

Climate Protection Programme (CaPP)
National Strategy Study
for the CDM in Chile

Summary in English

Published by:

Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH
Postfach 51 80, D-65760 Eschborn
Division 44 – Environment and Infrastructure
in cooperation with
Chilean Environmental Agency (CONAMA)
PN 2001.2184.8

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March 2003

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1 Introduction

In 1997, the World Bank and Switzerland together launched the National Strategies Studies (NSS) Programme, with the objective of supporting potential host countries of AIJ, CDM and JI projects in developing the necessary know-how and in identifying future projects. The German *Gesellschaft für technische Zusammenarbeit (gtz)* has financed this National Strategy Study for Chile, which has the support of the Chilean *Comisión Nacional del Medio Ambiente (CONAMA)*. The study was carried out by a project team involving the consultants *Cambio Climático y Desarrollo (CC&D)*, under the auspices of the *Fundación para la Innovación Agraria (FIA)*, the *Programa de Investigaciones en Energía at the Universidad de Chile (PRIEN)*. The *Öko-Institut* in Germany is providing international support. Several workshops have been conducted with relevant stakeholders and interested parties in order to disseminate information on the CDM as well as to identify possible CDM projects. Likewise, the Steering Committee as well as several other institutions and individuals have provided helpful input to the study.

The study aims at assessing promising areas for future CDM projects, analysing the potential and mitigation costs of CDM projects, identifying possible barriers for their implementation, and developing the necessary institutional requirements of starting CDM projects in Chile. In this summarized English version, we have emphasized those parts of the study which address the specific national circumstances for the development and implementation of CDM projects in Chile, since they may be of particular interest to our readers. The general introduction to climate change and the CDM, as well as the analysis of the international carbon market are not included, but can be found in the Spanish original of the NSS.

Chapter 2 presents a proposal on how to establish the necessary institutional arrangements to promote and to obtain official approval for CDM projects in Chile. The necessary prerequisites for investments and the general risks of investments in Chile are briefly described in Chapter 3. As a first step toward project identification, Chapter 4 illustrates greenhouse gas emissions in Chile by sector. Chapters 5 and 6 describe the Chilean energy (including utilities, transport, industry and the residential sector) and forestry sectors and identify interesting areas for CDM projects. Finally, Chapter 7 assesses the potential and mitigation costs of several CDM projects and constructs a marginal mitigation cost curve for CDM projects for both the energy and forestry sectors.

2 Institutional arrangements for the CDM in Chile

2.1 Designated National Authorities for the CDM

According to the modalities and procedures for the CDM (Annex to decision 17/CP.7, adopted at the Seventh Conference of the Parties as part of the Marrakech Accords), CDM projects must be approved by the government of the host country. For this purpose, each country has to designate a responsible national authority.

This designated national authority has several responsibilities:

- ≠ According to the modalities and procedures for the CDM, the designated national authority should conform that a CDM project activity pursues the goal of achieving sustainable development and that participation in the project is voluntary.
- ≠ If a government authorizes private and/or public entities to participate in CDM projects, the government is to ensure that the projects are conducted in accordance with the modalities and procedures for the CDM. For this purpose, it is proposed that the designated national authority certify that the arguments put forth by the project participants, in addressing additionality and selecting the baseline, are consistent with the predominant understanding in the country on the business-as-usual course of investment in new projects in the respective sector.

- ⊘ Additionally, the designated national authority must verify that proposed CDM projects comply with relevant national legislation, including environmental and fiscal legislation.
- ⊘ Another important task, which may be conducted by the designated national authority or another institution, is the promotion and identification of CDM projects, as well as the dissemination of information on the CDM in general. For Chile, it is proposed that the designated national authority also be in charge of this task. In this regard, the Chilean designated national authority will have two different types of obligations: one that is regulatory and one for the promotion of CDM projects. The following section proposes institutional arrangements for the fulfilment of these tasks, taking into account relevant Chilean legislation.¹

2.2 Assessment of environmental impacts and sustainability

The concept of sustainability has been adopted in Chilean legislation in Law 19.300, whereby sustainable development is defined as “*the process of sustainable and equitable improvement of the quality of life, based on appropriate measures to preserve and protect the environment in a way that does not compromise the prospects of future generations*”. This law provides for several procedures and instruments to protect the environment, including an environmental impact assessment, an environmental impact declaration (which is less stringent than the full environmental impact assessment) and procedures to assess the sustainability of projects or activities.

According to Law 19.300, most CDM project activities (such as power plants or reforestation projects) have to undergo an environmental impact assessment or an environmental impact declaration. However, for those CDM projects that currently do not fall under the jurisdiction of this law, it is recommended that the provision of an environmental impact assessment or an environmental impact declaration be made mandatory, as stipulated in Law 19.300. Consequently, the establishment of a separate procedure for sustainability assessment of projects not covered by Law 19.300 could be avoided and the process of project approval through the designated national authority would be facilitated.

2.3 Assessment of compliance with the modalities and procedures for the CDM

As part of the approval of CDM projects, the designated national authority will assess the compliance with the modalities and procedures for the CDM. Three aspects of the modalities and procedures for the CDM are considered to be particularly important for the credibility of proposed CDM projects:

1. An **appropriate baseline methodology** should be selected and additionality should be addressed in order to ensure emissions are reduced in comparison to those emissions that would occur in the absence of the CDM project. It is suggested that the designated national authority verify that the baseline is selected in a way that is consistent with the official understanding of the business-as-usual development in the country. For projects in the energy sector, the National Commission on Energy (*Comisión Nacional de Energía, CNE*) will be the responsible authority. Projects in the transportation sector as well as reforestation and afforestation projects will be under the guidance of the Sub-Secretary of Transportation (*Subsecretaría de Transporte*) and the Institute for Agrarian Innovation (*Fundación para la Innovación Agraria, FIA*), respectively.
2. Adequate **information** should be provided **on the financing of the CDM project** to demonstrate that the financing of the project does not lead to a decrease of Official Development Aid (ODA) provided by Annex I countries. If this is indeed the case, it is suggested that the designated national authority conduct an official inquiry with the equivalent entities of all Annex I countries involved in the project regarding this issue.

¹ Decisions on these matters will be taken by the Chilean Government.

3. **Comments by relevant stakeholders** must be collected and taken into account. As part of the environmental impact assessment, Law 19.300 already provides for an appropriate procedure for public participation. In the case of environmental impact declarations, the designated national authority has to ensure that public participation is similar to that of the environmental impact assessment.

2.4 Promotion of the CDM

In Chile, there is still a general lack of knowledge regarding the CDM, and in particular regarding flexible policy instruments for addressing environmental problems. Hence, there is a clear need for capacity building activities and dissemination of information. Overall, knowledge about the CDM should be increased in the private and the public sector and disseminated throughout the country, in particular with respect to:

- ≠ the results of the international negotiation process and experiences with the implementation of the CDM in other countries, e.g. regarding baselines and additionality
- ≠ the international carbon market (market prices, public CDM investment programmes, private investors)
- ≠ possible CDM project activities in Chile, particularly addressing the financial sector, etc.

For this purpose, it is proposed that the designated national authority develop and implement several activities to enhance the knowledge of the CDM and to facilitate the implementation of CDM projects. For example, the development of a national website for the CDM is envisaged to provide both national stakeholders and international investors with access to all relevant information.

2.5 Institutional arrangements for the designated national authority

In developing a proposal for the institutional arrangements for the designated national authority, several international experiences have been taken into account, e.g. from international projects to reduce greenhouse gases under the Convention (Activities Implemented Jointly). First of all, for non-Annex I parties, the CDM is an instrument to promote sustainable development and is not an instrument for environmental regulation. Therefore, national institutions in charge of the promotion of sustainable development should be involved. Furthermore, it is also important to involve the target group of the CDM, e.g. the trade associations, in order to facilitate their acceptance of this new mechanism. Thirdly, existing governmental capacities should be used in order to avoid the duplication of responsibilities and the creation of additional bureaucracy.

It is proposed that a **National Committee for the CDM** be created by combining stakeholders from both the public and the private sectors. This Committee will guide national policy in regards to the CDM. The following institutions will be officially represented in the National Committee for the CDM:

- ≠ Ministry of Economy and Energy
- ≠ Ministry of Planning and Cooperation
- ≠ Ministry of Agriculture
- ≠ Ministry of Foreign Affairs
- ≠ National Commission on the Environment
- ≠ National Commission on Energy
- ≠ Sub-Secretary of Transportation
- ≠ Production and Commerce Confederation
- ≠ Federation of Chilean Industry
- ≠ Forestry Union Trade Association
- ≠ Chilean Copper Commission
- ≠ Chilean Small- and Mid-Size Industry Association

Metallurgic and Metal-mechanic Industries Association

Exporters' Association of Non-Traditional Manufactured Products

The National Committee for the CDM will be supported by a Secretariat, staffed with the minimum personnel required to fulfil its functions, which could consist of the director, one assistant to the director, an IT specialist and a secretary. The Secretariat will co-operate with the other institutions involved in the approval process of CDM projects (*the National Commission on the Environment, the National Commission on Energy, the Sub-Secretary of Transportation and the Institute for Agricultural Innovation*).

3 Investments and risks in Chile

The economy of Chile is considered a free-market economy, which relies heavily on a market that is open to international investment, a State whose primary purpose is to allocate resources, as well as a State that oversees regulation and compensation. Over the last 20 years, foreign investment has been promoted, the market was liberalized and State companies, formerly under governmental control, were privatised. Economic growth is steady, inflation is under control, public finances show a surplus and state foreign debt is lower now than in previous years. In spite of the slow down of the world economy, the crisis in Argentina and the decline in copper prices, the Chilean economy has the highest growth rate statistics of all Latin American markets. In order to generate and strengthen the perspective for economic growth over the medium and long-term, Chilean authorities have made progress in approving certain structural reforms, such as the reformation of the capital and labour markets. Likewise, Chile is negotiating with the United States for the establishment of a free trade zone, as well as with the European Union in order to lay the framework for economic cooperation and commercial opportunities.

International evaluation agencies are not only taking notice of Chile's privileged position among Latin American nations, but they also rate Chile favourably among other emerging markets. According to Transparency International's index from the year 2000, Chile is the Latin American country with the lowest levels of corruption. Moreover, in a Price Waterhouse Coopers document, Chile is recognized to be the second most transparent country in doing business – an honour it shares with the United States.

All this goes to show that Chile is an attractive country for foreign investment. In fact, foreign investment in Chile comes from 64 countries, and there are two possibilities available in order to invest in Chile.² The first, the Statute of Foreign Investment, is known as Decree Law 600 (DL 600). A contract, containing specific norms that are applicable to a particular investment, establishes the relationship between the Chilean State and the foreign investor. The minimum investment accepted by Chile is one million USD. The second alternative, Article 47 of the Organic Constitutional Law of the Central Bank of Chile (also known as Chapter XIV of the Compendium of Regulations regarding International Exchange), permits capital influx in the form of foreign currencies and also allows for flexible operations without the necessity of signing a contract with the State.

4 Greenhouse gas emissions trends and projections in Chile

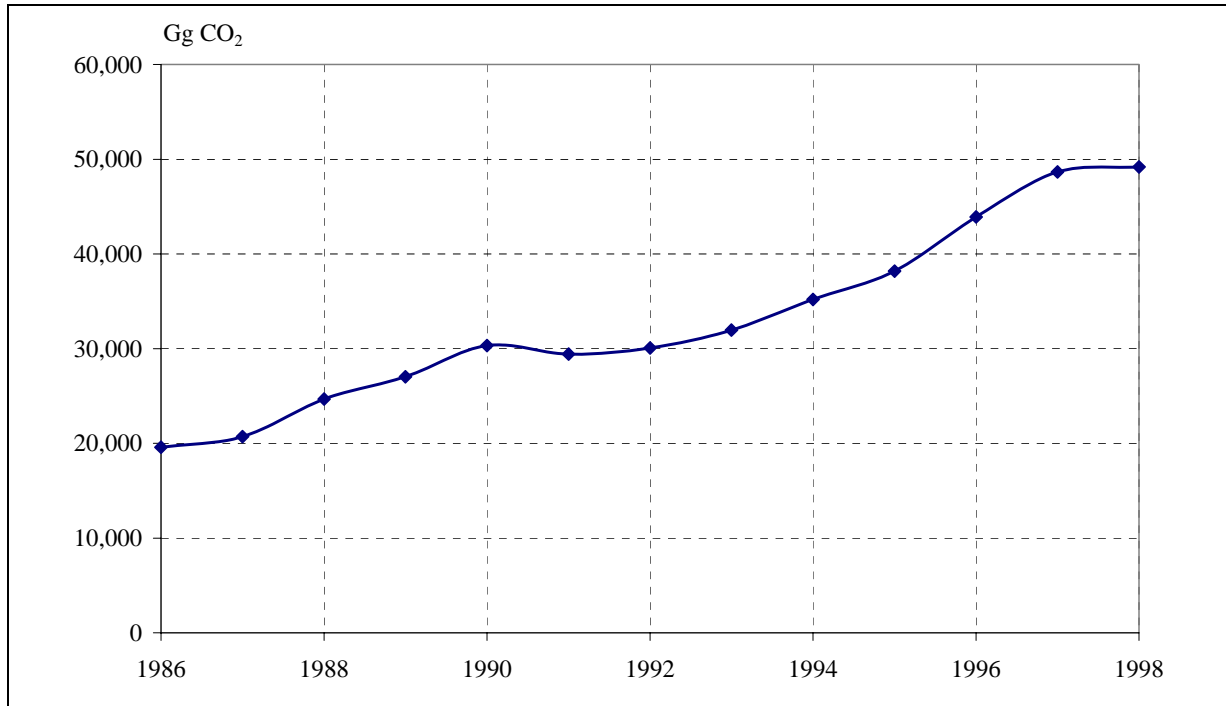
4.1 Greenhouse gas emissions trends

As in most other countries, CO₂ is the most significant greenhouse gas in Chile. Figure 1 shows the development of energy-related CO₂ emissions from 1986 to 1998 (without emissions or removals from land use change and forestry). The table shows that CO₂ emissions have grown rapidly from 20,000,000 tonnes of CO₂ in 1986 to 50,000,000 tonnes in 1998, mainly due to high growth rates of both the economy and energy demand during this same

² At www.foreigninvestment.cl foreign investors can find relevant information regarding making investments in Chile.

period. Chile’s per capita CO₂ emissions amounted to about 3.61 tonnes of CO₂ in 1998, which is above average for Latin America (2.15 in 1998), but significantly lower than levels of OECD countries (10.92 in 1998).

Figure 1: Evolution of energy-related CO₂ emissions (in Gg/year)



Source: PRIEN, “Inventario de Emisiones de Gases de Efecto Invernadero, Energía, Procesos Industriales y uso de solventes. Chile 1986-1998.” Report elaborated by CONAMA, Santiago, December, 2000.

Table 1 shows greenhouse gas emissions per sector in 1994. The table illustrates that fuel combustion is the most significant source of greenhouse gas emissions, due to higher emissions in road transportation, manufacturing industries and construction and energy industries. The agricultural sector in Chile is also a main source of methane and nitrous oxide emissions, contributing about as much as road transportation to overall greenhouse gas emissions, whereas methane and nitrous oxide play a minor role for energy-related emissions. However, large amounts of CO₂ are captured through a net stock change of carbon stored in biomass. Through the abandonment of managed land, about 50 million tonnes of CO₂ are removed annually, resulting in a net uptake of about 28 million tonnes of CO₂ equivalent in land-use change and the forestry sector.

Table 1: Greenhouse gas emissions in Chile in 1994 (Gg)

	GHG's (CO ₂ -eq.)	CO ₂ ⁽¹⁾	CH ₄	N ₂ O	CO	NO _x	NM VOC	SO ₂
Fuel combustion	36,455	35,227	33	2	885	162	134	146
Sationary combustion	23,217	22,341	31	1	505	80	60	140
Energy industries	8,475	8,440	0	0	3	26	1	59
Manufacturing industries and construction	9,351	9,255	2	0	33	39	3	49
Comercial / institutional / residential sector	4,781	4,050	29	0	465	15	56	28
Agriculture / forestry / fishery	611	596	1	0	5	1	1	5
Mobile combustion	13,241	12,887	2	1	380	82	75	6
Aviation	902	902	0	0	7	4	0	0
Road transportation	11,030	10,680	2	1	368	48	73	4
Railways	44	44	0	0	0	1	0	0
Navigation	1,071	1,069	0	0	3	25	1	2
Agriculture / forestry / fishery	191	191	0	0	2	4	1	0
Fugitive Emissions	855		41		1	0	13	7
Industrial Processes	2,162	1,870	2	1	11	4	78	1,815
Copper	0							1,775
Cement	1,021	1,021						1
Asphalt	0				0		46	
Glass	0						0	
Chemical Products	292		2	1		1	1	25
Iron and steel	812	812			1	0	0	2
Ferroalloys	37	37						
Pulp and paper	0				10	3	7	13
Food and beverage	0						25	
Solvents	0						28	
Agriculture	10,144		169	21				
Waste Management	1,138		44	1				
TOTAL (without LUCF)	49,900	37,097	248	24	896	165	241	1,961
Land-use change and forestry (LUCF)	-28,238	-29,709	58	1				
Forest management	-1,900	-1,900	0	0				
Conversion of natural forests into agricultural soils and grasslands	2,694	2,630	3	0				
Conversion of natural forests into commercial forests	5,551	5,452	4	0				
Extraction of trees from natural forests	7,014	6,917	4	0				
Abandonment of managed land	-50,917	-50,917	0	0				
Combustion of forest residuals ⁽²⁾	18,711	17,940	31	0				
Forest fires	8,297	7,856	17	0				
Urbanisation	252	252	0	0				
TOTAL (with LUCF)	21,662	7,388	306	25				

Source: PRIEN, "Inventario de Emisiones de Gases de Efecto Invernadero: Energía, Procesos Industriales y Uso de Solventes", Final Report for the National Commission on the Environment (CONAMA), January, 1999.

Notes: (1) The CO₂ total does not include emissions resulting from biomass.
(2) CO₂ emissions from combustion of forest residual are not accounted for, as it can be assumed that the biomass is regenerated within a year.

4.2 Projections of greenhouse gas emissions

Greenhouse gas emissions in Chile are projected in two scenarios: A baseline scenario without policies and measures to reduce greenhouse gas emissions, and a greenhouse gas mitigation scenario that takes into consideration the policies and measures carried out in order to reduce greenhouse gas emissions. In the mitigation scenario, measures were also considered that are economically attractive for the end-users, but that are currently not implemented due to barriers that exist in the market. In the energy sector, both scenarios assume that the electricity grid of Chile will not be connected with the electricity grid of Argentina. Table 2 outlines the result of the estimation of baseline and mitigation scenarios for energy-related CO₂ emissions.

Table 2: Projection of energy-related CO₂ emissions in Chile, baseline and mitigation scenario (Gg CO₂)

	1994	2000	2005	2010	2015	2020
Baseline scenario	35,022	54,390	62,842	77,733	89,044	101,743
Mitigation scenario	35,022	54,241	60,697	72,465	79,698	86,372
Emission reductions	0	149	2,145	5,268	9,346	15,371

Source: PRIEN, "Mitigación de gases de efecto invernadero. Chile, 1994-2020", report carried out for the CONAMA, Santiago, 1999.

In the LUCF sector, agricultural imports significantly influence greenhouse gas emissions. Therefore, two different scenarios with import rates of 30 % and 50 % were considered. Table 3 below shows a significant net removal of greenhouse gases for both 1994 and 2020, mainly due to the abandonment of managed land. However, the net removal of greenhouse gases is estimated to be from 6.4 % to 9 % lower in 2020 as compared to the totals from 1994. Fewer agricultural imports in 2020 would lead to an increase in greenhouse gas emissions mainly due to the reduction of overall surface area of native forests.

Table 3: Greenhouse gas emissions from LUCF activities in 1994 and 2020 according to the business-as-usual scenario (Gg CO₂ equivalent)

Activity	Emission in 1994	Projected in 2020 (30%)	Relative with respect 1994	Projected in 2020 (50%)	Relative with respect 1994
Forest	-1,900	-2,917	53.6%	-2,917	53.6%
Conversion of natural forests agricultural soils and	2,694	3,015	11.9%	2,739	1.7%
Conversion of natural into commercial	5,551	5,274	-5.0%	4,793	-13.7%
Extraction of trees natural	7,014	5,777	-17.6%	5,777	-17.6%
Abandonment of managed	-50,917	-44,315	-13.0%	-44,602	-12.4%
Combustion of forest	771	1,704	121.1%	1,705	121.2%
Forest	8,297	5,857	-29.4%	5,919	-28.7%
Urbanisatio	252	47	-81.4%	47	-81.4%
Total	-28,238	-25,572	-9.4%	-26,548	-6.0%

Source: First National Communication of Chile to the UNFCCC (CONAMA 1999)

In the mitigation scenario several measures to decrease emissions or increase the removal of greenhouse gases have been taken into consideration, including:

- ≠ Regular educational and training programmes, aimed at generating positive changes in the society's valuation of environmental patrimony
- ≠ Measures to preserve carbon stored in vegetal formations
- ≠ Measures to reduce direct CO₂ emissions deriving from fires, the burning of biomass and the preparation of lands
- ≠ Increasing the capture of CO₂ through the forestation of arid and semi-arid lands, forestation or reforestation of soils in the process of desertification and/or eroded lands, the recuperation of deteriorated meadowlands, and the increase of urban area density
- ≠ Increasing the offer of biomass through augmenting forestry plantations and by taking advantage of forest waste, and as indirect measures
- ≠ Decreasing the use of fossil fuels and synthetic agro-chemicals through better use of organic residues with improved recycling, substituting pesticides and increasing the cultivation of leguminous plants, and

Actions directed toward reducing methane emissions through the aerobic treatment of sewage, and the aerobic oxidation of solid residential wastes of an organic nature.

Table 4: Greenhouse gas emissions from LUCF activities in 1994 and 2020 according to the mitigation scenario (Gg CO₂ equivalent)

Activity	Emissions in 1994	Projected emissions in 2020 (30% importations)	Relative change with respect to 1994	Projected emissions in 2020 (50% importations)	Relative change with respect to 1994
Forest management	-1,900	-3,297	73.5%	-3,297	73.5%
Conversion of natural forests into agricultural soils and grasslands	2,694	2,256	-16.2%	2,051	-23.9%
Conversion of natural forests into commercial forests	5,551	3,190	-42.5%	2,901	-47.7%
Extraction of trees from natural forests	7,014	4,430	-36.8%	4,430	-36.8%
Abandonment of managed land	-50,917	-46,778	-8.1%	-47,124	-7.4%
Combustion of forest residuals	771	853	10.6%	864	12.1%
Forest fires	8,297	4,945	-40.4%	4,991	-39.8%
Urbanisation	252	43	-82.9%	43	-82.9%
Total	-28,238	-34,361	21.7%	-35,154	24.5%

Source: First National Communication of Chile to the UNFCCC (CONAMA 1999)

The results of the mitigation scenario in the LUCF sector are summarized in Table 4. In comparison with the business-as-usual scenario, the annual net removal of greenhouse gas emissions in 2020 is about one third, or 8.7 million tonnes of CO₂ equivalent, higher in the mitigation scenario. Likewise, the net removal of greenhouse gas emissions also increases by about 22-25 % with respect to 1994. The proposed measures to mitigate climate change will not impact the cultivated surface area, but would involve a significant expansion of the areas with forest species (about 20 %), which basically occur at the expense of the surface area with natural vegetation such as natural meadowlands and brushwood. Additionally, native forest would be better preserved.

The principal difference between the two scenarios, which respectively prefigure 30 % and 50 % rate of imports, is explained for exerting less demand on terrains to cultivate cereals, which would in turn invoke less pressure on the native forests and what is left of native vegetation, while causing less significant changes to agricultural land usage and forestry plantations.

5 Potential and benefits of greenhouse gas mitigation in the energy sector

5.1 The Chilean energy sector

The accelerated growth of the national economy over the last few years has been translated into an extraordinary expansion of the demand for primary energy. In effect, between 1986 and 2000, the demand for petroleum derivatives grew at an average annual rate of 5.9 %, and the demand for electricity by 8.2 %. It is foreseen that the demand for energy will continue along the trends of the last few years, given the elevated growth rate of industrial automobile parks, industrial development and the process of residential and commercial electrification. Nevertheless, energy intensity shows a certain tendency to decline as a result of the relative decrease in firewood consumption (decreasing from 25 % of the energy total to just 20 %), as well as a greater electrification of the economy. Table 5 illustrates the development of the energy sector from 1986 to 2000.

Table 5: Evolution of the GDP, energy consumption, electricity consumption, energy intensity and electricity intensity

Years	GDP (billion \$ ₁₉₈₆)	Energy consumption (TJ)	Electricity con- sumption (TJ)	Energy intensity (kJ/\$ ₁₉₈₆)	Electricity intensity (kJ/\$ ₁₉₈₆)
1986	3,140	345,065	43,693	110	14
1990	4,484	437,266	55,559	98	12
1996	7,305	657,204	96,774	90	13
2000	8,493	788,738	131,775	93	16

Sources: *Bulletin of the Central Bank and Yearly Balance of the National Commission on Energy.*

Note: *Provisional statistics of the GDP for 2000. Energy consumption in terms of energy balances is expressed in PCS in order to be compatible with the methodology used by the IPCC, PCI was employed for fuels.*

The primary energy consumption in Chile in 2000 is distributed in the following manner: 41 % petroleum, 23 % natural gas, 6 % hydro-electricity, 17 % firewood and 13 % coal. Total energy consumption is distributed according to sector as such: 24 % for transportation, 26 % for industry and mining, 19 % for residential, commercial and public sectors, and 31 % for electricity generation.

Four different electric systems exist in the country: the *Interconnected System of Norte Grande* (abbreviated *SING* in Spanish), the *Central Interconnected System* (*SIC* in Spanish), the *Electric System of Aysén* and the *Electric System of Magallanes*. Additionally, various isolated (self-producing) electricity-generating systems also exist. The *Central Interconnected System* (*SIC*) is the most important electricity grid, supplying approximately 93 % of the population and representing about 64 % of the available generation capacity in the entire country, of which 62.6 % is based on hydro-electricity. In contrast, the *SING* is mainly based on coal and gas power plants and is, therefore, equally important with respect to greenhouse gas emissions. The *SIC* and the *SING* both produce about 7 million tonnes of CO₂ emissions annually. On the demand side, the industrial and mining sectors, consuming approximately 67 % of total electricity demand, are the most important consumers.

Chile produces and imports coal, oil and natural gas. Recently, projects have gotten underway to import large quantities of natural gas from Argentina, which is fired in combined cycle power plants in industrial sites and also the residential sector. The import of natural gas was started in 1997. Today, five gas pipelines supply several combined cycle power plants.

5.2 Complementary environmental benefits

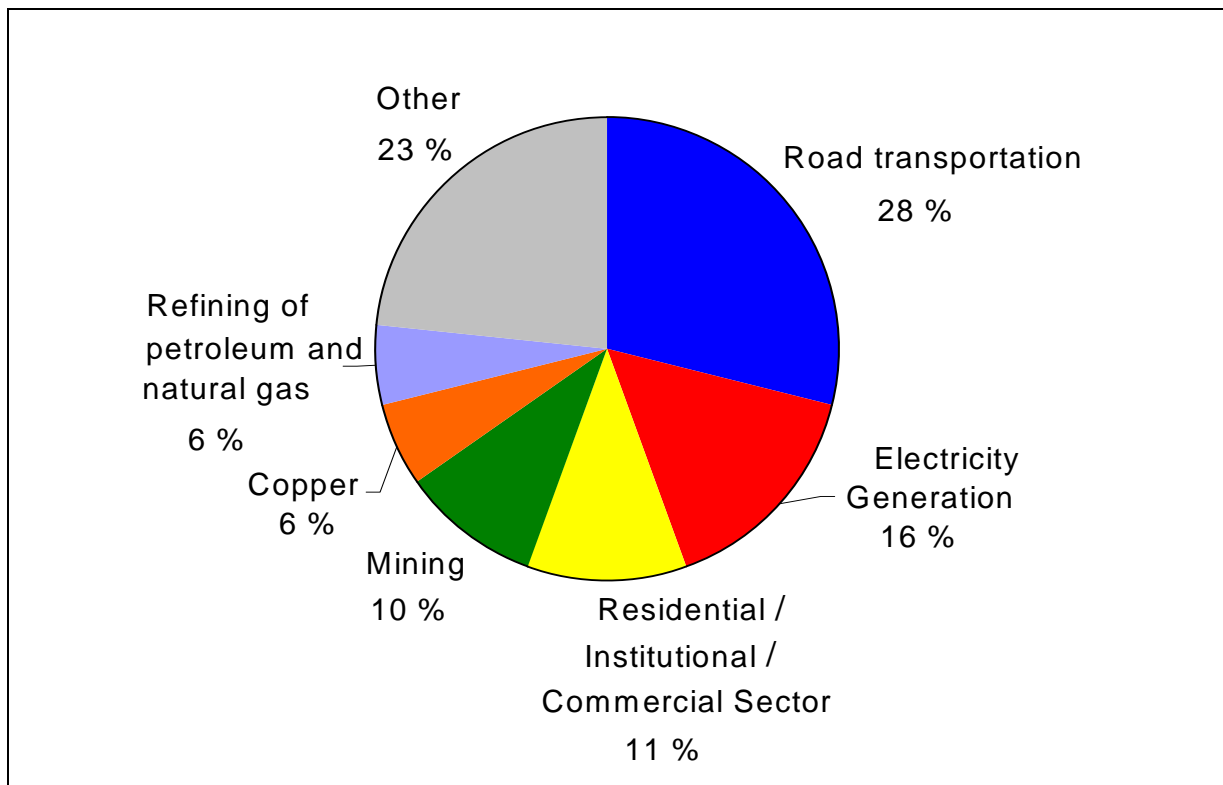
In contrast to the forestry sector, where the social and environmental impacts are of great importance, policies and measures to mitigate climate change in the energy sector will have fundamentally positive impacts in terms of pollution levels, first and foremost regarding the atmosphere.

In effect, the substitution of energy sources like the replacement of coal by natural gas or the development of hydro-electric generation displacing the generation from fossil fuels as well as the efficient use of energy, the introduction of renewable sources, instead of the conventional options or other measures stipulated by use of the CDM, will not only reduce GHG emissions, but also particulate matter, sulphur dioxide and nitrogen oxides. The emissions of the latter effect public health and contribute to the development of acid rain.

5.3 Areas of interest for the development of CDM projects

In Chile, there are several sub-sectors that appear particularly promising for CDM projects. A starting point for the identification of promising areas for CDM projects is the contribution of greenhouse gas emissions of the various sub-sectors, as illustrated in Figure 2.

Figure 2: Absolute and relative CO₂ emissions by sector in 1994



Source: PRIEN, "Inventario de Emisiones de Gases de Efecto Invernadero, Energía, Procesos Industriales y uso de solventes. Chile 1986-1998." Report elaborated by CONAMA, Santiago, December, 2000.

5.3.1 Road transportation

Figure 2 above shows that road transportation is the most important source of CO₂ emissions in Chile, representing 28 % of total CO₂ emissions. Therefore, many mitigation measures may be conducted in this sub-sector.

The Metropolitan Region (MR) suffers from the effects of severe atmospheric pollution, which in large part is caused by public and private transportation. As a result of this situation, beginning in the 1990's the national and regional governments began important efforts to reduce air pollution. Since 1997, as a result of an assessment of the *Plan of Prevention and Atmospheric Pollution Reduction of the Metropolitan Region*, a new pollution reduction plan for the Metropolitan Region for the period 2001-2010 is being taken into consideration. In the transportation sector, among other measures, it is foreseen that 2,700 buses will be retired because of their high pollution levels, that high-quality diesel (50 ppm of sulphur) for 5,000 buses will be introduced by 2004, and that 1,000 buses with low emissions will be incorporated.

One possible CDM project or programme could be the introduction of 1,000 new buses operating on natural gas instead of diesel fuel. Even though this may seem an interesting option, the available antecedents appear to suggest that the reduction of GHG emissions may not be significant, and that a project of this type could be better justified due to the mitigation of other atmospheric pollutants such as particulate matter and sulphur dioxide.

Another option may be the introduction of electric buses, or in the future buses with fuel cells, that would replace diesel buses. Greenhouse gas emissions may be reduced significantly, taking into account that electricity is largely produced by hydro-power plants in Chile.

5.3.2 Electricity generation

Electricity generation is the second largest source of greenhouse gases in Chile. Important mitigation measures include the replacement of power plants, energy efficiency improvements in coal-fired and hydro-power plants, the expansion of cogeneration and the use of renewable energy sources.

In general terms, thermal power generation in Chile is characterized by the recent introduction of very efficient combined cycle power plants fired with natural gas. Therefore, improvements are not expected in this area, although this does not presuppose the complete replacement of coal-fired plants, particularly in the SING zone, due to demands dealing with system stability. In coal-fired plants there is a significant potential to improve energy efficiency due to the fact that some plants currently have a relatively low energy efficiency, ranging from 30 % to 35 %. Consequently, the improvement of energy efficiency or the replacement of coal-fired power plants may be promising CDM projects.

In the case of hydroelectric generation, some very old units, which have a relative low performance due to the deterioration of the turbine vanes, are currently operating in the SIC. The replacement of turbines would increase energy efficiency and could replace electricity generation in fossil fuel based power plants elsewhere.

The recent incorporation of natural gas should favour the expansion of cogeneration in the country, which is currently restricted to the production of cellulose and some other industries. It is estimated that in hospitals, commercial installations as well as medium-sized industries, a potential exists, that according to conservative estimates, could respectively reach a capacity of 240 to 340 MW for the years 2010 to 2020.

There is no policy in the country that strongly promotes the use of renewable energies, which together with the low costs of electricity generation and an elevated coverage of the centralized systems leave little room for the important development of renewable energies, except in isolated rural areas. In Chile, wind energy and geo-thermal energy appear to be the most promising options for renewable energy sources. A wind power plant of 2 MW capacity is already in operation and a wind park is planned as a CDM project. Geo-thermal projects of 1,000 MW have been identified in the north as well as in the centre of the country.

5.3.3 Industrial and mining sectors

Of the total industrial CO₂ emissions, the most important sub-sectors are Copper, Cellulose and the Small and Medium Sized Industry and Mining. In the case of Cellulose, Small and Medium Sized Industry and Mining, the consumption of biomass is particularly important. Possible CDM projects include:

- €# Improvements in the efficiency of electricity consumption, particularly regarding motors and the internal distribution of electricity and, possibly, with respect to the use of fuel cells. Efficient electric motors would in many cases be a profitable option for industrial users, but are often not used due to several barriers. The massive introduction of more efficient motors could be promoted through a CDM program, which could in turn finance the differential costs between standard motors and motors with a high energy efficiency. The CDM program could include the replacement of existing inefficient motors with the introduction of new, more efficient motors;
- €# Improvements in the combustion process in boilers or ovens, in vapour transportation, and in heat usage as well as the fuel switch to natural gas in industrial and mining installations. According to the GHG inventory, approximately 3.6 million tonnes of CO₂ were emitted in 1994 by small and medium enterprises, which suggests that energy is probably used in a very inefficient manner. It is estimated that a program destined to introduce automatic combustion control technology, replace burners, isolate tubes that transport vapour and condensate, as well as introduce cost cutting mechanisms will permit important reductions of CO₂ emissions;

The increase of the penetration rate of natural gas in the industrial sector. A CDM programme could finance access to the gas grid for those industries whose current provisions are not attractive for the gas companies. The complementary financing granted by the CDM programme could positively modify the profitability of the fuel switch to natural gas.

Although the industrial and mining sectors are the most sensitive to price fluctuations, both sectors under-invest with respect to energy efficiency for reasons similar to those of other industries. Significant barriers include the lack of awareness and knowledge about mitigation options within the companies, as well as the fact that in most companies energy costs represent a reduced percentage of total expenditures and, therefore, do not constitute an incentive for identifying means to save on energy consumption.

5.3.4 Residential, commercial and public sectors

The residential, commercial and public sectors contribute about 11 % of the total greenhouse gas emissions in Chile. Possible measures to reduce greenhouse gas emissions include the introduction of efficient refrigeration systems; improvements in lighting efficiency; the introduction of more efficient appliances (for example washing machines in the residential sector); improvements in the thermal quality of buildings and the conversion of certain household equipment (water heaters, stoves and heaters) to the use of gas.

Such improvements in energy efficiency on the demand side may be carried out as part of larger CDM programmes that promote more efficient consumer behaviour through different incentives. For example, CDM programmes could cover part of the additional acquisition costs for more efficient equipment or promote other methods that could contribute to overcoming the significant barriers for a more efficient use of energy in this sector. A specific barrier in this sector is that the purchasers of equipment are often not the end-users of the equipment, who in the end have to pay energy-related costs. In the area of housing, for example, building contractors of flats do not often inhabit these flats in the end and – in the case of renting – the future users of the flats do not participate in the design of the flats. Furthermore, the designers of flats and buildings try to keep the cost low for market reasons, which in turn affects the quality of features like the thermal quality of the flat that cannot be detected by the future user.

Additionally, consumers tend to purchase appliances that have the lowest initial purchasing cost, without taking into consideration the operational and maintenance expenses throughout the lifetime of the equipment. Likewise, energy efficiency is mistakenly associated with the lack of comfort. Another problem is the reduced income of an elevated percentage of the population, which impedes them from acquiring equipment at a higher initial cost or replacing equipment that has higher operational costs. Consumers also lack credible information on the real costs, the performance and the lifetime of conventional and energy efficient equipment. Other problems include the lack of an adequate supply of energy efficient equipment and the slow rotation of domestic appliances.

6 Potential and benefits of greenhouse gas mitigation in the forestry sector

6.1 The Chilean forestry sector

Located between the Andean mountain range and the Pacific Ocean, Chile is characterized by the large and narrow extension of its land, which measures approximately 4,000 km in length and variably between 90 and 400 km in width. The climate is extremely variable, with very arid conditions exist in the extreme north of the country, semi-arid and sub-humid conditions in the centre and humid to very humid conditions in the south.

These physiographic and climatic characteristics contribute to creating wide zones of the country's lacking in vegetation, or whose use is only marginal for agricultural purposes. The most important categories of land usage include areas lacking in vegetation (representing 32.7 %), meadows and brushwood (27.4 %) and forests (20.5 %), most of which are native forests. Different levels of soil erosion affect about 45 % of the territory.

6.1.1 Native forests

Beginning in the nineteenth century and extending up until the 1970's, Chile's native forests were the target of large fires and other forms of destruction implemented in order to make the soils viable for agriculture and cattle-raising. Extensive areas of the country witnessed a change in land usage, going from forests to land extensions dedicated to farming and livestock, in spite of the fact that a large part of these soils presented serious limitations to these types of cultivation. This situation has resulted in a strong diminishment of the land's surface area covered with native forests, as well as the existence of large swaths of land with little or no vegetation, which are subject to grave processes of soil erosion, degradation and desertification. Beginning in 1970, a process was initiated to control the destruction of native vegetation. Today, the majority of land surfaces covered by native forests are found in the southern regions of the country.

6.1.2 Planted forests

Due to the severe erosion and degradation, the Chilean government has since adopted financial incentives to promote the forestation of these types of terrains. As a result, large areas (about 2 million ha) have been planted and replanted with introduced species over the past 30 years, primarily with *radiata pine* (*Pinus radiata*), but also with diverse species of *eucalyptus*.

6.1.3 Wood consumption as a combustible and industrial raw material

In Chile, timber is also important as fuel for the provision of energy and industrial raw material. The consumption of firewood for fuel combustion is estimated at the order of 11.3 million m³ per year, of which about two-thirds is obtained from forests and native brushwood.

Total timber consumption in industrial processes is more than 24.4 million solid m³, most of which derives from planted forests (about 94 %). Thus, although the native forests constitute 85 % of all Chilean forestry resources, the planted forests are the principal source of provisions for the forestry industry. Likewise, the consumption of timber for industrial use has multiplied seven times in the period from 1975 to 2000, while the consumption of firewood has only grown three times as much in the same time span.

6.1.4 Industrial timber production

Chile has been a sawnwood producing country since the beginning of the twentieth century, primarily by taking advantage of its native forests. Later, at the beginning of the 1950's, the timber industry incorporated the production of pulpwood, paper and cardboard, boards and panels and, in the 1990's, the massive production of wood chips. Just as in the consumption of industrial timber, 94 % of the production consists of exotic species from planted forests, primarily *radiata pine*, with only 6 % of the production obtained from native forests.

6.1.5 The forestry sector in the Chilean economy

Market liberalization in the middle of the 1970's, as well as the adoption of policies beginning in the 1980's that promoted timber activity, allowed the Chilean timber industry to gradually increase its contribution to the overall development of the national economy. In 2000, the contribution of the forestry sector to the Gross National Product (GNP) rose to around 2.7 %, whereas national industrial production maintained levels of almost 7 %. Pulpwood and paper production is the most important activity (about 53 %), followed by the industries that produce sawnwood, boards and panels (about 37 %). The forestry sector has primarily orientated its

development toward exportation, which with 13 % of total national exports is second only to the mining sector.

6.2 Criteria for the identification of forestation projects in Chile and areas of interest for the development of MDL projects in the energy sector

The following preliminary criteria, that have been identified for CDM projects in the forestry sector, maintain their foundations in the principals that guide the LULUCF activities in the Kyoto Protocol as well as the current Chilean forestry legislation, while at the same time also taking into consideration the criteria for sustainable national development:

- ≠# **Environmental criteria.** This includes the recuperation of eroded and deteriorated soils, as well as soils in the process of desertification, the protection of waterways and their sources, the use of adapted and wild forest species in the country that do not present environmental uncertainties, and the prevention of substitution of native forests.
- ≠# **Social criteria.** This includes the alleviation of rural poverty through activities that increase employment and worker training, the improvement of living conditions for small and medium-sized land owners in order to prevent rural emigration, as well as the improvement of living conditions of indigenous families and communities.
- ≠# **Economic criteria.** This includes the use of species with an economic value in order to strengthen income for the local population in the near future, the improvement of the economic situation of small and medium sized land owners, the use of national forestry incentives in order to increase the profitability of forestation, and to incorporate the largest number possible of land owners in order to take advantage of existing public and private institutional possibilities, especially the experience and infrastructure offered by the CONAF and the timber companies, in order to reduce the organizational, administrative and operational costs of the projects.

6.3 Identification of project types for the CDM

On the basis of these criteria, three different types of projects have been identified, which appear promising for the CDM in Chile:

1. Forestation in indigenous communities or in small, privately owned plots of land, in conjunction with the National Forestry Corporation (CONAF)
2. Associative forestation through sharing agreements or diverse levels of participation between small farmers and timber companies
3. Forestation in order to recuperate eroded and deteriorated soils, as well as those in the process of desertification, which could be carried out in any type and size of rural property.

6.3.1 Forestation of small farms

Beginning in 1990, the National Forestry Corporation (CONAF) began to develop diverse programmes designed to encourage forestation of already existing eroded and degraded soils in the plots of small farmers, in order to recuperate soils as well as to improve living conditions for the rural population. Nevertheless, the participation of the small farmers proved to be difficult, for a variety of reasons (see section 6.5 below). As a consequence, only a small share of forestation activities are carried out with small farmers. The proposed CDM project category aims to help overcome these barriers.

This type of forestation project has been selected as one of the most important, due to its direct and positive impacts on sustainable development in Chile. CDM projects in this area may, inter alia, reduce rural emigration, mitigate urban poverty levels, improve income levels and living conditions of the country side, increase the value of small farms through the recuperation of the most degraded soils, facilitate access to small farms by way of the road work required for forestation, and diversify agricultural production.

A possible CDM programme would be managed by CONAF, which would initially identify the relevant geographical and administrative areas. In a second step, CONAF would establish a process of information, promotion and selection of eligible farmers. Based on technical studies, the individual land holdings of the participating farmers would need to be declared as areas eligible for participation according to Chilean legislation. Finally, CONAF would also supervise and monitor the appropriate implementation of the forestry activities. In order to recuperate operational costs, CONAF would participate in a yet to be defined percentage of the sale of eventual certified removals that each forestation project would eventually produce on a regional level.

6.3.2 Associative Forestation

Associative Forestation involves cooperation between small farmers and timber companies, which would permit the forestation of vast areas of eroded or deteriorated land plots whose owners lack the technology and knowledge to recuperate them. Likewise, the timber companies can contribute with their experience and advanced technology, thereby assuring the quality and development of these plantations without this central part of their normal business operations since they are not actually buying the land. Likewise, the land will remain in the hands of the owners, who will continue to live off of the best plots.

This type of project is also expected to have important positive effects on Chile's sustainable development, similar to the Forestation of Small Farms.

The projects of the Associative Forestation (FAS) on small farms will be made through contracts between timber companies and the owners of the land, with CONAF limited to a mediating role. The owner will select and offer the adequate land for plantation, and use of the land will be granted to the company for the lapse of the rotation. The timber company will carry out the preparation of the land and accept all related costs as well as the planting of genetically modified plants, fertilisation, the control of thickets, management of the plantation and the provision of all necessary infrastructure for this operation. The wood products of the thinning process and the final harvest will be divided in equal or different percentages, which will be agreed upon in each contract between the owner and the company.

The timber company will act as executive and administrator of the MDL project, thus centralizing monitoring and verification activities of CO₂ removals. The property of the CER will be determined according to the characteristics of each agreement.

6.3.3 Forestation in deteriorated soils

This type of forestation project can be realized in any type and size of rural property, and it consists of plantations destined to recuperate eroded and deteriorated soils, or soils in the process of desertification. Properties will be considered eligible in the MDL by constituting the formation of new CO₂ drains in terrains that have been deforested and lack biomass, whose recuperation is very difficult without direct human intervention. Moreover, the simple existence of current forestry incentives is not a sufficient stimulus for landowners to reforest these terrains.

6.4 Suitable species for CDM projects and their characteristics

Species selection, which appears promising for CDM projects, has been carried out according to previous forestation experience in the country. Species are primarily selected that present a greater level of adaptation to extreme conditions, soils in diverse grades of deterioration and lands in the process of desertification. Secondly, those species are selected that have a high annual growth rate. Thirdly, those species that have a rotation cycle of more than 20 years, which leads to a more significant uptake of carbon, are selected. The suggested species for most circumstances is *radiata pine*, which in Chile is highly disseminated and developed in marginalized and deteriorated soils. The usual rotation period is 20 to 22 years. In the southern region, the suggested species is *Pseudotsuga menziesii* (*oregon pine*), which has a rotation cycle of about 30 years.

The carbon content for solid mass of dry or anhydrous commercial timber of *radiata* and *oregon pine* without bark was settled by using its specific weight, 0.43 tonne cubic metre (m³ssc), and considering a 50 % default carbon content in the wood.

To estimate all carbon accumulated both above and below the soil, a biomass expansion factor of 1.3 can be assumed for the above soil biomass with respect to the determined biomass in the stems, while the total above and below soil biomass is about 1.75 times the biomass of the stems. However, in determining the potential of CDM projects in section 7.2, a more conservative expansion factor of 1.5 is applied. These considerations are summarized in Table 6.

Table 6: Carbon content and CO₂ of the wood from radiata and oregon pine and expansion factor for total biomass

Dry or anhydrous density of wood	0.43 ton/m ³
Carbon content of anhydrous wood (factor suggested by the IPCC)	50 %
Carbon equivalent for m ³ of anhydrous wood	0.215 tC
CO ₂ equivalent for m ³ of anhydrous wood	0.788 tCO ₂
CO ₂ equivalent for measured m ³ , with an expansion factor of 1.5	1.182 tCO ₂

Source: Measurement of Carbon Uptake in Chilean Forests, Instituto Forestal and the Universidad Austral de Chile, 2001.

Note: The calculations take into consideration the measurement of commercial timber in stems; the biomass expansion factor includes tips, branches, foliage, stumps and roots.

6.5 Barriers for the implementation of forestation CDM projects in Chile

Barriers for the implementation of CDM projects exist above all for the forestation of small farms. Farmers usually have a low level of education and a strong agricultural tradition. They use traditional production techniques and have poor technical and commercial knowledge and little access to state-sponsored training systems. The small farmer is generally located in dry lands and mountain slopes, which have serious restrictions for the traditional agricultural crops of the region. Also, their properties average only about 50 hectares, and in many cases have legal limitations to land titles, which prohibits them from receiving credits from the Institute of Agricultural Development (INDAP), nor state or commercial banks, resulting in a lack of capital.

Therefore, small farmers hardly benefited from state incentives in the past. As a consequence, in 1998 Chilean legislation (DL 701) was modified in order to provide a preferential treatment for small farmers. Nevertheless, in practice this appears insufficiently attractive, since forestation rates of small farms are still quite low.

In the case of timber companies and large landowners, forestation rates today are similar to those during the 80's and the early 90's. However, Chilean legislation does not provide sufficient fiscal incentives for the forestation of territories suitable for forest. Prices for soils increased significantly in the 1990's and other Latin American countries have also started to promote forestation activities. Likewise, most large forest companies already have forestation projects underway that cover their needs for the next 20 years.

6.6 Complementary environmental and social benefits

In Chile, vast surfaces with bare soils suffer from partly irreversible processes of erosion and degradation, as well as desertification. These soils possess both sparse and scarce vegetal cover, dominated by herbs and shrubs that on the whole have either been introduced or are wild. These terrains have deteriorated to the point that agricultural activities are no longer profitable for traditional crops and especially for small farmers, who in many cases have

abandoned their lands, thus increasing the already existent rural poverty of the Chilean countryside.

Forestation of these terrains is practically the only activity that can lead to a productive recuperation of the soil, reduce the surface runoff of rainwater and avoid erosion. This contributes to a general improvement of the hydrological system and brings about more favourable conditions for wildlife.

Moreover, the CDM projects are expected to have important socio-economic benefits. Small farmers can increase their income, which also helps to mitigate the problems from migration to urban areas. Small farmers will also benefit from capacity building activities, which will enable them to increase their yields. Participatory systems of forest production may help to resolve existing conflicts between environmental and social non-governmental organizations and timber companies. In the Associative Forestation, a major advantage for the timber companies is that they extend their activities without acquiring new land, which often times results in rural depopulation. At the same time, timber companies show a social and environmental commitment.

7 Project Portfolio

In the following section, greenhouse gas mitigation potential and mitigation costs are assessed for a couple of possible CDM projects in Chile. Different approaches are taken for the energy and forestry sectors.

In the energy sector, the assessment is conducted for four reference prototype projects: a run-of-the-river hydro power plant, similar to the Chacabuquito project under implementation in Chile by the Prototype Carbon Fund; a wind powered farm, similar to the Calama project planned as an Activity Implemented Jointly under the Convention; an efficient lighting project; and a project to promote the diffusion of efficient motors. These projects have been selected according to data availability. Their main purpose is to illustrate methodologies for establishing base lines for projects in the energy sector with a potential use also in other projects. It is necessary to stress that these type of projects do not reflect the overall greenhouse gas mitigation potential in the energy sector in Chile. Other promising areas for CDM projects are identified in section 5.3 above.

In the forestry sector, three types of projects have been identified: Forestation in small properties, associative forestation and forestation on degraded soils. For each project type the overall potential CO₂ removal is estimated for plantation activities from 2003 until 2012. For this purpose, relevant forestation areas in Chile are divided into three macro-areas with similar characteristics. Project potential and mitigation costs are calculated separately for each macro-area and for each project type, resulting in a differentiation of nine virtual CDM projects, which cover the overall potential of CDM forestation projects in Chile.

In all the evaluations, the estimation of the marginal costs of reducing the equivalent to one tonne of CO₂ was made after taking into consideration the value of one tonne of CO₂ equivalent that reduced the net financial flow of the project to zero. Furthermore, an average return rate of 12 % is assumed, to reflect the capital expenditures for national enterprises.

7.1 Energy sector

The proposed projects for the energy sector generate electricity by way of renewable energy sources (wind and hydro-electric), or increase the efficiency of electricity usage. Baseline emissions are determined for all projects using a common baseline methodology as suggested by the OECD/IEA.³ The approach taken combines the effect of CDM projects on the operation of existing power plants (operational margin) and on the construction of new power

³ OECD/IEA (Organisation for Economic Co-operation and Development/International Energy Agency) 2002: Practical Baseline Recommendations for Greenhouse Gas Mitigation Projects in the Electric Power Sector. Sivan Kartha and Michael Lazarus SEI-Boston/Tellus Institute with Martina Bosi, International Energy Agency. Paris.

plants (build margin). In the case of the operational margin, hydro-power plants have not been considered, since they are the first power plants that are dispatched in the merit order and their operation can be assumed to be independent of the CDM project activity.⁴ Also, for the operational margin baseline, emission factors have been discounted by 10 % after the first seven years of project operation in order to reflect future efficiency improvements in Chilean power generation. The baseline emission factors result as the arithmetic average between the operational margin and the build margin approach.

Although four electricity systems exist in Chile, baseline emission factors are determined for the Interconnected System of Norte Grande (SING) and the Central Interconnected System (SIC), which together represent 94 % of total electricity generation. In the case of the efficient lighting project and the project to promote the diffusion of efficient motors, electricity consumption is reduced in both grids, and baseline emission factors are determined according to the relative consumption in each grid. Table 7 summarizes the resulting baseline emission factors for each project during the first seven years of operation.

Table 7: *Baseline emission factors in the energy sector*

CDM Project	Grid	Baseline Emission factor (ton CO ₂ /GWh)
Hydro power plant (Chacabuquito)	SIC	333.7
Wind power farm (Calama)	SING	586.5
Efficient lighting	SIC/SING	464.5
Efficient motors	SIC/SING	506.0

Source: *Own calculations*

The run-of-the-river hydro power plant is exemplified by the Chacabuquito project. The construction of a 26 MW run-of-the-river power plant in the Aconcagua river, about 100 km from Santiago de Chile, is a project currently being developed and implemented by the Chilean electricity supply company Hidroeléctrica Guardia Vieja S.A. and the Prototype Carbon Fund. A maximum crediting period of 21 years has been assumed. An environmental impact assessment has been conducted and environmental and socio-economic impacts are assessed to be relatively small. Nonetheless, data and assumptions used to carry out the evaluation of the reduction potential and mitigation cost of this type of project originate from our own elaboration.

The wind power farm is exemplified by a project that was originally foreseen as an AIJ project, and is located in the region of Calama in the North of Chile. The initiator, CODELCO, plans to install 50 turbines of 750 kW capacity, generating 111 to 148 GWh electricity per year. The technical lifetime of the project is assumed to be about 20 years. As in the previous case, data and assumptions used to carry out the evaluation of the reduction potential and mitigation cost of this type of project, originated from our own elaboration.

The proposed efficient lighting project involves the massive dissemination of compact fluorescent lamps (CFL's) in Chilean households during a five year period. The project lowers the acquisition costs for CFL's by subsidising the difference in purchase prices between CFL's and conventional lamps. These costs are refinanced by charging an additional cost to the electricity bill of the consumers. The program aims at reaching 70 % of Chilean households. The overall crediting period of the project is 9 years.

⁴ An exception to this standard are the exceptionally humid years, which are considered in the determination of the baseline emission factor by discounting the emission factor from the probability of humid years (4%).

The proposed project to promote the use of efficient motors should work in a similar manner. It addresses industrial consumers of electricity that need to purchase new motors. Industrial clients should be motivated to acquire more efficient motors by reducing the purchasing costs and by charging the cost difference to their electricity bill. The total crediting period of the project is 21 years.

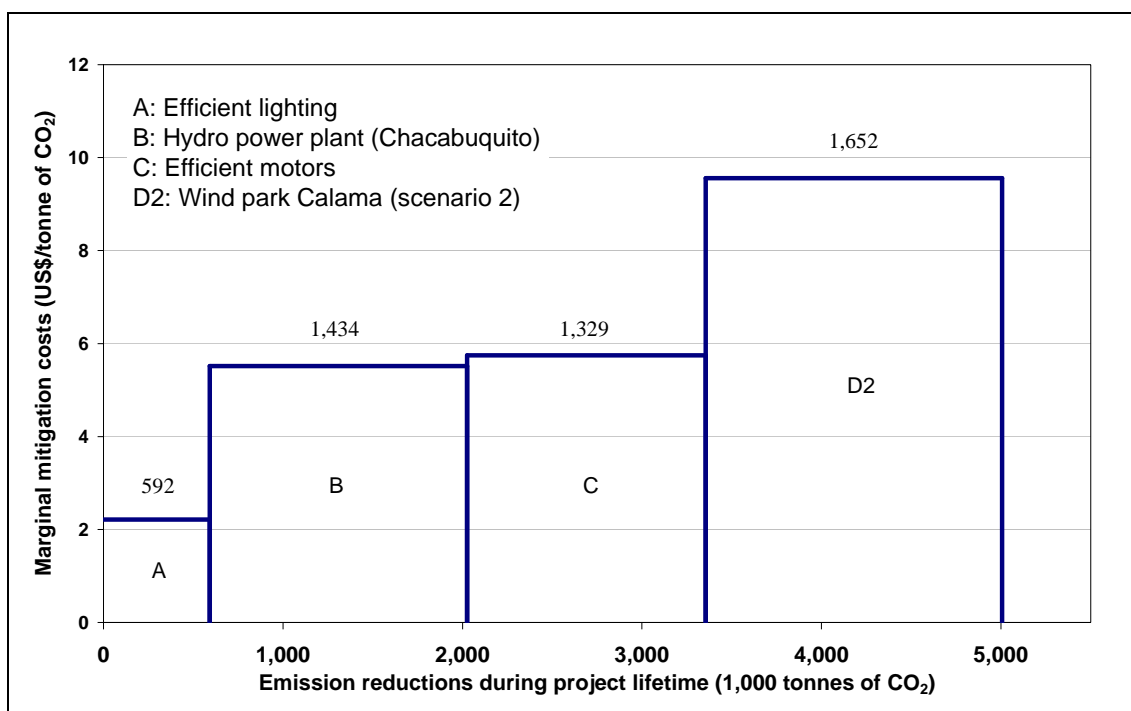
Table 8 summarizes the main results of the calculations for the four proposed CDM projects. In Figure 3 a marginal cost curve is constructed from this data.⁵

Table 8: Potential and mitigation costs of the proposed CDM projects in the energy sector

	Hydro Power Plant (Chacabuquito)	Wind farm (Calama) Scenario 1	Wind farm (Calama) Scenario 2	Efficient Lighting	Efficient Motors
Investment (US\$)	37,000,000	37,500,000	37,500,000	11,600,000	13,200,000
Internal Rate of Return without CDM	11.2%	5.6%	10.1%	10.5%	6.4%
Net Present Value without CDM (US\$)	-2,370,200	-13,960,400	-4,456,100	-96,500	-1,211,400
Net Present Value of overall transaction costs (US\$)	1,100,000	800,000	800,000	700,000	900,000
Reduced emissions (tonnes CO ₂)	1,433,600	1,245,400	1,651,500	591,900	1,329,200
Marginal mitigation costs (US\$/ton CO ₂)	5.5	34.3	9.6	2.2	5.7
Generated or reduced electricity (GWh)	3,360	2,229	2,957	1,513	2,983

Source: Own calculations

Figure 3: Marginal mitigation cost curve for the energy sector



Source: Own calculations

The four analysed projects have a total greenhouse gas mitigation potential of about 5 million tonnes during their whole crediting period. Marginal mitigation costs are below 10 USD\$ per

⁵ Assuming scenario 2 for the wind farm project.

tonne of CO₂.⁶ However, the overall emission reduction potential in Chile appears much larger with a potential of about 15 million tonnes per year.⁷

7.2 Forestry sector

The potential of CDM projects in the forestry sector is determined in several steps. As a first step, the potential surface area for CDM projects in Chile is estimated with the help of Chilean statistics. In a second step, baseline emissions and removals in the absence of the project are determined. In a third step, the carbon uptake of the plantations in the different areas is estimated. Based on this data, the potential and mitigation costs of CDM forestation projects are calculated.

7.2.1 Estimation of the potential surface for CDM forestation projects

The estimation for the potential surface area that is available for CDM forestation projects in Chile is made using Chilean statistics. For this purpose, the country is divided into three macro-areas, which cover 90 % of the forest plantations in Chile and which have similar natural conditions for the plantation of forests:

- # *Macro-area 1* comprises the official districts VI and VII, and has a surface of about 47,000 km². The general conditions are semi-arid and sub-humid, with precipitation varying between 600 and 900 mm yearly.
- # *Macro-area 2* comprises the official districts VIII, IX and X with a surface area of about 136,000 km². The conditions are sub-humid to humid, with precipitation from 900 to 2,000 mm in the southernmost regions.
- # *Macro-area 3* comprises the official district XI with a surface area of about 109,000 km². Precipitation varies between 1,800 and 2,200 mm annually.

It is assumed that forestation activities can only be conducted on meadowlands and brushwood. Table 9 shows the respective surface of these areas in the three defined macro-areas. The total surface of meadowlands and brushwood in the three macro-areas is about 5.8 million ha. However, taking into account that the conversion of meadowlands and brushwood is only attractive in regions that are lower than 800 metres above sea level, the potential area for forestation is only about 1.3 million hectares.

Table 9: *Potential of possible areas of forestation in Chile (hectares)*

	Forestable and (area below 800 m	Total grasslands brushwoo
Macro-area	209,867	1,407,18
Macro-area	952,466	3,100,39
Macro-area	159,753	1,299,88
Total	1,322,08	5,807,46

Source: *Calculations by FIA*

Another important factor for the estimation of the potential of CDM projects is the distribution of land tenure, since the proposed CDM activities particularly address small farmers. The distribution of land tenure according to Chilean Statistics is illustrated in Table 10. Less than

⁶ Assuming scenario 2 for the Calama wind farm. In scenario 1, with lower electricity generation due to poorer wind conditions, the marginal mitigation costs are estimated to be about 34 USD\$ per tonne of CO₂.

⁷ Study realized by PRIEN: "Mitigación de gases de efecto invernadero. Chile, 1994-2020", prepared for CONAMA, Santiago, 1999.

1 million ha of the total area of about 12.7 million ha belong to the 163,000 small farmers, whose average property size is 6 ha. It is assumed that only about 2 % of those owners would participate in a CDM programme due to the limited expanse of their properties. For the approximately 60,000 owners that have an average of 56 ha, it is assumed that about 30 % could participate in a CDM programme, planting about 30 % of their land. For medium-size and large holdings, it is assumed that about 2 % of the land would be destined to forestation activities. Consequently, the potential surface area for forestation would be approximately 475,000 hectares. Additionally, it is assumed that only about 50 % of this area will be available due to requirements of the modalities and procedures of the CDM.

Table 10: *Distribution of land tenure in Chile*

Category	Very small properties	Small properties	Medium-size properties	Large properties	Total
Size (ha)	0,5 - 20	20 - 200	200 - 500	> 500	
Number of owners	162,908	59,974	5,248	3,181	231,311
Total surface (ha)	967,772	3,330,270	1,605,537	6,753,913	12,657,492
Average surface per owner (ha)	6	56	306	2,123	55

Source: *Chilean Statistics*

In estimating the potential for CDM projects, it was assumed that plantations are carried out between 2003 and 2012. *Forestation on small farms* occurred at rates of about 8,000 ha annually during the last decade. According to information from the Agricultural Ministry, forestation rates could be increased to about 12,000 ha annually. Currently, no forestation activities occur as *Associative Forestation*, and it is assumed that about 2,000 ha could be forested annually under this scheme. For *forestation on degraded soils* an annual forestation rate of 6,500 ha is assumed. Over a period of ten years, from 2003 to 2012, this would result in an overall potential of 202,000 ha.⁸

7.2.2 Baseline emissions and removals

The potential removals of CO₂ through plantations are compared with a baseline scenario that reflects the removals and emissions of CO₂ that would occur in the absence of the plantations. In this regard, the carbon content of the existing vegetation that will be destroyed through the plantations particularly has to be taken into account. Carbon dioxide released from natural vegetation as a consequence of the plantations will consequently be subtracted from the carbon dioxide removed from the plantations.

Data on the above ground biomass content of the existing natural vegetation is based on research carried out by the *Instituto de Investigaciones Agropecuarias (INIA)*. In macro-areas one and two, the natural vegetation is dominated by the "espinal",⁹ which is found to be in a state of severe to very severe degradation. Measurements carried out by the INIA establish that in the espinal, the production of dry material above the surface of the herbaceous species and pastures of degraded meadowland is between 0.2 to 2 tonnes of dry material per hectare, with an average of one tonne. However, the pastures and annual herbs are not considered for the calculation of a baseline study, since they consist of a biomass that is formed and dies out each year, independent of the coverage of the natural shrubby stratum or the tree canopy of the plantation.

The shrubby stratum of the degraded espinal primarily consists of dispersed individual specimen of espino, with an average of 150 stems per hectare, within a range of 100 to 600 plants per hectare. In the sectors that experience a severe level of degradation, espino has been replaced with *Baccharis linearis* (Rosemary), which is a ligneous herb of scarce development, as well as other species less present. It is estimated that dry material per hectare of

⁸ In 2003, smaller forestation rates are assumed.

⁹ Some *Acacia caven*, a kind of thorny bush or little tree that grows in steppe conditions.

the degraded espinal can reach an average of four tonnes per hectare. The annual growth rate of dry material in the shrubby stratum does not surpass 0.15 tonnes per hectare per year.

In general, the timber companies develop plantations by digging individual holes for each plant, either in furrows or by subsoiling. In the preparing terrain for the plantation, all precautions are taken to avoid cutting the existing shrubby vegetation. In the majority of the cases, planting is done among the existing shrubs on the site, and any cutting or cleaning of natural vegetation is seldom carried out for the preparation of the terrain.

Under these circumstances, the baseline estimates for the forestation projects in macro-regions two and three is of an emission rate of 16 t CO₂ per hectare, considering a greater precipitation, which permits a greater development of the natural vegetation. For macro-region one, an emission rate of 15 t CO₂ per hectare is estimated, due to the more adverse climatic conditions, and because less biomass will be replaced through plantation.

7.2.3 Estimation of carbon uptake

The estimation of carbon uptake is effected through growth models that are commonly used in Chile. CO₂ uptake has been determined for the three macro-regions and for the three types of projects (forestation on small farms, associative forestation, forestation in degraded soils, see also section 6.3 above for more details). In order to provide conservative estimates, CO₂ uptake is only measured in ligneous organs of trees, without taking into account the organic carbon content of the soil. Likewise, it is assumed that the wood of a plantation is only measured following the fifth year of rotation. A maximum crediting period of 21 years is also assumed.

In the case of forestation on small farms, it is assumed that the growth rate of the forest will be more than 15 % less than that of the businesses, since they generally lack access to soil treatment techniques through subsoiling, technified systems of fertilisation and weed control as well as to genetically modified plants. The main characteristics and assumptions for the three macro-areas are summarized in Table 11.

Table 11: Total carbon uptake for different forestation activities

	Duration of the rotation cycle (years)	Effective duration of carbon uptake (years)	Annual carbon uptake (t CO ₂ /ha)	
			Forestation in small farms	Other forestation activities
Macro-area 1	20	19	226	268
Macro-area 2	22	21	366	435
Macro-area 3	30	21	203	244

Source: Calculations by FIA

In the table, one can see how macro-region 2 presents better conditions for the physical potential of CO₂ uptake due to a higher growth rate of *radiata pine*, especially in the types of Associative Forestation Projects (FAS) and of degraded soils (FSD), since they deal with technified forestation and genetically modified plants.

In order to determine the current annual increment or the real annual growth rate, CO₂ uptake will be measured on a yearly basis or in a periodic form, through internationally approved methods of forestry inventories, which measure commercial timber according to beneficial diameters of the wood.

7.2.4 Marginal mitigation costs

In calculating the marginal mitigation costs, all costs and income involved with the plantation of forests are considered over the whole rotation cycle. It is assumed that the price of timber

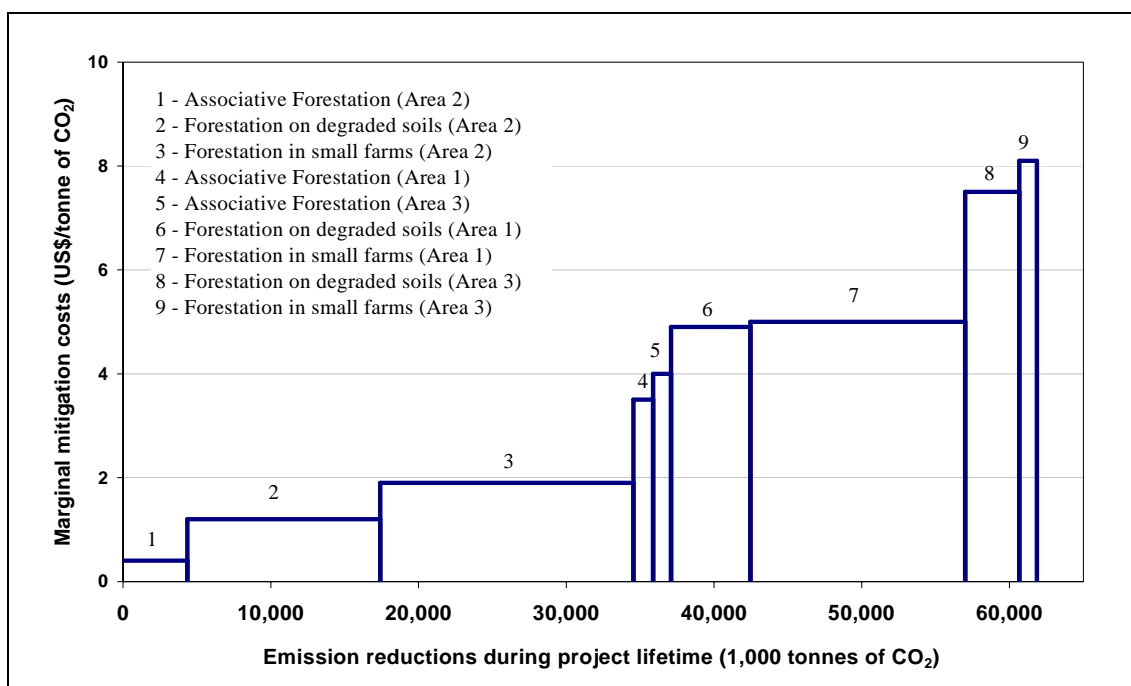
per cubic metre (m³) that can be obtained by small farmers will be less than 15 % of that which can be obtained by businesses or large landowners, since small farms lack the means of commercialisation and generally sell their production to intermediaries. In the three types of projects, the cost of reforestation was included in the same year as the harvest, since in all cases they were considered as forestation incentives whose dispositions oblige the landholder to reforest terrains declared as apt for purposes of forestation following any cutting or harvest. Neither the last year of rotation nor harvest year are included in the calculation and accounting of CO₂ uptake. The results of the calculation are summarized in Table 12. Figure 4 shows the marginal cost curve for the different project types in the different regions.

Table 12: Marginal mitigation costs and carbon removal of forestation projects

Project type	Macro-Area	Marginal mitigation costs (US\$/t CO ₂)	Carbon removal per hectare (t CO ₂ /ha)	Forested surface (1,000 ha)	Carbon removal during crediting period (1,000 t CO ₂)
Associative forestation	2	0.4	435	10.0	4,350
Forestation on degraded soils	2	1.2	435	30.0	13,050
Forestation in small farms	2	1.9	366	46.8	17,129
Associative forestation	1	3.5	268	5.0	1,340
Associative forestation	3	4	244	5.0	1,220
Forestation on degraded soils	1	4.9	268	20.0	5,360
Forestation in small farms	1	5	226	64.4	14,543
Forestation on degraded soils	3	7.5	244	15.0	3,660
Forestation in small farms	3	8.1	203	5.9	1,188
Total				202.0	61,839

Source: Calculations by FIA

Figure 4: Marginal mitigation costs in the forestry sector



Source: Calculations by FIA

As the table above reveals, the least marginal cost per t CO₂ is found in macro-region 2, which offers better conditions for the growth and development of *radiata pine*, with a rotation rate of 22 years. Macro-regions 1 and 3 present higher marginal costs due to lower levels of

growth of the plantations and, especially in macro-region 3, for having a rotation period of 30 years while the crediting period considered is only up to 21 years. therefore, one can conclude that in the time period from 2003 to 2012 MDL forestation projects could be carried out on a total of 202,000 hectares, of which a total uptake potential reaches about 62 million tonnes of CO₂, whereby verifiable CO₂ uptake could begin in 2008 and finish in 2032.

Finally, Table 13 shows how the possible uptake of carbon is distributed over time, considering the plantation of forests only from 2003 until 2012.

Table 13: Carbon uptake of forestation projects over time

Period	Capture of CO₂ (1,000 t CO₂)
2008-2012	2,840
2013-2017	12,563
2018-2022	21,362
2023-2027	18,501
2028-2032	6,573
Total	61,839

Source: Calculations by FIA