



Electricity generation in Chile using non-conventional renewable energy sources – A focus on biomass



Carlos Rodríguez-Monroy^{a,*}, Gloria Mármol-Acitores^b, Gabriel Nilsson-Cifuentes^{c,d}

^a Universidad Politécnica de Madrid, Madrid, Spain

^b Spanish Authority for Markets and Competition, Madrid, Spain

^c Universidad Politécnica de Madrid, Madrid, Spain

^d RESITER, Santiago, Chile

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ABSTRACT

This article presents the development of biomass for electricity generation in Chile within the country's complex energy framework which is still unable to strengthen and encourage renewable energy development and relies heavily on fossil fuels, increasing the latent risk of suffering an energy crisis in the medium term, due to the slow incorporation of new energy power plants to meet the growing energy demand forecast. This article provides a background of the power generation status in Chile, along with an analysis of the country's electricity market and its regulations, focusing on non-conventional renewable energy (NCRE), ending with the description of the current development status of biomass for electricity generation in its three physical states, its features, applications, conversion processes, advantages and disadvantages. Chile presents a low proportion of renewable energy technologies within its energy mix, in which solid and gaseous biofuels are mainly used for low power energy generation, through cogeneration and biogas extraction and use, while liquid biofuels are under research through the development of pilot plants managed by several entities for industrial production and the transportation industry.

1. Introduction

Power generation in Chile using non-conventional renewable energy (NCRE) represents an economic and environmental alternative that is feasible for the provision of energy to remote communities (rural areas) and for the expansion of the installed electrical capacity, either through isolated systems or through projects connected to the grid [1]. Chile is endowed with the resources that are required to develop hydraulic, solar, geothermal, wind and biomass systems, and therefore to facilitate the diversification of the country's energy mix. Additionally, electricity generation from renewable sources is environmentally beneficial, as it decreases greenhouse gas emissions, produced as a result of the combustion of fossil fuels.

However, Chile presents a complex energy situation, given the important growth in electricity demand, the target goal for installed capacity by 2020 outlined by the Government, the lack of technological development, the high dependence on fossil fuels, and the low diversification of its energy mix [1]. In this sense, the country is very dependent on coal and natural gas, which represent a significant share in power production, about 16% and 30%, respectively [2]. No matter what is the route chosen for energy development in a country, it will

generate tensions among the different pillars of sustainability. NCRE has become one of the main trends in sustainable energy growth in developed countries and it represents major challenges for emerging countries and more specifically for Chile [3]. The reforms in the electricity industry implemented in Chile in the 1980's was based on the private investments in the generation, transmission and distribution assets and led to a significant expansion of installed capacity. However, the regulatory framework showed important weaknesses when it faced adverse conjunctures such as the severe drought which caused rationing of the electricity supply at the end of the 1990's, the restrictions on the natural gas imports from Argentina and the reduced hydrology which has affected Chile in recent years. For these reasons, Chile underwent a transition towards coal and diesel oil power plants. The complex energy situation does not respond to a long term strategic planning. After more than three decades of unplanned growth, the vulnerability of the electricity sector is evident [3].

In this context, NCRE can play a significant role in diversifying the energy mix, improving the environmental impact of energy use, improving the decisions to localize energy projects and granting greater legal coverage in the process of approving new power plants. The complexity of electricity systems with the growing need to incorporate

* Corresponding author.

E-mail addresses: crmonroy@etsii.upm.es (C. Rodríguez-Monroy), gloria.marmol@gmail.com (G. Mármol-Acitores), gnilssonc@gmail.com (G. Nilsson-Cifuentes).

Nomenclature		NEC	National Energy Commission
CDEC	Centro de Despacho Económico de Carga	NSWP	National Solid Waste Program
CDM	Clean Development Mechanism	SEIA	System of Environmental Impact Assessment
LNG	Liquefied Natural Gas	SIC	Central Interconnected System
MGS	Generation means with installed capacity ≤ 9 MW	SING	Northern Interconnected System
MSW	Municipal Solid Waste	UGM	Unconventional Generation Means with installed capacity < 20 MW
NCRE	Non-Conventional Renewable Energy		

the variables of competition, transparency, greater security of supply and reliability in order enhance the development of clean and efficient energy resources require the revision of the structures, functions and roles of the different institutions involved [3]. Chile can face these challenges successfully if it implements a strategy based on NCRE. Taking into account that biomass represents 28.9% of the primary energy matrix it can play a relevant role in achieving Chile's strategic objectives considering the potential it offers as an abundant and autochthonous resource [4,5].

Biomass is considered an NCRE, as it presents both renewable characteristics due to its low environmental impact and non-conventional characteristics given its relation with new technologies that are still under development. The potential of this type of energy in Chile is favored by the existing technical level in its forestry sector, the land extensions that could be used for energy crops, as well as the large amount of waste from forestry activities, lumber companies, agricultural waste and solid municipal waste, among others. However, the use of this type of energy through energy crops should be strategically managed and regulated, in prudent and sustainable ways, considering its potential impact on the production of food crops [6,7].

2. Background

2.1. Power generation status and demand coverage in Chile

In 2012, more than 65% of the primary energy and more than 55% of the final energy in Chile were based on fossil fuels and oil products, respectively. However, Chile only produces small quantities of fossil fuels and oil products, importing more than 90% of the oil, natural gas and coal it uses, as well as more than 45% of the oil-derived products the country consumes [4].

The most important sectors in terms of final energy consumption in the country are industry and mining (36.0%), transportation (30.7%), and commercial and residential sectors (25.8%), while the sectors with

a higher electricity consumption correspond to industry and mining (63.8%), and commercial and residential sectors (29.4%) [4]. In 2012, the average contribution of domestic production for local consumption of oil, coal and natural gas was 3.7%, 5.6% and 25.2%, respectively [4]. It is relevant to mention that a decline in the imports of natural gas started in 2004 due to the crisis with Argentina, with import levels reaching their lowest levels in 2008 [8]. However, with the liquefied natural gas (LNG) regasification plants that were put into operation in 2009, the import levels of natural gas began to increase again (Fig. 1) [8].

The countries that supplied Chile with fossil fuels and their participation in 2011 were the following [9]:

- a) Coal: Colombia (47%), USA (40%), Indonesia (7%) and Australia (6%).
- b) Oil: Brazil (43%), Colombia (18%), Ecuador (17%), Argentina (10%), United Kingdom (8%) and Peru (4%).
- c) Natural gas: Argentina (100%).
- d) LNG: Guinea (34%), Trinidad and Tobago (31%), Qatar (16%), Egypt (3%), USA (2%), Indonesia (2%), Yemen (1%) and others (11%).

Although Chile still has a strong dependence from Argentina in relation to the provision of natural gas, generating a country risk as it happened in 2004, it should be taken into consideration that in 2011 imports of natural gas from Argentina represented just 7% of the total amount of imported natural gas, where the remaining 93% was obtained in the form of LNG from several countries, reducing, therefore, the geopolitical risk significantly. With respect to Chile's other neighboring countries, such as Peru and Bolivia, it must be mentioned that there is no infrastructure built or specific energy agreements with them for fossil fuel imports to Chile, and international relations with Peru and Bolivia are currently marked by natural boundary issues and definitions of access to the sea. In December 2015, the country's net

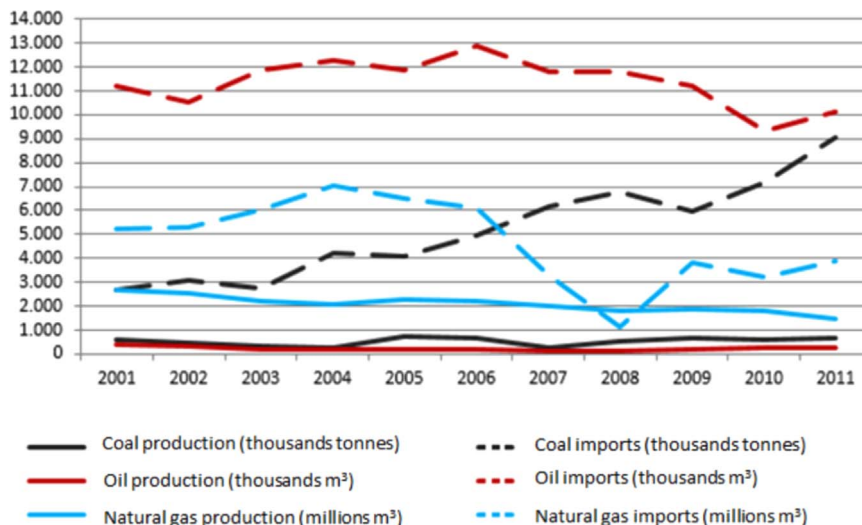


Fig. 1. National production and imports of fossil fuels (period 2001–2011).

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