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Sustainability analysis of biofuels in Chile

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Abstract

The increasing worldwide energy demand and the dependence on imported oil in particular has lead to governments enhancing the energy security of its countries. There is a strong trend to look for fossil fuel substitutes; nowadays the leading option seems to be the biofuels. The high fossil fuel prices and the technological improvements are making biofuels more attractive. Moreover, the growing biofuels production capacity in the USA and the European orientation toward this source of energy, are signals for the small countries to join this initiative.

Chile is not the exception and belongs to this group; the government is leading the study of this alternative. The country is highly dependent on fossil fuel, being a 97% of them imported. So, biofuels represent a plausible alternative for diversifying the country's energy matrix. The Chilean conditions to grow energy crops are favorable, but not with the Brazilian comparative advantages (climate and land availability); the most evident drawback of Chile is the resources availability. However due to the country sustainable development aim, there are other factors that deserve attention. For this reason this document explores the biofuels project in Chile taking as a framework the concept of sustainable development.

The research analyzes the stakeholders' reasons that drive this initiative in Chile, which were obtained through interviews and public documents. In order to put the biofuel project in a sustainable development perspective a sustainability analysis of the biofuels' value chain was developed. Finally the stakeholders' drivers were assessed against an analytical framework based on the four dimensions of sustainable development.

The research found that there is a fragmented vision about biofuels among the stakeholders, lacking a systemic view. Base on the sustainability analysis it seems advisable that the country does a careful quantitative integrated assessment of the biofuels option in order to define the action path, which could be to orient the actions toward second generation biofuels. Given the topic complexity, this study has provided the understanding and the base to develop the next evaluation step, the modeling to asses quantitatively from a systems analysis point of view.

Keywords

Bio-fuels; Renewable energy; Sustainability.

List of Acronyms

Bx	Blend containing: x% biodiesel, (100-x)% diesel; e.g. B5: 5% biodiesel, 95% diesel
CNE	Comisión Nacional de Energía, Chile (National Comission of Energy).
CO	Carbon monoxide.
CO_2	Carbon dioxide.
CONAMA	Comisión Nacional del Medio Ambiente, Chile (National Environmental Comission).
CORFO	Corporación del Fomento de la Producción, Chile (Corporation of Production Foment).
CORMA	Corporación de la Madera, Chile (Corporation of Wood).
ENAP	Empresa Nacional del Petróleo, Chile (Oil National Company).
Ex	Blend containing: x% ethanol, (100-x)% gasoline; e.g. E5: 5% ethanol, 95% gasoline
FIA	Fundación para la Innovación Agraría (Foundation for the agricultural innovation).
GDP	Gross domestic product.
GHG	Green House Gases.
GMO	Genetically modified organism.
IEA	Internacional Energy Agency
IVA	Impuesto al valor agregado (Value added tax).
MUCECH	Movimiento Unitario Campesino, Chile (Peasant Unitary Movement).
NO_x	Nitrogen oxides
ODEPA	Oficina de Estudios y Políticas Agrarias, Chile (Office of Studies and Agricultural Policies).
OECD	Organization for Economic Co-operation and Development.
OLADE	Organización Latinoamericana de Energía (Energy's Organization Latinamerican).
PM	Particulate matter.
SEC	Superintendencia de Electricidad y Combustibles (Superintendency of Electricity and Fuels)
SNA	Sociedad Nacional de Agricultura, Chile (National Society of Agriculture).
SO_x	Sulfured compounds.
toe	Tons of oil equivalent.
UN	United Nations.
UNDP	United Nations Development Programme.
UTM	Unidad tributaria mensual (Monthly tax unit)
VOC	Volatile organic compounds

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Introduction

Governments worldwide are showing an increasing interest in the production and use of first generation biofuels (ethanol and biodiesel from crops). This source of energy, in comparison with fossil fuels, represents a desirable option to increase the energy security, improve economic conditions in some segments and reduce environmental impact (IEA, 2006). The benefits derived of biofuels are not always easily quantifiable, however research and practical experiences in different countries show that can be reached aspects as "improve energy security, reduce greenhouse gas and pollutant emissions, improve vehicle performance and enhance rural economic development" (IEA, 2004). Probably one of the most important drawbacks that biofuels face is the production cost; the majority of the governments give incentives or subsidies to compensate the higher cost in comparison with fossil fuels (IEA, 2006).

The economic globalization has lead to consider the global energy demand. According to the United Nations Development Programme, in 2001 79.4% of the primary world energy corresponded to fossil fuels, of which 44% was oil (UNDP, 2004, p30). Countries are being attracted to biofuels due to the trend of increasing fossil fuels prices based on limited resources (Hamelinck, 2005); this sector is now mature with a growing production capacity of ethanol and biodiesel (IEA, 2006). Brazil was the biggest ethanol producer until 2005 when production reached 8.17 [Mtoe] from sugar cane (IEA, 2006). USA headed the worldwide ethanol market in 2006, its production in 2005 was 7.50 [Mtoe] from corn and it is expected to double this quantity by 2008 (Hernández, 2006; IEA, 2006). Thus, Brazil and USA dominate the world ethanol production with a combined market share of 91% (IEA,2006).
The combination of these factors (prices, demand and reserve) and the cost reduction of biofuels production (by the technology and process improvement experimented during the last years) (IEA, 2006), are encouraging many countries to join the biofuels trend. Australia, India, Thailand are starting their biofuel projects, and others like Colombia and Costa Rica are working on the biofuels' legislation (OLADE, 2007). Argentina approved all the legislation one year ago and plans to produce 200 million liter of ethanol by 2010 (Cavieres, 2006).
Regarding biodiesel, its world production was almost tripled during the period 2000-2005 (IEA, 2006). Currently, Germany is the biggest producer with a production capacity is 3.6 million tons, equaling to 50% of the European capacity (Bockey, 2006).

Considering this worldwide scenario and the growing interest in Chile to incorporate biofuels into its energy matrix, it is interesting and contingent to investigate how this initiative fit in a country with limited agricultural resources and committed to guide its development in a sustainable way. Currently the country's authorities are working on policy elaboration that will guide the biofuels sector in Chile.
Chile's high energy import dependence in addition to biofuels contribution to agriculture appear to be the main factors to promote this new energy source; however they are not the only aspects concerning biofuels. There are important issues as energy balances, emissions, food market equilibrium and risks that deserve to be incorporated in the analysis as a country in order to asses the biofuels fitting with the Chilean sustainable development aim.

1. Relevant antecedents and Problem definition

The main primary energy source for Chile is crude oil, in 2003 it represented a 41% of the total primary energy; and a 97% of it was imported (CNE, 2005). The second source of primary energy is natural gas, 31% of total primary energy in 2003 and 76% was imported (CNE, 2005). The remaining primary energy comes from hydroelectricity, fuelwood and others (CNE, 2005). The energy coming from hydropower is directly affected by the climatic conditions (pluviometry). These circumstances put the country in a vulnerable position by the dependence on external sources and variation in climatic conditions. An example of this vulnerability has been the effects of the low reliance of the natural gas imported from Argentina, when in 2004 started disruptions in the supply affecting the country productivity and the social well being (AGN, 2005; CNE, 2006b; UNDP, 2004).

The present Chilean government in 2006 defined a Energy Security Policy that states actions in short and medium term to: "i) Diversify the country's energy matrix (in terms of both fuels and suppliers); ii) Achieve greater energy autonomy; and iii) Encourage the efficient and intelligent use of energy" (CNE, 2006b). Among the medium term actions, i) activities to promote non-traditional renewable sources of energy; and ii) a policy for the development of biofuels, creating a work team to study a proposal for liquid biofuels (ethanol and biodiesel) was included (CNE, 2006b). Nowadays two teams (Public-Public Committee[1] and a Public-Private Committee[2]) coordinated by the government are researching and evaluating the first generation biofuel possibilities for Chile. As a result of these signals, private companies have shown increasing interest in this new business.

The countries involved in the biofuels path have different resources availability and reasons to pursue this option, such as competitive advantages (e.g. production efficiency), comparative advantages (e.g. land available and climatic conditions), emission regulations, energy source diversification. Comparing the limited agricultural possibilities of Chile, 1.4 million hectares of annual or permanent crops and 0.4 million hectares of grassland (Odepa 1997, table 4,05) with Brasil, that used approximately 6 million hectares to grow sugarcane for ethanol producing in 2006 (Hernández, V., 2006); or with Argentina that in 2005 reached a grain (corn, wheat, soy, sunflower and others) production of 84 million ton in a surface of 26,5 million hectares (Almada, 2006); this lead to the questions *why should Chile, a small country in terms of agriculture capacities, join to biofuels from the production stage?, should Chile include biofuels as a new source of energy, considering the sustainable development aim?.*

These questions take special relevance in the *Chilean* case due to its declared *commitment with the sustainable development concept* coined by Brundtland in 1987. This concept implies the integration of all the aspects related with sustainability (the environment care, the social well being and the economic development). To answer these questions it is necessary to asses the project with a holistic view in order to know the net benefits or disadvantages of the whole system. An evaluation like this would be useful for the decision makers to compare biofuels with other energy

[1] Members of the Public-Public Committee: are bodies that belong to the public sector CONAMA, CORFO, CNE, FIA, ODEPA, Finance Ministry, Economy Ministry, SEC, ENAP.
[2] Members of the Public-Private Committee: representing the private business sector and NGO are the Sociedad Nacional de Agricultura (SNA, Nacional Society of Agriculture), la Corporación de la Madera (CORMA, Corporation of Wood), el Colegio de Ingenieros Agrónomos (Agronomy Engineering College), la Facultad de Agronomía de la Universidad de Chile (Agronomy Faculty of University of Chile), Iansa, Biodiesel América, el Movimiento Unitario Campesino (MUCECH, Peasant Unitary Movement) y Chile Sustentable (NGO). Representing the public sector are: CONAMA, CORFO, CNE, FIA y ODEPA

possibilities, in order to face the Chilean challenge of providing the energy required for its development.
The current energy conditions of Chile, characterized by high external dependency, are a key factor to look for new energy alternatives and resources. The international trend to join to biofuels tends to put to a sort of invisible pressure to get in biofuels market. Moreover, the fact that biofuels come from renewable resources give this source of energy a positive connotation that is not necessarily always correct according with the local conditions.
For these reasons and the Chilean commitment with sustainable development, it is indispensable to evaluate the biofuels option, based on the country resources and the dimensions of sustainability.

2. Research framework

2.1. Objective, research questions and thesis structure

The research objective is to analyze and critically assess the biofuels debate in Chile from a systematic point of view, through the following research questions:

1. *Could biofuels be sustainable in Chile?*
2. *What uncertainties are related with the biofuel market in Chile?*
   - Possibilities to reach the benefits expected and biofuels disadvantages.
3. *Why should Chile attempt to get in the liquid biofuel market? or Does the liquid biofuels represent a good opportunity to Chile?*
   - Drivers to get in the biofuels market.

To answer these questions the work is divided in four key areas:

- Mapping the energy situation of Chile and the options considered by the country to produce biofuels and the resources required.
- Identifying the stakeholder drivers that promote the liquid biofuels production in Chile.
- Analyzing the relation between the resources available and required.
- Determining the convenience of incorporating the liquid biofuel in Chile.

These key areas are split in four sections. The first part (chapter 3) will give an overview about energy and fuel in Chile. The purpose is to provide the basic information relative to energy, sources, consumption and policies that guide this sector in the country. Knowing these contextualizing aspects, the background exposes the situation regarding fuels; it means fuel market regulations, consumption and transport sector growth. With the previous antecedents will be identified the potential levels of biofuels demand.

The second part (chapter 4) aims to discover the drivers among the stakeholders to introduce the country in the liquid biofuels market. These drivers represent the benefits expected by every interest group by the incorporation of biofuels in the energy matrix of Chile.

The third part (chapter 5) will provide a sustainability analysis of biofuels in Chile. It will be scrutinized under the criteria of each one of the four pillars of sustainability (environmental, social, economic and institutional). This chapter will correspond to an integral assessment of the liquid biofuels introduction in Chile considering the whole biofuels chain.

The last part (chapter 6), based on the three previous ones, will discuss the convenience of the Chilean incursion in the biofuels initiative. This section will confront the stakeholders' drivers (the partial views of the interest groups that motivates the biofuel initiative) and the sustainability analysis to asses critically this opportunity for the country.

Finally, chapter 7 will give the conclusions and comments based on the previous discussion and information provided in this document, identifying a global position about the problem.

The Figure 1 provides a scheme to visualize the thesis structure.

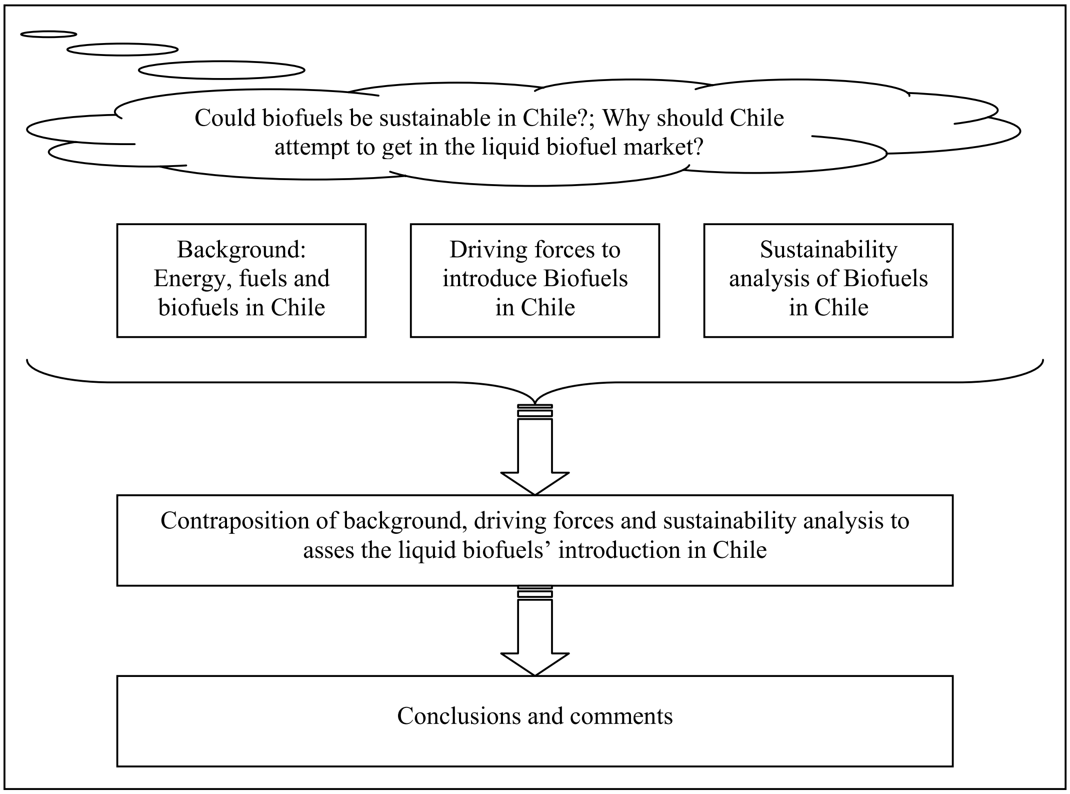

Figure 1: Thesis structure.

2.2. Methodology

The thesis formulation is a qualitative case study taking as analytical framework the concept of sustainable development defined by Brundtland in the report "Our common future" (UN, 1987). This sustainability approach requires a holistic view about the biofuels in Chile, in order to visualize the conditions that can affect the future, individually and by their interaction.

The thesis gathers knowledge, information and data from different sources. Books and papers have been reviewed to get knowledge regarding liquid biofuels, energy and sustainable development. Publications and information available on Internet in different formal organizations in Chile, such as National commission of energy (Comision Nacional de Energía, CNE), Finance Ministry (Ministerio de Hacienda), Office of studies and agricultural policies (Oficina de Estudios y Políticas Agrarias, ODEPA), Foundation for the agricultural innovation (Fundación para la Innovación Agraría; FIA), National institute of statistics (Instituto Nacional de Estadísticas, INE), among others, have been used to build the thesis background as well as the stakeholder approach.

The information and facts collected from these organizations, regarding fuel consumption, land productivity and biofuel yield, have been used to do estimations about the resources required to produce biofuels in Chile with different raw materials and from different authors' points of view.

A qualitative research can have three conceptions of objectivity: freedom from bias, intersubjective knowledge and reflecting the nature of the object (Kvale, 1996, p64).
The two first points are considered in the semi-structured interviews[3] conducted to eleven people[4] who represented of the stakeholders (in Chile) to know their perception about liquid biofuels, their interest and the sustainability approach on them. In order to avoid bias from personal appraisals and to obtain information from people with real knowledge about the biofuels, the interviewees were directly related with the biofuels project inside of their organization.
For the interviews it was chosen semi-structured interviews because this kind of interview allows following a conduction line with ad-hoc follow-through questions (Freebody, 2003, p133). Given that the vision obtained from the interviewees could not necessarily represent faithfully the organization's approach and that there is scarce official documentation, this information is crosschecked with declarations published on public communication media (news paper and magazine) to avoid bias. Dialogical intersubjectivity was procured going through the same interview structure.
The information obtained was the base to build in an objective way (from the author's perspective) the chapter four.

The third point, concerning objectivity in a qualitative research is fully applied in the sustainability analysis. It employs result of scientific information and field data available, so it is based on the natured of the object studied. The sustainability analysis is done under a systematic point of view, covering by the pillars of sustainability the aspects concerning with the biofuels value chain.

Finally the discussion takes the background, the driving forces and the sustainability analysis, to going on understanding the different perspectives regarding liquid biofuels in Chile, building a global vision and conclusions to answer the research questions.

2.3. Scope and Limitations

This thesis considers only the liquid biofuels for the transport sector, embracing just the first generation biofuels[5]. The focus is put on this biofuel branch due to the potential conflict for the country's development because of the limited resources available. Under this approach it does not make sense to include in this research bio-gas and second generation biofuels[6], because these ways of energy are obtained by processes that do not have the same apparent conflict with the agricultural food market.

Considering that the thesis assesses the biofuels in Chile under a sustainable development point of view, it will be used the concept defined by Brundtland, which correspond to the same formal guide of Chilean development. However, the study does not judge this definition of sustainable development and its suitability for the country.

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[3] The interview questions are available on annexes, page 50.
[4] The list of interviewees is available on page 49.
[5] First Generation Biofuels: Obtained from sugar crops (cane & beet) and grain crops (wheat, corn) through sugar/starch biochemical conversion; and from oil through transesterification.
[6] Second Generation Biofuels: Obtained from lignocellulosic material (crop residues, grasses, woody crops) through a biochemical conversion or a thermochemical conversion.

Regarding the stakeholders, the study does not consider consumers because this is a very atomized group; it was difficult to obtain a realistic view of their perceptions taking into account the time and resources available in Chile.

According to interviews done and studies available, the likely raw materials to produce biofuels in Chile are corn and wheat for ethanol and rapeseed for biodiesel. For this reason only these crops will be considered for the sustainability analysis.

Finally, traffic planning, public transport, mobility management and vehicle fuel are important approaches to improve the sustainability of the transport sector and the energy aspects linked to it. But, this work deals only with biofuels as a resource for the transport sector.

2.4. Theoretical framework

Around four decades after the first public signals of awareness about environmental damage and the identification of the human beings action as the cause, this awareness has gained momentum and now features in national and international public agendas under the concept of sustainable development.

Understanding sustainable development as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 1987, p54), it leads to incorporate the political will to look further, considering impacts in medium and long term. The *sustainable vision* is based on the interrelation between the *environmental* and *economic* problems with the *social* and the *institutional* or *political* factors (UN, 1987, p49). These four dimensions are considered as the pillars for the sustainable development. The harmonic consideration of the aspects linked to each of them will move the country for a sustainable path in long term.

Environmental sustainability is the ability to preserve the environmental conditions to have the capacity for continuance into the future (Ekins, 2000, p70; UN, 2003, p32). Economic sustainability corresponds to "condition of non-declining economic welfare projected" (Ekins, 2000, p70), it means to keep the growth possibilities. Social sustainability can be conceived as the society capacity "to maintain the means of wealth-creation, to reproduce itself and, a shared sense of social purpose to foster social integration and cohesion" (Ekins, 2000, p73). Institutional or political sustainability is linked with the governability and the conditions that guarantee the respect for the rights of human beings (UN, 2003 p32), through the participation in political decisions (Spangenberg, 2004).

The concept of sustainability is closely related with the resources exhaustibility and interlinkages ideas presented by Ekins. In his vision all the resources used for an economic activity are exhaustible, except solar radiation (Ekins, 2000, p31). Ekins (2000, p20) highlights that among the unsustainability symptoms it is easy to find reinforcing loops that exacerbate the negative effects.
"Sustainable development concept provides a framework for the integration of environment's policies and development's strategies" (UN, 1987, p50), this is a key aspect because it puts the focus to actions rather than results. Behind this rationale is the idea of anticipation (pro-active) instead the quest for the symptoms solution (re-action). However it does not mean that society should not take actions to remediate effects of past behaviors and trends.

Development in a sustainable way requires international contribution, since many effects lead to global problems. In that sense, a country should consider its impact over others countries' sustainable development possibilities (UN, 1987, p51, 59). At the national level, the government plays a fundamental role in this process for the pursuit of common well. Economic growth is one part of the sustainability concept, and usually it increases stress of the environmental resources and brings potential damages (UN, 1987, p50). In this sense policies and policy makers have the mission to assure that economic development does not leave aside the environmental, social and institutional aspects. Guiding a country and the society for a sustainable path is a continuous process under changing conditions

Making decisions under a sustainable development pathway "depend on the widespread support and involvement of an informed public and of NGOs, the scientific community and industry" (UN, 1987: p36). This path searches for stakeholders' rights consideration and for consensual and harmonic decisions, as a way to minimize the potential negative effects of them.

3. Background: Energy and Biofuels

Energy is recognized as an important factor in a country's development, having a direct impact over the quality of people's life and the development of industries (UN, 2003). The production, transport and use of energy can have big influence over the environment (UN, 2003). A country's growth (economic development) is directly related with its energy consumption (World Bank, 2000). Chilean gross domestic product (GDP) per capita in 2005 was 7,089 US$ (Ministerio de Hacienda, 2007). The GDP has been growing a rate of 3.5% annually during the last ten years (Banco Central, 2007), and the energy primary consumption at 5.7% (CNE, 2005).

3.1. Energy situation in Chile, past, present and future

3.1.1. Sources and consumption

Chile for the period 1990-2003 in average imported 57% of the total primary energy consumed, but importing a 45.5% of this primary energy in 1990 and a 69% in 2003 (detailed data 2003 in table 1) (CNE, 2005). In 2003 the energy imports corresponded to 58% crude oil, 31% natural gas and 11% coal; and the crude oil imports have had an average growth of 4.3% in the period 1990-2003 (CNE, 2005). According to CNE, Chile in 2003 had a primary gross energy consumption of 1,133,609 [P J], where a 78% correspond to fossil fuels and 22% to renewable resources.

Table 1: Primary energy consumption in Chile by source, year 2003

Primary Energy Source	Gross Consumption [Peta Joule]	Imports [%]
Crude Oil	468	97%
Natural Gas	312	76%
Coal	102	84%
Hydroelectricity	81	0%
Fuelwood and others	171	0%
Total	1,134	69%

Source: CNE, 2005.

Regarding the secondary energy sources, the highest consumption corresponds to oil derivates which represented in 2003 a share of 37% (see detail in table 2), and 64% of them were utilized by the transport sector (CNE, 2005).

Table 2: Distribution of secondary energy consumption in Chile by source, year 2003

Secondary Energy Source	Fraction, %
Oil derivates	37%
Combustible oil	6%
Diesel	15%
Gasoline	8%
Others	8%
Electricity	13%
Natural gas	25%
Wood	14%
Total	100%

Source: CNE, 2005.

During the period 1990-2003 the average consumption of secondary energy for transport, fuels (gasoline, diesel and aviation gasoline) and electricity, was 24% of the gross energy consumption (CNE, 2005). In figure 2 it is possible to see how the gross energy consumption increased steadily from 1990-2003 (blue bars in the chart), and how the total energy used in transport experienced a similar tendency (green bars in the chart). The energy consumption for road transport was approximately doubled in a 14-year period.

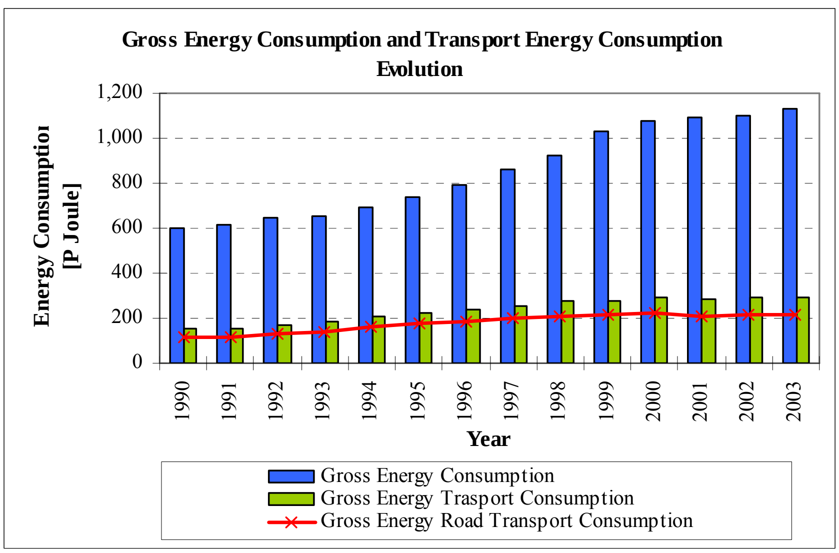

Figure 2: Gross energy consumption and evolution of the transport energy consumption.
Source: CNE, 2005.

3.1.2. National Development Policy and Energy policy

The Chilean growth path is based on the concept of sustainable development coined in Brundtland report (CONAMA, 2004). Then the country procures that the development be compatible with the economic growth, environment protection and social equity (Bachelet, 2005). This commitment as country has a wide impact given sustainability conditions that every single project should comply, including all the projects related with energy generation.

The political orientation and the action plan to face the future energy supply situation of Chile are clearly oriented to gain autonomy as a country in order to minimize the impacts of international market disturbances, as was announced by the President in the annual report on May 21st, 2006. In the speech she highlighted the importance of having an energy supply system strong enough to support the country growth, based on autonomy, independence, diversification and efficiency of the energy. Within the diversification aspect, she presented the alternative of "agro-energy" (Bachelet, 2006a). In addition, she announced a study carried out by the Energy and Agriculture Ministry together with ENAP (Empresa Nacional del Petróleo) for biofuels introduction in Chile (Bachelet, 2006b). These public announcements were formalized in the "Chile's Energy Security Policy", where the Chilean regulatory framework aims to foster the development of renewable energies, and in accordance to that the Government set as a target of 15% of the new energy supply (baseline 2006) should comes from non-conventional renewable resources by 2010(CNE, 2006b).

The national position in energy matter is clear, having the possibility of including biofuels in the country development under three premises: i) energy security; ii) productive and environmental sustainability to ensure the supply; and iii) production cost (ODEPA, 2007). At the same time, the biofuel policy for production from feedstock must be complementary with the strategy of food security and convert Chile into agriculture and food potency (ODEPA, 2007).

In order to create a proposal of biofuel policy, within the Chilean Agriculture Ministry a Bio-energy Unit was created. This unit coordinates the work of a Public-Private Committee in the biofuels evaluation stage by the government.

3.2. Fuel market actors and main regulations

In Chile the fuel industry is led by ENAP, a company created on June 19th 1950 by the state. According to a statement published by them, "its business is the exploration, production and commercialization of hydrocarbons and their derivatives, which it does both in Chile and abroad" (ENAP, 2007). Today ENAP process 220,000 barrels of oil per day, having a production that supplies around the 85% of the fuel consumed in the country (ENAP, 2007b).

So the fuel production in Chile is controlled by ENAP who sell gasoline and diesel to wholesalers (Shell, Esso, Copec, etc), who commercialize the products through the retailers to reach the consumers. Figure 3 illustrates the basic components in the fuels supply chain.

Until 1975 ENAP had the exclusivity to refine and produce fuels, but after this year a law was derogated allowing the production to any company that would comply with the general norms (Fuentes, Paredes and Vatter, 1994; ENAP, 2007b). In addition in 1978 the wholesalers were allowed to import crude oil and its by-products (gasoline, diesel, kerosene) (Fuentes, Paredes and Vatter, 1994; ENAP, 2007b).

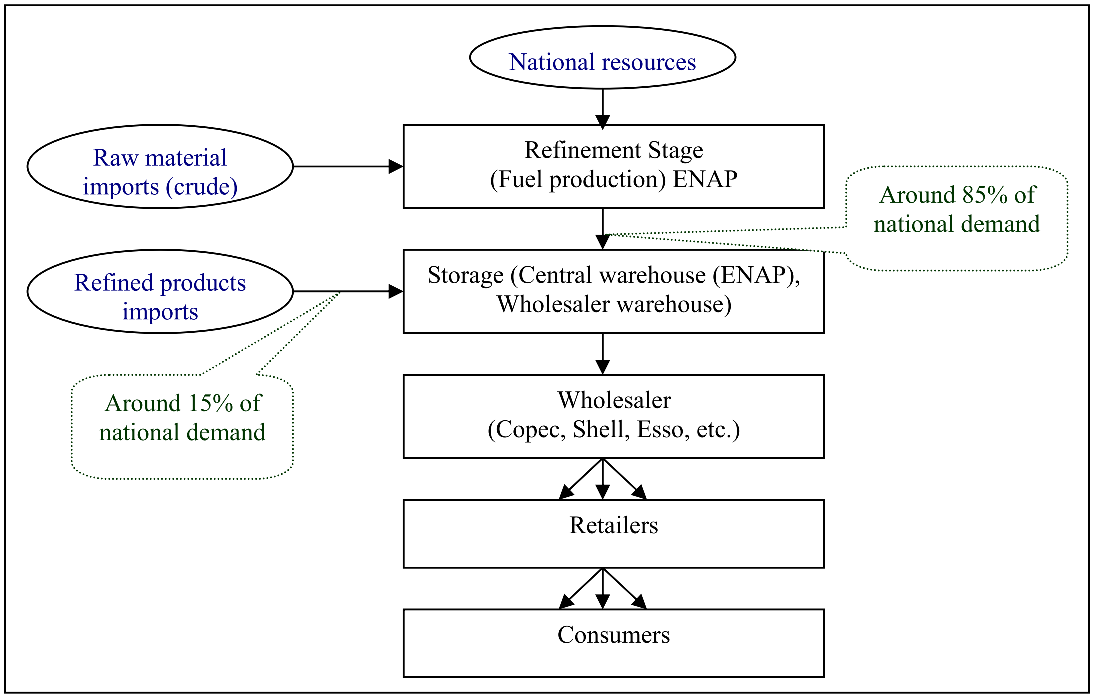

Figure 3: Combustible supply chain in the Chilean market

Source: Fuentes, Paredes and Vatter, 1994; ENAP, 2007b.

According to the law, fuels in Chile pay two taxes, one is the normal tax applied for any kind of product called IVA (Impuesto al valor agregado, value added tax). The other is a specific tax for fuels, gasoline pays 6 UTM/m^3 and diesel 1.5 UTM/m^3, (UTM, Unidad tributaria mensual, monthly tax unit[7]). So as result, in the price paid by the consumer, around a 53% of the value in gasoline are taxes and analogously a 34% for diesel (own calculates based on CNE, 2007).

3.3. Fuel consumption and transport sector growth

The amount of private vehicles in Chile in the last eight years has grown at 3% average annually; in 2005 the country had 2,444,571 private vehicles (INE, 2006a) and a total population of 16,267,278 inhabitants (INE, 2006d). While the number of vehicles for public transport and freight has stayed almost constant around 300,000 units (INE, 2006a). The energy consumed by the road transport sector (gasoline plus diesel) has had a growing trend during the period 1990-2004 (see figure 4), but diesel has experienced the faster growth rate, as a consequence of the people's preference for diesel vehicles; which increased 45,8% in the period 2002-2005 (INE, 2006b).

From figure 4 it is possible to observe too that the total consumption of fuel per capita presents an increasing trend, which is due to the fuel consumption rate is higher than population growth rate. The annual average growing rate of fuel consumption (diesel plus gasoline) for the period 1990-2004 was 4.6%, while the annual growth average of the country population for the same period was 1.4% (own calculations based on CNE 2005 and INE 2006d).

[7] UTM (monthly tax unit) is an economic index defined monthly, for the year 2006 it had an average value of 32.206 Chilean pesos, it means around 61 US$ (Banco Central, 2007b).

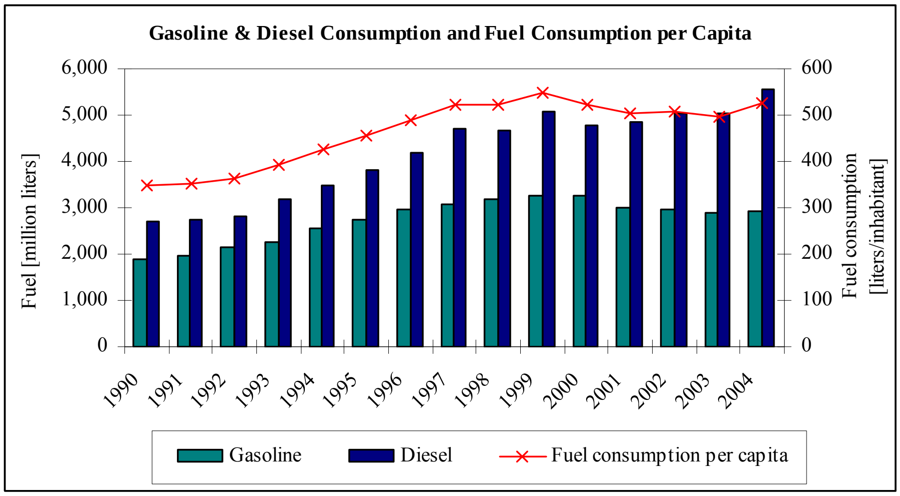

Figure 4: Gross gasoline and diesel consumption in Chile.
Source: CNE, 2005, INE 2006d.

According to CNE's projections liquid fuel consumption for transport will grow around 8,500 million liter of diesel and 3,700 million liter of gasoline by 2014 (CNE, 2006).

3.4. Biofuel options in Chile

Regarding how to produce biofuels in Chile, the potential crops to produce ethanol are wheat, corn, oat, sugar beets and potatoes; analogously to produce bio-diesel the options are rapeseed and sunflower (ODEPA, 2007). According to Iansa (a potential biofuel producer) officials, wheat and rapeseed are the most suitable crops to produce ethanol and biodiesel respectively (Interview, January 19th 2007); similar conclusions obtained ODEPA (Interview, January 26th 2007).

The raw materials selected to produce biofuels will depend on the policy adopted by the government, whether a decision is made to introduce ethanol or biodiesel or both as fuel. However, the raw materials selection for the biofuels production is important, because the different crop options present dissimilar water demand and require diverse soil characteristics and climatic conditions. Moreover they potentially have different impact on the environment.

3.5. Potential demand of biofuel and resources required

According to CNE's projections the gasoline and diesel consumption by 2010 will reach 3,326 and 7,626 million liters respectively (as cited in ODEPA, 2007). The introduction of biofuels in Chile could be mandatory, it means all the fuel expended would have a biofuel fraction, but this is not defined yet. The studies have assumed three possible scenarios, the incorporation of biofuel in a proportion of 2%, 5% and 10%, which would imply a demand of ethanol of 66.52, 166.3 and 332.6 million liters respectively by 2010. Analogously for the biodiesel case, the demand would be 152.52, 381.3 and 762.6 million liters (ODEPA, 2007).

If a 5% fraction of ethanol and biodiesel is adopted, by 2010 the land required to produce the raw material would be the indicated in table 3. This table provides the basic facts about land yield and raw material productiveness from different authors, which have been used to calculate the land required in each case (columns 5,7 and 9). Concerning this estimations, the range of land necessary vary from 7% to 34% per kind of crops.

Table 3: Acreage necessary by crop to supply 5% of biofuels in the fuel consumption in 2010.

Biofuel / Crop	Biofuel yield **[lt/ton]** Concawe[1]	Average Yields 2000-2006 **[ton/ha]** ODEPA[2]	Biofuel yield **[lt/ha]** Concawe; ODEPA[3]*	**Hectares to produce 5% Concawe; ODEPA***	Average biofuel yield **[lt/ha]** Cavieres	**Hectares to produce 5% Cavieres***	Biofuel production **[lt/ha]** ODEPA	**Hectares to produce 5% ODEPA***
Ethanol								
Corn	390.2	10.73	4,186,8	***39,720***	4,480	***37,121***	6,300	***26,397***
Wheat	355.7	4.4	1,586.4	***104,827***	1,683	***98,841***	1,800	***92,389***
Bio-diesel								
Rapeseed	429	3.49	1,494.2	***254,674***	na	na	1,400	***272,357***

Sources: CONCAWE 2002; ODEPA 2006; ODEPA 2007; Cavieres, 2006.
Notes:
1: Values correspond to the average yield.
2: Values correspond the average yield for crop obtained in a 6 years period in Chile. Data source: ODEPA, 2006.
3: Values correspond to the potential biofuel productivity in Chile considering the Chilean crops yield and the raw material yield to produce biofuel.
*: Values were calculated based on the previous columns data.

As indicated ODEPA, the studies until now show that biodiesel has more potential in Chile, in comparison with ethanol, due to the resources necessaries and available. This vision is shared by Iansa, who sees in rapeseed an excellent crop for rotation with sugar beet and different cereals; but sugar beet is already processed by the company[8] (Laroze, Irrazabal, Interviews January 26th and 19th 2007 respectively).

Chile currently imports wheat and corn to satisfy the national demand[9] (Cotrisa, 2007 a&b;Dowling, 2006). The extra demand of these crops to produce ethanol will generate a huge impact within the food market; the situation has already had an effect by the increasing international prices of these grains due to the ethanol production in United States[10] (Laroze, Irrazabal, Interviews January 26th and 19th 2007).

3.6. Biofuel market in South America

Today the biofuels sector is headed in South America by Brazil, which is the second largest producer of ethanol in the world, with vast experience in the ethanol from sugar cane industry given its early start in the 1970s. Brazil nowadays supports ethanol projects through raw material provision and know-how in many countries. An example is Venezuela (a powerful country in terms of fossil fuels production) that is planning to invest $90 million dollars to build 15 ethanol plants by 2010 that would be capable of producing 20 million barrels per year (Webber, 2006).

[8] Iansa: Company that base it business in sugar production from sugar beets, using a contract agriculture modality with the farmers.
[9] In 2006 wheat and corn imports reached respectively 949,647 ton and 1,742,205 ton. (Cotrisa, 2007, a&b).
[10] The corn price in Chile has raised 73% in the last year, Jan/06 – Jan/07 (El Mercurio, 2007b). The corn and wheat prices have raised a 26% and 45% respectively in Argentina, a reference market for Chilean buying (Meersohn, 2006).

Peru in 2003 created a law to promote the biofuels market, and later in 2005 to promote the investment to produce and commercialize them. Colombia in 2004 (Law 939), established the disposition to stimulate and commercialize biofuels from vegetal or animal origin (OLADE, 2007). Similarly, Bolivia in 2005 (Law 3207) established that in a period of 10 years biodiesel will be gradually blended with diesel until reach a 20% (B20), being the biodiesel free of the specific tax applied to the fossil fuels (OLADE, 2007).

Argentina approved the policy and regulation for biofuels, stating that from 2010 the gasoline will be a blend containing a 5% of ethanol (Webber, 2006). It is important to consider the potential capacity of Argentina as biofuels' producer; its forecast is exporting around 1.5 million tons per year (Webber, 2006). The biofuels' trade represents an attractive opportunity for Latin-American countries with suitable climatic conditions, land availability and cheap labour costs to export biofuels to Europe and USA. In this line under the IEA approach, the bioenergy trade with the time will became a commodity in the market (IEA, 2005).

4. Driving forces to get in the liquid biofuel market, the stakeholders' approach

Materializing a project as the biofuels, where there are stakeholders along the whole social and hierarchic structure, is not an easy task because there are different orientations and rationality behind every interest group to support or refuse the project. Joined to that in a democratic government system, as the Chilean case, which looks for consensus leads to discussion and evaluation of the project from every stakeholder's standpoint. For this reason the biofuels initiative is being evaluated by two committees, the "public-public" integrated for different governmental bodies related in some way with the project, and the "public-private" integrated for governmental bodies, but with the participation of NGO, farmers' representative, agronomist engineering board, companies interested in the business and agriculture societies.

4.1. Public Side

4.1.1. Governmental bodies

There are several governmental bodies related with biofuels project, some in strategic aspects and others in technical ones. Within the firsts it is possible to classify, the CNE, the Agriculture Ministry through ODEPA and FIA, and the Finance Ministry. The second group consists of the Economy Ministry through the SEC, the Transport Ministry and CONAMA.

It is important to know that, the initiative of studying a policy about biofuels in Chile arose from the Presidency as an action within the Chile's Energy Security Policy to *diversify the energy matrix and gain more autonomy*, it means heading to "energy security". From the interviews conducted, it is possible to affirm that this conceptualization of the biofuels project is present in all the governmental bodies, even though every body shows different nuances.

National Commission of Energy's (CNE) view

The CNE, through its Hydrocarbons Area Chief, remarks the energy importance as the engine of the economy and its influence over people quality of life, thus highlighting the strategic importance of energy; the government's aim is to *diversify the energy matrix following a "friendly environmental path"* (Ruiz, Interview, January 12th 2007). In a broad scope, biofuels are seen as a *"product available" in the world market, a situation that leads to create a normative* regarding biofuels use. Besides, it is believed that the biofuels incorporation to the market *will bring a feeling of modernity to the society* (Ruiz, Interview, January 12th 2007).
For this public repartition is clear that biofuels contribution to the total net demand of fuels is quite low, due to the limited resources available and the unfavorable climatic conditions to grow cheapest and more efficient crops as sugar cane to produce ethanol (Ruiz as cited in Dowling, 2006; Interview, January 12th 2007).

Office of Studies and Agricultural Policies' (ODEPA) view

ODEPA sees this initiative as a *challenge due to the limited agriculture land existing in the country* (1.4 million hectares with annual and permanent crops; 0.4 million hectares of planted grassland (ODEPA, 1997, table 4,02)). But at the same time it represents a big opportunity to give a *new dash to the depressed traditional agriculture*, which for example today is decreasing the quantity of cultivated land (Laroze, Interview, January 26th 2007).

Chile due to its isolation characteristic by its natural limits, the Pacific Ocean and the Andes Mountain, has been favored in terms of low plague proliferation benefiting the agriculture standards. A fact that joined to the professional capacities, the economic and institutions stability give a good opportunity to exploit its agricultural possibilities (Irarrazabal, Interview January 19th 2007; Ministerio de Agricultura, 2000). The present government has defined five axis to guide the agriculture, food and forestry policy: i.) *consolidating Chile as agriculture and food potency*, ii) *generating an inclusive development, diminishing the gaps in the rural sector*, iii) modernizing the public institutions, iv) *contributing to wide and diversify the energy matrix, promoting the energy generation from renewable sources*, and v) promoting the sustainable use of resources and biodiversity protection (Ministerio de Agricultura, 2000). Then for ODEPA and FIA, the points i), iv) and v) represent axis that should be kept in equilibrium with the biofuels development.

For the Agriculture Ministry, biofuels can be developed in the country *taking advantage of the soils with less opportunity cost*, and introducing the biofuels in an incremental way. *The initiative should impulse the small farmers agriculture*, being oriented with some incentives to avoid land concentration and industry vertical integration (Laroze, Interview January 26th 2007). Problems derived from water, pesticides and fertilizers use are not identified as relevant, because water demand will stay stable (by the change of crops) and fertilizers and pesticides use is controlled for the farmers in order to maximize the productivity but caring about the land capacity (Laroze, Interview January 26th 2007).

Finance Ministry's view

From the Finance Ministry's perspective, biofuels are understood as an energy diversification option, and represent a kind of *"insurance to be more protected in relation to external fluctuations in the fossil fuel market"* (Noe, Interview January 17th 2007). In November 2006, this Ministry announced a tax exemption for biofuels (Ministerio de Hacienda, 2006), being the first public incentive for this renewable source of energy. However as said by Noe (2007), the Ministry *is not in* *favor of any other direct economic incentive, because it does not make sense to put the resources in something that the country is not able to do "well" or efficiently*. The incentives should not produce distortions in the agriculture market, so it is better if the country puts effort in more productive areas (Noe, Interview January 17th 2007).

National Commission of the Environment's (CONAMA) view

In a broad perspective, CONAMA is providing information and conducting studies to organizations which are evaluating the biofuels initiative, and it is caring the inclusion of the relevant environmental aspects in the analysis that is been followed (Farías, Interview January 22th 2007).

According to CONAMA, besides energy diversification and agriculture empowerment, the biofuels are seen as an *opportunity to decrease the contamination in the Metropolitan Region* by the particulate material diminishing (Farías, Interview January 22th 2007). Based on the national standards this region is considered a saturated zone (Farías, Interview January 22th 2007), this situation should lead to evaluate the vehicles emissions which burn biofuels or blends carefully. In the emissions debate, biofuels have another benefit, the *potential of diminishing CO_2 emissions*, but at the same time *it represent a risk because higher emissions of aldehydes in ethanol* (Farías, Interview January 22th 2007).

Superintendency of Electricity and Fuels (SEC) and Transport Ministry view

Other governmental bodies as SEC and the Transport Ministry, have a technical approach towards biofuels. They are studying the product quality specifications, blend emissions and limits, security aspects in production, storage and distribution. At present they do not have a defined position about biofuels, but they know that the project implementation will bring potential new activities in their repartitions.

Finally it is important to highlight that all interviewed people in governmental bodies indicated that even though there are possibilities to create a first generation biofuel market in Chile supported by national production, they recognize this *stage as a learning process to be "ready" for the second generation's biofuels*. So this stage could be distinguished as a strategic step more than substantial contribution to the energy matrix.

4.1.2. Fuel producer

The main national producer and provider of fuels, ENAP, evaluates the projects as every private company, where the purpose is to maximize the benefits complying with all regulations and conditions stated by the Chilean law; ENAP takes no responsibility concerning the social benefits' maximization, this role belongs to the government (Barría, Interview January 18th 2007).

For ENAP, the biofuels market represents an option that should be carefully studied at the national level. From a study conducted in alliance with Iansa, it was determined that ethanol does not represent a good option, biodiesel has more potential (Barría&Guerrero, Irarrazabal, Interviews January 18th and 19th 2007).

In matter of product quality, they indicated that fossil fuels quality nowadays is quite good (Ferrando, Barría&Guerrero, Interviews January 9th and 18th 2007), for this reason biofuels should have high standards in order to keep the final product quality in the potential blends (gasoline-ethanol, diesel-biodiesel). Considering the vast experience of ENAP in the fuels business, the company is *aware of the distribution problems* of biofuels in the market for two reasons, i) currently the distribution is through oil pipes, and this would not be possible for the ethanol, and ii) knowing the geography of Chile, distribution is an important issue (Guerrero, Interview January 18th 2007).

In addition to other organizations, ENAP pointed out the relevance for the country to enter the market of the first generation biofuels, in order to *gain the knowledge and experience to face a second generation* in better conditions (Barría and Guerrero, Interview January 18th 2007).

Recently ENAP manifested publicly, through its CEO, that the company is not going to enter into biofuels production, but the it could act as a big wholesaler to make blends and later sell them (El Mercurio, 2007c).

4.2. Private Side

4.2.1. Raw material producers

The farmers and the agricultural grain market are witnessing increases in the prices of cereals. In Chile the corn scenario had change dramatically in comparison with past years; prices are making corn more profitable for the farmers (El Mercurio, 2007b). Agriculture products always present cycles (in production and prices) due to the global production changes and the climatic conditions effects; however the circumstances today seem different. The impact by the ethanol production in the United States (USA) from corn (60 million ton of corn in 2006 (El Mercurio, 2007b)) would lead structural changes in the corn market. As result of this tendency the *farmers' expectations are growing.*

According to Serrano (President, Consorcio agrícola del sur), the interest for corn will compete with other crops (because the limited land available in Chile), especially those which are irrigation intensive such as the sugar beet (as cited in El Mercurio, 2007b). This situation would threaten the future of some sugar factories that are producing at minimum capacity due to lack of raw material, so it *puts in risk the availability of others crops option for the future*, manifested Jorge Guzman (President, National federation of sugar beet producers) (as cited in El Mercurio, 2007b). In a similar situation was rapeseed which almost disappeared from the Chilean fields in 2002[11] due to the tax removal for the food-oil market in South America (by Mercosur agreement). This crop is increasing thanks to its recent uses in salmon food, a growing industry in the south of Chile that today is the second world producer of farmed salmon (Salmon Chile, 2006).

4.2.2. Potential liquid biofuel producer

For one of the companies interested in the biofuels production, Iansa, an *excellent opportunity to diversify their business has opened* (satisfying the owners request), *contributing to the society with the environmental and social externalities* of the biofuels production and consumption, and taking advantage of its expertise and experience of working with small-scale producers. Regarding this point, they heighten the crop yields under a contract modality by the support given to the farmers (Irarrazabal, Interview January 19th 2007).

ODEPA and Iansa agree that the yearly crop agriculture is having a bad period, the trend indicates that some farmers just let grass grow to feed animals, because crops do not represent an economic incentive (Irarrazabal & Laroze, Interviews January 19th &26th 2007). Under this perspective they believe that *biofuels can help to revitalize the agriculture*, an opinion that is shared by von Baer

[11] Rapeseed plantation reached the 61,000 ha in 1989, and in 2002 the fall to 750 ha. (ODEPA, 2006).

who created a company to provide rapeseed oil for the food salmon industry, and would be one of the potential biodiesel producers (as cited in El Mercurio, 2007a).
For Iansa (2007) the biofuels starting point is through biodiesel production, because ethanol production will alter the grain market that currently is not able to support the national demand. The company argues that an effort to reach 100.000 hectares of rapeseed is possible and will not produce distortion in the food market as would be the grains' case (Irarrazabal, Interview January 19th 2007).

Iansa considers the *prioritization of the objectives about biofuels announced by the President of Chile to be highly relevant,* i) diversify the energy matrix, ii) over a sustainable base, and iii) at good cost. So, for the company this is a key signal that gives the incentive to get into this business, even though the costs are slightly higher compared to fossil fuels. This stakeholder believes it is necessary some economic incentives (besides the fuel tax exemption) along the production chain, because based on the national reality is difficult to get biodiesel prices lower than fossil fuels (at current values). In the same line a basic condition to get in this business is that biofuel consumption be compulsory, it means to have ensured demand (Irarrazabal, Interview January 19th 2007).

As other stakeholders, Iansa sees in this new market a key step for the second generation biofuels, it is believed that is not possible to have a second generation of biofuels without experience in the first generation biofuel technology (Irarrazabal, Interview January 19th 2007). Besides, the development of first generation will be a powerful signal for forestry companies in the medium term, which could join the second generation, where Chile has the potential of using any kind of cellulosic biomass and agriculture waste (Irarrazabal, Interview January 19th 2007).

Regarding operative aspects like water demand, problems are not expected, nor for the intensity of fertilizer use (Irarrazabal, Interview January 19th 2007).
In the controversial topic of GMO, this stakeholder believes that in Chile there is a double standard about GMO, because the country produces GMO seeds only for exports but it is prohibited growing, even though Chile can import agriculture products obtained from transgenic seeds. The company considers that if the products coming from GMO seeds are not going to use for human consumption there is no risk (Irarrazabal, Interview January 19th 2007).

Finally, this stakeholder remarks that Chile's opportunity to buy technology and know how to produce biofuels from developed countries that have similar climatic and agricultural conditions and today are the biggest producer of ethanol and biodiesel (USA&Germany) (Irarrazabal, Interview January 19th 2007).

4.2.3. Retailers

According to Ferrando (2007), the lead wholesaler in Chile (Copec) and its net of distribution to consumers through its own service station and retail, the biofuels represent a *new business opportunity*. If biofuels are introduced in the Chilean market, Copec will be the first to supply the product to the consumers, on the understanding that its business gives a good service (through fossil fuel or biofuel) (Ferrando, Interview January 9th 2007).

4.3. Summary of driving forces and drawbacks identified

The drivers to incorporate biofuels into the energy matrix, identified from the stakeholders, aim primarily to strengthen the energy supply of Chile. A variety of parallel benefits are recognized from this initiative, which are highly desirable by the Government because they help to reach aims in social and economic areas.

The next table summarized the driving forces identified.

Table 4: Driving forces to incorporate biofuels in the energy matrix of Chile.

Driving force	***Sector***
Diversifying the energy matrix and gain autonomy (energy security).	Public
It is suitable to have the normative for a product available in the world market.	Public
Bringing to the society the feeling of modernity.	Public
Impulsing the small farmers' agriculture. Reactivating a depressed agriculture, increasing farmers expectative.	Public-Private
Having an "insurance" to protect the country against growing fossil fuel prices.	Public
Decreasing the air contamination (for PM) in the Metropolitan Region.	Public
Potential diminishing in CO_2 emissions.	Public
Learning process anticipating 2nd generation biofuels.	Public-Private
New business opportunity.	Private
Prioritization of biofuels objectives given by the Republic President, considering the cost after energy diversification over a sustainable path.	Private

Source: Own elaboration, based on interviews responses and opinions expressed in public media discussed in 4.1-4.2.

Table 5 summarizes the stakeholders' awareness, identifying the drawbacks and limitations regarding biofuels production and use in Chile.

Table 5: Drawbacks and limitations of incorporating biofuels in the energy matrix of Chile.

Drawback or limitation	***Sector***
Limited and relative small arable land for agriculture.	Public-Private
Climatic conditions are not suitable for more efficient crops for biofuel production.	Public-Private
Degree of competition with aim of "Chile: agriculture and food potency"	Public
Currents grain import; extra demand will impact downstream food markets.	Public-Private
Investment in a potential inefficient industry.	Public
Risk of increasing contaminant air emissions (by new substances).	Public
Complexity of the distribution logistic net.	Public
Risk of crops concentration, damaging other industries and reducing future possibilities.	Private

Source: Own elaboration, based on interviews responses and opinions expressed in public media discussed in 4.1-4.2.

The stakeholders' vision about biofuels is fragmentized according to their own interest areas. But sustainable development leads to the unified vision, because the sum of the parts is not necessarily equivalent to the whole. Taking the sustainable development vision that is based on four dimensions (economic, environmental, social and institutional) and the drivers and drawbacks pointed out individually by the stakeholders (summarized in tables 4 and 5), it was constructed the Figure 4. It represents the stakeholders' particular approach organized under a holistic view to know if there is a gap between the biofuels project evaluation done by them and the sustainability approach (next chapter).

Figure 4 shows the stakeholders' drivers that motivate the biofuels project within the oval; they are linked to the sustainability pillar where they would have a positive effect. Surrounding the oval are the drawbacks identified by the stakeholders, threatening the objectives related to the drivers.

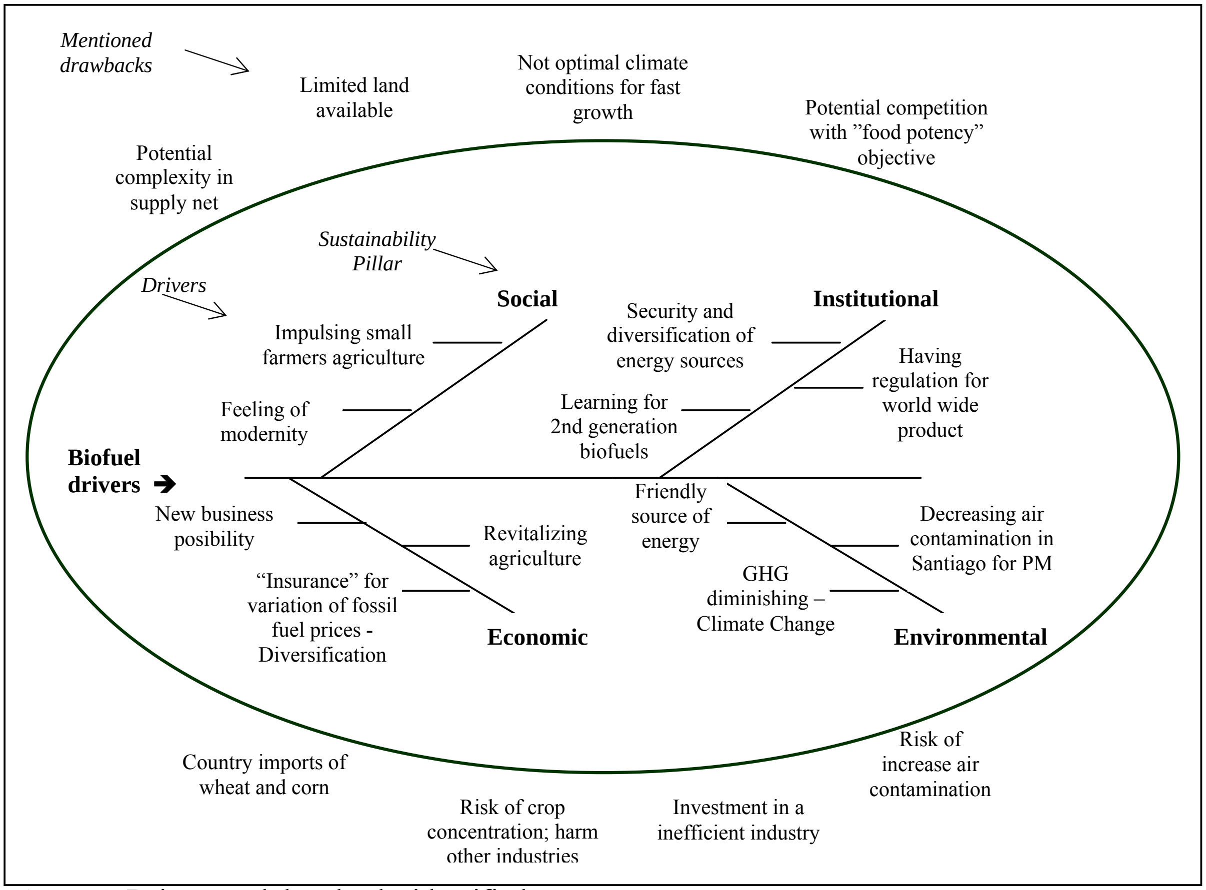

Figure 4: Drivers and drawbacks identified.

Source: Own elaboration.

It is important to highlight that Figure 4 is the unification of the stakeholders' partial views under a systematic sustainable development framework, for this reason this organized partial view may have omitted some drawbacks and drivers.

Having these antecedents, the next chapter is oriented to assess the biofuels initiative in Chile, according to the country conditions and knowing the impacts and benefits from the production to use of biofuels researched by the scientific sphere.

5. Liquid biofuels sustainability analysis

Chile is committed to sustainable development. This concept supported in four dimensions (environmental, social, economic and institutional) leads to the analysis of the biofuels project in Chile from these four perspectives. These dimensions can have aspects that concern just to one of them, but given they are interrelated, events in one dimension can have impact over the others.

This chapter is oriented to present the biofuels sustainability assessment based on the compilation of results of scientific research and quantitative information. Environmental sustainability embraces the aspects that put pressure over the environment, generating a risk to preserve the environmental conditions that allow keeping the ecosystems services in long term. Economic sustainability is associated to welfare creation (growth), through the economic resources availability. The sustainability analysis for these two pillars (environmental and economic) is done through the whole biofuel chain presented in figure 5. The biofuels chain includes just the main stages, leaving aside details that are not going to be analyzed.

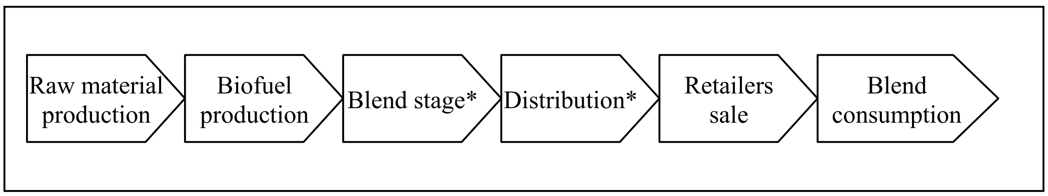

Figure 5: Basic stages on biofuels production/consumption.

Source: Own elaboration.

*: these stages can have another order or structure depending on the legislation adopted by the country.

The social dimension comprises the aspects that allow the people to increase living standards and to have better quality of life. Given its characteristics, this dimension is analyzed in relation to the effects of the actions along biofuel chain in the environmental and economic pillars.

Finally institutional sustainability, which is related with how the existing institutions guarantee the human rights and people participation, it is analyzed from a global point of view. Institutions therefore have greater concerns than just the biofuel chain.

5.1. Environmental sustainability

Environmental sustainability embraces the aspects related with, the natural conditions of the country or locality, resources exploitation, utilization of ecological services and as well with the elements that form the biosphere (the common goods). Scientists have investigated the environmental effects for the different biofuel chain stages. These effects in the first stages are more linked with the local impacts, while the last are global.

Raw Material Production

Starting in the raw material generation stage, the feedstock production has some considerations about environmental sustainability. Rapeseed cultivation (potential raw material for biodiesel in Chile (Irarrazabal & Laroze, Interviews January 19th and 26th 2007)) is intensive in fertilizer and pesticide use, the fertilizers change the soil equilibrium by acidification and can cause eutrophication if they reach a water system; pesticides are a source of toxic pollution on surface water (Frondel & Peters, 2006; Universidad de Chile, 2002, p87). Besides, these compounds

(pesticides and fertilizers) are transported in the water system (surface water and ground water by the leaching) having a negative impact over other habitats and increase the levels of nitrate and nitrite in drinking water from wells (Hill, et al, 2006; Universidad de Chile, 2002, p87).
These facts deserve consideration though the land has been utilized for agricultural production before, because rapeseed is intensive and could lead long term detriment of local conditions. Frondel & Peters (2006) indicate that wheat acreage or other sowing utilize less fertilizers and pesticides than rapeseed.
These potential impacts of the fertilizers and pesticides become more important if the land has changed its use, for example from pasture for cattle to rapeseed crop, because previously the system did not include the use of these agrochemicals.

The corn production presents similar drawbacks for the agrochemicals use, especially for nitrogen and phosphorus compounds. According to Patzek et al (2004), modern corn hybrids are the most nitrogen fertilizer and pesticide intensive of all food crops, and indicating that "corn production erodes soil about 18 times faster than it can be reformed".

Chile still has not stated formally the water quality standards for superficial waters, but "the levels of nitrates on rivers are usually acceptable" (OECD, 2005, p.73). Some measurements of water quality are taken by the Dirección General de Aguas (General direction of waters) (Universidad de Chile, 2002). However, if the country does not have some normative regarding this matter it is quite difficult to know the current impact of the fertilizer and pesticides from agriculture. According to OECD (2005), the Chilean increase in the agricultural products exports has been based on production intensification. In the 1980's the use of nitrogened fertilizers rose to 223% and the pesticides imports increased 8 to 9 fold, later in the 1990´s this situation improved and in this decade the production is more unlinked from agrochemicals use (OECD, 2005, p.95). But still Chile has high consumption rates of nitrogened based fertilizers (12 [ton/km^2]) in comparison with the OECD European countries (8.8 [ton/km^2]), analogously for pesticides the values are 0.46 [ton/km^2] and 0.21 [ton/km^2] (OECD, 2005, p.95).

In matter of water consumption in Chile, the agriculture consumes the 84.5% (OECD, 2005, p.73), existing along the country competence for this resource among different sectors (industry, mining, agriculture and human consumption). Chile has had little progress to improve the water use efficiency in agriculture (OECD, 2005, p.78). This situation is not a minor fact if feedstock production for biofuels considers the change of the land use from pastures to water demanding sowing. In Chile, 97% of the corn production is irrigated, whereas less than a 13% of wheat and 3% of rapeseed production are irrigated; wheat and rapeseed are concentrated in the south of the country (ODEPA; 1997). The geographical conditions of Chile lead to a 40% of agriculture surface irrigated, a value that is quite high in comparison with the 13.7% average for Latinamerica (OECD, 2005, p.93).

Biofuels production

The water demand for biofuels production is intensive for ethanol production; one bushel of corn demands 35 gallons of water (Patzek, 2004). The water required to produce ethanol to supply the country gasoline demand with E5 (instead neat gasoline) (table 3), will be around 2,200,000 [m^3/year]. The quantity of water is approximately equivalent to the total potable water supplied to 600,000 inhabitants monthly in the X region on Chile (southern region, see figure in annex) (Superintendencia de Servicios Sanitarios, 2007).

The water availability is higher from the Metropolitan region to the south (see figure in the Annex) (Universidad de Chile, 2002, p69), and these regions (from the V till the X region) concentrate the agriculture activity and have the potential for the energy crops (ODEPA; 2007).

The following stages of the chain are the biofuels blend, distribution and use. These stages present advantages and drawbacks for biofuels in comparison with the products that they are substituting (diesel and gasoline). Some effects have local impact and others global ones.

Blend & Distribution

E10 represents an increase in the risk and severity of the soil and ground water contamination (Niven, 2004), where the explanation is ethanol hydrophilic characteristic. Gasoline-ethanol blends experiment "phase separation on contact with water"; moreover this blend have higher steel corrosion capacity, a situation that lead to increase risk of leakages of storage tanks (Niven, 2004).
In addition ethanol raises the petroleum constituents in water, when leaks occur ethanol augments the monoaromatic gasoline compounds in aqueous phase (hazardous compounds as benzene, toluene, ethyl benzene and xylenes) inhibiting the biodegradation of petroleum compounds (bacterias prefer metabolize ethanol (Patzek, 2004)) (Niven, 2004). Reducing anaerobic conditions make longer the natural restoration times (Niven, 2004). So as result of these properties there is an extension of the "plume of gasoline-contaminated" (Niven, 2004). According the same author dissolved benzene plume is predicted to increase extension "by a 7-150% over a 20-year-period" (Niven, 2004); the longer the plume the higher possibilities of having water well contamination (Patzek, 2004).

Blend Consumption

Probably the most studied issue about biofuels are their emissions once that they are burned by engines; possible for two reasons. First the impact of vehicles emission on cities pollution, and second for the CO_2 emissions and their role in global warming and climate change (McMichael et al, 2006).

Pollutants emitted by vehicle engines are divided in primary and secondary, "the main primary pollutants are: carbon oxides, nitrogen oxides (NO_x), alcohols, aldehydes, ketones, sulfur compounds (SO_x), and hydrocarbons. Those pollutants can react with each other or with the sunlight to produce the so-called secondary pollutants: ozone, peroxyl acetate nitrate (PAN), among others" (Machado&Arbilla, 2006).
Emissions from diesel and gasoline have different profiles, "diesel emission contains hundreds of organic and inorganic compounds, partitioned in the gaseous and particulate phase" (Machado&Arbilla, 2006). Among these compounds some are carcinogenic molecules such as aldehydes and mono-aromatic hydrocarbons, which are unburned molecules or by-products during the combustion, nevertheless these undesirable combustion products are present in the fuel (Machado&Arbilla, 2006).
Biodiesel is free of sulfur compounds, or containing just 50% less than diesel, and aromatic compounds (Frondel & Peters, 2006), for this reason biodiesel is an attractive option. The emissions of blends with a 5% of biodiesel (B5) have an average reduction of mono-aromatic compounds of 8.2% and 21.1% for B20; analogously for poly-aromatic compounds the reduction is 6.3% for B5 and 17.2% for B20 (Machado&Arbilla, 2006). Similar conclusions regarding organic volatile compounds were reached by Hill et al (2006) and Dwivedi (2006).

Green house gas balances are positive for biodiesel, first considering that biofuels in general are CO_2 neutral, and second because the CO_2 related to the whole process (well to wheel) including the by-products give a positive balance (Frondel & Peters, 2006). "The different GHG emission estimates for one liter of biodiesel are between 22% and 59% of the emission benchmark for fossil diesel" (Frondel & Peters, 2006; Hill et al, 2006). However according to these authors (2006) the effect over photochemical smog by biodiesel is unclear.

The case of ethanol is slightly different. The results of GHG balance are not coincident; in spite of this the average is favorable (IEA, 2004, p53). The E10's GHG emissions are reduced around 1%-5% in comparison with neat gasoline, while a 19-70% for E85 or E100 is achieved, but the results depend on the feedstock used to produce the ethanol (Niven, 2004) and the source of the energy used in the distillation process. However the GHG balance is more favorable for ethanol from cellulosic material (IEA, 2004, p.62; Hägerdal et al, 2006).

The emissions of volatile organic compounds (VOC) and particulate matter (PM_{10}) are also less for blends with a low ethanol fraction (Hill et al, 2006; Niven, 2004). However for high levels of ethanol blends (E85), the emissions of CO, VOC, PM_{10}, SO_x and NO_x are higher than the emissions per unit of energy of conventional gasoline (Hill et al, 2006). This potential increasing in pollutants that leads to photochemical smog is a big drawback, especially for cities with high pollutants problems, e.g. Santiago.
Researches show that E10 produces notable emissions of acetaldehyde (ethanal) with levels over 100–200% and in some cases by up to 700% in comparison with E0 and higher levels of NO_x (Niven, 2004). Fonaro&Gutz (2003) showed that in Sao Paulo (highest user of E20) a 44% of the rain acidity can be explain by carboxylic acids, which came directly from vehicle emissions or by the reaction of aldehydes emitted by the cars; besides Sao Paulo presented the highest carboxylic acids concentration in comparison with other urban cities and rural areas.

The air conditions in Chile related with the compounds analyzed previously, during the period 1990-2000 experienced some improvements and declines. The SO_x emissions decreased by 64% (mainly by the improvements in the copper industry, but in the same period were duplicated by the transport sector from 4,400 to 8,800 ton/year) (OECD, 2005, p.45). The NO_x emissions were duplicated (explained in a 40% by transport emissions) and CO & VOC increased around 60% (OECD, 2005, p.45).

In absolute terms vehicles emissions are responsible by the 40% of NO_x, 30% of VOC, 25% of CO and 1% of SO_x. (OECD, 2005, p.45-46). Comparing Chile's NO_x & SO_x emissions per unit of GDP with OECD countries, in 2000 Chile had one and a half times NO_x emissions and four and a half times SO_x (OECD, 2005, p.47).

In relation to PM_{10}, the biggest problem in Chile is the metropolitan region, the average annual daily concentration in the 1990's was 100[$\mu g/m^3$] and 70[$\mu g/m^3$] in 2003 (OECD, 2005, p.48). The regulation states that, the norm is exceeded when the annual daily average concentration is over 50 [$\mu g/m^3$] (average of three consecutive years) (Ministerio Secretaria General de la Presidencia, 2001).

Based on these local issues and considering the biofuels emissions, ethanol introduction does not represent an advantage to improve air conditions, it could increase the current problems faced by the country. On the contrary, biodiesel from the emission point of view gives some incentives, especially for the cities with big air contamination problems.

5.2. Economic sustainability

Economic sustainability is concerned with the possibility of growth (UN, 2003, p.31), but this growth must have consideration of the other dimensions of sustainability. Within a system where the variables are interlinked, the changes in one sector can have influence over the others. In the case of biofuels, the production efficiency has to deal with production costs (economic dimension), but at the same time the rate of use of the feedstock (environmental dimension).

Raw Material Production

The first stage in the biofuels chain, the raw material production depend on crops yields. This subject has influence on the economic, environmental and social aspects, generating a link among the dimensions. The positive gap between the incomes received by farmers (from crops) and the production cost is an essential condition for economic sustainability; that has a direct impact over social sustainability. Higher incomes can be possible with higher efficiency of the land production; this could be obtained by the increasing fertilizer and pesticides use. This production efficiency will improve the profitability (if chemical costs are lower than extra incomes). However this intensification in the agrochemical uses could be negative in environmental terms (because the reasons given in 5.2.). According to Irrazabal, the contract agriculture is a tool that leads to reach higher crop yields without necessarily increases the use of agrochemicals (Irarrazabal, Interview January 19th 2007).

The crop prices are related with the first link in the value chain (figure 5), but have an important impact over the biofuel price. The net feedstock cost for ethanol production (from wheat and corn) represents a 38% - 43% of the production costs (IEA, 2004, p.72), so grain production and total demand are important factors for the economic viability of biofuels.

The world market of grain currently is affected by biofuel production (El Mercurio, 2007b, Irarrazabal, Interview January 19th 2007), because there is a competition for a product from two sectors, the food market and the energy market. In the future the competition for the agricultural products will grow due to the worldwide increasing biofuel production capacity; so the land availability is the central restriction for biofuel production (Frondel & Peters, 2006). Then as a result it will be possible to have a strong economic impact with positive consequences on the agricultural sector (for the bigger gap between production cost and price). But at the same time all the products that use some "energy feedstock" in their production process may experience rising prices, with a net effect over the whole society that is not clear (IEA, 2004, 177). Based on experiences of the USA, using 10% of a crop as a source of energy, the food market prices were raised by 8-14% (Frondel & Peters, 2006).

The extra demand for specific crops can induce a price rise in other agricultural products due to the reduction in supply, because it may require the same sort of land for its production. (Frondel & Peters, 2006). This impact on the agriculture market could be avoid, if the land use for bioenergy crops were not use currently for food production. In the Chilean case this is a complex situation, only 1.4 million hectares of land with annual or permanent crops and 0.4 million hectares of grassland[12] (located mainly in the south of Chile) (ODEPA, 1997, table 4,05) does not allow for fallow land. The product availability is even more restricted considering the need for crop rotation (Frondel & Peters, 2006). Hill et al (2006) are categorical stating that "neither biofuel can replace much petroleum without impacting food supplies".

[12] This value does not consider the area destined to forestry exploitations and grassland (perennial and yearly) for fodder.

Since 1980 in Chile wheat acreage has experience a reduction (from around 600,000 till 300,000 hectares), while corn has remain relatively stable (around 100,000 ha) (ODEPA, 2006). The production of these acreages (1,403,689 wheat ton and 1,381,894 corn ton, harvest 06/07 (ODEPA, 2006)) are not enough to satisfy the national demand, in 2006 wheat and corn imports reached respectively 949,647 ton and 1,742,205 ton (Cotrisa, 2007a&b). The wheat imports in 2006 came from Argentina (59%), USA (31%) and Canada (10%), and corn imports from Argentina (66%), USA (24%) and Paraguay (9.6%) (Cotrisa, 2007a&b). For both products (wheat and corn) Chile is supplied mainly by Argentina and USA.
Argentina in 2010 will produce 200 million liters of ethanol (Cavieres, 2006) and USA will double its 2005's production for the year 2008 (Hernández, 2006). Then the main Chile's suppliers will consume more of their grains production. For this reason potentially they will diminish the stock for exports and the prices will rise, producing a cascade effect.
However, the rising cereal price would be an incentive to farmers to produce these products that in the last years have shown prices that do not compensate the productions cost (El Mercurio 2007b). For 2006-2007's harvest, the prices have risen in the international market by the extra demand of cereals to produce ethanol and the lower production in Australia (57% less), USA (14% less) and Europe (5% less) due to climactic conditions (El Mercurio, 2007d). This situation favors the farmers and has created a bigger interest to produce grains for the energy market. In some cases, it has started to work to change the land use from livestock to cereal production (El Mercurio, 2007d). But at the same time this tendency is creating huge concern in the livestock industry that uses cereals for feedlot (El Mercurio, 2007d).

Land availability and agricultural product prices are related with raw material supply, a key aspect for biofuel supply continuity and the energy security aim. Energy security is one of the drivers for the biofuels incorporation into the energy matrix, so the imports of raw material, semi-processed or final product make the security aim debatable. This condition became an extra challenge for the national reality.

Biofuels Production

Following the biofuels chain, an aspect that has deserved big attention are the energy balances in biofuels production; matter related with the economic and environmental dimensions. The net energy balance is more favorable for biodiesel than ethanol. The ratio between the energy contained in the biofuel and the energy input into the whole production chain, is on average 2.2 for biodiesel varying from 1.5 to 2.9 (Frondel, 2006). But for ethanol, scientists point out divergence on the results. The average ratio for ethanol from wheat is 1.6, but oscillates from 1.02 to 2.25; similarly for ethanol from corn the average is 1.4 within a range of 0.7 and 2.2 (Börjesson, 2006).However, better efficiencies are being achieved in second generation ethanol (from lignocellulosic material), the average is 3.2 varying from 1.88 to 5.6 (Börjesson, 2006).

Distribution

Related with the energy balance, for the ethanol case in Chile it is important to consider the extra energy to deliver this product within the country. The ethanol physical-chemical characteristics do not allow the use of pipeline distribution that currently exist (Barría and Guerrero, Interview January 18th 2007). Therefore product delivery will be by truck and/or ship, adding extra cost, spending more energy and generating extra gases emissions; a situation that is not negligible given the Chilean geography (from north to south means cover around 4,200 km).

Blend Consumption

The Chilean government announced the specific fuel tax exemption for biofuels; this incentive will be applicable to the blends but only for the renewable portion on it (Ministerio de Hacienda, 2006. Fuel price will be determined basically for the component with higher presence in the blend. According to the signals given to the market, the government is not going to give any other economic incentive (subsidy or tax free) to promote biofuels (Noe, Interview January 17th 2007). The incorporation of biofuels in blends represents a decrease in fiscal incomes. Assuming that the whole country would consume B5 and E5, the public incomes by taxes will decrease around 72 million euros in 2010; this represents a 0.35% of the 2007 net tax incomes for the state[13]. At the same time biofuels will bring new operation cost in some public repartitions, due to the new inspection process required along the biofuel production chain (Cabello, Interview January 15th 2007).
Given the lesser public incomes and the higher expenditures, it is important to be conscious about the alternative use that this resources could have and the benefits. For Coviello (as cited in Dowling, 2006), the Chilean investment in biofuels must be evaluated comparing the environmental and social benefits with its investment in health or education.

Concerning biofuels subsidies, researchers have different visions. Hill et al (2006) point out that "biodiesel provides sufficient environmental advantages to merit subsidy". For Wassell&Dittmer (2005) the subsidies or economic incentives should be applied in the most efficient way, it means that they would be efficient over the "least expensive method of reducing diesel pollution". According to the same authors, today biodiesel is economically efficient, but if the normative requires an incorporation of more technology for pollution reduction the scenario will be different.
A different conclusion reached Frondel & Peters (2006) arguing that, even though the GHG balances are positive is unclear whether the whole environmental balance is positive too. For them "biodiesel is not a cost-efficient emission abatement strategy", the use of biomass for power generation is more efficient (Frondel & Peters, 2006).
However the conclusions reached by Hill, Wassell&Dittmer and Frondel&Peters are not perfectly comparable, because the last ones analyzed the situation from a broader point of view (comparing with power generation) and not only comparing diesel and bio diesel.

5.3. Social sustainability

Social sustainability looks for the proper quality of life (living standards, health, dignified life and social cohesion and integration), which depend on the environmental and economic factors. The biofuel project presents a set of impacts on the environmental and economic pillars (reviewed in 5.1 and 5.2), so social sustainability analysis examines how they affect people's lives.

Effects by environmental aspects

The environmental positive externalities of biofuel use have not only impact on nature; they have a relation with people's quality of life. The emissions reduction leads on one hand to reduce the morbidity and mortality. For PM research is concluding, for long term exposure to PM affects the "respiratory symptoms, lung growth, and function of the immune system" and leads to increased the "total, cardiovascular and infant mortality" (Kappos et al, 2004). For short-term exposure, a

[13] The 2007 net tax incomes projected are 20,000 million € (14,139,227 million Chilean pesos) (Dirección de presupuestos, 2007).

relationship between "daily concentrations of PM with mortality and morbidity on the same day or the subsequent days" has been identified (Kappos et al, 2004).
Recently, Jacobson (2007) has shown the relation between health risks and ozone. It is important to remember that ozone is a product formed by primary pollutant reaction, which in the ethanol case increases mainly by the aldehyde emissions (for blend with low or high ethanol fraction). Jacobson (2007) found "that E85 may increase ozone-related mortality, hospitalization, and asthma by about 9% in Los Angeles and 4% in the United States as a whole relative to 100% gasoline".

The previous research results are related with effects experienced for the same generation of people responsible by the emissions. In spite of, GHG emissions lead to impact future generations due to climate change. The next generations will face extreme events (floods & draughts, and its effects in land yields), loss of livehoods, microbial proliferations, thermal stress and changes in vector-pathogen host relations and in infectious diseases (McMichael, 2004), facts that certainly will affect social sustainability.
If biofuels can contribute to decreases in PM and GHG emissions, they will have a positive effect on social sustainability. However the increasing of aldehyde emissions (in ethanol-gasoline blends), could bring a potential damage to the society.

Similar is the situation with land, water and ground water contamination by leakages or spills. As was mentioned above, ethanol implies worse effects for blend leaks than neat gasoline. This fact represents a threat for human health because the increasing chances of contamination, in time horizon and physical coverage.

Effects by economic aspects

Besides the previous factors that are related with health aspects, there are other aspects associated with human well being. The level of income is a direct factor over the quality of life that people can achieve. The expected improvement in farmers' economic situation due to higher prices on the agricultural products, would lead to improvements to their life conditions and at the same time decrease the rural-urban migration. But these social benefits for farmers will means higher costs of life to the whole society in the country due to the food market alteration. So, from the farmers point of view the situation will be positive, and they will have better economic conditions based on the country effort, then this biofuel project can be seen as a tool to redistribute wealth.

The agriculture sector formed by small farmers is facing the most depressed conditions in the country side (Neuenschwander, Laroze; Ruiz, interviews 17th, 26th and 12th January 2007). Analyzing the figures, the agriculture has contributed over the last 6 years, 4.3% of the GDP annually on average (Banco Central, 2007c), and employs the 13% of the national working force (INE, 2006c).

Regarding the rural property distribution and education, one third of the land used for crops belongs to small farmers (less than 20 hectares) that represent 69% of the land owners (252,067 people) (INE, 1997, table 4,05), and 638,568 inhabitants depend on that land; 833,940 inhabitants of the national population were dependent on agriculture in 1997 (INE, 1997, table 3,04). The small farmers have the lowest educational level in comparison with the groups that own bigger land areas, in the small farmers group only 24% of them has completed primary education (12-school years) and only a 7% had some superior education (INE, 1997, table 1,10).

From the total production of corn and wheat of the country a 23% and 31%, respectively, is produced by small farmers (INE, 1997, tables 5,02). But, the yields obtained for both crops are lower for this group in comparison with bigger producers (INE, 1997, tables 5,08). Small farmers

face disadvantages sowing industrial crops due to the high level of mechanization that these commodity products have (Machado&Arbilla, 2006).
Regarding rapeseed, the sowing has been so low the last years (ODEPA, 2006), that it is not possible to observe a pattern.

The relation between the educational level, production yield and income for the small farmers, let to infer that there is a vicious cycle that makes it difficult to get better life conditions. In this sense, an improving in their situation achieved only by increasing prices of their agricultural products represent a situation that is potentially weak and unsustainable in long term. It corresponds to a temporal solution that could help to move the system in a first moment from its inertia, but requires more actions to achieve stable improvements in long term.

Finally, for the whole Chilean society the use of biofuels as 5% blends (B5 and E5) would means an extra cost around of € 33 million in 2010 for B5 users and a save around € 29 million in 2010 for E5 users[14], considering the currents fossils fuel prices and the estimated cost for biofuels. However given the quick oscillations in fossil fuel prices and the raising trend of corn and wheat prices, is not possible be conclusive.

5.4. Institutional sustainability

The institutional sustainability embraces a global coverage, where policies guide the actions plan securing the human rights (UN, 2003 p32). The political decisions under a sustainable vision must be done with wide participation (Spangenberg, 2004) and not reduced to elite. This characteristic allows keeping the balance in the decisions and respecting the people's rights.
In the biofuel framework these two points (rights and participation) can be related with: i) security in product supply, ii) energy provision that allow country development, iii) procedure to study and define the biofuels policy and iv) the institutionality, public and private, to raise up and implement the project.

i) Security in product supply.

The biofuel security provision depends on the fraction of ethanol and biodiesel that are going to have the blends. Supplying high fractions of biofuels, as in E85 or B85, for the national fuel demand based on national production is unimaginable. The acreage necessary would approximately 450,000ha of corn and 4 million hectares of rapeseed (based on table 3), approximately the half and four times the national land available for crops. Supplying low biofuels fraction (E5 and B5), is technically possible but having a clear restructuring inside the food market, due to the currents levels of imported cereals (facts in page 27). Considering delivery issues, for remote regions (especially the south, XI and XII) secure product availability would be more complicated due to the access difficulties.

[14] The estimation consider: biodiesel cost = 446.25$/lt (375$/lt+19%IVA) (ODEPA; 2007); Biodiesel efficiency: 1.08 lt biodiesel are equivalent to 1 lt diesel (Wassell&Dittmer, 2005); diesel price=421.7$/lt (average 2007 at 19th march, CNE, 2007).
Ethanol cost = 302.4 $/lt (0.47US$/lt+19%IVA; 1US$=540$, march 2007) (Downling, 2006); Ethanol efficiency: 1.5 lt ethanol are equivalent to 1 lt gasoline (Patzek et all, 2004); gasoline price=576.5$/lt (average 2007 at 19th march, CNE, 2007)

ii) Energy provision for the country development

The Chilean's growth is supported by different economic sectors. In 2005, the manufacture industry generated 17% of the GDP, financial and business services 14%, commerce 12%, mining 8.1% and agriculture 4.9%. The country development depends on these sectors evolution, which at the same time rely on resources for their growth. Energy is a transversal input for all of them, but having different use intensity. Liquid fuels are present in all the areas as source of energy, directly or indirectly, so the fuel continuity supply is a key condition for growth. The incorporation of low biofuels fractions allows does not technical adjustment of vehicles (IEA, 2004, p101). So if by law E5, E10, B5 or B10 are expended instead of neat fuels, in critical cases of lack of biofuel supply, it does not mean a system crash; because it would be possible to utilize 100% fossil fuels (if there is available).

The future biofuel supply is linked with the chance to produce them from other sources. Among these possibilities, lignocellulosic process seems to be the closer option which is starting to growth with pilot plants in Canada, USA and Spain (Hägerdal et al, 2006).

A second aspect linked with the country growth is the biofuel project interference with the development of the cited economic areas. Given the small quantity of land available in the country, it is important the level of competence between two governmental goals; biofuels and food-producer potency. The strengthening of energy crops could lead to the agriculture development for a path different from the main agriculture sector aim (food-producer potency).

iii) Procedure to study and define the biofuels policy

The mechanism that is being used by the government to study the biofuel project and elaborate a policy proposal considers the participation of public and private stakeholders, through the conformation of two committees. The Private-Public Committee[15], lead by ODEPA and constituted for representatives of private and public organizations; and the Public-Pubic Committee[16], leaded by the CNE and ODEPA and formed only for representatives of governmental organizations.

The stakeholders' participation in the study of a project like this one is quite desirable for the process (OECD, 2005, p17). Even though this wide participation means divergent rationalities; it allows considering all the aspects involved. In this sense, the State plays a key role in the mediation as well assessing the divergence between the private and social costs and effects over the environment (OECD, 2005, p133). The State is the superior organization at national level to care about the global social conditions and to improve the sustainability of the development; so it must guide the incorporation of these basic aspects in the projects.

Early stakeholder participation during the evaluation stage could speed up norm generation and legislative change process; as well it could facilitate the implementation stage, due to the previous analysis and discussion among the parts.

[15] The members were indicated in page 7 (footnote 2).
[16] The members were indicated in page 7 (footnote 1).

iv) Institutionality, public and private, to raise up and implement the project.

The politic stability in Chile, the macroeconomic conduction, the infrastructure quality and the financial system are good cataloged internationally, favoring foreign investment. The country has received a very good classification in terms of economic risk (the classification A2 for short term and Good for long term (Coface, 2006), 59 points over the Treasure Bonds by JP Morgan)). These facts give good signals to foreign companies to invest in Chile in new business, as would be the biofuels case.

Besides these conditions, there are other aspects linked with the institutionality to rise up the biofuels project. These aspects are related with the process of change behind a project that involves a new technology, as biofuels; have to do with institutional rigidities, laws&regulations, industry and society (Kemp, 1994). According to the current legislation is not possible to utilize biofuels, so whatever be its origin it is essential to have the regulation to incorporate them in the market.
Biofuels are a substitute product, which does not represent a technological difficulty for the consumers at the levels that Chile plans to introduced them (10% maximum as blend) (IEA, 2004, p102-109). So, its incorporation in the energy matrix should not represent a massive opposition, this initiative would be better welcomed by the society in comparison with other projects that could have an impact on life style.

5.5. Sustainability analysis reflections

There are three issues to reflect on after the sustainability analysis. First the exclusion of some drawbacks by the stakeholders; second the pros and cons of ethanol and biodiesel; and third the sustainability.

i) The drawback exclusion.

Considering the drivers and drawbacks pointed out by the stakeholders and the analysis done by sustainability dimension along the biofuel chain, it is possible to highlight the existence of factors that were not recognized as relevant by the stakeholders. These factors are: a) pesticide use, b) fertilizer use, c) gasoline-ethanol blend leaks and d) increasing water demand. Every one of these factors has direct effect over at least one pillar of sustainability.
Figure 6 exhibits the sequence of troubles and the final effects due to the pesticides and fertilizer use. Analogously, the Figure 7 presents the troubles and effects due to blend leaks.

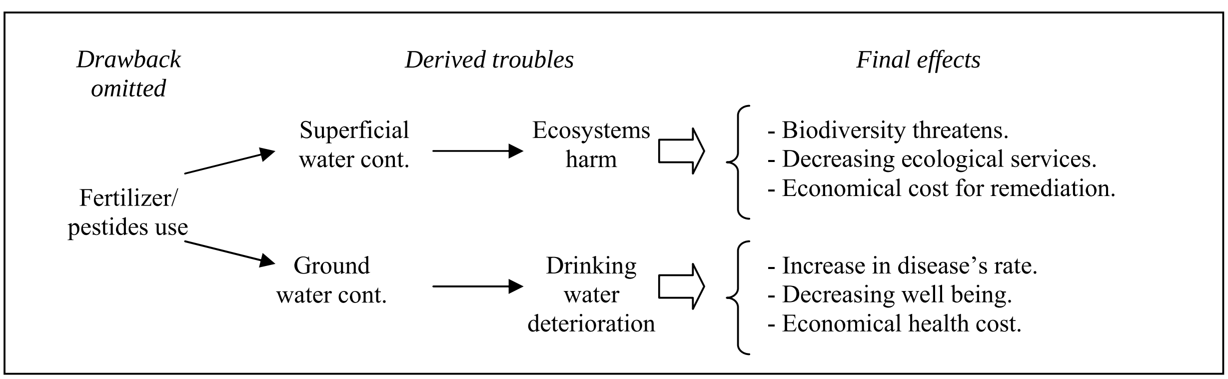

Figure 6: Effects for fertilizer and pesticides use.
Source: Own elaboration.

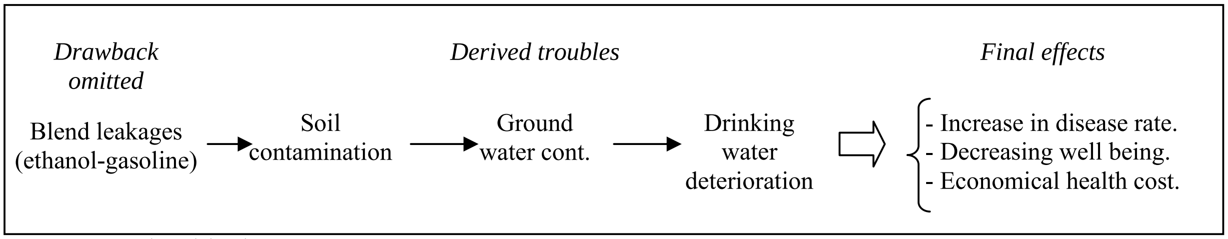

Figure 7: Blend leakages.
Source: Own elaboration.

In Chile the awareness about water contamination is just recently being formalized, nowadays is available the blueprint project for a norm that states the maximum and minimum values for compounds and elements on the water courses in order to protect the natural resources (work started on December 2004, blueprint approved on February 2006) (Conama, 2007). Nonetheless the impact on water and soil quality for the use of pesticides and fertilizers should be considered in the biofuel project evaluation by the stakeholders. Based on the scientific results these effects are not negligible, having influence over present and future generations. Furthermore, even stakeholders pointed out the small-scale farmers self-control to use agrochemicals, although past facts about this matter do not show such trend; Chile uses more agrochemical than the average OECD countries.

The effects of blends leakages are related to the operational stages at the end of the biofuels chain. There is no visible awareness of this matter. The safety measures that will norm the blends likely will be so similar to the existing today for gasoline and diesel (Cabello, Interview January 15th 2007). Remembering that sustainable development concept is related with pro-activity, results necessary to have in consideration the blends properties to define the regulation to avoid future consequences by blend leakages. The potential problems due to operational aspects at the end of biofuels chain can be prevented utilizing the proper materials and stating safety norms.

The water demand can be affected in two ways, firstly the increasing requirement of irrigation water; and secondly for the water demand for ethanol production. Regarding irrigation water the impact will be strong for those cases where the land use will be changed or current crops be replaced for other water greediest. This potential demand plus the water required for ethanol production should be considered by the competent organization, in order to evaluate the total demand and harmonize it with other demands that could arise from other industries, avoiding future conflicts.

ii) The advantages and disadvantage of ethanol and biodiesel.

Based on different stakeholders' vision, the incorporation of biodiesel in the energy matrix of Chile seems more convenient than ethanol. Nevertheless both options present favorable and unfavorable characteristics. Table 6 (page 38) present a selection of those positive and negative aspects of ethanol and biodiesel with certain effects.
Biodiesel positive aspects are: energy balance, the lower PM emissions, the absence of other harmful emission as the acetaldehyde in the ethanol case and low rapeseed demand in the local market (reflected in low acreage and inexistence of imports).
The main stakeholders' argument to support biodiesel is that rapeseed will not interfere with wheat and corn markets, which already show a raising price trend. However, since the land available for agriculture is small (1.4 million ha), sowing rapeseed means to leave aside other crops or do it in pasture land (total available 0.4 million ha). Rapeseed is cropped from the center to the south of

Chile, from V to X regions (see diagram in annex, page 50). A total of 60% of the rapeseed sowed is concentrated in the IX region, the same region that produces 38% of the national wheat production (ODEPA, 2007). So increase the rapeseed production would spill over in higher grain and corn prices through the increase in land-costs, unless be utilized some of the pasture land. Therefore the stakeholders' argument is highly debatable.

Regarding ethanol, its positive aspects seem not to give incentive enough to promote them, moreover considering the number of inconvenient along its value chain.

iii) The sustainability.

A sustainable choice among ethanol, biodiesel, both or none of them should have into account the certain positives and negative aspects of them but as well the uncertain ones, and taking a long term evaluation. So, going one step up until worldwide level, its population's growing rate and the demand by food, carry to question whether will be enough the land available in the future to supply resources for food and energy. Even though this is supranational aspect and is out of the thesis scope is important to keep it in mind, because finally the countries' decisions set global sustainability.

There are several aspects that defy the biofuels sustainability in Chile, some ones correspond to direct consequences over the environment and the society (contamination and resources degradation); and the others to indirect effects over the society (food markets alteration). Regarding the first ones, to procure sustainability ad hoc regulations and control mechanisms would be imperative, but for the second ones given its cause (limited land) do not seems possible find solutions within the country borders.

A key aspect to attain sustainability for ethanol and biodiesel in Chile is the awareness about the potential problems. The higher level of consciousness the higher prevention possibilities; so this represent an opportunity to minimize as much as possible the drawbacks linked to biofuels.
Knowing that currently the country has not a full information platform for all the concerning issues, e.g. levels of soil and water contamination, the awareness raised in this matter from biofuels project will be useful to start collecting the information; and this will be valuable for other projects or activities which require the same data. So, although collecting this information means a parallel task, it will be helpful for other new projects and the country sustainability.

Finally it is important to add that, given the variables interrelation the changes of the situation of one should lead to analyze again the whole project and not only the issues concerning directly with the change. So no matter the magnitude of the change, the final result in the system can be bigger or smaller than the original change.

Table 6: Selected positive and negative aspects of ethanol and bio diesel.

Ethanol		**Biodiesel**	
Positive	*Negative*	*Positive*	*Negative*
	- Hybrid corn is the crop most demanding of fertilizer & pesticides use	- Good rotation with wheat and sugar beet.	- Rapeseed is intensive in fertilizer & pesticides use
-Wheat production: 13% irrigated	- Corn production: 97% irrigated	- Rapeseed production is mainly not irrigated	
- Yield Corn-etha. ≈ (Wheat-etha.)*3	- Corn production: ≈1.38 million ton (≈130,000 ha) - Corn imports: 1.7 million ton	- Rapeseed production: ≈47.150 ton (≈16,000 ha) - Rapeseed imports =0; but is imported almost all oil-food.	- Yield Rapeseed-biodie. ≈ Wheat-etha.
	- Wheat production: ≈1.4 million ton (≈280,000 ha) - Wheat imports: ≈0.95 million ton		
	- Industrial crop that benefit the yield for bigger producer.		
- E85➔ GHG reduction 22%-70%	- E10➔ GHG balance aprox. equivalent to E0	- GHG emissions reduction: ≈ 41%-78%	
	- E10➔ acetaldehyde emissions increase: 100-200%	Free of SOx	
	- E85➔ higher emissions of CO, VOC, PM10, SO_x and NO_x than gasoline	B5➔ mono& poli aromatics emissions' reduction: 8.2% & 6.3%	
	- Water demand in ethanol production.		
	- Energy out/in [0.7; 2.8]; average 1.5	- Energy out/in [1.5; 2.9]; average 2.2	
- Production cost is lower than biodiesel. Tax exemption is 6 UTM/m^3			- Production cost is higher than ethanol. Tax exemption is 1.5 UTM/m^3
- Price is forecasted slightly lower than gasoline.			- Price is forecasted slightly higher than diesel.
	- Requiring special distribution system	- Can use the distribution by piping.	

Source: Own elaboration.

6. Discussion, the drivers and sustainability

This chapter is oriented to discuss the stakeholders' drivers that support the biofuel project (chapter 4) with the sustainability analysis based on the compilation of scientific research results, quantitative data and official information (chapter 5&3). The discussion is divided in two issues that deserve to be considered: i) The contraposition between the stakeholders' driving forces and the sustainability analysis; ii) The energy policy as a part of the national development policy.

i) The contraposition between the stakeholders' driving forces and the sustainability analysis.

Stakeholders' support of biofuel introduction in Chile is based on the benefits that will come from the drivers identified in table 4, but they are aware of the drawbacks related (table 5). The negative aspects recognized by the stakeholders are highly coincident with the results of the scientific research available. For this reason they are not discussed. Nevertheless, as was mentioned in section 5.5, relevant aspects were not considered by the stakeholders that deserves attention at national level. It is essential to evaluate its impact by the organizations and committees that are working in Chile in the project's assessment.

The Table 7 provides a discussion per every stakeholder's driver (drivers illustrated inside the oval in the Figure 4) with the objective of knowing its potential success degree after implementing the biofuels project.

Table 7: Environmental dimension, drivers discussion.

Env. Dim. drivers	***Drivers discussion***
- Friendly source of energy.	This driver is highly debatable since there are pros and cons. From the production point of view, the "friendly degree" depends on rate use of agrochemicals and proper land rotation. From the use point of view, the net CO_2 emissions are more favorable for biofuels than fossil fuels. Biodiesel presents lower emissions of PM, SOx, but for ethanol, such benefits are only valid for low ethanol fraction in blends. It is important to highlight that, the fact that biofuels are "bio" and come from renewable resources does not mean necessarily that they are "environmentally friendly". Comparing 1st with 2nd generation, the last ones present better CO_2 balances and a best use of the resources, given the use of the whole plant ant not only the grain or seeds.
- GHG emissions.	Based on the scientific results, this goal would be achieved due to the average positive CO_2 net balances for biodiesel and ethanol. But for ethanol balance there is not scientific consensus. The results depend highly in the way that the energy used in the distillation process is obtained (example, from coal, natural gas or hydroelectricity).
- Air contamination in Santiago for PM	Taking in account the contamination by PM, it is possible to have better air conditions by the biodiesel incorporation. But, the ethanol does not mean any improvement in this point and could increase health problem caused by higher ozone levels (produced by the higher aldehydes emissions).

Table 8: Economic dimension, drivers discussion.

Econ. dim. drivers	***Drivers discussion***
- New business opportunity.	Biofuels means a new industry generating new jobs, but mainly at the biofuel production stage and not at the raw material production. Given that cereals and rapeseed are highly industrialized crops, they do not represent a proportional increase in the manual labor demand.
- Revitalizing agriculture.	The higher grain demand for the energy market will raise crops prices, making the energy crops more profitable. However, by the international conditions in cereal and grain markets, the same effect could be reached without the biofuels' production in Chile. The revitalization will be direct over the grain and cereal sectors, and indirectly by the market forces over other agriculture sectors. Nevertheless the new market equilibrium could obstruct the Chilean aim of "agriculture-food potency".
- Insurance for fossil fuel price variations	It will depend on the policy adopted. If it only considers national biofuels production, the aim is not going to be reached because the production capacity of first generation biofuels in Chile is quite limited. Moreover, to be really "protected", biofuels should be more than 10% in blends, on the contrary the high fraction of the fuel's price still depend on the fossil fuel price variations. Besides biofuel prices are likely to follow gasoline and diesel prices in raising trends.

Source: Own elaboration.

Table 9: Social dimension, drivers discussion.

Social dim. drivers	***Drivers discussion***
- Improving small farmers' agriculture.	The small farmers' economic conditions can be improved, due to increasing prices of the "energy crops" and the rest of the crops. Then, as indirect effects small farmers could reflect on their daily quality of life the higher incomes (e.g. housing conditions, kids' attendance to the school, and so forth). However as a result of the high industrialization degree of the "energy crops", increasing in the manual labor demand is not expected, especially if there is only a substitution of sowed crop.
- Feeling of modernity.	Even though the consumers were out of the thesis scope, this driver leads to think if this project is a good tool to promote the feeling of modernity in the society in an efficacious and efficient way.

Source: Own elaboration.

Table 10: Institutional dimension, drivers discussion.

Inst. Dim. drivers	***Drivers discussion***
- Energy diversification and security.	Dividing this driver in two, diversification aim is achievable incorporating biofuels to the energy matrix, because it means to have the regulation and structure to use a new source of energy. The security aim is not attainable due to the country does not have the resources enough (wheat, corn or rapeseed) to satisfy the energy and food market. Biofuels would mean increase grain imports and depend on third countries, even though the number of suppliers can be higher than the fossil fuel ones.
- Having regulation for world wide product	The creation of the normative to allow the biofuels' use is the basic step to develop the chain. This step in the energy market will give a signal of the country opening to other sources of energy, and could facilitate future incorporation of renewable sources.
- Learning for 2nd biofuels generation.	Entering to biofuels now certainly will mean gaining know-how in operative aspects, facilitating later the biofuels expansion in the market by the incorporation of 2^{nd} generation biofuels production. However, since the country is going to buy the technology and knowledge to initiate the production (in 1^{st} or 2^{nd} generation), enter later (directly to the 2^{nd} generation) will mean to face the same difficulties (if there are) but later and having altered less the market food.

Source: Own elaboration.

Based on the previous discussion and the sustainability analysis reflections, figure 8 presents the modification of figure 4. Then, figure 8 incorporates the relevant factors omitted as drawbacks (purple font) by the stakeholders, and classifies the drivers (within the oval) by their potential degree of success (red font = the benefit is not reachable; font orange = the benefit is partially reachable; green font = the benefit is reachable). Since some biofuel drivers have a failure risk and knowing certainly the drawback effects, the biofuels option in Chile should be analyzed with more detail by the pertinent authorities, in order to assess individually all the benefits and costs.

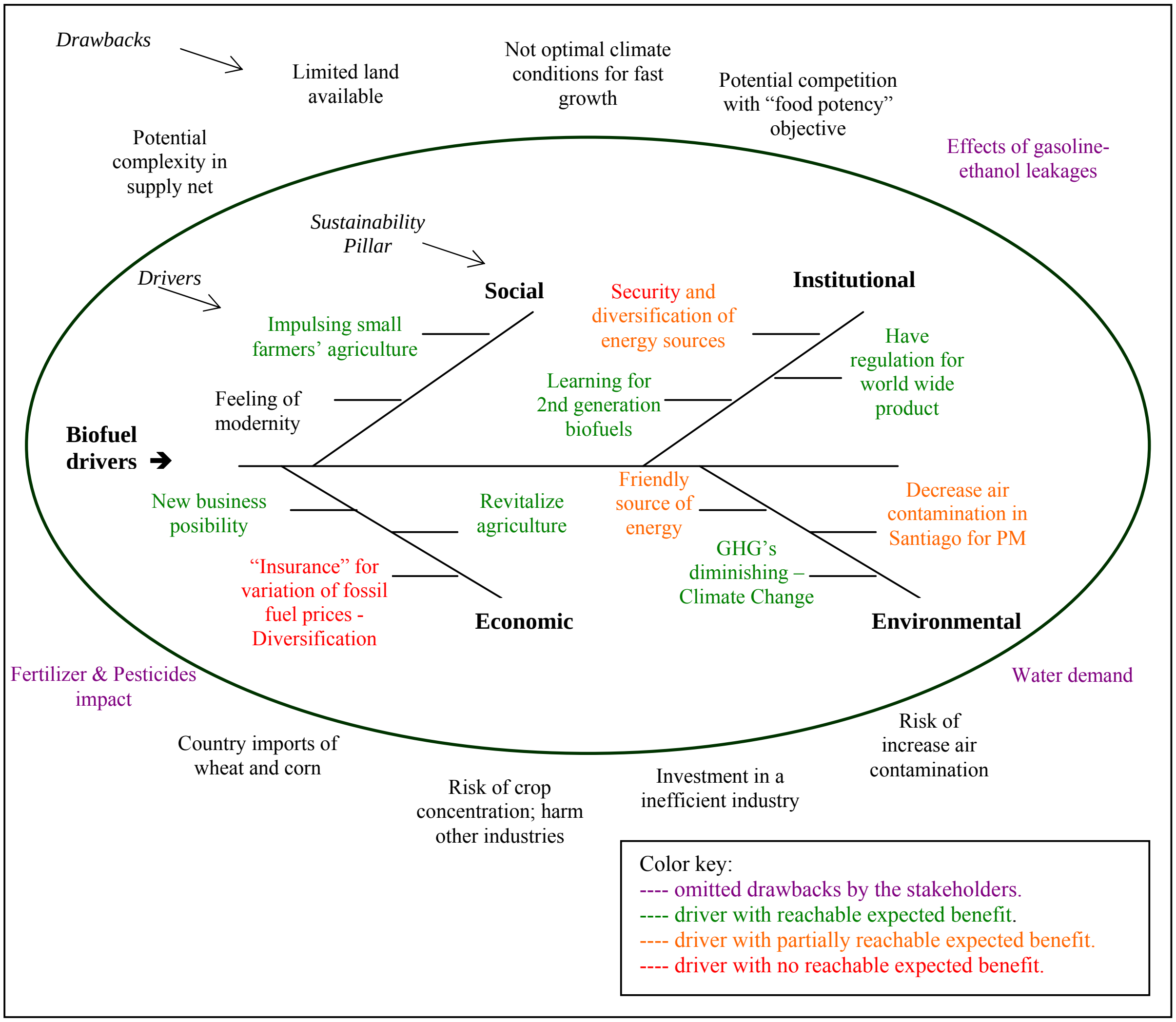

Figure 8: Drivers and drawbacks for biofuels, sustainable point of view.

Source: Own elaboration.

There are many alert voices about first generation biofuels, showing that this is an inappropriate way to produce energy (Hägerdal et al, 2006; Pimentel, 2002; Wald 2007) in comparison with biomass use for power generation (Frondel & Peters, 2006) or with second generation biofuels (Hägerdal et al, 2006; Wald 2007). Second generation production of ethanol allows a doubly of yield per hectare, and possibility of electricity generation with the by products (Hägerdal et al, 2006; Wald, 2007). Similar it is the situation for co-production of biodiesel by Fischer-Tropsch and synthetic natural gas (Zwart & Boerrigter, 2005). Even though these technologies would not help to fully reach the benefits expected by the stakeholders' drivers, they diminish the negative effect of the drawbacks making the whole system more sustainable.

The researches results about health risks of ethanol emissions deserve to be taken into account. Given that researches on this issue are becoming more common, it would be prudent to apply the precautionary principle until research be concluded to take determinant decisions about ethanol introduction and look for vehicle technological improvements to curb these emissions.

ii) The energy policy as a part of the national development policy

The country development aim constitutes the framework for all the sectorial policies, as the energy policy (OEDC, 2005, p.151). Considering the sustainable development path that Chile has chosen, the energy policy should be aligned with the economic, social, environmental and political objectives. It means the energy policy should be transversal and has influence over the ability to reach the objectives in the four areas. In this sense the results of biofuel experiences in other countries can be use as reference, but the local starting point should be the national energy policy, its objectives and instruments (OEDC, 2005, p.137). Under this context the national energy policy has three big objectives (energy diversification, greater energy autonomy, and efficient use of energy (detail page 6, 2nd paraghraph)), but none of them are directly oriented to strengthen the energy provision from renewable resources; this renewable orientation is presented just at medium-term action within the Energy Security Policy.
The government promotion of the non traditional renewable resources is through two set of actions pointed out in the energy policy for medium term. The first set join actions such as: a special treatment to the micro-generation station (under 20 MW), financing project evaluation for power generation from non traditional renewable resources and proportioning information about wind conditions in the country, potential to produce electricity from biogas and potential for power generation from forestry industry residues, among others. The second set is the development of biofuels, indicating some actions to do it.

The biofuel project has positive and negative externalities in diverse aspects, even though from the drivers' point of view most of them are related with rural development and energy security. Taking into account the results from the sustainability analysis, these two points (rural development and energy security) are relevant but not the only ones to consider from a sustainable development standpoint. Moreover as was discussed previously, an energy policy is transversal in a country's development and actions. So within this framework how the biofuel project fits in the sustainable development agenda of Chile, goes further than the benefits of a couple of sectors, it should be related with the policies in every area looking for harmonic development.

The existence of clear and coherent policies and action plans in every sector gives the framework to develop properly any kind of project. In the biofuel project, this framework is essential to handle the negative externalities with the appropriate tools. However given that biofuels will be a new sector within the country's development, besides of complying with the existent pertinent norms, the new ones are keys to avoid the damages as much as possible from the drawbacks.

7. Conclusions and comments

This study under a sustainability framework has done a critical assessment of the biofuels incorporation at the energy matrix of Chile. This step allowed obtaining the first appreciation of the project and understanding all the factors involved. Even though it was possible to build a global vision by the union of all the stakeholders' drivers and drawbacks, it is possible to say that there is a lack of integral evaluation, it means putting all the aspects together under a sustainability systems analysis approach.

As was stated by Hill et al (2006), biofuels "to be a viable alternative, a biofuel should provide a net energy gain, have environmental benefits, be economically competitive, and be producible in large quantities without reducing food supplies"; this combination of factors does not appears viable in Chile at present. Nevertheless the economic competitiveness is a fact that deserves deeper analysis.
The sustainability of first generation biofuels in Chile is rather weak. In terms of environmental sustainability, the most promising effects are related with emissions of particulate matter and GHG. However, there are aspects linked to the raw material production, blend and distribution stages, which present undesirable consequences.
The economic dimension of sustainability is positive to the agriculture sector, but at the same time biofuel production will mean raising prices of the food market. Moreover, biofuels do not constitute a path to avoid increasing in local fuel prices by international fluctuation of fossil fuel prices.
Social sustainability is not clearly positive or negative as well. Farmers, especially the bigger ones will obtain benefits; however by the evolution that is being observed in international cereal and grain markets, these benefits would be equally reached. But costs for increasing health risk and environmental contamination could exist.
Regarding institutional sustainability, biofuels do not markedly improve overall energy security, although they would represent a shield for eventual scarcity situations. Besides, biofuels as a new renewable source in the energy matrix would a signal to encourage the development other renewable energy projects.
Considering the international trend towards biofuels, the existence of a norm to regulate its use is suitable to avoid risk. Finally the participatory way to define the policy gives a solid base to the process.

The driving forces or arguments to support first generation biofuels do not seem strong enough to classify this initiative as sustainable. However, depending on operational conditions such, agrochemical use, land rotation, source of energy to feed the process, and security measures for leakages, the sustainability can vary strongly existing possibilities to improve the whole system. On the other hand, the uncertain effects of aldehydes emissions could represent a serious disadvantage, but the technological improvements could ameliorate this problem.

Considering all these aspects and based on the Chilean conditions, efficient resources use is a key issue. For this reason, second generation biofuels option deserves more merit and support than the first generation.

Finally under this study results, it is possible to say that encouraging first generation biofuels are unlikely to the best path for the sustainable development of Chile. This leads to do a careful integrated and quantitative assessment of the biofuels option by the government in order to define the action path.

Further research

Given the complexity of the project by its links with other sectors, this work constituted an indispensable step to identify the actors and forces related. With this base a model and later quantitative sustainability analysis can be done. Then, with the model evaluation would be possible to know the magnitude of the social, economic, environmental and institutional costs and benefits under a systems analysis approach. It means including the actions and variables related with the sustainability pillars, which allow seeing the results of the variables interrelation.

Knowing the high level of expectation on the second generation biofuels, an evaluation of the country potential developing this industry is advisable, as well a quantitative system analysis. But given that for the ethanol case, emissions drawbacks would remain; a mechanism to handle this problem should be investigated.

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2. *Cabello, Hilda*. Technical Liquid Fuels Department, Electricity and Fuels Sub-secretary. Economy Ministry. January 15th, 2007. Santiago, Chile.
3. *Ferrando, Jorge*. Studies Manager. Empresas Copec. January 09th, 2007. Santiago, Chile.
4. *Farias, Fernando*. Contamination Control Department. CONAMA. January 22th, 2007. Santiago, Chile.
5. *Guerrero, Marcelo*. ENAP. January 18th, 2007. Santiago, Chile.
6. *Irarrazabal, Rafael.* Corporative Development Manager. IANSA. January 19th, 2007. Santiago, Chile.
7. *Laroze, André.* Bio-energy Unit Chief. ODEPA. Agriculture Ministry. January 26th, 2007. Santiago, Chile.
8. *Neuenschwander, Aquiles.* Forestry Advisory, Executive Direction. FIA. Agriculture Ministry. January 17th, 2007. Santiago, Chile.
9. *Noe, David.* Executive, Finance Ministry. January 17th, 2007. Santiago, Chile.
10. *Ruiz, José.* Hydrocarbons Area Chief, CNE. Ministry of Mining and Energy. January 12th, 2007. Santiago, Chile.
11. *Santana, Roberto.* Norms Division Chief. Transport and Telecommunication Ministry. January 16th, 2007. Santiago, Chile.

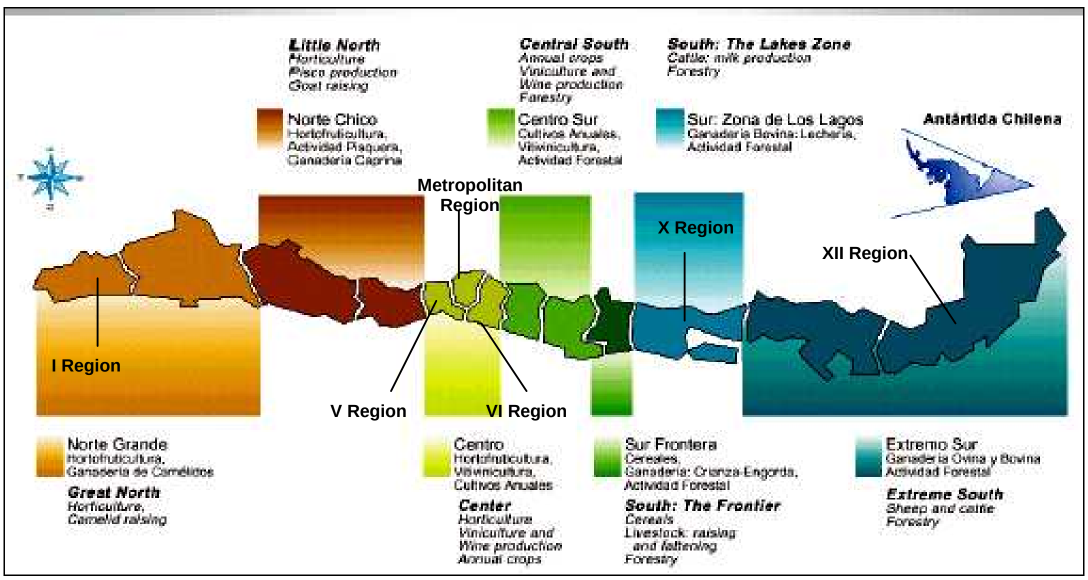
Annexes

Interview questions

List of question to guide the interviews

1. Which is the general approach regarding energy supply?
2. According to the previous analysis results about biofuels, which is the vision and perspectives?
3. Which are the drivers to create a biofuels policy?
4. Which are the biofuels policy objectives in medium and long term?
5. Which are the basic guidelines to create a biofuels policy?; which are the agents involve?
6. Which are or could be the main characteristics of the biofuel policy?
7. Is it considered the imports of raw material, intermediate product or final product?, Will be considered some restrictions regarding sustainability?
8. Would represent the incomes reduction for the State a critical aspect?
9. Which are the guidelines to develop this market in a sustainable way?, Has been thought in a special normative to address the cause(s) of biofuels negative externalities in order to minimize them?

Territorial division of Chile and its main agricultural use



Source: Dr. Raúl R. Vera. Country Pasture/Forage Resource Profiles. Retrieved 08/04/07 from