that control the exchange of mass, vorticity, energy and biogeochemicals between the deep ocean and continental shelf and their variations form the interseasonal to the interannual scale.	2006-2010	Universidad de Concepción
Bajando la montaña: entendiendo la vulnerabilidad de las comunidades andinas a la variabilidad hidroclimatológica y el cambio ambiental global (Coming down the mountain: understanding the vulnerability of Andean communities to hydroclimatological variability and global environmental change)	Examine institutional capacity to respond to the impacts of climate change on both agriculture and water, in the basins of Mendoza (Argentina), Choquecota (Bolivia) and Elqui (Chile).	2007-2009	Universidad de Chile, Universidad Católica del Norte, Instituto de Ecología Política, Universidad de La Serena
Cambio climático y riego en la agricultura: hacia una mejor comprensión de las fuerzas motoras y las retroacciones entre los tomadores de decisiones, el ambiente biofísico y sus impactos en el ciclo hidrológico y el uso de la tierra. (Climate change and agricultural irrigation: towards a better understanding of driving forces and setbacks among decision makers, the biophysical environment, and their impacts on the water cycle and land use)	Analyze the impacts of climate change on irrigation agriculture and identify feedback mechanisms among growers for the relationship between water supply and demand.	2007-2009	Pontificia Universidad Católica de Chile, Dirección Meteorológica de Chile

Sources: http://www.iai.int/; http://www.shnoceano.gob.ar y http://saemc.cmm.uchile.cl.

4.2.3 Economic Commission for Latin America and the Caribbean (ECLAC)

In recent years, ECLAC has been intensely involved in analyzing aspects of climate change, including its regional impacts. With the collaboration and financial support of the IDB, the governments of Germany, the United Kingdom, Denmark, and Spain, and the European Union, in 2009 and 2010 ECLAC coordinated the regional study Economics of Climate Change in South America (ERECC-SA) (www.eclac.cl/erecc/homepresent.html). This initiative analyzed the socioeconomic consequences of climate change, contributed to policies for mitigation and adaptation, and provided funds for actions addressing global climate change. Chile participated in the project along with Argentina, Bolivia, Colombia, Ecuador, Paraguay, Peru and Uruguay.

The Chilean research team that prepared the national study entitled "La economía del cambio climático en Chile" (The Economics of Climate Change in Chile) (ECLAC, 2009) included members of the Centro de Cambio Global at the Universidad Católica, ECLAC researchers and local and international experts. It was conducted with the support of an Advisory Committee that included representatives from several public institutions and was coordinated by CONAMA and the Ministry of Finance.

The study evaluated the economic impacts of climate change on water resources (with emphasis on the availability of water for irrigation, hydroelectricity generation, and mining activities), the agriculture and forestry sector, biodiversity and ecosystems, coastal resources and human health. The researchers also studied adaptations to climate change related to water resource availability, forestry, biodiversity and infrastructure. Historic and projected GHG emissions were also examined, along with adaptation measures for the energy and non-energy sectors, accompanied by a discussion of the costs and cobenefits of those measures.

Table 9 summarizes selected results of the study, including the cumulative cost for different productive sectors in Chile that will be impacted by climate change. The assessment considered two timeframes, 2050 and 2100, and four different discount rates for two climate scenarios (the IPCC's A2 and B2 scenarios).

Photo: Ministry of the Environment Government of Chile

TABLE 9. Summary of cumulative economic costs of climate change in Chile

Absolute values in Millions of US$								
Scenario Horizon	Discount rate 6%		Discount rate 4%		Discount rate 2%		Discount Rate 0,5%	
	A2	B2	A2	B2	A2	B2	A2	B2
2050	22,005	15,717	31,745	21,580	47,802	30,569	66,950	40,592
2100	30,044	14,110	57,689	15,787	139,950	7,913	321,522	-25,914
Values as a percentage of GDP								
Scenario Horizon	Discount rate 6%		Discount rate 4%		Discount rate 2%		Discount rate 0,5%	
	A2	B2	A2	B2	A2	B2	A2	B2
2050	0.66	0.48	0.69	0.47	0.70	0.45	0.71	0.43
2100	0.73	0.34	0.82	0.23	0.96	0.06	1.09	-0.09

Source: ECLAC, 2009.

It is important to note that this impact should be considered to be in the low range, as only sectors with comprehensive information were analyzed and the assessment was carried out using moderate, not extreme, conditions. Even so, the net economic impact could reach more than US$300 billion, depending on the horizon, rate of discount and climate change scenario used. This loss is equal to an annual amount of approximately 1.1% of Chile's GDP up to 2100.

Nevertheless, not all of the scenarios evaluated indicate net costs. For example, the aggregate impacts of scenario B2 up to 2100, using a discount rate of 0.5% indicates net benefits of around US$ 25 billion. In general terms, it is observed that the impacts associated with scenario A2 (with the highest GHG emissions) are greater than those associated with scenario B2. Indeed, the latter even forecasts net benefits for the horizon that includes the final 50 years of the 21st Century. In the case of scenario A2, in which the negative impacts are concentrated at the end of the century at a lower discount rate, the present value of the impact is greater, as it is for considering a more remote horizon. The opposite occurs with scenario B2, where it can be observed that the greatest negative effects occur in the intermediate period and in the case of the more distant horizon the greatest negative effects are presented with a higher discount rate (ECLAC, 2009).

4.2.4 Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) is the global main scientific and technical body for climate change matters. It was created in 1988 by the World Meteorological Organization and the United Nations Environment Programme (UNEP). The Panel is composed of experts in climate change science from around the world and its mission is to foster greater understanding of the risks associated with climate change by periodically assessing the state of international scientific knowledge on climate change and publishing reports that summarize the results available in the international scientific literature.

As an intergovernmental entity, the IPCC relates to individual countries through National Focal Points. In Chile, the Ministry of the Environment performs this role. However, the country's involvement is not limited to that of the Focal Point, but includes the contributions of the scientific community and other Chilean stakeholders. For the 2006–2010 period, Chile interacted with the IPCC in the following ways:

Participation of Chilean researchers in IPCC activities

Chile had three nominated co-authors in the two special reports that the IPCC is working on: the "Special Report on Renewable Energy Sources and Climate Change Mitigation," set to be published in 2011, and the "Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation," scheduled for publication in 2012.

In addition, in early 2010, 19 Chilean experts applied to participate in the preparation of the IPCC's Fifth Assessment Report, which is expected to be published in 2013 and 2014. The IPCC nominated seven Chilean scientists as co-authors of the Fifth Report, covering all volumes that will be part of the final document[2]. This nomination positioned Chile 4th in terms of the number of scientists nominated for the IPCC's Fifth Assessment Report in Latin America, after Mexico, Brazil and Argentina.

In addition, Chile is represented on the 44-member IPCC bureau, specifically on the task force on greenhouse gas inventories. Chilean scientists also sit on the governing board of the IPCC task groups on "Data and Scenario Support for Impacts and Climate Analysis" and "Editorial Board of the Emission Factor Database."

a) Review of draft documents prepared by the IPCC and submission of opinion on behalf of the public sector.

The national focal point coordinated the review and submission of opinions on behalf of the public sector on the following documents: 4th IPCC Assessment Report, consisting of three volumes and a summary document published in stages in 2007, and the IPCC technical report Climate Change and Water, published in June 2008.

b) Organization of IPCC meetings in Chile

In 2009, for the first time Chile hosted official meetings of IPCC experts, being only the third South American country to have done so (along with Brazil and Argentina). Approximately 40 experts from five continents attended each of the two meeting sessions held in Santiago, which were the 7th Meeting of the Editorial Board of the Emission Factor Database and meetings between IPCC experts and sectoral representatives to discuss emission factors for the agriculture and forestry sector and soil.

4.3 CHILEAN RESEARCH CENTERS WORKING ON ISSUES RELATED TO CLIMATE CHANGE

4.3.1 Center for Scientific Studies (CECS)

CECS (www.cecs.cl) is located in Valdivia and conducts permanently research on glaciology, among other topics. The Center has a rich portfolio of research projects, which it implements in partnership with internationally renowned research centers. The Center also organizes talks, international symposiums and conferences, and conducts activities and research projects related to climate change. Some of its topics are listed below:

- Glacier inventory, as a contribution to the National Glacier Registry prepared by the DGA
- Glacier-volcanic interaction and glacier monitoring in active volcanic sites
- Studies of the recent calving activity of Patagonian glaciers in connection with hydrographic and geological processes
- Emptying of preglacial lakes in Patagonia and modeling of future events
- Study of glacial hydrology in the Northern Patagonian Ice Field
- Historic fluctuations of glaciers in southern Chile, intended to demonstrate long term variations in Chile's far south
- Stability and recent behavior of glaciers in the Antarctic Peninsula, including their interaction with ice platforms. The aim of this study was to investigate the impact of glacial dynamics on the disintegration of floating ice platforms.
- Glaciological research on Glaciar Unión, Western Antarctica
- Glaciological study in the Antarctic interior using an array of geophysical prospecting methods.

[2] In the previous Assessment Report (approved in 2007), the authors of which were nominated in 2003, three Chilean scientists participated as co-authors.

4.3.2 Chilean Antarctic Institute (INACH)

The INACH promotes high quality Antarctic research in Chile by coordinating different scientific and technological projects through competitive grants. One of these projects is focused on global warming and climate evolution and the impact of global warming in Antarctica.

The Institute's current projects can be classified according to their funding source:

- PBC & PIA programs: Study of glaciers on the Antarctic Peninsula and the effect of UV radiation on endemic species.
- INACH field projects: Investigation of fine aerosols; flora and warming; climate change biomarkers; *colobanthus* and global change.
- Special projects: Tephrochronology.
- INACH undergraduate and graduate theses on the effect of climate change on sea birds.
- International cooperation activities, including research on the Antarctic and South American climate and study with airborne sensors.

4.3.3 Center for Global Change, Pontificia Universidad Católica

The Center for Global Change (Centro de Cambio Global UC) is the first research center operating from within a Chilean educational establishment that focuses exclusively on analyzing global change issues in the country. It was created in 2008 through an alliance of four of the university's faculties—agronomy and forestry engineering; biological sciences; engineering; and economic and administrative sciences—and concentrates on basic and applied research on biophysical and human dimensions of global change. The Center has conducted studies on aspects of GHG emissions mitigation in the energy and non-energy sectors, climate change vulnerability and adaptation studies on Chile and the region, and economic assessments of the impacts of climate change. The Center's projects have been financed by Innova Chile and CONICYT, among other agencies.

4.3.4 Universidad de Concepción

Several groups within the Universidad de Concepción conduct research on issues related to climate change and its effects. These include the Center for Oceanographic Research in the South-East Pacific (Centro COPAS), housed in the Faculty of Natural and Oceanographic Sciences; the Department of Geophysics in the Faculty of Physical and Mathematical Sciences; the Center for Environmental Science, EULA-Chile; the Faculty of Social Sciences; and the Research Center on Patagonian Ecosystems (CIEP). These different units conduct pure and applied scientific research that focuses on the national and local impacts on key resources that are associated with climate variability and climate change. The Universidad de Concepción has prepared a detailed report that also serves as a compendium of the institution's collective efforts (U. de Concepción, 2011).

4.4 STRENGTHENING RESEARCH PROGRAMS: SPECIFIC NEEDS AND PRIORITIES

Chile faces the challenge of building permanent mechanisms with stable financing to conduct research and facilitate technological developments pertinent to climate change. The role that CONICYT can play in leveraging additional sources of funding at the national level should also be highlighted.

In regard to mitigation, specific technologies must be studied and adapted to local conditions. A case in point is that of agricultural burning and the enormous potential for using agricultural waste to generate energy and/or as fertilizer. To advance in this direction, it is necessary to inform local agricultural stakeholders about the scientific and technological research and build relationships between producers and technology research and development centers. Another priority research area is plant species; specifically, this means developing suitable varieties and conducting greenhouse studies on adaptation to temperature changes, CO_2 concentration, changes in precipitation regimes, and other effects of climate change.

At the same time, there is a need for more prospective studies on climate variability and the vulnerability of populations and ecosystems. In recent years studies have been carried out on the expected impacts of climate change in Chile in sectors such as agriculture and forestry and on the availability of water and energy. Although valuable, this new information is not itself sufficient for making completely informed decisions; more knowledge in these areas and others such as biodiversity, biomass, and ecosystems most vulnerable to climate change is therefore needed.

It is also important to build adequate knowledge about climate forcing on arid ecosystems, the cryosphere and an array of representative ecosystems of major importance to global climate stabilization. Another key area of study is oceanographic studies, especially the stabilizing effect of the South Pacific on global environmental changes.

In the area of adaptation to climate change, special mention should be made of the role that water in all forms (lakes, rivers, snow and ice, groundwater, etc.) plays in sustaining life and productive activities in 21st Century Chile (Reyes, 2010). In this regard, adaptation does not only refer to biophysical systems, but also to the interaction of the social and economic system with the surrounding environment. Particularly, adaptation to climate change related to water requires more in depth study. The short length and sharp drop in altitude (between the mountains and the sea) of many of Chile's water basins makes them particularly vulnerable to climate change.

5. EDUCATION, TRAINING AND AWARENESS RAISING FOR CLIMATE CHANGE

This section describes and analyses recent advances in education, training and awareness raising focused on climate change. It highlights changes over the past decade (2000–2010) in regard to public participation and public access to information on climate change, as well as the expected outcomes of public education and awareness raising programs. The following four specific issues are addressed:

- The institutional framework and initiatives designed to promote public education and awareness.
- Initiatives and programs implemented or planned for primary, secondary and higher education.
- Educational, training and awareness raising campaigns already carried out.
- A compilation of climate change activities undertaken from 2000 to 2009, obtained from the 1st National Survey on Climate Change (CC&D, 2009).

5.1 LEGAL AND INSTITUTIONAL FRAMEWORK FOR PROMOTING CLIMATE CHANGE EDUCATION AND AWARENESS IN CHILE

Over the 2000 to 2010 period, CONAMA (now the Ministry of the Environment) was responsible for promoting and, in many cases, implementing environmental education programs and fostering an environmentally aware culture in Chile. While these efforts were more broad-based and not exclusively focused on climate change education, they are worth mentioning as they constitute the cornerstones of public action in this area.

The National System for Environmental Certification of Educational Establishments (SNCAE) includes complementary lines of action for strengthening environmental education and environmental protection and care for building networks for local environmental management. This program is coordinated by the Ministry of the Environment, the Ministry of Education, the National Forestry Corporation, the Chilean Association of Municipalities, the General Water Directorate, the Council for Sustainable Development and the United Nations Educational, Scientific and Cultural Organization (UNESCO).

The SNCAE supports actions that promote a sustainable culture and foster environmental values and conservation among children and youth, with the aim of improving the quality of education in Chile. It also promotes education for sustainable development in Chile and contributes to cultural change by encouraging environmentally responsible behavior. The system also establishes environmental standards that measure the presence of environmental concerns in three areas of education: curricula, educational administration and relations with surroundings.

The second initiative in the institutional framework that is worth noting is the recently developed National Educational Policy for Sustainable Development, which sets out principles, objectives and strategic lines of action to promote active citizenship and Chile's sustainable development through education.

This policy was approved by CONAMA's Council of Ministers on 9 April 2009. Its general objective is to strengthen educational processes and develop values, ideas, abilities, skills and attitudes for individual and collective citizenship for the purpose of building and enjoying a sustainable society. The policy's main actions include promoting existing environmental education activities and generating informative material and teacher support materials, as well as implementing specific educational projects for sustainability with a focus on local stakeholders and conditions.

Other public institutions in Chile have undertaken sector-specific actions to educate and train their staff members in regard to climate change. However, these are usually marginal or supplementary to the traditional functions of these entities and do not necessarily complement the activities of other institutions with similar policies.

Throughout the past decade, funding of educational and awareness raising activities oriented towards climate change came mainly from external sources, primarily multilateral cooperation agencies and research entities. A major exception to this rule, in terms of funding and the focus on climate change, is the Environmental Protection Fund (Fondo de Protección Ambiental, FPA), which was originally administered by CONAMA and is now managed by the Ministry of the Environment.

The FPA was established in 1997 through Article V of Law 19.300 on the General Environmental Framework. It is the first and only fund in Chile that provides support and partial or total funding for activities and projects implemented by social organizations working on environmental protection and recovery, sustainable development, the preservation of nature and the conservation of the environmental heritage. Since its launching, the FPA has been used as an instrument for citizen participation and environmental education for environmental management. The Fund is designed to encourage the active and constructive involvement of social organizations in protecting the environment.

Operatively, the FPA has begun to address the complexity and diversity of environmental problems and the global challenges that have been incorporated into the environmental agenda. As such, since 2008, climate change and non-conventional renewable energies have been eligible for financing. Presently, the Fund offers financing in three thematic areas:

- Climate change: supports, promotes and guides initiatives and actions for preventing and reducing greenhouse gas emissions, adapting to the effects of climate change and building capacities for and awareness of this issue.
- Biodiversity conservation: encourages projects for the sustainable care and use of the natural heritage, including biodiversity with conservation value.
- Education and the environment: encourages community-based projects for environmental education and training processes to prepare individuals and groups to create a sustainable society with environmentally supportive values, ideas, skills, abilities and attitudes.

By 2010, the FPA had provided more than US$ 12 millions for more than one thousand projects involving five thousand social organizations in Chile, including neighborhood associations, NGOs and universities (www.fpa.mma.gob.cl). Of that total, close to US$ 4 millions were allocated for 315 projects and initiatives related to climate change throughout Chile. Some of the most successful, replicable experiences were showcased in a video, and a newsletter was also produced to disseminate local actions in this area.

Photo: Ministry of the Environment Government of Chile

	Sample FPA project under the climate change line
Project Name	Reutilización de aguas grises para creación de un área de protección de flora nativa regional (Reuse of greywater to establish an area for the protection of regional native flora).
Implemented by	Centro general de padres y apoderados de la escuela básica Angelina Salas Olivares. (Parent's Council of the Angelina Salas Olivares Primary School)
Location	Chañaral, Atacama Region.
Project Rationale	Chañaral, located 174 km. from Copiapó, has a contaminated bay area due to large scale copper mining activities. These activities have caused accretion in the bay and the suspension of sand from wind action. This situation could be mitigated by tree planting, however, the lack of water resources makes it indispensible to create a suitable water management plan. The project represents an adaptation measure that addresses the present and future water scarcity and could offset the harmful effects of climate change.
Project Description	Public awareness-raising activities were organized locally on recovering greywater to sustain green areas, sound use of water resources, and reducing potable water use. The school intends to establish green space on the property that incorporates native flora to enhance education on the biodiversity of regional fauna and suitability.

In 2011, the Fund intends to diversify its portfolio and expand its actions under a new management model that includes four competitive funding programs—the local environmental management fund, the special fund for indigenous communities and associations, the fund for environmental networks, and the fund for research and information. Projects related to climate change can be implemented under any of the first three funds, including mitigation, adaptation and capacity building.

In 2008 CONAMA created the Environmental Certification System for Municipalities (SCAM), which seeks to make municipalities models of comprehensive environmental management by encouraging the participation of staff members and local residents through actions such as incorporating environmental concerns into municipal bylaws and carrying out concrete actions to protect the environment and decrease local GHG emissions. By 2010, Antofagasta, Valparaíso, Magallanes and the Metropolitan regions were in the process of being certified under this program, and by 2012 it is expected that the program will be operative in all regions of Chile.

Despite the important work that the Government of Chile has carried out to promote education and public awareness about climate change, we must also recognize the many efforts to raise awareness and educate people about climate change that have been organized by civil society organizations and international entities through courses, seminars, and informal educational workshops. Much of this work has been carried out since 2007, as the descriptions in this chapter show.

Photo: Ministry of the Environment Government of Chile

5.2 PROJECTS AND PROGRAMS PLANNED AND IMPLEMENTED IN PRIMARY, SECONDARY AND HIGHER EDUCATION

Educational programs that address climate change have only recently been developed in Chile. In the early 2000s, school curricula did not include this phenomenon in their content, while in higher education climate change was included in only a few technical and scientific environmental programs, or in life sciences and engineering careers.

The first effort to incorporate climate change specifically in the primary education curriculum came about in 2009 as a result of the National Climate Change Action Plan (PANCC), which affirmed that the issue of climate change should be a central aspect of the school curricula at different levels and should be framed within a national education program focused on climate change.

To support this process, in 2009 CONAMA financed the Guide to Climate Change for Teachers for the second cycle of basic education. The Guide provides information on climate change that teachers can incorporate into different subject areas. It was prepared using the official educational curriculum, including the modifications proposed by MINEDUC (June 2009 version) and the different learning progress maps. It also incorporated knowledge from environmental and sustainable development initiatives in education, making the Guide coherent with the model proposed under the SNCAE.

The Guide was presented at a training course for 50 teachers and education officials from the municipalities of San Bernardo, Recoleta and Maipú, in the Metropolitan Region. The training was certified by the Ministry of Education's Center for Pedagogical Development, Experimentation and Research (CPEIP) and funded as part of the project to prepare this Second National Communication.

Photo: CONICYT. Government of Chile

Additionally, since 2009 the Ministry of the Environment and the Ministry of Education have been holding annual environmental education encounters "Habla Educador(a)" (Speak, Educator), which brings together close to 300 teachers from around the country for three days to share and promote replicable educational experiences, methods and practices on environment related topics. These encounters offer an opportunity for sharing knowledge and experiences on these topics and for engaging in dialogue and feedback with other teachers. The topic of climate change has been present at these encounters from the beginning because of the great interest teachers have in this phenomenon.

Another initiative worth mentioning in the educational context was begun by CONAMA in 1999. The "Club Forjadores Ambientales" (Environmental Trailblazers Club) was created to encourage young people to become leaders in environmental protection and to promote the development of an environmentally aware culture in their schools, homes and communities. The Club was created to support initiatives already underway in many schools that involved environmental objectives, practices, and issues, most of which focused on waste treatment, forestation and the creation of green spaces. It was intended to create leadership opportunities for young people and to contribute to environmental education and management within the school community. The Club currently comprises a network of 1,500 educational establishments that joins together primary and secondary school students across the country.

Under the framework of the Joint Declaration of the II Meeting of the United States-Chile Joint Commission for Environmental Cooperation, Chile's Ministry of Education is implementing the GLOBE program in educational establishments in Chile. This global initiative provides a methodology and resources for curricular development and strategies for local environmental management with a focus on specific territories and using water basins as a natural geographic unit. Studies conducted under the GLOBE program, moreover, provide accurate and relevant information that can be used for different purposes ranging from enforcement to strategy-building to address the environmental impacts of anthropogenic issues such as climate change. The GLOBE program includes the following areas of investigation: atmosphere and climate, water quality (hydrology), soil studies and biological coverage. The synergy among these topics encourages research that focuses on the biophysical relationships within a given water basin. GLOBE is a tool that can be used to enhance the quality of education in Chile by linking its content with the objectives of education in Chile. It is also a good instrument for encouraging creative thinking among students, as it allows them to propose solutions to issues they identify in their observations of the environment around them.

At the university undergraduate and graduate level, Chile has no specific programs focused specifically on educating climate change professionals, although some graduate programs do include courses directly related to climate change. In regard to accessibility, the Government's Becas Chile program (www.becaschile. cl) finances masters', doctoral and postdoctoral studies. One criterion of this competitive grant program is that the applicant be enrolled in one of three priority areas—economics, social sciences and interdisciplinary programs, which can include studies in energy, environment and biotechnology.

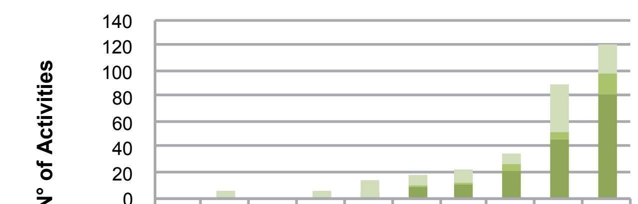
5.3 PUBLIC EDUCATION AND AWARENESS CAMPAIGNS IMPLEMENTED BY THE GOVERNMENT OF CHILE

Chile's first national public awareness campaign on climate change was implemented in 2009 under the title "Enfrenta el cambio climático" (Face Climate Change). The campaign was intended to bring the issue of climate change to the forefront within Chilean society and to emphasize the urgent need for the country to mitigate and adapt to its effects. The campaign included radio and television spots and a website.

Between 2005 and 2009, several campaigns were implemented in the country that did not address climate change specifically but did contribute to efforts to mitigate climate change. These campaigns focused mainly on a rational use of energy in response to drought conditions or energy security. They included the "Gracias por tu Energía, sigamos haciéndolo bien" (Thanks for your Energy, let's keep doing the right thing) (2008) and "Únete a la buena energía de Chile" (Be a part of Chile's good energy) (2009), which were implemented under the National Energy Efficiency Program operating at the time.

5.4 COMPENDIUM OF CLIMATE CHANGE ACTIVITIES IN THE 2000–2009 PERIOD

In 2009, the consulting firm CC&D conducted a study entitled "Levantamiento de información de catastro sobre acciones en cambio climático en Chile" (Compendium of Climate Change Actions in Chile), financed by the Second National Communication project. The idea was to build an inventory of studies, publications, programs, and other initiatives implemented over the 2000–2009 period in Chile in the area of climate change. The results of the study showed a gradual increase in the number of activities (actions, training and studies), with a significant increase between 2006 and 2009 (Figura 2), as a result of increased awareness of the issue in Chilean society.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Studies	2	4	2	4	10	9	10	9	38	22
Training		1	2			1	3	5	6	17
Actions				1	4	9	10	21	46	82

Figure 2. Number of activities in Chile related to climate change, by type of activity, 2000–2009
Source: CC&D, 2009

5.5 GAPS, NEEDS AND PRIORITIES FOR CLIMATE CHANGE EDUCATION AND AWARENESS

After publication of the fourth report of the IPCC in 2007, concern about climate change rose sharply around the world, including in Chile. The results of national studies on climate vulnerability led citizens to realize the importance of addressing climate change. However, more still needs to be done to raise public awareness of the issue.

Still, there are ample opportunities to translate public awareness of climate change into actions that foster lower carbon development in Chile. To take advantage of these, learning processes must become more reflective, encouraging people to question reigning values and practices, to analyze opportunities for changing their behavior, and to offer alternatives for addressing problems and taking responsibility. At present, formal structures for raising awareness and educating the public about climate change are few, with the issue limited to just a handful of public institutions and lacking systematic public dissemination.

Public awareness of climate change is crucial, as it allows citizens to incorporate the concept into their daily lives and achieve changes in their behavior. Such awareness can be raised, for example, through educational, informative and training activities implemented under the country's sustainable development policy.

6. LOCAL AND NATIONAL CAPACITY BUILDING FOR CLIMATE CHANGE

This section contains a description of local and national capacity building activities related to climate change. It includes information on the creation of national priorities by the Government and advances in capacity building around climate change in the private sector and among non-governmental organizations and local organizations. The information here complements that presented in other sections of this chapter describing capacity building on climate change in Chile.

6.1 NATIONAL CAPACITY BUILDING PRIORITIES

Capacity building for climate change is one of the three priority areas (along with mitigation and adaptation) in Chile's National Climate Change Strategy, published in 2006. Based on this priority, the National Climate Change Action Plan (PANCC) includes a general line of action for capacity building, the objective of which is "To inform the population about environmental problems and, in particular, to raise awareness about the effects of climate change and to encourage education, awareness and research on this subject in Chile." (CONAMA, 2008). The Government expects that following this line of action will generate good quality, accessible information about climate change, which will in turn improve public and private decision making and contribute to building Chile's official position in the international context.

Capacities can be seen as a response to the needs, options and priorities that have driven their creation and development in the second half of the 2000–2010 decade. In general, efforts have focused on improving information, education and research on climate change, improving the quality of information available, and enhancing capacities for climate observation. Other efforts have focused on developing institutional capacities for facing the challenges of mitigation and adaptation, developing and transferring mitigation and adaptation technologies, reinforcing international cooperation, and establishing synergies between actions oriented towards climate change and those related to other global environmental problems.

6.2 CAPACITY BUILDING IN THE PRIVATE SECTOR

Three initiatives involving private sector partnerships with the academic community and the public sector were launched in 2009. These focused on studying and analyzing the implications of climate change in Chile.

The project "Fortalecimiento de capacidades del cambio global para enfrentar los desafíos del cambio climático en Chile" (Strengthening capacities for global change to address the challenges of climate change in Chile) takes an innovative approach that combines co-financing by public sector institutions (Innova-CORFO and the Ministry of the Environment) and the private sector (the electricity company Colbún S.A.). The three-year project was launched in 2009 with the UC Center for Global Change as the implementing agency and with support from the Stockholm Environment Institute. The project aims to "develop comprehensive analyses and support systems for decision making to manage the impacts of global change on productive sectors" (http://cambioglobal.uc.cl/fortalecimiento). The project includes research into risk analysis, decision-making and uncertainty representation associated with climate change. It also addresses hydrological-water resource modeling, soil-energy use; environmental monitoring and the use of satellite images; carbon capture in forest lands and ecosystems and carbon footprint management; and the relationships between large cities and global change.

The second initiative is funded primarily by Chile's private sector and involved the establishment of the Chilean chapter of the Corporate Leaders' Group on Climate Change (CLG-Chile), based in the Faculty of Economics and Business at the Universidad de Chile. CLG-Chile, which works in collaboration with the British-Chilean Chamber of Commerce, was established in 2009 on the occasion of the visit of His Royal Highness Prince Charles to Chile. The Group is part of a network of similar centers around the world that is coordinated by Cambridge University. More than ten Chilean companies are members of the Group, which aims to "foster the formulation of policies and actions to successfully address the challenge of climate change while enabling Chilean companies to take advantage of the business opportunities that emerge as a result of moving to a lower carbon economy" (www.clgchile.cl/conozca.html).

Lastly, in 2009 the Chilean Chamber of Production and Commerce financed a study that was commissioned to the Center for Innovation in Energy at the Universidad Adolfo Ibáñez. The study examined the potential impact on economic growth in the country resulting from measures to reduce greenhouse gas emissions. The measures examined include the introduction of a carbon tax and the recognition of the market value of tradable emission permits (considering Chile as a price taker). The study found that reducing emissions would come at a considerable economic cost to the country and that this impact would be distributed unevenly across different sectors of the Chilean economy.

6.3 CAPACITY BUILDING IN NON-GOVERNMENTAL ORGANIZATIONS (NGOS)

Civil society organizations have been crucial for developing a culture of environmental sustainability in Chile. Despite a lack of regular funding and formal, effective mechanisms for civil society participation in policymaking for climate change, some Chilean NGOs have worked systematically on the issue and have become respected sources of information, reflection and debate on climate change in the country.

Chilean NGOs have become more and more interested in climate change over the past decade as interest in the topic has risen both within the country and internationally. In 2010, a significant number of NGOs was participating in climate change activities in Chile, some of them offering major support for capacity building efforts. Some of their contributions are described below.

Since 2002, the Chile Sustentable Program (www.chilesustentable.net) has published many documents related to climate change, focused mainly on energy efficiency, non-conventional renewable energies, and analyses of Chilean policies related to water resources and their sustainability.

The NGO Fundación Terram (www.terram.cl) also has experts working on issues of climate change and sustainability and has produced several analytical and informative documents on the issue. In 2010, this NGO designed and published a citizen's primer on climate change in order to inform and educate the public about the issue and encourage public participation in discussions and problem-solving at different levels.

Fundación Chile (www.fundacionchile.cl) is a private, non-profit organization that works to improve research, innovation and technology in Chile. It is the first organization focused on technological innovation in Latin America to obtain a carbon neutral classification. Specifically, the foundation purchased certified emission reductions equal to 1600 annual tons of CO_2 in the voluntary carbon market. The organization has also taken steps to reduce its own carbon footprint.

Fundación Casa de la Paz (www.casadelapaz.cl) has also promoted responsible energy use, focusing mainly on the use of NCREs and on energy efficiency. In 2009 the foundation participated in the program "Fomento de la eficiencia energética" (Promotion of Energy Efficiency) in the municipality of Lo Espejo. The project included the construction of public housing equipped with energy efficiency systems and devices. The project was intended to provide a sustainable urban housing model and instruct the community about efficient energy consumption and environmental conservation. Within this initiative, in 2010 the foundation implemented a project in the Region of Antofagasta entitled "Sierra Gorda: La primera comuna en disminuir su huella de carbono" (Sierra Gorda: The first municipality to reduce its carbon footprint). The initiative sought to leverage the organized participation of a variety of local and municipal stakeholders and employees of Minera Spence S.A. to promote efficient energy use with domestic appliances that operate with non-conventional renewable energies, such as solar hot water collectors.

The Alianza por la Justicia Climática (www.webcodeff.cl) is an association of many different civil society organizations concerned about the serious consequences of global warming, particularly its effects on the most directly affected communities in Chile. The members of the association include Acción Ecológica, Acción por la Tierra, Comité Nacional pro Defensa de la Fauna y la Flora (CODEFF), Defendamos la Ciudad, Chile Sustentable, Defensores del Bosque Chileno, Observatorio Ciudadano, Observatorio Latinoamericano de Conflictos Ambientales (OLCA) and the Red de Defensa de la Precordillera de Santiago. The group monitors national and international policies, agreements and mechanisms related to climate change. It also engages in discussions and works with key climate change stakeholders such as public officials and experts, researchers, social leaders and industry leaders. The alliance also carries out outreach activities, training, participatory planning, media campaigns and public acts on the issue and formulates proposals to address climate change.

In preparation of participation in the UNFCCC Conferences of the Parties held in 2009 in Denmark and 2010 in Mexico, NGOs collaborated to produce their own technical documents. One of these was the Copenhagen Climate Treaty, in which NGOs presented their positions on the negotiation process occurring at the Convention.

6.4 CAPACITY BUILDING AMONG LOCAL COMMUNITY ORGANIZATIONS

Local community organizations, understood as organizations that are based and operating in a given territory (as defined in Law 19.418 of 1995 on neighborhood associations and other community organizations), are oriented to resolving community problems and building capacities to enable community members to directly improve the quality of their lives, identify their needs and advocate for their own interests. These organizations have taught themselves to demonstrate their interest in and willingness to address problems related to climate change in their communities. Their willingness is expressed in their eagerness to compete for grants from the few Chilean agencies that funds projects of this sort, such as the Environmental Protection Fund (FPA), which was described earlier in this chapter. Indeed, 43% of all funding applications to the FPA in 2011 were focused on climate change. The proposals are oriented mainly towards spreading the word about climate change and its implications within local communities and implementing simple but meaningful measures to adapt to the changes (Ministerio del Medio Ambiente/ División de Educación Ambiental, 2010).

Photo: Ministry of the Environment Government of Chile

7. FINANCIAL RESOURCES AND TECHNICAL SUPPORT FOR ACTIVITIES RELATED TO CLIMATE CHANGE

The international technical and financial support that Chile has received over the decade covered in this National Communication has been crucial for the development, promotion and strengthening of climate change activities in the country.

This section reports on the financial resources and technical support for climate change-related activities that have been provided by the Global Environment Facility (GEF), through environmental cooperation agreements between the Government of Chile and external funding sources, and through financing from the Government itself.

7.1 GEF-SUPPORTED CLIMATE CHANGE INITIATIVES IN CHILE

The Global Environment Facility, GEF, has been the main source of funding for climate change projects described in this Second National Communication. Past and present GEF-financed projects in Chile have been implemented by a variety of agencies, most notably the UNDP, the World Bank, and the Inter-American Development Bank. Table 10 provides details of GEF-supported projects in Chile implemented between 2000 and 2010.

TABLE 10. GEF-funded projects related to climate change, 2000–2010

Project	Description	Implementation period	Agency responsible	Implementing agency
Reducción de GEI (GHG Reduction)	The project focuses on two mining operations, establishing two sub-enterprises to supply energy services, the benefits of which are energy savings for their clients. The project also involve a detailed feasibility study to assess technical and economic aspects for a pilot biomass methanol plant in Chile.	1995-2003	CONAMA	UNDP
Eliminación de obstáculos a la electrificación rural energías renovables (Elimination of barriers to rural electrification with renewable energies)	There are an estimated 170,000 homes without electricity in rural areas of Chile. Many of these are located in remote areas, beyond a feasible connection to a municipal or private grid. Gasoline and diesel powered generators are traditional options for supplying power in remote areas, but renewable energy technologies such as photovoltaic, wind power and hydro power could be less costly in certain localities. The government of Chile implement a comprehensive project to eliminate barriers and make these renewable technologies practical and viable options for rural electrification.	2001-2007	CNE	UNDP
Transporte sustentable y calidad del aire para Santiago (Sustainable transportation and air quality for Santiago)	The project seeks to reduce GHG emissions associated with on-road transport in Santiago by promoting more efficient and less polluting modes of transportation. With this objective, the project supported Santiago Urban Transport Plan for 2000–2010, which is coherent with the main objectives of GEF's sustainable transport operational program.	2003-2008	CGTS	IBRD-World Bank

Project	Description	Implementation period	Agency responsible	Implementing agency
Capacidad nacional de autoevaluación de la gestión del medio ambiente mundial (National Self-assessment capacity for global environmental management)	Identify the country's needs, limitations, and opportunities related to its international commitments in the areas of biodiversity conservation, land degradation and climate change.	2003-2005	CONAMA	UNDP
Chile: Actividad de apoyo al cambio climático (financiamiento adicional para la creación de capacidad en sectores prioritarios) (Chile: Climate Change Support Activity-Additional financing for capacity building in priority sectors)	Additional financing for capacity building in priority areas associated with climate change.	2001-2002	CONAMA	UNDP
Manejo sustentable de la tierra (Sustainable Land Management)	Develop a national incentive program to formulate a plan and practices for sustainable land management in order to combat land degradation, conserve biodiversity of global importance and protect vital carbon resources.	2012-2018	ODEPA, Ministry of Agriculture	IBRD
Promoción y fortalecimiento del mercado de eficiencia energética en el sector industrial. (Promotion and strengthening of the energy efficiency market in the industrial sector)	Promote and strengthen energy efficiency in Chile's industrial sector by supporting the development of an energy efficiency market.	2009-2011	PPEE (National Energy Efficiency Program)	IDB
TT-Piloto (GEF-4): Promoción y desarrollo local de tecnologías solares en Chile (TT- Pilot (GEF-4): Local promotion and development of solar technologies in Chile)	Support the Government of Chile and the National Energy Commission (CNE) in the development of a solar technology industry for both hot water heating and energy generation in Chile. Specific objectives are to: (i) promote technology transfer, institutional strengthening and human capital development in solar technology; (ii) foster demonstration projects using solar technologies for hot water heating and electricity generation; (iii) support the design of incentives, funding mechanisms and public awareness campaigns to promote solar technology for hot water and electricity generation. (US$ 3 million; total cost: US$ 35.1 million)	2010-2014	CNE	IDB
Fomentar el establecimiento y consolidación del mercado de servicios de energía en Chile. (Promoting the creation and consolidation of energy services market in Chile)	Contribute to the creation of en energy efficiency market in Chile by promoting the active participation of engineering and energy services companies as intermediaries in the development of energy savings projects. (US$ 2.6 million; total cost: US$ 15.3 million)	2010-2018	PPEE (National Energy Efficiency Program)	IDB

Source: http://www.thegef.org/

7.1.1 Support for the preparation of National Communications

The First and Second National Communications were financed primarily with GEF funds allocated to countries in fulfillment of Article 12 of the UNFCCC.

The amount allocated for Chile's Second National Communication was US$ 420,000, which was less than the actual cost of preparing this document. However, because of the country's strong commitment to this issue, the ministries of the Environment and of Agriculture provided funds from their own budgets to successfully complete this Communication and meet the deadline established for its submission by GEF (August 2011) (Table 11).

It should be noted that the significant drop in the value of the US dollar in Chile during the preparation of this National Communication made it impossible to complete all activities and studies originally envisioned in the project.

Also worth noting is the positive contribution of UNDP-Chile, as the implementing agency for the Second National Communication project. It must also be noted, however that, despite the size of the project, the inflexibility of some UNDP processes delayed the procurement process. In some instances direct allocation would have been faster than more extended processes, as neither Chile nor the region have a critical mass of consulting firms that can adequately handle certain climate change issues, which made it difficult to obtain at least three proposals for tender.

TABLE 11. Contributions from Government ministries for the preparation of Chile's Second National Communication on Climate Change

Ministry	Amount (US$)	Year	Observations
Agriculture	261,000	2007-2009	Includes only funds spent and reported in the 2CN
Environment	196,000	2009-2010	

Source: Ministries of the Environment and Agriculture

7.2 IMPACT OF INTERNATIONAL ENVIRONMENTAL COOPERATION AGREEMENTS FOCUSED ON CLIMATE CHANGE

Over the past ten years Chile has maintained active bilateral cooperation ties with developed countries that have supported the implementation of environmental projects, including several focused on climate change. The results of some of these initiatives are described below.

7.2.1 Germany

For several years now, environmental protection has been a priority for cooperation activities between Chile and Germany. In addition to traditional bilateral cooperation programs there are special funds available, one of which is provided by the Federal Ministry of Economic Cooperation and Development (BMZ) and another by the Federal Ministry of the Environment, Environmental Protection and Nuclear Security (BMU). The funds' priority issues are energy efficiency and promotion of energy efficiency, promotion of NCREs, climate protection and sustainable waste management, among other things. The funds operate through non-refundable contributions, cooperation development loans and German technical cooperation for promoting the EE/NCRE sector and environmental protection in Chile. Germany's financial (KfW) and technical (GTZ) cooperation agencies coordinate their respective activities in this area closely.

7.2.2 United States of America

In the past decade Chile and the U.S. cooperated in three main areas with an impact on climate change.

- CONICYT-State Department: seeked to strengthen cooperation in science and technology in the areas of astronomy, climate change, renewable energies, health sciences, earth sciences, agribusiness and forensic sciences. These areas are strengthened by the U.S.-Chile Free Trade Agreement and the implementation of successful projects.

- Department of Energy-CONAMA: financed local climate change activities and studies, particularly the study of climate variability in Chile for the 21st Century.

- Chile-California Agreement: Under this agreement, partners work together on projects and research in a wide variety of areas, including climate change, biodiversity and ecosystems, air quality, water resources, sustainable development, integrated and toxic waste management, environmental education and civil society participation, corporate environmental responsibility, environmental goods and services and compliance with regulatory frameworks.

7.2.3 Japan

International cooperation between the governments of Chile and Japan (via the Japanese International Cooperation Agency, JICA) has included several projects linked to issues of climate vulnerability, emissions mitigation and capacity building for climate change. The following projects have and/or are being implemented under the banner of this cooperation initiative:

- Study of Capacity Building and Forestation and Reforestation Promotion under the CDM.

- Development of an Environmental Education Model to Strengthen Local Capacities.

- Participatory Environmental Conservation and Rural Development in the Mediterranean Dryland (INIA).

- Sustainable Bovine Production in Small- and Medium-scale Agriculture (UACH).

- Restoration for Sustainable Water Basin Management (CONAF).

JICA also operates a training and dialogue program and funds internships and technical exchanges for Chilean and Japanese professionals. Climate change is one of the training areas targeted, which has enabled Government of Chile professionals to attend during the past decade courses in Japan focused on climate vulnerability and adaptation and on the financial instruments of the Kyoto Protocol.

7.2.4 Spain

The Government of Spain coordinates the Iberian-American Network of Climate Change Offices (RIOCC), and Chile has been a member since it was founded in 2004 at the IV Iberian American Forum of Ministers of the Environment. The Network's principal objectives are to maintain an ongoing dialogue to explore the priorities, difficulties and experiences of Iberian American countries in the area of climate change; to foster the effective implementation of UNFCCC decisions, particularly those regarding adaptation and mitigation; and to promote capacity building and knowledge generation on technology transfer, systematic climate observation, and climate change adaptation options, among other topics. Additional objectives of the Network are to contribute to achieving consensus at international negotiations for climate change and sustainable development; to promote the inclusion of climate change in official development aid strategies, without diminishing existing cooperation funding under this criteria; to facilitate public-private relations in Chile to increase the benefits of CDM projects by working collectively on identifying and removing barriers; to promote competitiveness and market access in the region by identifying and developing supply and demand; and to foster the signing and application of memoranda of understanding.

This Network has provided a permanent channel for dialogue on climate change mitigation and adaptation and other opportunities for cooperation among its members.

7.2.5 European Union

The Lima Declaration signed in 2008 at the V Latin America and Caribbean-European Union Summit includes the Euroclima Program for regional environmental cooperation, which is focused especially on climate change. The Program was designed to share knowledge, foster formal dialogue, regulate at all levels, and promote synergies and coordination of current and future actions among signatory governments. This program gives Latin American officials and the scientific community access to more comprehensive knowledge about climate change and its consequences, which can enhance sustainable development strategies. The project is financed by the EuropeAid Cooperation Office.

The program's objectives are to reduce populations' vulnerability to the effects of climate change, in a framework of poverty alleviation and sustainable development; to improve understanding of the regional impacts of national actions; and to reduce social inequality, especially that related to climate change, and facilitate sustainable social development. Additional objectives include reducing the socioeconomic consequences of climate change by introducing profitable adaptations capable of generating subregional and regional synergies, and strengthening dialogue on regional integration to create a permanent mechanism for consultation and review of shared objectives.

7.2.6 Canada

Chile and Canada have promoted collaboration among their respective research centers to observe the impacts of climate change on water, glaciers and polar regions in both countries. For example, the project "Conservación del agua en comunidades rurales de la Región de Coquimbo" (Water conservation in rural communities of Coquimbo Region) was implemented from 2004 to 2010 by the Universidad de La Serena in Chile and the University of Regina in Canada.

7.3 NATIONAL GOVERNMENT FUNDING FOR CLIMATE CHANGE MANAGEMENT

Government of Chile funding of climate change management began in the 1990s, when professionals in various ministries and in CONAMA began working on this issue. But it was not until 2008 that a separate item was established for climate change studies in CONAMA's budget. In 2009 and 2010, financial and human resources earmarked for the issue gradually increased, and in 2010 the Office of Climate Change was established under the Undersecretary of the Environment, within the newly created Ministry of the Environment. This placed climate change directly under the purview of the highest environmental authorities in Chile. Budget items for climate change have been established and are gradually increasing in the ministries of Agriculture and Energy as well.

8. FOLLOW UP TO THE CONCLUSIONS PRESENTED IN THE FIRST NATIONAL COMMUNICATION ON CLIMATE CHANGE

Chile's First National Communication on Climate Change, published in 2000, included a section entitled "Final Conclusions and Actions to be Undertaken," which comprised a series of climate change initiatives that were deemed important at the time. Table 12 details the activities and outcomes of those initiatives, divided by area and indicating the status of each one (finalized–F, or partially complete–P) carried out by the Government of Chile up to 2010.

TABLE 12. Summary and status of actions identified in the First National Communication on Climate Change

Descriptor	Action	Status	Observations
National Action Plan	Define a national action plan for climate change to guide the Government's lines of action in this area.	F	The National Climate Change Action Strategy was published in 2006 and the National Climate Change action plan was published in 2008.
Use of CDM	Explore opportunities arising from the application of funding mechanisms under the UNFCCC and the Kyoto Protocol. Develop an institutional framework to use the CDM in Chile.	F	Chile established its Designated National Authority in 2003. This entity is currently under the purview and coordination of the MMA. Cooperation agreements have been signed with industrialized countries for CDM projects and technology transfer, which has been a key move in developing CDM projects, especially in the NCRE sector.
Technical and institutional capacity to identify projects and conduct specific studies	Land use, land use change and forestry sector (LULUCF): *Improve understanding of processes that have led to higher CO_2 emission in this sector. *Improve understanding of carbon capture in abandoned areas (especially regeneration of native forest and bushes). *Propose actions to improve the efficiency of fuel wood consumption.	P	Studies related to climate change have been conducted for: assessing mitigation options in the forestry sector and for degraded soils (CGC-UC, 2011; ECLAC, 2009); assessing vulnerability and adaptation in the agriculture, livestock and forestry sector; and Chile's water and soil resources (Agrimed, 2008). Other relevant studies include: • Evaluación socioeconómica del impacto del cambio climático en el sector silvoagropecuario (Socioeconomic assessment of the impact of climate change in the agriculture and forestry sector"). PUC for ODEPA, 2010 • Estudio de la variabilidad climática en Chile para el siglo XXI (Study of climatic variability in Chile for the 21st Century). Universidad de Chile for CONAMA, 2007.
	Energy and industrial processes sectors: * Identify and assess mitigation options for the transport sector. * Assess the cost-benefits of introducing EE standards for household appliances. * Explore other areas (different from rural electrification)	F	In 2010, SECTRA completed a study to assess mitigation options in the transport sector. CONAMA and the Ministry of Energy also conducted a study of this issue (2010). The National Energy Efficiency Program (PPEE, now the Chilean Energy Efficiency Agency) has a working group for the transport sector. The PPEE has a line of action focused on residential devices. Advances have also been made in applying EE concepts in other sectors. Law N°20.257 was enacted in 2008 and is intended to promote NCREs in Chile. In 2005, a project to support electricity generation using renewable sources was launched by CNE and CORFO. The project has worked on more than 200 initiatives, 29 of which were in operation or under construction in December 2010. The Centro de Energías Renovables was created in 2009 as a joint initiative of the CNE and CORFO. Most relevant studies: • Análisis y desarrollo de una metodología de estimaciones de consumos energéticos y emisiones para el transporte (Analysis and development of a methodology for estimating energy consumption and emissions for transportation). Sistemas Sustentables for SECTRA, 2010. • Análisis de opciones futuras de mitigación de GEI para Chile en el sector energía (Analysis of future options for mitigating GHGs in Chile's Energy Sector). CCG/POCH for CONAMA/Sinergia, 2010.
GHG Emission Inventories	Update GHG inventories	P	An inventory of GHG emissions of all sectors was established. Time series are available for the 1984–2006 period. Most relevant studies: • Complemen tos y actualización del inventario de GEI para Chile en los sectores de agricultura, uso de la tierra y cambio de uso de la tierra y forestal, y residuos (Complements and update of Chile's GHG inventory for the agriculture, LULUCF and waste sectors). INIA for CONAMA, 2010.

Descriptor	Action	Status	Observations
Mitigation options for future scenarios	Project future scenarios for 2020, including a baseline. Study mitigation options for each sector and assess economic aspects and implementation conditions.	P	• Desarrollo y aplicación de una metodología local de cálculo de emisiones Bunker para gases de efecto invernadero (Development and application of a methodology for local calculation of Bunker emissions for GHGs) . Sistemas Sustentables for CONAMA, 2010. • Aplicación de metodologías para producir series de tiempo nacionales de emisiones de gases de efecto invernadero en los sectores energía, procesos industriales y uso de solventes y otros productos (Application of methodologies for producing national time series data on GHGs in the energy, industrial processes and solvent and other product use sectors). Poch Ambiental for CONAMA, 2008. Preliminary mitigation options have been identified for the energy, transport, forestry, agriculture, construction, mining and fisheries sectors in studies conducted by COFRO in 2009; CONAMA /MINENERGIA in 2010; SECTRA in 2010; ECLAC in 2009. Most relevant studies: • Huella de carbono en productos de exportación agropecuarios de Chile (Carbon footprint of Chile's agriculture and livestock exports). INIA for FIA, 2010. • Potencial de mitigación del cambio climático asociado a la ley sobre recuperación de bosque nativo y fomento forestal (Climate change mitigation potential associated with the law on the recovery of native forest and forestry development). INFOR for ODEPA, 2010. • Estrategia y potenciales de transferencia tecnológica para el cambio climático (Strategy and potential for technology transfer in relation to climate change). POCH Ambiental for CORFO, 2009. • Evaluación del potencial productivo de biocombustibles en chile con cultivos agrícolas tradicionales (Assessment of the productive potential of biofuels in Chile using traditional crops). UST for ODEPA, 2007.
Vulnerability and Adaptation Studies	Study productive activities and geographic zones vulnerable to climate change. Study in-depth: *Replacement of crop varieties, relocalization, etc. *Assess the impact of climate change on protected wilderness areas. *Impacts of the alteration of hydrothermal regimes on native forest species. *Effect of climate change on desertification. *Use of integrated pest control systems. *Early warning systems for El Niño and La Niña events. * Creation of a communications network for irrigation, meteorological information and early warning signs. *Assessment of groundwater resources in different basins. *Infrastructure for hydrological regulation at the national level. *Include a national climate change adaptation strategy in the action plan.	P	Studies have been commissioned on the impact of climate change on the agriculture and forestry sector (ODEPA 2009, CONAMA 2008, FIA 2009). The study Vulnerabilidad de la biodiversidad terrestre en la eco-región mediterránea, a nivel de ecosistemas y especies y medidas de adaptación frente a los escenarios de cambio climático (Vulnerability of terrestrial biodiversity in the Mediterranean eco-region at the ecosystem and species level, and adaptation measures for climate change scenarios) (IEB, 2010) was also conducted. In the study Análisis de vulnerabilidad y adaptación del sector silvoagropecuario y de los recursos hídricos y edáficos de Chile frente al cambio climático (Analysis of vulnerability and adaptation to climate change in the agriculture and livestock sector and in regard to water and soil resources in Chile), vulnerability scenarios set out in the First National Communication were updated and changes in water resources in certain water basins due to climate change were also studied. A National Glacier Strategy (DGA, 2008) was also formulated. One of the main priority lines of action in the National Climate Change Action Plan (PANCC) is Adaptation, which affirms the need to formulate a national adaptation plan and associated sectoral plans. Most relevant studies: • Evaluación socioeconómica del impacto del cambio climático en el sector silvoagropecuario (Socioeconomic assessment of climate change impacts in the agriculture and forestry sector). PUC for ODEPA, 2009 • Impacto, vulnerabilidad y adaptación al cambio climático en el sector silvoagropecuario de Chile (Impact of, vulnerability to and adaptation to climate change in Chile's agriculture and forestry sector). INIA for FIA, 2009 • Análisis de vulnerabilidad y adaptación del sector silvoagropecuario y de los recursos hídricos y edáficos de Chile frente al cambio climático (Analysis of vulnerability and adaptation to climate change in the agriculture and forestry sector and in relation to water and soil resources in Chile). AGRIMED for CONAMA, 2008. • Portafolio de propuestas para el programa de adaptación del sector silvoagropecuario en Chile al cambio climático (Portfolio of proposals for the climate change adaptation program of the agriculture and forestry sector in Chile). ASAGRIN for CONAMA, 2010.
Scientific investigation of climate change	Foster scientific research on climate change, prioritizing specific areas of study. Consider the inclusion of climate change study in formal education. Install GHG monitoring stations in Northern Chile.	P	CONICYT has no specific research line for climate change, but during the past decade the agency has financed multiple research initiatives on topics related to climate change. The Government of Chile has also supported research in this area through its ministries of Environment and Agriculture (mainly) and services such as the DMC and SHOA.
National strategy for GEF	Define a National Strategy to use GEF resources more effectively.	P	An internal institutional structure has been established with the MMA as a focal point and resources have been obtained for several initiatives financed by GEF in Chile.

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CHAPTER 6

Barriers, Gaps and Needs For Financing, Technology and Capacity Building

PHOTO: MINISTRY OF THE AGRICULTURE

HOME

1. INTRODUCTION

For Chile, undertaking the great task of meeting its commitments under the United Nations Framework Convention on Climate Change (UNFCCC) means overcoming major obstacles and gaps and covering needs for financing, technology and capacity building at the local level.

As a developing country, Chile has pledged to contribute to national and global efforts to mitigate and adapt to climate change. The advances and achievements the country has made to date are the result of both national efforts and international support. Collectively these contributions have enabled the country to develop its environmental institutional structure, build technical capacities and develop new lines of work in this area, demonstrating the importance of support from developed countries to the achievement of the Convention's ultimate objective.

Chile's National Climate Change Action Plan (PANCC) was launched in 2008 and engaged several public institutions in efforts to address the issue of climate change. The Plan's final goal for 2012 is to develop national and sector-specific mitigation and adaptation plans, and to this end it mandates for the first time the allocation of funds and the development of technical capacities to address the issue of climate change in Chile.

In August 2010, the country voluntarily joined the global effort to mitigate greenhouse gases (GHGs) by presenting data for the Appendix II of the Copenhagen Accord to the Convention Secretariat. In the document, Chile pledged to carry out mitigation actions that will allow the country to reduce its emissions to 20 per cent below its 'business as usual' emissions growth trajectory in 2020, as projected from the year 2007. According to the document, most efforts will be focused in the energy efficiency, non-conventional renewable energies, and land use, land use change and forestry (LULUCF) sectors. The country will require both internal and external financing to meet this objective and will need to boost existing funding levels by incorporating new funding sources established by developed countries for this purpose.

Beginning in 2011, the country will begin implementing actions mandated under the Cancun Accord, which include nationally appropriate mitigation actions (NAMAs) and the measurement, reporting and verification processes associated with these. In addition to this, the Accord mandates that National Communications be prepared more frequently and that progress reports be issued every two years. The latter must include updated information on the national greenhouse gas inventory and on mitigation actions and financial support received. The Accord also encourages developing countries to draft low carbon development plans or strategies and invites all countries to increase their adaptation actions under the Cancun Adaptation Framework. Chile is already taking action in virtually all of these areas with both internal and external support.

This chapter identifies national barriers to achieving Chile's commitments under the UNFCCC and proposes ways to overcome them. Specific issues addressed include:

- The need for technical and financial resources to implement the mitigation, adaptation and capacity building activities required to face climate change.
- Improving aspects of inter-institutional coordination at the national level.
- Review of the technical and technological needs of different productive sectors and priority programs and projects.

2. FINANCIAL RESOURCES AND TECHNICAL SUPPORT

The main challenges of moving towards lower carbon development in Chile are to put in place local and international funding mechanisms that are permanent and adequate for implementing climate change mitigation and adaptation projects and for measuring, reporting and verifying greenhouse gas emission reductions; and strengthening the country's research and technology development capacities.

2.1 MITIGATION ACTIONS

Chile supports the notion of a realistic change in current GHG emission patterns for developing countries by 2020 and reiterates its belief that this effort be primarily voluntarily, in the form of Nationally Appropriate Mitigation Actions (NAMAs). As agreements for long term cooperation are reached in the process launched under the Bali Plan of Action, the country will implement locally supported NAMAs and internationally supported NAMAs, the latter through funding and technology transfers from Annex I countries of the UNFCCC. In both cases, it is extremely important that these actions lead to emission reductions that are measurable, reportable and verifiable.

The country also proposes that the support received from developed countries (through technology transfer, funding and capacity building) also be measurable, reportable and verifiable.

2.2 ADAPTATION ACTIONS

According to the National Climate Change Action Plan for 2008–2012 (PANCC), adaptation actions in Chile should focus on relevant sectors of the economy such as agriculture and forestry, energy, infrastructure, health and fisheries, as well as on strategic resources like water, glaciers and biodiversity. Adaptation measures should also be considered for key locations such as urban coastal zones.

Identifiable adaptation measures must be prioritized and designed for each sector. This will require a decision making process that takes into account future scenarios and their associated costs and benefits, especially where natural resources are affected. As a preliminary measure, the PANCC calls for the collection of the information indicated in Table 1.

Photo: Ministry of the Environment Government of Chile

TABLE 1. Vulnerability and adaptation measures in specific sectors in Chile

Sector	Vulnerability/adaptation measure
Water resources	Determine level of vulnerability in each basin. Determine availability of water for different uses. Analyze monitoring networks operated by the DGA to identify: aquifer monitoring networks, fluviometric networks, and lake and reservoir networks in order to establish their spatial coverage and use their results for defining climate change adaptation measures.
Biodiversity	Identify the most vulnerable ecosystems, habitats and species.
Agriculture and forestry	Update information on the sector's vulnerability under climate change scenarios.
Energy	Determine the vulnerability of hydroelectric generation in Chile
Infrastructure in urban and coastal zones	Evaluate the impact on major infrastructure in coastal zones, riverside zones and zones close to inland waterways, for the design of irrigation works and river flooding defense systems, and Incorporate these into planning instruments (rainwater master plans).
Fisheries	Estimate the vulnerability of Chile's fish resources.
Health	Strengthen health systems in relation to climate change.

Source: PANCC, CONAMA, 2008

To identify the country's specific vulnerabilities and effectively adapt to climate change, a wide variety of material, financial and human resources will be required. Internal funding will be insufficient for dealing with the negative impacts caused by climate change. Funds allocated for sector-specific and global adaptation actions in the budgets of national, regional and municipal institutions will therefore need to be complemented with those from bilateral and multilateral sources and from international agencies. In many cases these actions must be undertaken in collaboration with the private sector, which must internalize a portion of the financial resources required in their productive costs.

To ensure that investment in adaptation programs, studies and activities is effective, an effort must be made to minimize uncertainty about the real impacts of climate change and to assess these on an ongoing basis. As the effects of climate change are gradual, they will not significantly affect the country's economic development in the short term, which makes it imperative to invest as much as possible in this task as soon as possible. This is a major global barrier to implementing adaptation measures.

2.3 CAPACITY BUILDING ACTIONS

Capacity building for climate change has been promoted with the support of international cooperation and locally through the efforts of Chile's public, academic, research and non-governmental sectors. However, it is crucial that such efforts be of sufficient scope to generate the human and scientific capital required to address the causes and consequences of climate change in the form of permanent institutional capacities. To achieve this, it is necessary to identify the opportunities that will offer the most effective support for capacity building for climate change in Chile.

Another challenge to capacity building for climate change is having sufficient financing to take effective action. The GEF-financed study "Autoevaluación de necesidades de fortalecimiento de las capacidades del país en los temas: biodiversidad, cambio climático y degradación de tierras" (Self-assessment of needs to strengthen the country's capacities on the issues of biodiversity, climate change and land degradation) (Ceam, 2008) proposes that a fund be established to coordinate and promote multidisciplinary and transdisciplinary research with a medium and long-term perspective. The research areas proposed include extreme climate events, territorial vulnerability, mitigation and adaptation alternatives, carbon sinks and capture.

The country must also increase private investment in research related to climate change and improve access to information, which is often not available to organizations and to the general public.

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Recently, the Ministry of Economy sent a legislative bill to Congress to expand the tax incentive for research and development (R+D). This bill, Law 20.241, seeks to increase private investment in R+D, including that associated with climate change. The law provides tax incentives for promotional and other activities that foster private investment in climate change related research.

3. IMPROVEMENTS NEEDED IN INTERINSTITUTIONAL COORDINATION

The governmental work undertaken in 2008 that concluded with the formulation of the National Climate Change Action Plan generated consensus among different ministries regarding their responsibilities under the Plan. It also established strategic considerations for addressing climate change in Chile as well as priority lines of action for the implementation period. The process also highlighted the importance of coordinating efforts around the issue of climate change, which affects a multitude of sectors. One challenge Chile faces is to update, reorient and coordinate its sectoral policies in areas such as energy, public works, transportation, mining and agriculture to ensure that these contribute to climate change mitigation and adaptation efforts. The country must also take advantage of policies that, while not aimed specifically at climate change, produce results related to that phenomenon.

In recent years, great strides have been made in Chile to improve interinstitutional coordination around the issue of climate change to include the governmental, academic, private, and organized civil society sectors, which have displayed a growing commitment to the issue over the decade covered in this Communication.

In this initial stage the focus has been on sharing the information generated by these different sectors; but there is an urgent need to identify immediate priorities and the technological, financial and capacity building needs of the sectors involved, as well as to coordinate the cross-sectoral policies that are currently being designed. In effect, the main challenge is to incorporate the climate variable into current development processes and into national, regional and sectoral planning. The positions of Chile's different productive sectors (industry, mining, agriculture, fisheries and forestry) on this issue are still heterogeneous and varied.

The country also needs to create suitable mechanisms for coordinating the work of different sectors and institutions involved in the implementation of Chile's commitments under the UNFCCC. In this regard, it is important to better delineate institutional and sectoral roles, responsibilities and competencies, which will streamline and improve the effectiveness of actions undertaken.

4. SECTOR-SPECIFIC TECHNICAL AND TECHNOLOGICAL CAPACITY BUILDING NEEDS

To prepare to face the challenges of climate change, Chile must develop new capacities and enhance existing ones in a variety of arenas and sectors. The country must also integrate climate change concerns into its public policies, including those for economic growth and poverty eradication. The development of a technological base and the transfer of technology that constitute responses to these concerns will play a special role in this regard. Care must be taken, however, that the resources needed to carry out such actions be made available; the contributions of international cooperation agencies are highly important in this regard. Technology transfer in particular is crucial for accessing the innovations needed to face the many problems associated with climate change.

In the coming years, individual sectors in Chile must also make an additional effort to build and strengthen capacities related to climate change.

4.1 NATIONAL GREENHOUSE GAS EMISSIONS INVENTORY (INGEI)

The agreements made in Cancun under the UNFCCC stipulate that Non-Annex I countries should increase the frequency of their National Communications to once every four years, following the allocation of financial resources by Annex I countries. The agreement also proposes that developing nations, in accordance with their abilities and predetermined level of support, should submit a report every three years with updated greenhouse gas emissions, among other information. Chile is intending to launch an initiative to systematically improve the preparation of its greenhouse gas inventories, which is expected to significantly improve its ability to prepare these reports. To this end, the country is considering opening a National Greenhouse Gas Inventory Office to direct efforts to provide information on its emissions and removals. Before the initiative can be launched, however, some issues need to be defined, including the purview, technical and financial aspects, and organizational structure of this office.

Other aspects to be considered include improving those sectors defined as key categories in the INGEI in regard to the use of methods greater than the current level 1.

4.2 WATER RESOURCES IN CHILE EXPOSED TO CLIMATE CHANGE

The vulnerability of Chile's water resources to local changes occurring as a result of climate change is an issue of importance both strategically and in terms of sustainability. A decrease in the availability of water will threaten productivity in the country and human development in general. The sections below present three areas in which work should be done in the short term to support water resource management in the context of climate change.

4.2.1 Collection and generation of information by water resource observation networks

While some progress has been made in collecting hydrological information at the national level, the level of coverage is sometimes low, or discontinuous, or only partially available owing to the lack of adequate mechanisms for collecting and storing that information in databases. Indeed, the national hydrological network needs to be modernized, expanded and updated and the different ways of measuring data must be integrated to prevent the proliferation of small local networks that are unsustainable in the long term and tend to be produced according to their own measurement criteria and are therefore difficult to standardize.

Another issue is that the information that is generated is not sufficiently disseminated or available. To be effective, the data obtained needs to be made publically available and published in a timely manner.

In regard to information use, the capacity for operating permanent models for water resource quality and quantity also needs to be improved. This will enable a more precise determination of the local and regional impacts of climate change and the establishment of adequate plans and programs to protect this resource.

Lastly, in terms of human resource development, the professional capacities associated with these tasks need to be strengthened and technical knowledge continually updated.

4.2.2 Glaciers

According to the National Glacier Strategy (CECS, 2009) Chile has conducted studies on the variation, behavior and characteristics of its most emblematic glaciers. However, the information is still too fragmented to draw conclusions at the national level and there are gaps in some key areas that must be addressed, particularly in regard to assessing the water resources that derive from glaciers, their effect on the climate, and the risks associated with changes in Chile's glaciers.

The main information needs in this area are to develop a system for collecting metadata and to update historic data sources, some of which are less precise and not directly comparable with current information (CECS, 2009). The challenge in addressing these needs will be to increase the installed capacity for glacier research by developing an extensive national monitoring system. A system of this kind must overcome methodological limitations (standardizing criteria and indicators) and logistical challenges while improving spatial and temporal representativeness at the same time.

The programs, projects and study proposals presented below (Tables 2 and 3) complement and outline several previously examined areas and fields, but do not supersede that work. This list was based on a literature review and as such it does not include sectoral priorities.

TABLE 2. Selected programs, projects and studies planned for generating adaptation measures for water resources

Source	Program/Project/ Study
National Climate Change Action Plan (CONAMA 2008)	Assess groundwater resources in different basins, especially in North and Central Chile.
Chile 2020 Public Works for Development (MOP)	Monitor rises in flow levels related to climate change, increase coverage and density of Chile's hydrometric network.
	Studies on aquifer management (characterization, assessment and use).
	Conduct a hydrogeological study of groundwater the Araucanía Region.

TABLE 3. Selection of programs, projects and studies planned to assess glacier vulnerability

Source	Program/Project/ Study
National Glacier Strategy (DGA 2009)	Complete glacier inventory for the entire country by 2020, including all rock glaciers (update the 2010 inventory).
	Conduct the first systematic national study of areal variation
	Conduct ongoing studies of mass and energy balance, and meteorological and hydrological measurement of glaciers.
	Elaborate glacier precision topography maps annually and subglacier topography maps.
	Conduct detailed, multidisciplinary studies on glaciers in Central Chile and begin modeling hydrological and glaciological variables.
	Analyze the impacts of climate change on water quality.
Study "La Economía del cambio climático en Chile" (The Economics of Climate Change in Chile), Centro Cambio Global UC (2009)	Monitor glaciers and build water supply scenarios

4.3 SYSTEMATIC OBSERVATION OF CLIMATE VARIABILITY AND CLIMATE CHANGE

Although a few environmental variables related to climate change have been observed on an ongoing basis[1], Chile has no systematic observation network for monitoring variables related to climate change. Nevertheless, the country does generate valuable information for use in sectors such as agriculture, maritime navigation and weather in general. The information currently generated by several systematic climate observation networks also facilitates a limited amount of applied research on climate change in Chile.

To enhance systematic observation to support more applied research on climate change, the PANCC highlights the need to establish a basic national network for atmospheric, oceanic and terrestrial observation designed for monitoring and studying climate change. This will expand the amount of systematized, digital information available for a greater area. The Plan also points to the need to design and implement early warning systems for the El Niño and La Niña phenomena.

The final point is that systematic observation of climate change must be incorporated into the mission and duties of different Chilean institutions. In this regard, improving inter-institutional coordination will enable the identification of priorities for observation and the establishment of connections and mechanisms among public institutions for fostering research, while encouraging research by the country's academic and scientific community as well.

4.4 ELECTRICITY GENERATION AND ENERGY EFFICIENCY

The electricity generating sector is one of the country's main sources of GHG emissions and as such major mitigation efforts are expected in this sector in the coming years. In this regard, the implementation of Law N°20.257 to promote the use of NCREs in Chile will imply some challenges for the electricity sector, in terms of capacity building in the public (regulation and promotion of NCREs and human capital) and private sectors (compliance with standards and implementation in the direct and auxiliary industry, as well as human capital development). The law also implies technological needs, as almost all technologies associated with NCREs must be imported, which raises the cost of these measures while at the same time requiring a learning process among institutions and industries that will pioneer their use in the country. For this reason, technology transfer must be accompanied by actions to disseminate those technologies.

The availability of information for adequate monitoring, reporting and verification of mitigation actions should be prioritized and should be based on the continuous monitoring of the current and projected baseline. This will illustrate the natural evolution in demand and identify new conditions for the country's energy supply.

Chile also needs to consolidate and take advantage of the potential of energy efficiency measures among different groups of energy consumers. Indeed, energy efficiency measures are expected to supply a significant percentage of new energy demand up to 2020. Lastly, a culture of energy conservation must be actively promoted through regulations and incentives that favor the adoption of measures to optimize energy consumption.

4.5 TRANSPORTATION

The transportation sector, and especially road transport, is also one of the most relevant sources of GHG emissions. The environmental lines of action implemented by the Ministry of Transportation and Telecommunications contribute directly to mitigating those emissions. These action areas can be categorized as follows:

- Promoting penetration of low carbon vehicle technologies in Chile
- Restructuring the urban public transit system
- Replacing vehicle fleets with newer technologies
- Promoting alternate modes of transportation

[1] For example, the DGA's network documents changes in the country's water regime, and the DMC observes climate and atmospheric variables and is part of an international initiative that is documented in Chapter 5.

- Implementing energy efficiency measures in high priority fleets.

Measures for overcoming obstacles, gaps and needs related to local financing, technology and capacity building in this sector should be coherent with the above lines of action.

Similarly, the programs, projects and study proposals presented in Table 4 complement some of the focal areas and sectors outlined above, but are not a substitute for them.

Photo: Transantiago, Government of Chile

TABLE 4. Selected programs, projects and studies planned on biofuel use in the transportation sector

Source	Program/Project / Study
Biofuels: Challenges and opportunities for Agriculture (INIA)	Continue searching for alternative crops for marginal growing zones: non-irrigated interior and coastal land, Non-irrigated foothills zones.
	Genetic improvement to increase starch and/or oil content of crops.
	Introduction of species and identification of native species with high yield potential for biofuels.
	Development of sustainable crop management technologies to increase yields of biofuel crops.
	Grower specialization as dependable, long-term suppliers of raw material.

4.6 DEVELOPING INFRASTRUCTURE FOR ADAPTATION TO CLIMATE CHANGE

Environmental and climate change concerns, must have a direct influence on the planning, design and operation of the country's infrastructure as well as on activities related to building that infrastructure, which includes reservoirs and works to improve connectivity such as ports and roads. This applies to zones of central and south-central Chile that were affected by the earthquake of 27 February 2010 and those that were unaffected by it.

By way of example, the PANCC affirms that hydrology projections based on climate change must be considered in the design of new bridges and hydraulic works, including their associated risk management. It also emphasizes the importance of incorporating the impacts of this process on regulatory plans in order to prevent urban development along coastal and riverside zones. It also calls for assessing potential changes in climate-oceanographic conditions that could have a major effect on the future operation of Chile's ports.

4.7 AGRICULTURE, LIVESTOCK AND FORESTRY ACTIVITY

The development of mitigation projects for the forestry sector requires mechanisms for financing the fixing of forest carbon stocks. In this regard, the use of the REDD[2] and REDD+[3] concepts to combat deforestation and forest degradation in developing countries could offer an opportunity to improve the management of some Chilean forests. For this to be the case, Chile needs to develop a specific REDD+ strategy that allows the government to coordinate stakeholder participation in order to establish a national forest baseline with permanent monitoring.

[2]REDD refers to activities that reduce GHG emissions by preventing deforestation and forest degradation.
[3]Refers to REDD activities that also contribute to conservation, sustainable forest management and improvement of existing forest carbon stocks.

Law 20.283 on the recovery of the native forest and forestry development also can facilitate the inclusion of native forest projects within the country's mitigation options, provided that projects are tied to forest conservation and/or the provision of financial support in the form of subsidies to property owners for maintaining, expanding or recovering ecosystem services.

In the agriculture and livestock sector, the study "Análisis de opciones futuras de mitigación de gases de efecto invernadero para Chile asociadas a programas de fomento el sector silvoagropecuario" (Analysis of future options for greenhouse gas mitigation in Chile associated with agriculture and forestry development programs) (Centro de Cambio Global PUC, 2010) found that the measures with the greatest mitigation potential in the agriculture subsector are those that optimize fertilizer use and improve irrigation practices. In the livestock subsector, the measures selected for analysis included: carbon capture by soil, implementation of large and small scale biodigestion, the use of improved forage varieties, the use of ionophores in bovine diets and greater concentration of bovine diets. Tools must be made available to facilitate the implementation of these measures, where suitable conditions exist over different timeframes.

The programs, projects and study proposals listed in Table 5 complement and identify some areas and topics previously detailed, but are not a substitute for them. The list was based on a review of the literature and therefore no sectoral priorities are assigned.

TABLE 5. Selected projects and studies planned for the agriculture and forestry sector on climate change vulnerability, adaptation and mitigation

Source	Program/Project/ Study
National Climate Change Action Plan (CONAMA, 2008)	Identify and expand knowledge of the impact of climate change on desertification and erosion processes in Northern and Central Chile
	Evaluate and promote research on the use of integrated pest and disease control systems.
	Implement the Genetic Improvement Program to develop crop and forestry varieties adapted to new climate change scenarios.
Infor: www.infor.cl	Put in place a permanent monitoring system for carbon stocks in Chile in the context of REDD+ and LULUCF.
"Estudio sobre impacto, vulnerabilidad y adaptaciónal CC en el sector silvoagropecuario" (Study of Climate Change Impacts, Vulnerability and Adaptation in the Agriculture and Forestry Sector) (INIA, 2009)	Analyze production strategies for raspberry, blueberry, cherry, and apple, as productivity and economic margin simulations indicate sharp reductions in these areas.
	Establish a work unit focused on measuring carbon footprints of productive systems and establish micro programs for landowners to reduce greenhouse gases.
	Technical cost-benefit study of the use of agricultural waste and different kinds of sludge.
	Support and enhance support for adopting modern technologies such as precision agriculture, emphasizing fertilizer reduction and efficient use.
	Investigate alternatives to fertilizers such as biofertilizers and nanofertilizers.
	Research and design of new food technologies for bovine cattle, integrating complementary institutional capacities.

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4.8 BIODIVERSITY

To anticipate and mitigate the potential effects of climate change on Chile's biological diversity, its impact on zones of high environmental value must be assessed, especially in regard to protected species. In addition, institutional mechanisms must be generated or strengthened to adequately address the challenges of global climate change to biodiversity.

Adequately assessing the responses of critical species, ecosystems and habitats depends heavily on the data available and the methodological approach used. In this regard, it is important to update and maintain assessments of climate change's impact on biodiversity. This work should include agreed upon projections that have been estimated for Chile and particularly monitoring of species and habitats that could experience changes in their distribution, with special attention paid to those that are protected.

It is also necessary to strengthen the current Protected Wilderness Area System by taking into account connections that facilitate the migration of certain species. To accomplish this, it is essential to improve the representativeness of the National System of State-protected Wilderness Areas (SNASPE) in Central Chile, which will foster the protection of Mediterranean ecosystems and species that have been identified as the most vulnerable to climate change. This work must include projected changes in the distribution and density of those species. Coastal and marine areas must also be incorporated into the SNASPE. In regard to mitigation, it would be advisable to begin to evaluate the potential impact that the country's protected wilderness areas could have on capturing emissions.

5. STRENGTHENING PARTICIPATION IN NATIONAL CLIMATE CHANGE ACTIONS

Including and reinforcing climate change issues in national priorities will require a renewed effort from a range of stakeholders. One challenge in this regard is to include more Chilean experts in the design and application of climate change management instruments.

Additionally, a recent recurring demand in Chile has been to improve the participation of all of Chile's regions in regional public policies and decisions related to climate change. In particular, considering that adaptation issues have a strong local component, ways must be found to incorporate local authorities, research centers with a regional focus, regional trade associations, and regional civil society organizations, including local community groups. Depending on the origin of local GHG emissions, mitigation measures may also have a regional component that could address the issue of emission reduction by applying measures on a different scale than that applied in national approaches.

The dissemination of information also has a special local component, which must be used and strengthened more proactively.

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