FGV | SÃO PAULO SCHOOL OF BUSINESS ADMINISTRATION
Center for Sustainability Studies

RENEWABLE ENERGY OVERVIEW: INDUSTRIAL SECTOR AND LATIN AMERICA

NOVEMBER | 2016

Konrad Adenauer Stiftung

branco

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FGV | SÃO PAULO SCHOOL OF BUSINESS ADMINISTRATION
Center for Sustainability Studies

WITH THE SUPPORT OF

Konrad Adenauer Stiftung

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GVces. **Renewable Energy Overview: Industrial Sector and Latin America** Centre for Sustainability Studies of the Getulio Vargas Foundation School of Business Administration São Paulo: 2016.

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Preface

Freedom, justice, and solidarity are the basic underlying principles of the work of the Konrad Adenauer Foundation (KAS). KAS is a political foundation with links to the Christian Democratic Union of Germany (CDU), with over 80 offices overseas and projects in over 120 countries, our objective is to make a unique contribution to the promotion of democracy, the rule of law, and a social market economy. Together with the specific national programs being promoted by KAS offices in Latin America there are also transnational regional programs focused on specific areas. One of them is the Regional Program for Energy Security and Climate Change in Latin America (EKLA), based in Lima, Peru. The EKLA regional program was designed as a platform for dialogue, in order to drive political decision-making processes. Society and the global economy face enormous ecological challenges. There is a need to react to climate change and the scarcity of resources, as well as the growing demand for energy, particularly in emerging countries. In recent years, KAS has worked intensely on these issues. However, the enormous importance and urgency of responding to these demands led to the establishment of EKLA-KAS, which has the capacity to focus exclusively on these issues. The Latin American region is ideal for the implementation of environmental projects due to the abundance of green energy sources, such as sun, water, geothermal, wind, and biomass. Exploring and developing that potential will help Latin America satisfy its growing energy demand. As such, KAS supports this study, organized in cooperation with our partner, the Centre for Sustainability Studies (GVces) of the Getulio Vargas Foundation School of Business Administration (FGV-EAESP), with the aim of providing information to decision-makers and politicians in Latin America on how innovative and efficient economic instruments, along with public policy proposals, can promote renewable energy in the region. We would like to thank GVces for their partnership in putting this document together and for their fruitful collaboration in numerous projects, as well as all the researchers and authors who contributed to this publication. Happy reading!

Dr. Christian Hübner
Director EKLA-KAS

Introduction

Electricity is an essential input for industrial activity and guaranteeing its supply is fundamental for the development of the economy and the growth of industrial production. As such, in order to guarantee more adequate conditions of productivity and competitiveness for the industry, a possible route is to become more energy efficient. In this sense, actions that promote the implementation of energy efficiency (EE) and the adoption of renewable energy (RE) are influential on environmental and economic issues.

Of the totality of EE projects developed in Brazil, which consist of making processes more efficient and increasing and improving production while lowering energy consumption, 40% are allocated in the industrial sector. This indicates the performance of this sector in respect to EE. However, it is also necessary to encourage the diversification of the energy matrix of the sector, aiming for greater security in meeting energy demand, with an emphasis on renewable sources. These are important elements for the strengthening of the Brazilian industry in the global market.

This study aims to present an overview of industrial energy consumption of renewable sources in Brazil and some Latin American countries, such as Chile, Colombia, Mexico, and Peru. Product of a partnership between the Center for Sustainability Studies of the Getulio Vargas Foundation (GVces) and the Konrad Adenauer Foundation (KAS), the study presents elements for the promotion of the use of RE in the Brazilian industrial sector, both from the perspective of public policy and finance mechanisms for such projects. The report provides a comparative analysis of international experiences on the subject, addressing the features of each country in relation to its use of RE, legal frameworks, obstacles, and financing mechanisms.

The first chapter presents the context of climate change and greenhouse gas (GHG) emission reduction targets adopted by the countries analyzed which encourage the adoption of RE as a way of mitigating and adapting to the effects of climate change. The second chapter presents the international experiences of the Latin American countries under analysis. It also provides an overview of the RE status and energy consumption of the industrial sector in each country. The third chapter presents a comparative analysis of the aspects put forth in chapter 2, discussing the obstacles and opportunities for the progress of RE in the industrial sectors of each country. And, lastly, the final considerations of the work are presented.

Context

According to the fifth report of the Intergovernmental Panel on Climate Change (IPCC), human influence on climate systems is evident and increasing. The report states, with greater accuracy than in previous assessments, that greenhouse gas (GHG) emissions and other anthropogenic drivers have been the dominant cause of global warming since the mid-twentieth century. The report concludes that the atmosphere and oceans have warmed up, that snow and ice volumes have decreased, sea levels have risen, and that concentrations of carbon dioxide have risen to levels unprecedented in the last 800,000 years. Increasingly evident in all continents, global warming increases the possibility of serious, widespread, and irreversible impacts on society and ecosystems.

However, the report also states that there are ways to limit climate change and that many of them contribute to economic development. The adoption of measures of mitigation is necessary and urgent to curb global warming and its effects, while measures of adaptation help reduce risks and vulnerabilities. As such, a transition to a low carbon economy is technically viable and must be facilitated by public policy and adequate financing mechanisms.

In this context, the world is moving towards a new and significant climate agreement which encourages the adoption of measures to mitigate climate change, including the promotion of RE. The Paris Agreement, concluded in 2015 within the framework of the United Nations Conference on Climate Change, should support national public policies that promote sustainable development with a focus on reducing GHG emissions. This agreement aims to reinforce the global response to threats from climate change and restrict the temperature rise to up to 2°C, based on pre-industrial levels, and continue efforts to limit temperature increase to 1.5°C.

Signatory countries of the agreement have established their own targets for reduction of GHG emissions, called Nationally Determined Contributions (NDCs), which must be updated every five years. However, the success of the agreement hinges on, among other things, that countries strive to constantly diminish their use of fossil fuels and encourage, on a large scale, the use of renewable sources in their energy matrix. The importance of this change lies in the fact that two-thirds of global GHG emissions come from the energy sector.

The targets set forth at the COP 21 point to an internationally accepted agreement and should guide public policies that foster the development of a low carbon economy. Each country signatory to the agreement has set a general goal of reducing its GHG emissions and some have set specific sectoral targets. The following are the targets proposed by the countries of this study, including specific RE incentive targets, where applicable:

- **Brazil:** Has committed to reducing its emissions by 37% in relation to 2005 levels by 2025, and by 43% by 2030. Specifically regarding the energy sector, Brazil has committed to drawing between 28% and 33% of its energy matrix from renewable resources in addition to hydroelectric energy by 2030.

- **Chile:** has committed to a 30% reduction of its emissions in relation to 2007 levels by 2030. In regards to renewable energy, Chile has committed to having 20% of its energy matrix from non-conventional renewable energy sources by 2025.

- **Colombia:** committed to reducing its emissions by 20% in relation to its projected targets for 2030.

- **Mexico:** committed to reducing its emissions by 25% in relation to the Business as Usual scenario by 2030.

- **Peru:** has committed to reducing its emissions by 20%.

Of the countries analyzed up to October 2016, Brazil, Mexico and Peru have ratified the Paris Agreement, while Chile and Colombia are making progress to this end. This agreement will give strength to the development of different public policy incentives for a low-carbon economy, such as the National Policy on Climate Change (PNMC) in Brazil. The PNMC, released in 2009, aims to reduce GHG emissions in the main sectors of the Brazilian economy. In 2012, several sectoral plans were prepared, among them the Sectoral Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Economy in the Transformation Industry, referred to in this document as the Industry Plan. The main objective of this plan is to prepare national industry for a future scenario in which the carbon emission intensity per unit of output is as important as labor productivity and other factors of production which define the international competitiveness of the economy[1].

Given that the selected countries have GHG reduction targets agreed to internationally via the Paris Agreement, and that energy is an essential input in industrial economic development, this study will present an overview of the use status of RE, in general and in the industrial sector. The relevant aspects for understanding the contribution of the industrial sector towards achieving these targets are presented here - based on the fact that the promotion of RE is an important for the mitigation of emissions.

The following chapter presents the methodological approach used for the comparative analysis of the obstacles impeding or hampering the large-scale development of renewable energy generation projects in each of the countries analyzed.

1 In order to contribute to the implementation of the Industry Plan, the GVces - via the Businesses for Climate Platform - prepared a study in 2015 that identified the obstacles, opportunities, and potential financing mechanisms for EE projects in the Brazilian industrial sector. This report is available at www.gvces.com.br.

Methodological Approach

This study was developed through bibliographical research, consultation of reports and public documents on legal frameworks, public policies, and financial instruments for RE. The quantitative data presented in the report was, where possible, obtained from sources that made the information available to all countries of interest, so as to allow for a comparative analysis. Primary data was obtained through interviews with national and international actors connected to the subject of energy generation from renewable sources in Brazil and Latin America.

When studying the RE scenario in Latin America, several concepts applicable to the countries under analysis were identified. Therefore, this study takes into account the RE framework definitions per country as shown in Table 1.

Table 1 Concepts and RE framework by country (Source: own elaboration)

Country	Reference	Types / Sources of Energy	Hydropower	Observations
BRAZIL	ANEEL - Energy Atlas	Wind, Solar, Geothermal, Sewage, Garbage, Waste, and Tidal	Including large size plants	None
CHILE	Ministry of Energy	Hydraulic, Solar, Wind and Tidal	Maximum of 20MW	In order to classify biomass, geothermal, and biofuels as renewable, their method of extraction/production must be analyzed
COLOMBIA	Law 1.715 of 2014	Biomass, Wind, Solar, Geothrmal, Hydraulic, and Tidal	Small hydroelectric power	The types of sources presented are defined as: Non-Conventional Renewable Energy Sources (FNCER)
MEXICO	Law for Use of Renewable Energy and Financing of Energy Transition	Bioenergetics, Wind, Solar, Geothermal, Hydraulic and Tidal	Up to 30MW (there are specific restrictions in the Law)	As for Bioenergetics see Bioenergetic Promotion and Development Law for further definitions
PERU	Legislative Decree 1.002 of 2008 (updated in 2010)	Biomass, Wind, Solar, Geothermal, Hydraulic and Tidal	Maximum of 20MW	These resources are defined by Law as Renewable Energy Sources (RER)

In addition, in order to analyze the obstacles to the large-scale development of projects for generating energy from renewable sources in the selected countries, a typology of the obstacles found during the bibliographic review was created, taking into account the intensity of their impact, and whether they are direct or indirect. The concepts used to determine the sensitivity of each barrier are shown below:

Regarding direct or indirect influence:

- **Direct:** those obstacles which directly influence the decision of whether a project is executed or not, that is, there are material possibilities that the project will not go ahead.

- **Indirect:** those which indirectly influence the decision of whether a project is executed or not, that is, they can be overcome and do not directly influence the decision of whether a project goes ahead or not.

Regarding impact intensity:

- **Low:** obstacles which do not impede the execution of a renewable energy project via non-conventional renewable sources. As for example, when there is evidence of studies/ previously implemented projects, policies, and strategies for development of renewables already in place, legislation that is favorable and/or clear (transparent) enough.

- **Medium:** obstacles which will take more time and effort to overcome, but will not completely block the progress of the project, though possible making it slower and more cumbersome. For example, when there is evidence of studies/projects in a stage of implementation, policies and development strategies for renewables in advanced stages, as well as favorable and/or clear (transparent) legislation, approved or in approval phase by competent bodies.

- **High:** obstacles which may block or impede the development or implementation of a renewable energy project via non-conventional renewable sources. This is due to lack of legislation or its implementation, absence of previously developed renewable energy projects, lack of experience in the appraisement of these projects, as well as lack of or incomplete policies and strategies for developing renewable sources.

From the proposed typology a matrix can be generated that takes into account both aspects, whether the obstacle bears direct or indirect influence, and its intensity, individually shown by country and in aggregate form, compiling all obstacles analyzed in the five countries under study. Figure 1 illustrates the base matrix used for obstacle analysis.

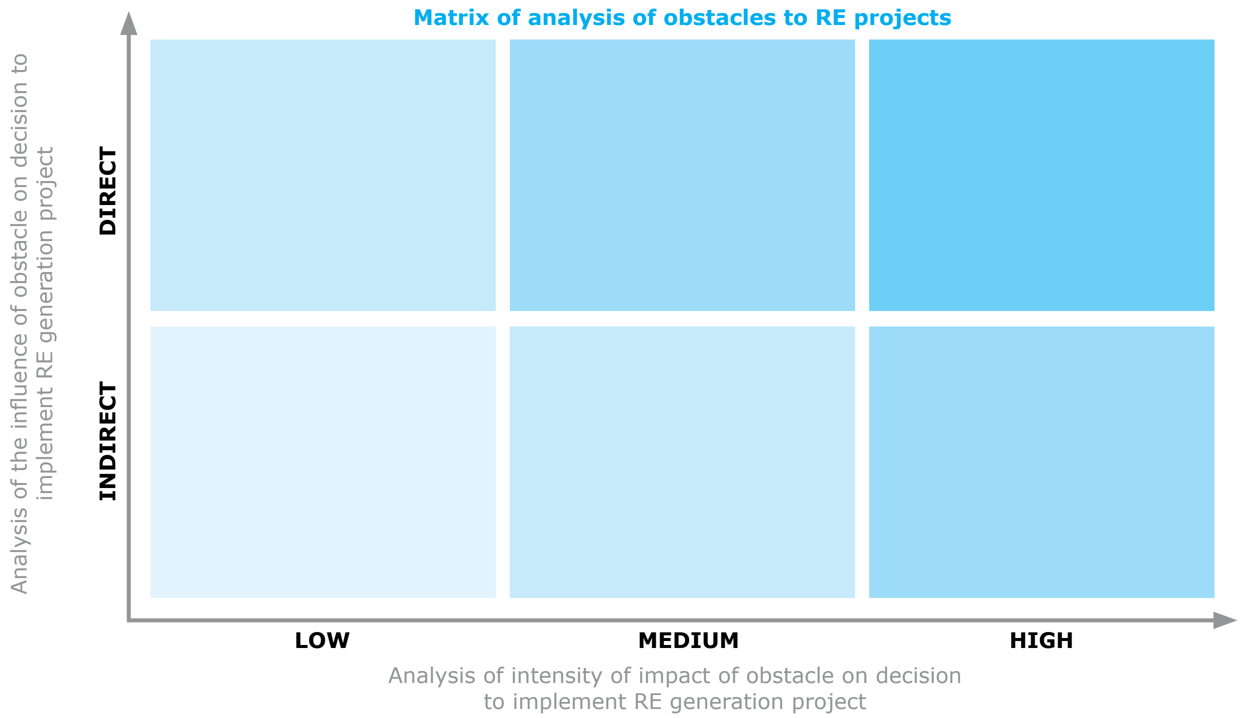

Figure 1: Proposed typology for the analysis of obstacles to RE energy projects in each selected country

This matrix allows for a mixed classification of RE project obstacles, which means that once the obstacles were classified as direct or indirect, they were then analyzed according to their respective intensity. The obstacles described below are common to the five countries under discussion, and form the basis of analysis for the study of the experience of each.

Direct Obstacles

- **Regulatory and Administrative** (including environmental licensing): related to administrative procedures to which energy generation projects of non-conventional sources must be submitted. Absence of, or insufficient information about which bodies/agencies the project should go through, necessary authorizations and environmental licenses and their providers, as well as required taxes. Finally, there is the delay in analyzing the information by the government bodies/agencies. There are cases, usually related to the environmental sector, where preliminary studies are required to obtain permits, and these studies can be time-consuming and costly for the project.

- **Social:** opinion/attitude of the community involved or in proximity of the location of installation of renewable plants, which may act negatively on the project. Society is often opposed to energy projects when their installation may compromise certain activities, such as tourism. This may also occur if the area where the renewable resource is found belongs to communities such as: indigenous, caboclos, among others, whose property is protected and guaranteed by law.

- **Economic Financial:**
  - Financial Risk: the lack of knowledge of the agents involved in the projects focusing on energy generation via non-conventional sources may cause difficulties in being accepted by investors. The ab-

sence of a previous plant/facility at the location of the analysis project also plays unfavorably with the market.

- Subsidy and Competition with Other Energy Sources: government subsidies are common with conventional sources, such as with fuels like diesel or coal, which are easily transported and stored, and used in thermoelectric generation in order to guarantee the power supply of a certain place. On the other hand, there may also be competition from other renewable sources, as is the case with Brazil, where new energy projects are usually compared in terms of: costs, return, generation capacity for large hydroelectric dams. In both cases, there are chances that the final price of renewable energy (excluding hydropower) will be greater than the others.

- Cost of Investment: related to the high investments needed for the implementation of renewable energy projects, the difficulty and assessment of risks, and the long return-on-investment time. Also included are the taxes on importing the necessary equipment.

- Financing: absence of local or international financial mechanisms to leverage energy projects of non-conventional sources. In some cases this may also be defined as difficulty to access funding mechanisms.

- **Technical:** related to the intermittence of renewable sources. Due to renewable resources being linked to natural phenomena (wind, sun, hydrological regime) their availability is not constant. Generating capacity is associated with resource availability, thus interfering with the amount of energy sent to the system. It is also related to the absence of specific technical standards that set forth the necessary parameters for the connection and operation of renewable sources to the grid system.

Indirect Obstacles

- **Regulation:** related to the lack of specific laws aimed at projects for the production of energy from renewable sources, or also the presence of specific legislation with incomplete or bureaucratic implementation, or simply unclear.

- **Renewable Energy Development Strategy:** related to the absence of or low government support via the inclusion (or lack thereof) of energy produced from renewable sources in long-term energy supply and demand plans/projects, as well as its use in diversifying the energy matrix.

- **Infrastructure and Logistics:** this obstacle is related to the geographical aspect, since locations which are difficult to reach, in most cases, have no grid presence, and are therefore difficult to connect to the grid.

- **Database of Renewable Resources:** lack of or few studies and surveys conducted on the effective availability of renewable resources in the country.

- **Technical Training:** absence or few personnel with the technical knowledge for projects, installation or maintenance. The ability to disseminate this knowledge is also required.

RE Implementation Scenario

This chapter aims to present the implementation scenario of energy generation projects from renewable sources in the countries analyzed (Brazil, Chile, Colombia, Mexico, and Peru): energy production characteristics and current and potential scenario for expansion of the energy renewal market. Specifically regarding the adoption of RE in the industry, it also presents the current policies and main obstacles to implementation.

BRAZIL:

Brazil has the largest economy in Latin America. In 2014, iron ore was the product with the highest export value, reaching 12.62% of the total, followed by agricultural products and petroleum products (fuels and mineral oils), with 10.44% and 9.17% respectively[2]. For the same year, GDP was US$ 2.416 billion[3], a 4.38% increase on the previous year. Its composition is presented in Figure 2.

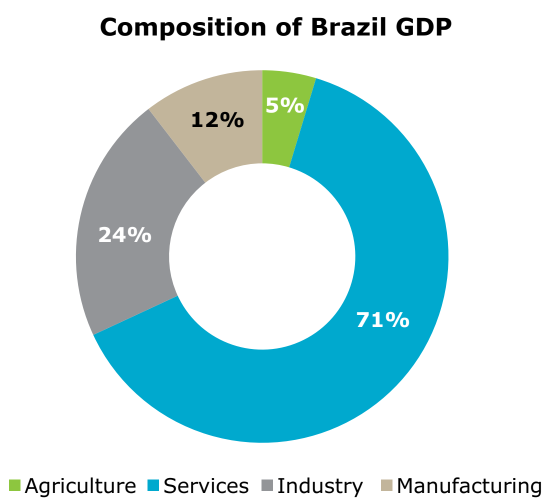

Figure 2 Composition of Brazil GDP in 2014 (Source: own elaboration with Global Edge data, 2016)

[2] http://globaledge.msu.edu/countries/brazil/tradestats
[3] http://databank.worldbank.org/data/reports.aspx?source=2&country=&series=SP.POP.TOTL&period=http://data.worldbank.org/data-catalog/GDP-ranking-table

Energy Context

In 2014, Brazil's primary energy production was 272.63 Mtoe, representing an 11.40% growth on the previous year. A comparison between the primary energy production profile between the years 1990 and 2014 (Figure 3) shows a relative increase in the diversification of the energy matrix through a reduction in the concentration of hydropower and firewood, and a significant increase in natural gas, oil, and other renewable energy sources. In general, the presence of renewable energy in the total primary energy of the two years compared drops significantly, by 18.2%, in relation to other sources and causing a reduction in hydropower and firewood.

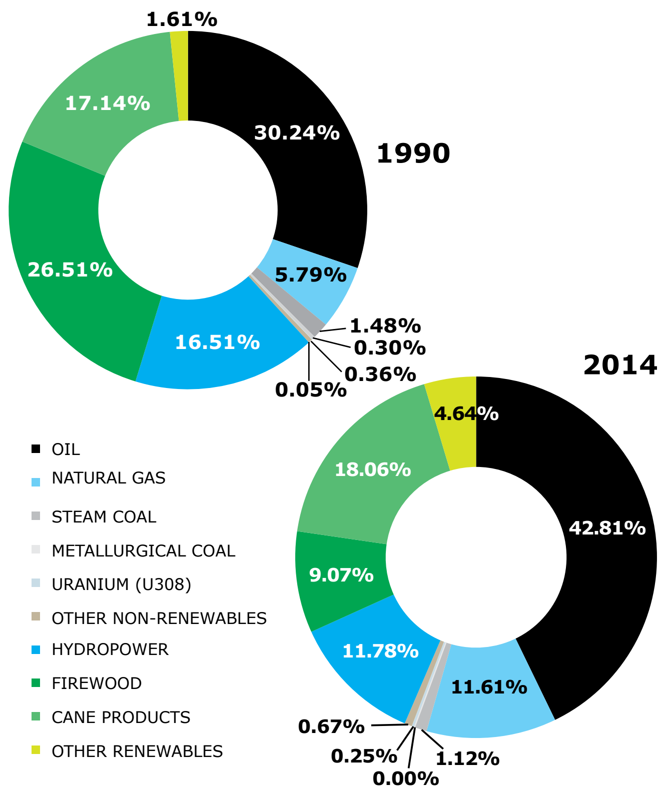

Figure 3 Comparison of the production profile of PE between the years 1990-2014 (Source: own elaboration with data from the National Energy Balance - BEN, 2015)

In 2014, Total Primary Energy Supply (TPES) in Brazil reached 305.6 Mtoe, equivalent to 2.2% of the world's supply. This represents an increase of 3.1% on the previous year, higher than the GDP growth of the same period (0.1%). Figure 4 shows the comparison between primary energy production capacity of the country and energy demand in 2014. Natural gas is the resource with the greatest difference between amount produced and amount consumed in the country, needing to be import-

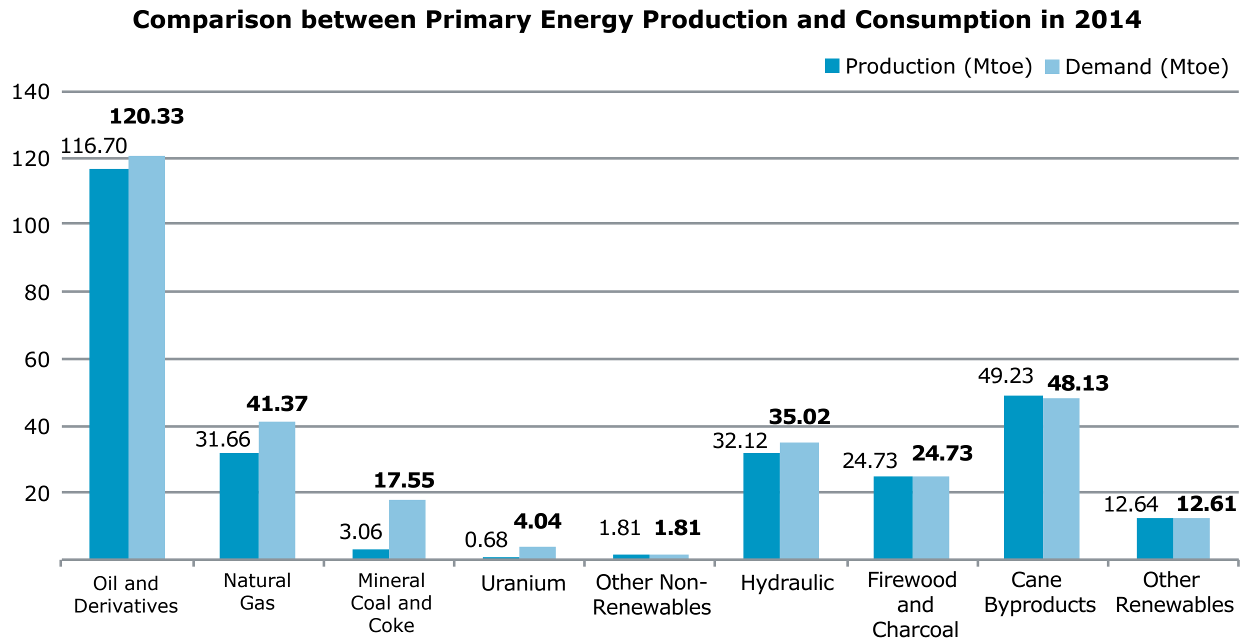

Figure 4 Comparison between energy production and supply (Source: own elaboration with data from BEN, 2015)

ed to meet Brazilian demand. It is also necessary to import metallurgical coal to meet domestic demand, particularly in the industrial sector.

In 2014, the industrial sector consumed 87.50 Mtoe, representing 32.91% of total energy consumption, which totaled 265.86Mtoe. There was a drop of 0.9% on the previous year, due to the country's lower economic growth, consequently resulting in lower energy consumption.

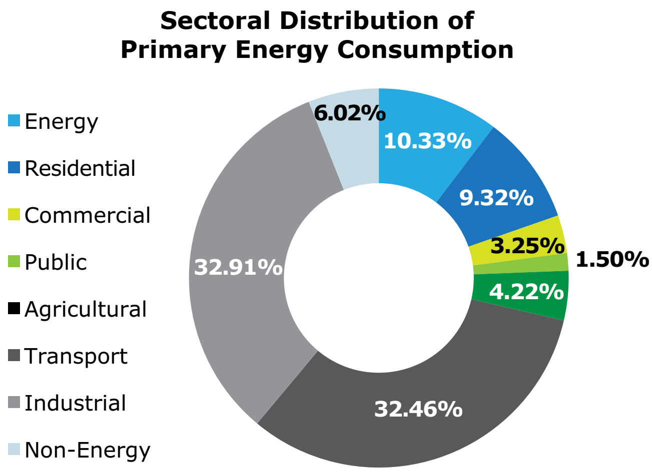

Figure 5 Distribution of energy consumption in 2014 (Source: own elaboration with data from BEN, 2015)

As illustrated in Figure 4, the non-energy consumption of primary energy was 6.02%, equivalent to 16 Mtoe of a total of 265.86 Mtoe. Industrial and transport sectors together accounted for 70% (173.81 Mtoe) of the total.

Brazil's economy underwent major transformations between the years 1990-2014, which directly influenced energy production and consumption, as shown in Figure 6.

The Energy Intensity Index (EII) shows the degree of efficiency of energy use in relation to the wealth of the country. This index correlates not only efficiency in the use of energy resources in general, but also economic aspects. In Brazil, it can be observed that even during the GDP growth period there was low energy consumption, with a downward trend. This may be linked to the modernization of some industrial sectors and efforts towards energy efficiency. Energy saved in the in-

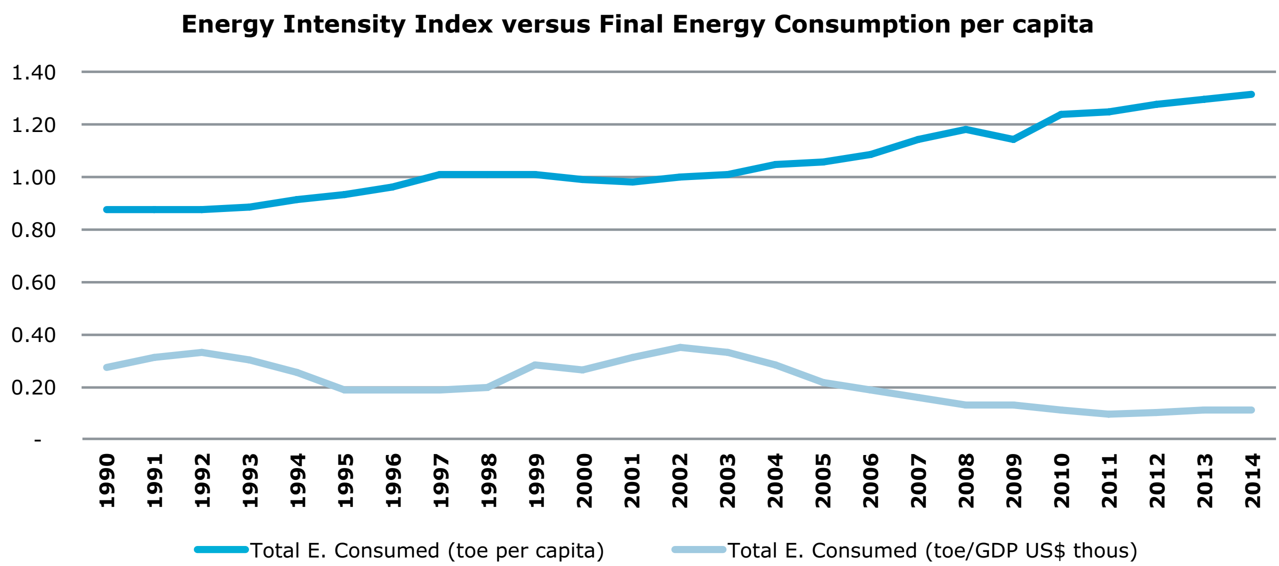

Figure 6 Comparison of energy consumption in Brazil (Sources: World Bank 2016; IEA, 2016; BEN, 2014

dustrial sector rose from 0.6% in 2012 to 3.3% in 2016, and aims to reach 6.9% in 2021[4].

On the other hand, the per capita energy consumption indicator shows a slight upward trend which reflects an improvement in the purchasing power of the Brazilian population over the years, making possible the acquisition of consumer goods that demand energy.

A portion of renewable resources are used for generation of electricity. In Brazil, there is a total of 4,556 plants generating electricity, corresponding to 159,988 MW of installed and granted capacity[5]. Their location, by type of generating plant and their respective percentage shares are presented in Table 2.

PLANTS IN OPERATION				
Type	**Quantity**	**Granted Power (MW)**	**Controlled Power (MW)**	**Share**
Hydropower Generating Plant (up to 1MW)	556	433.67	435.5	0.27%
Wind	379	9,315.41	9,264.73	5.82%
Small Hydropower Plant (1 to 30 MW)	449	4,856.18	4,835.54	3.04%
Solar Photovoltaic	40	26.96	22.96	0.02%
Hydroelectric Plant (> 30MW)	220	101,063.43	88,962.70	63.17%
Thermoelectric Plant	2,910	42,302.14	40,464.38	26.44%
Thermonuclear Plant	2	1,990.00	1,990.00	1.24%
Total	4.556	159.987,79	145.976,07	100,00%

Table 2 Installed and granted capacity of power plants in operation (Source: ANEEL - BIG; 2016)

[4] EPE, 2012s
[5] Generation Information Bank (BIG) of the National Electric Energy Agency (ANEEL)

According to data from the Statistical Yearbook of Electric Power 2015 produced by the Energy Research Company (EPE), a total of 590,479 GWh was produced during 2014, with all generating sources summed. Table 3 shows the data related to the production of electric power in the period 2010-2014, as well as the share of each of the sources in the year 2014, and the variation between 2013 and 2014.

Table 3 Power Generation by Source in Brazil, in GWh (Source: EPE, 2015)

	2010	2011	2012	2013	2014	Δ% (2014/2013)	Share % (2014)
Total	**515,799**	**531,758**	**552,498**	**570,835**	**590,479**	**3.4**	**100**
Natural Gas	36,476	25,095	46,760	69,003	81,075	17.5	13.7
Hydropower	403,290	428,333	415,342	390,992	373,439	-4.5	63.2
Oil Derivatives	14,216	12,239	16,214	22,090	31,668	43.4	5.4
Coal	6,992	6,485	8,422	14,801	18,385	24.2	3.1
Nuclear	14,523	15,659	16,038	15,450	15,378	-0.5	2.6
Biomass	31,209	31,633	34,662	39,679	44,733	12.7	7.6
Wind	2,177	2,705	5,050	6,578	12,210	85.6	2.1
Other	6,916	9,609	10,010	12,241	13,590	11.0	2.3

Renewable energy accounted for 72.9% of the total of energy generated in the country in 2014, placing Brazil in a prominent position in the global RE scenario. It can also be observed that the production of electricity via wind energy grew by 461%. Biomass, another renewable source, grew by 43%.

According to EPE data (2015), of the ten biggest global producers of electric power from hydroelectric plants, Brazil is in second place with an 8.6% share, behind China, who leads with a 25% share. Regarding energy generation from thermal sources, Brazil is 29th, with China and the US in first and second place respectively. This can be considered positive, as thermal generation has one of the highest rates of CO^2eq emission.

The table below shows a ranking of countries with the highest installed capacities of electric power generation from alternative sources. Brazil is in 9th place; the first three places account for 48.8% of the total (Table 4).

Table 4 Ranking of the 10 largest capacities (GW) installed in Alternative Energy Sources (Source: EPE; 2015)

	2008	2009	2010	2011	2012	Δ% (2012/2011)	Share % (2012)
World	**17,453.4**	**17,388.1**	**18,679.9**	**19,396.6**	**19,710.4**	**1.6**	**100**
China	3,054.1	3,270.3	3,781.5	4,264.3	4,467.9	4.8	22.7
United States	3,865.2	3,723.8	3,886.4	3,882.6	3,832.3	-1.3	19.4
Japan	961.6	935.1	994.8	983.2	921.0	-6.3	4.7
Russia	855.6	816.1	858.5	869.3	889.3	2.3	4.5
India	621.3	669.2	725.5	803.0	864.7	7.7	4.4
Germany	545.0	519.4	547.2	543.7	540.1	-0.7	2.7
Canada	561.6	523.8	526.3	543.7	524.8	-3.5	2.7
Brazil	428.3	426.0	464.7	481.0	498.4	3.6	2.5
South Korea	403.0	409.2	450.2	472.3	482.4	2.1	2.4
France	462.5	446.5	474.2	442.7	451.1	1.9	2.3
Others	5,703.9	5,656.2	5,979.5	6,113.1	6,253.1	2.3	31.7

The latest version of the 10-Year Energy Expansion Plan (PDE-2024[6]), prepared by the EPE, foresees an increase in the country's main sources of renewable energy - from 39.4% in 2014, to 45.2% in 2024 (Figure 7). Table 5 shows the current relationship of all plants that use renewable energy that are in operation, under construction, or beginning construction.

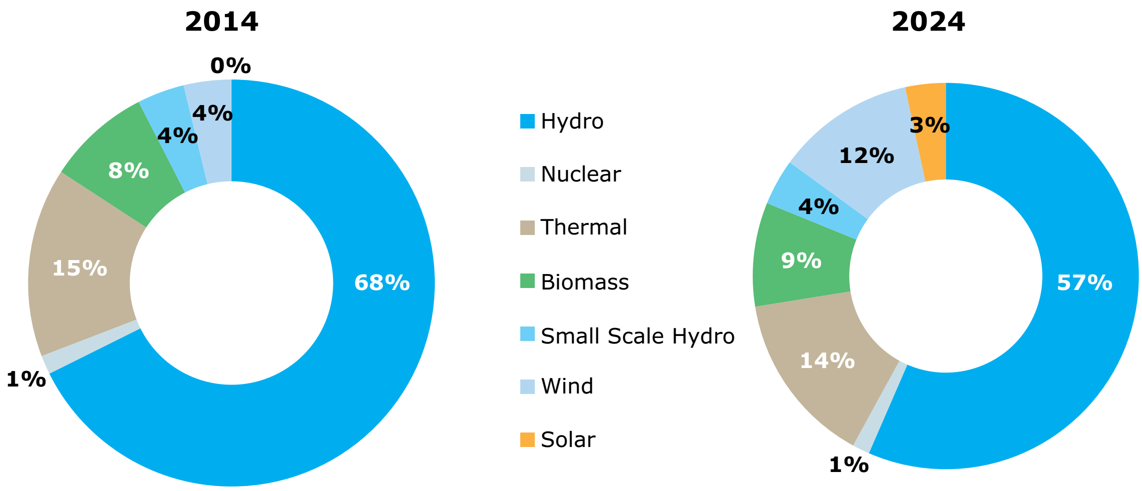

Figure 7 Comparison between the share of energy sources in the matrix in 2014 versus PDE forecast for 2024 (Source: PDE-2024; 2015)

[6] http://www.epe.gov.br/PDEE/Relat%C3%B3rio%20Final%20do%20PDE%202024.pdf

Table 5 Power plants which use RE in Brazil (Source: own elaboration with BIG data, 2016)

TYPE of RE		Capacity MW	Number of Plants
WIND	Under Construction	3,385.30	148
	Construction to begin	5,660.00	238
	In Operation	9,315.50	379
	Total Potential	12,700.80	527
	Overall Future Total	18,360.80	765
PHOTOVOLTAIC	Under Construction	90.00	3
	Construction to begin	2,877.00	107
	In Operation	26.92	40
	Total Potential	116.92	43
	Overall Future Total	2,993.92	150
HYDROELECTRIC (up to 1 MW)	Under Construction	0.84	1
	Construction to begin	26.60	39
	In Operation	433.67	556
	Total Potential	434.51	557
	Overall Future Total	461.11	596
SMALL HYDRO PLANT (1 to 30MW)	Under Construction	454.95	34
	Construction to begin	1,693.22	117
	In Operation	4,856.18	449
	Total Potential	5,311.13	557
	Overall Future Total	7,004.35	600
HYDROELECTRIC (>30MW)	Under Construction	1,967.10	7
	Construction to begin	629.00	6
	In Operation	101,063.43	220
	Total Potential	103,030.53	227
	Overall Future Total	103,659.53	233
BIOMASS (Bagasse and Biogas)	Under Construction	479.41	9
	Construction to begin	1,270.48	41
	In Operation	14,306.22	528
	Total Potential	14,785.63	537
	Overall Future Total	16,056.11	578
GEOTHERMAL	Under Construction	-	0
	Construction to begin	0.05	1
	In Operation	-	0
	Total Potential	0.05	1
	Overall Future Total	0.05	1

Of the total energy consumption of the industrial sector, the Food and Beverage sector is among those sectors with the greatest energy demand, consuming around 25.38% of the industrial sector load. Around 93% of this amount comes from renewable sources, of which sugar cane bagasse is prominent. This analysis is presented in Tables 6 and 7.

Table 6 Energy consumption by industry type in 2014 (Source: own elaboration with BEN data, 2015)

Industrial Sector Consumption		
Cement	5.34	6.10%
Cast Iron and Steel	16.35	18.69%
Iron Alloys	1.43	1.64%
Mining	3.43	3.93%
Non-ferrous Metals	6.62	7.56%
Chemical	6.71	7.67%
Food and Beverage	22.21	25.38%
Textile	1.02	1.16%
Pulp and Paper	11.42	13.05%
Ceramic	5.08	5.80%
Others	7.89	9.02%
Total	87.50	100%

The second largest energy consumer in the industrial sector is Cast Iron, with a consumption of 16.35Mtoe (18.69%), however unlike the Food and Beverage sector, only 17% of its consumption comes from renewable sources, specifically from charcoal. Mineral coal coke, a fossil resource, accounts for 45% of the total consumption of this sector.

Pulp and paper is the third largest energy consumer, with a consumption of 11.42 Mtoe in 2014, equivalent to 13.05%. This sector also derives 71% of its power consumption from renewable sources, particularly lye which accounts for 45.6% of energy used. The second largest source is electricity, with 15.6%.

Table 7 Distribution of energy consumption by source among industrial sectors (Source: BEN, 2015)

INDUSTRIAL SECTOR / SOURCE	Cement	Cast Iron	Iron Alloys	Mining and Pelletizing	Chemical	Non-ferrous and others	Textile	Food and Beverage	Pulp and Paper	Ceramic
Natural Gas	25.04	1,035.77	20.24	707.19	2,022.00	895.92	247.71	735.88	847.85	1,338.74
Mineral Coal	122.59	1,871.32	-	491.34	-	1,061.64	-	-	-	-
Steam Coal	-	-	-	-	168.52	-	-	65.95	117.18	50.42
Mineral Coal Coke	-	7,521.87	78.29	-	-	-	-	-	-	-
Diesel	71.83	35.37	-	424.17	19.57	50.52	4.56	248.67	164.44	26.11
Fuel Oil	14.25	34.95	-	166.12	322.94	1,200.38	33.70	148.24	364.65	101.80
Liquefied Petroleum Gas	-	25.79	-	28.15	217.19	-	40.08	315.41	72.56	171.34
Coke Oven Gas	-	1,242.13	-	-	-	-	-	-	-	-
Kerosene	-	-	-	1.04	-	-	0.00	0.05	-	-
Petroleum Coke	3,762.93	-	-	534.05	-	-	-	-	-	-
Other Petroleum Derivatives	459.70	132.78	244.63	-	1,879.73	595.02	-	-	-	357.30
Electricity	680.81	1,671.24	581.78	1,082.44	1,922.27	2,798.44	622.04	2,324.08	1,780.42	376.37
Firewood	79.00	-	-	-	48.81	-	69.31	2,250.00	1,712.66	2,657.02
Charcoal	121.51	2,783.48	506.22	-	17.86	13.64	-	-	-	-
Sugar Cane Bagasse	-	-	-	-	89.08	-	-	16,120.42	25.09	-
Lye	-	-	-	-	-	-	-	-	5,431.95	-
Other Renewables	-	-	-	-	-	-	-	-	905.79	-
Total	5,337.65	16,354.70	1,431.16	3,434.50	6,707.97	6,615.56	1,017.40	22,208.70	11,422.59	5,079.10

When analyzing the energy consumption of the industrial sector as a whole, renewable energy accounted for 38.56%, with sugarcane bagasse being the largest share, corresponding to 18.55%

Figure 8 shows the evolution of energy consumption of the industrial sector in the years 1990, 2004, and 2014. Sugarcane bagasse, electricity, and natural gas increased significantly, while there was a considerable reduction in fuel oil consumption. Firewood and other types of renewables also registered an increase in share, due to the increase in the use of waste (grain bark, wood chips, dry foliage, among others) by industry sectors.

Energy Sector Government Agencies

The following are the main bodies and Energy sector government agencies present in Brazil (the list is not exhaustive)

- **Ministry of Mines and Energy - MME[7]:** a direct administration body, which represents the Union and has the power to formulate public policy as well as supervise the implementation of these policies in geology, mineral resources, energy resources, use of hydro energy, among others. It is also responsible for rural energization, agro-energy, as well

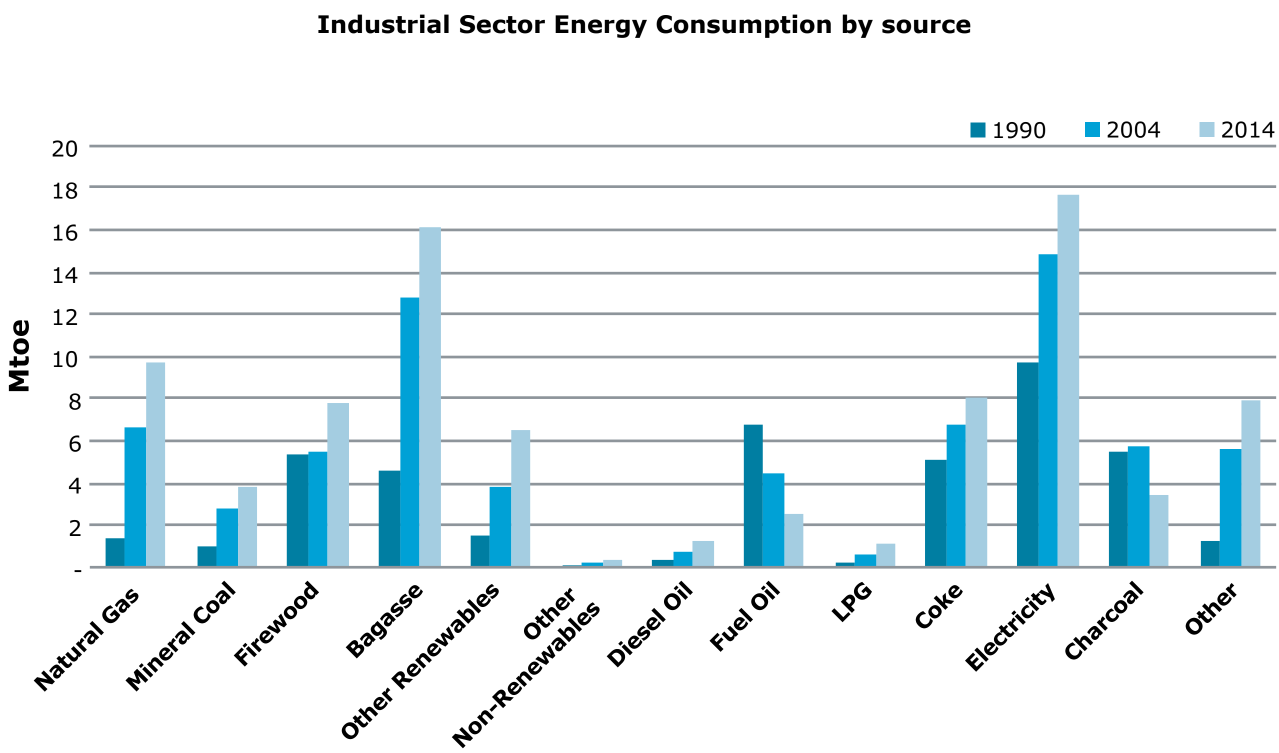

Figure 8 Comparison of energy consumption between 1990 and 2014 (Source: own elaboration with BEM data, 2015)

[7] http://www.mme.gov.br/

as ensuring the conjunctural and structural balance between supply and demand of energy resources in the country.

- **Secretariat of Petroleum, Natural Gas, and Renewable Fuels - SPG[8]:** subordinate to the MME, it promotes the study of the Brazilian sedimentary basins; proposes guidelines for the bidding of blocks for Exploration and Production (E&P); works in conjunction with ANP, among others.

- **Secretariat of Electric Power - SEE[9]:** subordinate to the MME, has as its main focus: to monitor the expansion of electrical systems to ensure a balance between supply and demand, in line with government policies; to monitor the performance of electricity generation, transmission, and distribution systems, taking into account continuity and safety, and providing technical assistance to the CNPE and the Electric Sector Monitoring Committee (CMSE).

- **Secretariat of Planning and Energy Development - SPE[10]:** subordinate to the MME and responsible for developing long-term structuring actions for the implementation of sectoral policies; functions as the core management of programs and projects in its area of competence and ensures sector integration within the scope of the ministry.

- **National Electric Energy Agency – ANEEL[11]:** an autarchy under a special regime linked to the Ministry of Mines and Energy, created to regulate the Brazilian energy sector. It began its activities in 1997 and its main attributions are the regulation of generation, transmission, distribution, and commercialization of electric energy; implementation of the policies and guidelines of the federal government regarding the exploitation of electric power and the use of hydropower potentials; to establish and formulate tariffs, among others.

- **National Agency of Petroleum, Natural Gas, and Biofuels – ANP[12]:** a federal autarchy, linked to the MME and responsible for the execution of national policy for the energy sectors of petroleum, natural gas, and biofuels, in accordance with the Petroleum Law (No. 9,478/1997). Regulates the activities of the petroleum, natural gas, and biofuel industries. Among its main purposes are: regulating and establishing of rules by means of ordinances, normative instructions and resolutions for the operation of industries and the trade of oil, gas, and biofuels; to promote bids and sign contracts on behalf of the Union with concessionaires in exploration, development and production of oil and natural gas, and authorization of the activities of regulated industries; conducting bids for areas of exploration, development, and production of oil and gas, among others.

- **Energy Research Company - EPE[13]:** provides services in the area of studies and research aimed at subsidizing the planning of the energy sector. The studies and research developed by EPE will support the formulation, planning, and implementation of MME actions within the framework of national energy policy. Among its main duties are: to carry out studies and projections of the Brazilian energy matrix; prepare and pub-

[8] http://www.mme.gov.br/web/guest/secretarias/petroleo-gas-natural-e-combustiveis-renovaveis/institucional/a-spg
[9] http://www.mme.gov.br/web/guest/secretarias/energia-eletrica/institucional/a-see
[10] http://www.mme.gov.br/web/guest/secretarias/planejamento-e-desenvolvimento-energetico/institucional/a-spe
[11] http://www.aneel.gov.br/ | [12] www.anp.gov.br | [13] www.epe.gov.br

lish the national energy balance; obtain the prior environmental license and the declaration of water availability required for biddings involving hydroelectric generation and electric power transmission projects selected by EPE, among others.

Legislation

The following are the main legal frameworks and present norms for the energy sector in Brazil (the list is not exhaustive):

- **Law No. 12,783 – Year 2013[14]:** addresses concessions for the generation, transmission, and distribution of electricity, the reduction of sector charges and tariff modality; amends Laws 10,438, of 26th April 2002, 12,111, of 9th December 2009, 9,648, of 27th May 1998, 9,427, of 26th December 1996, and 10,848, of 15th March 2004; revokes the provisions of Law 8,631, of 4th March 1993; among other provisions.

- **Normative Resolution No. 482 – Year 2012[15]:** establishes general access conditions for micro- and mini-generation distributed to electric power generation systems and the electric power compensation system. It presents a series of pertinent definitions; establishes that distributors must adapt their systems according to the entry and presence of distributed generation in the concession/operation region; the signing of contracts of use and connection as generating plant for the participants of the electric power compensation system; defines which consumers can join the compensation system, among other provisions.

- **Normative Resolution No. 687 – Year 2015[16]:** amends Article 2 of Normative Resolution No. 482 of 17th April 2012, where relevant definitions are altered and included; also amends the wording of consumers eligible for adhering to this system, establishes procedures for the distributor, for the billing of consumers that are part of the electric power compensation system, among other provisions (ANEEL).

- **Normative Resolution No. 488 – Year 2012[17]:** establishes conditions for the revision of plans for the universalization of electricity distribution services in rural areas, according to the institution of the LUZ PARA TODOS[18] program for the period 2011-2014 (ANEEL).

- **Normative Resolution No. 493 – Year 2012[19]:** establishes the procedures and conditions for the supply of electric energy by means of the Isolated Electric Power Generation and Distribution Microsystem (MIGDI) or Individual Power Generation System with Intermittent Power Supply (SIGFI)[20]. Determines relevant parameters, definitions, and restrictions, among other provisions.

- **Ordinance no. - 538 - Year 2015[21]:** Creates a Development Program for the Distributed Generation of Electric Power - ProGD, with the following objectives: to promote

[14] http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2013/Lei/l12783.htm
[15] http://www2.aneel.gov.br/arquivos/PDF/Resolu%C3%A7%C3%A3o%20Normativa%20482,%20de%202012%20-%20bip-junho-2012.pdf
[16] http://www2.aneel.gov.br/cedoc/ren2015687.pdf | [17] http://www2.aneel.gov.br/cedoc/ren2012488.pdf
[18] Luz para Todos Program (LPT): - instals solar panels in communities that do not have access to electricity, including the Isolated System. | [19] http://www2.aneel.gov.br/cedoc/ren2012493.pdf
[20] Any renewable energy resource that is not continuously available is considered to be intermittent due to factors beyond direct control, and for purposes of conversion to electricity by the generation system, cannot be stored in their original form. (https://www.mme.gov.br/luzparatodos/downloads/especificacoes_tecnicas.pdf)

the expansion of distributed generation of electric power based on renewable sources and co-generation; to encourage the implementation of distributed generation in public buildings, such as schools, universities and hospitals, and commercial, industrial, and residential buildings. It also determines relevant parameters and restrictions, among other provisions.

- **Incentive Program for Alternative Energy Sources - PROINFA[22]:** instituted with the aim of increasing the share of electric power produced by projects based on wind, biomass, and small hydroelectric power plants, in the National Interconnected Electric System. The aim is to promote the diversification of the Brazilian Energy Matrix, seeking alternatives in order to increase the security of the electric power supply, as well as allowing for the valorization of regional and local characteristics and potential.

- **Draft Law 4550/2008[23]:** addresses the production and sale of energy from incentivized and renewable sources, and amends laws 10,848 and decree 5,163/2008. Project aimed at encouraging the share of renewable energy sources in the production of electricity destined for the SIN. It also suggests that there be a preference for feeding the SIN with energy from these sources. It introduces definitions regarding renewable sources to be incentivized and suggests parameters and tariff formulations, among other provisions. According to information from Congress, this Draft was joined to Draft Law 630/2003.

- **Draft Law 630/2003[24]:** modifies Article 1 of Law no. 8,001, of March 13th, 1990, which "defines the percentages of distribution of the financial compensation referred to in Law no. 7,990, of December 28th, 1989, and other measures", which constitute a special fund for financing research and production of thermal and electric energy from wind and solar energy.

- **Draft Law 1563/2007[25]:** addresses renewable energy sources, with the aim of promoting the universalization, distributed generation, and streamlining of energy, and modifies Law no. 10,438, of April 26th, 2002, in order to modify Proinfa and increase the share of alternative sources in the national energy matrix.

- **Draft Law 4332/2016[26]:** addresses the program for the incentive of solar energy use and other renewable sources in multifamily buildings, commercial, mixed, and single-family buildings in horizontal or vertical condominiums and other measures.

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[21] http://www.mme.gov.br/documents/10584/1942329/Portaria_n_538-2015/49ab0708-5850-404c-a924-2760bbd22bbc;jsessionid=ED0860CFCB0813E9E9B8A7BCE4EAFD28.srv155?version=1.1
[22] http://www.mme.gov.br/programas/proinfa/
[23] http://www.camara.gov.br/proposicoesWeb/prop_mostrarintegra?codteor=627322&filename=PL+4550/2008
[24] http://www.camara.gov.br/proposicoesWeb/prop_mostrarintegra?codteor=122715&filename=PL+630/2003
[25] http://www.camara.gov.br/proposicoesWeb/prop_mostrarintegra?codteor=481976&filename=PL+1563/2007
[26] http://www.camara.gov.br/proposicoesWeb/prop_mostrarintegra?codteor=1431855&filename=PL+4332/2016

Financing Mechanisms

There are a series of specific financial products in Brazil that aim to finance industry adoption of RE. Even though not strictly focused on this sector, some instruments may help to advance the implementation of RE projects. Currently, there are mechanisms with a greater focus on financing solar technology, in response to the greater development and potential of this technology in the country. Table 8 presents the highlights of the available financial products.

It is worth highlighting that in October 2016, BNDES announced a new funding policy for the energy sector in Brazil. It increased the participation of Long Term Interest Rate loans for power generation projects from solar sources, while at the same time establishing a reduction of its participation in hydroelectric projects. In addition, it terminated support for all coal and oil thermal projects, and transmission lines.

In addition, international funds are available to Brazil, which aim to finance sustainable development, including RE projects. The BID, through its Action Plan on Climate Change, paid out US$ 390 million in 2014 in Brazil, and a total of US$ 470 million by the CAF[27].

Table 8 Financial products available for RE in Brazil (Source: Own elaboration)

Bank	Product	Product Description
BNDES	**Energy Efficiency**	Any Corporate Loan client in need of financing for buildings, with a focus on air conditioning, lighting, envelopment and distributed generation; including co-generation, for new or already existing units (retrofit), production, with a focus on co-generation, use of process gases as an energy source and other interventions prioritized by BNDES; smart grids.
BNDES	**Renewable Energy**	Department of biofuels: better credit conditions for investments in renewable energy sources, where the portfolio include wind, biomass, and small hydroelectric (PCH) projects.
BNDES	**Funtec**	Technological development and innovation in the areas of renewable energies, environment and health.
BNDES	**Climate Fund**	Support for the implementation of ventures, acquisition of machinery and equipment and technological development related to reduction of GHG emissions and adaptation to climate change and its effects.
Caixa	**Producard**	Any Corporate Loan client in need of financing for energy micro-generation systems, solar, and wind
Caixa	**Construcard**	Any Personal Loans client in need of financing of solar water-heating systems and micro power generating systems - solar and wind
Banco do Nordeste	**FNE Sol**	Any client in need of financing for all components of micro- and mini-generation photovoltaic, wind, or biomass energy systems, as well as the installation of these
Sicredi	**Solar Energy**	Any Corporate Loan client associated with Sicredi in need of financing for electric power through solar energy
Itaú Unibanco	**Line of credit BID**	Credit line aimed at financing sustainability projects. The focus is on investments in renewable energy, energy efficiency and "clean" production methods.
Santander	**Sustainable CDC**	Any Corporate Loan client in need of financing for machinery and equipment for the promotion of energy efficiency, rational use of water, sustainable construction and accessibility, residue treatment, and corporate governance.

[27] CEPAL, 2015

Main Obstacles to the Implementation of RE

Figure 9 shows the matrix constructed for the analysis of obstacles which affect the development of renewable energy projects in Brazil, based on the methodological approach proposed in this study.

BD	Renewable resources database
CT	Technical training
CI	Cost of investment
ED	RE development strategy
F	Financing
IL	Infrastructure and Logistics
RA	Regulatory and Administrative
R	Regulation
RF	Financial Risk
S	Social
SC	Subsidy and competition with other sources
T	Technical

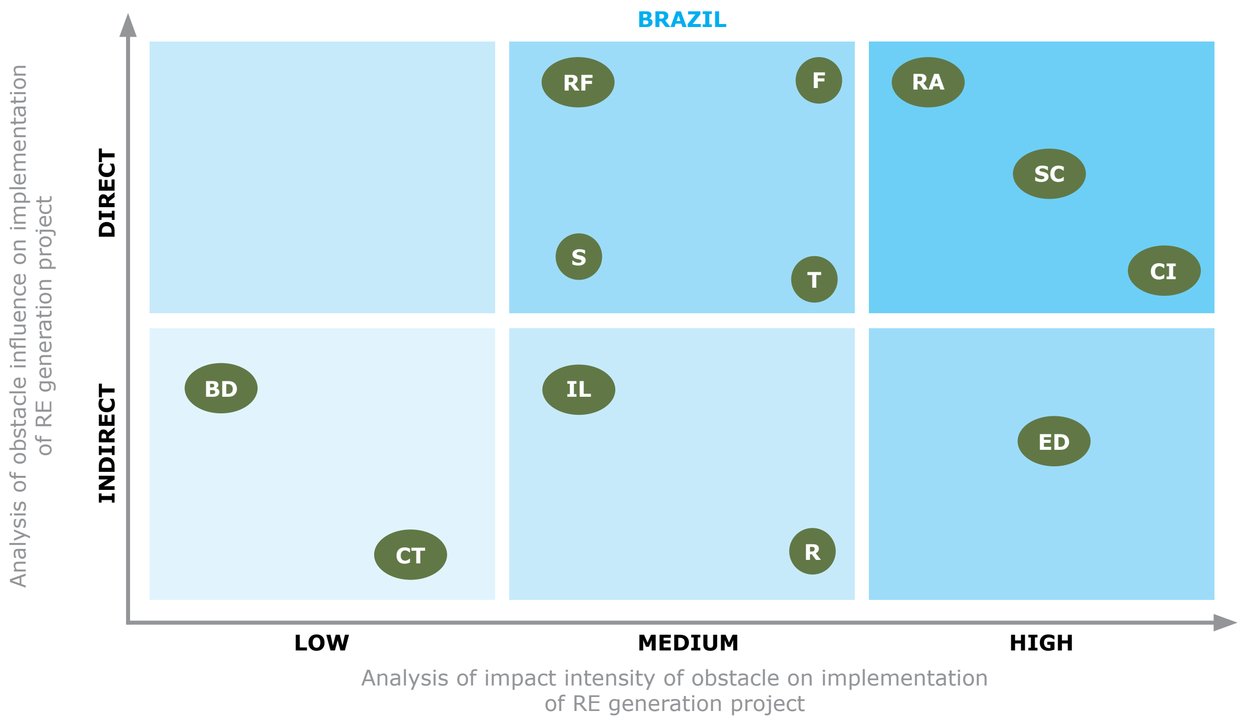

Figure 9 Matrix of obstacles in Brazil (Source: own elaboration)

In Brazil, the complexity and cost of transaction for starting a renewable energy project, coupled with the economic situation and investment costs, as well as competition with other traditional energy sources, were identified as direct obstacles with the greatest intensity.

Among the direct obstacles with medium impact intensity are those linked to financing, due to the delays in obtaining it and cost of transaction. Associated to these factors are the greater financial risks of renewable projects from non-conventional sources. Finally, there is a technical obstacle, since renewable energies are usually intermittent generators of power, that is, not continuous, due to non-controllable factors such as climate conditions or storage unfeasibility.

Regulatory aspects are also direct obstacles, given that the technical standards of regulatory agencies pertaining to renewables are diffuse. Another direct obstacle is the country’s lack of infrastructure. Often places with the greatest potential for generating energy from renewable resources also present difficulties in connecting to the grid. Such difficulties could be overcome with investment in transmission lines and better access to generation sites.

In Brazil, some renewable energy projects face resistance from local communities, even those not connected to large scale hydroelectric projects. This was considered a social obstacle. Within the indirect obstacle category, the lack of disclosure of the mapping of areas abundant in renewable resources for power generation and their capabilities was considered. Likewise, in Brazil there are several programs for technical training of human resources with specific knowledge for action in projects linked to renewable energy.

It is important to highlight that although electric power coming from a hydroelectric plant with over 30MW of capacity in Brazil is considered a source of renewable energy, the obstacles described, in a general sense, do not apply to large hydroelectric projects due to there being specific legislation, as well as an accumulation of knowhow developed on national soil, which eliminates obstacles such as technical training, infrastructure, and connection to the grid. According to Souza et al (2001)[28], one of the main problems related to the environmental issue, apart from the slowness of the process as a whole, are the costs involved, which are considered to be very high for renewables in the country. There are, additionally, social obstacles, which via the resistance put up by local communities can interfere with or delay the implementation of the project.

CHILE:

Chile's main natural resources are copper, iron ore, molybdenum, nitrates, wood, and water. The Chilean mining sector accounts for 34% of world copper production and has an estimated reserve of over 100 million tones. Lithium is the second most abundant ore in Chile, which accounts for 50% of world production with around 27% of the world's reserves[29].

Chile's GDP for 2014 was US$258.1 billion, a 6.71% drop compared to 2013. GDP composition is shown in Figure 10. For the same year, inflation registered at 4.395%.

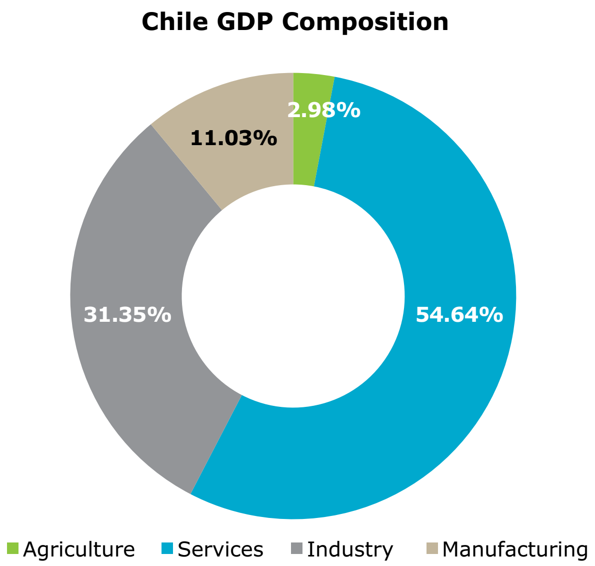

Figure 10: Composition of Chilean GDP in 2014 (Source: Own elaboration based on Global Edge data, 2016)

[28] www.sbpe.org.br/socios/download.php?id=173
[29] https://www.kpmg.com/Ca/en/industry/Mining/Documents/KPMG-Mining-country-guide-Chile.pdf

Energy Context

In 2014, the total consumption of primary energy in Chile was 31.42 Mtoe, while the country's total production was 13.74 Mtoe. Crude oil was highest in demand with 10.35 Mtoe, equivalent to 33%. This is the highest registered energy consumption deficit. For that year, production was only 0.48 Toe, corresponding to 3.5% of primary energy produced. Figure 11 shows a comparison between production and primary energy consumption by source type.

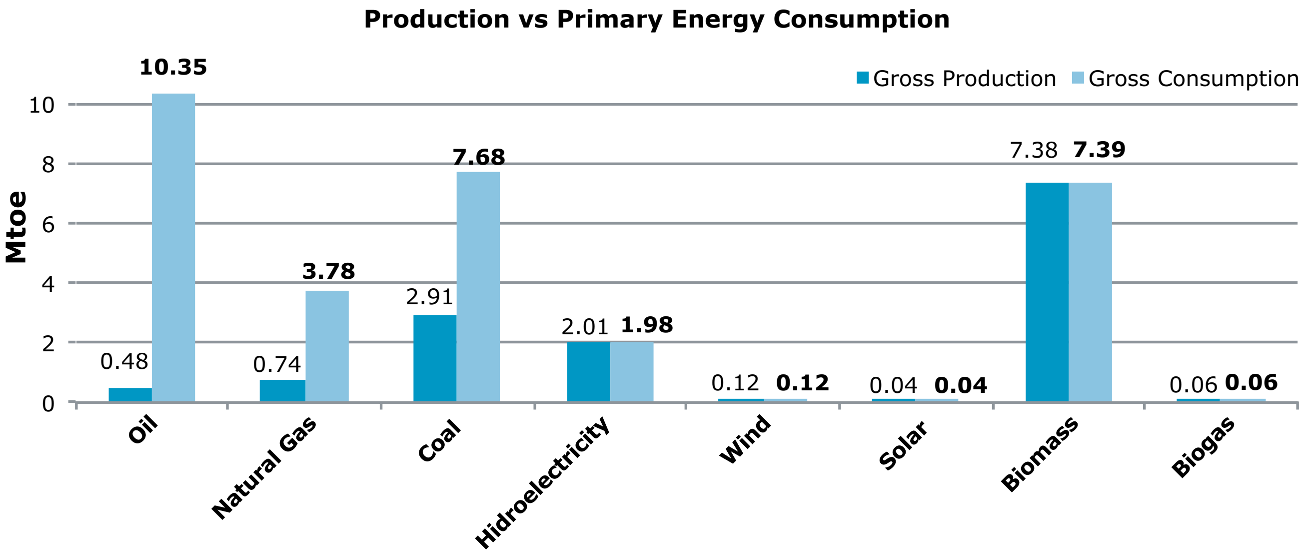

Figure 11 Production versus primary energy consumption (Source: own elaboration based on BNE data, 2015)

Biomass is the main local energy, followed by hydroelectricity. Its production equals 53.7% of the total primary energy produced, while its consumption is 23.53%. On the other hand, wind, solar, and biogas production, in total, correspond to only 1.6% of the total, and their consumption is equivalent to 0.70%.

The three largest consumers of biomass as an energy source are processing centers (CTR)[30], the residential sector, and the pulp and paper industry, as can be seen in Figure 12 (BNE, 2014).

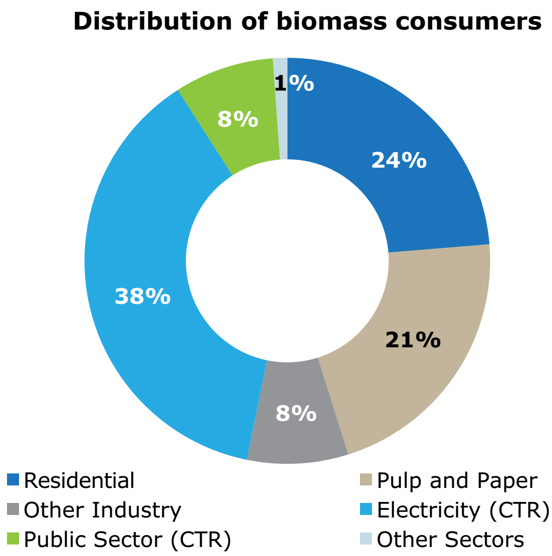

Figure 12 Distribution of biomass-consuming sectors (Source: own elaboration with BNE data, 2014)

[30] CTR: Processing plants, for example, a refinery or CTR transforms crude oil into derivatives. These CTRs are present in steel mills, refineries, gas plants and others.

Figure 13 shows the behavior of the Energy Intensity Index (IIE) as well as the final energy consumption per capita in Chile. Even with the oscillations and peaks throughout the period, the IIE shows a downward trend while the opposite occurs with per capita consumption.

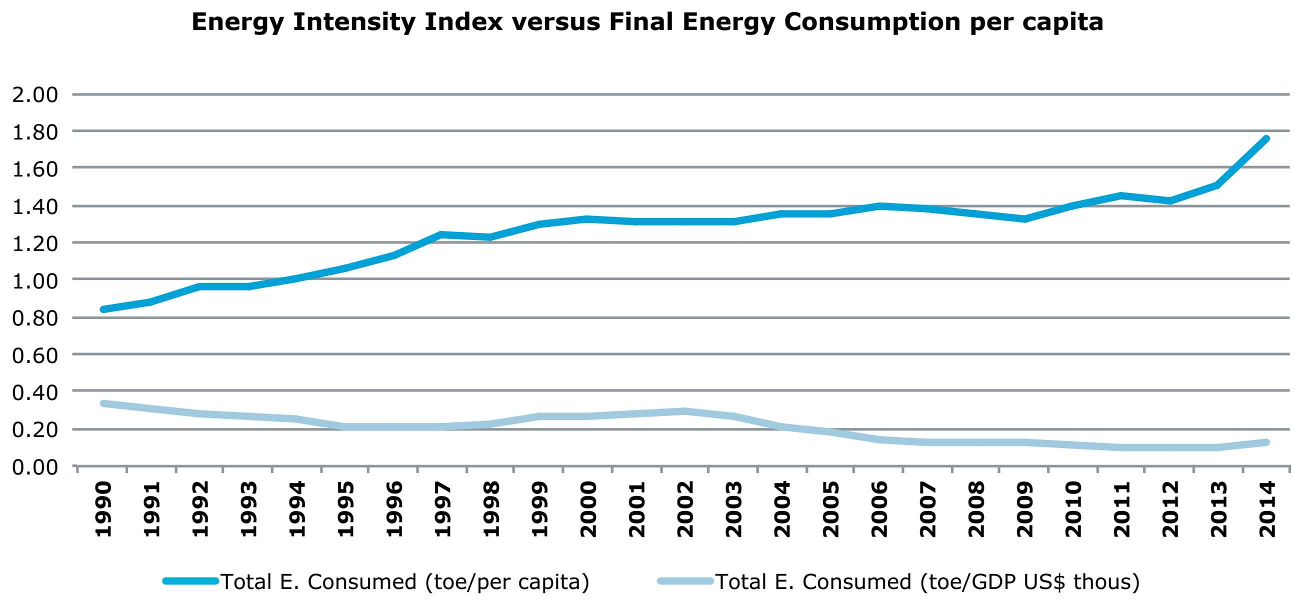

Figure 13 Comparison of PE production and total energy consumption by GDP and per capita (Source: Own elaboration with data from: IEA; World Bank; CIFES and Energia 2016)

The downward trend in the Chilean IIE is the result of efforts to increase the country's energy efficiency, not only in industrial processes but also general consumption, including in the public sector. Within this sector there are projects for public lighting to be delivered with LED technology, which is less energy consuming, for example. An agency dedicated to energy efficiency was created: the Chilean Energy Efficiency Agency[31].

The Total Energy Consumed per capita indicator grew during the same period due to the better performance of the Chilean economy, which attracted more investment in industrial facilities, thus extending energy networks and other factors which democratize energy consumption.

Despite Chile being a country with a considerable potential for the development of RE such as solar, wind, geothermal, and tidal, close to 40% of energy generated in the country still comes from fossil resources, most of which are imported. Being aware of this, the Ministry of Energy set forth targets for RE energy generation: for the year 2025, close to 20%; by 2035 the figure is 60%; and finally in 2050, 70% of energy generated in the country should be via RE. The target becomes less ambitious if energy from hydroelectric plants is included in these figures. Table 9 shows the evolution of energy projects in the period from 2014 to 2016.

[31] Chilean Energy Efficiency Agency http://www.acee.cl/

Table 9 Evolution of energy projects (Source: own elaboration based on data from the Ministry of Energy, 2015 and 2016)

Evolution of Energy Projects				
Type of Energy (MW) Period	**Mar/14**	**Jul/15**	**Mar/16**	**Variation (2014 to 2016)**
Hydro	653	963	962	47.3%
Thermal	632	1,364	1,441	128.0%
Solar	223	1,038	1,151	416.1%
Wind	350	274	508	45.1%
Other NCRE	91	95	43	-52.7%
Total MW	1,949	3,734	4,105	110.6%
Total Projects	28	39	59	110.7%
Investment (US$ - billions)	6	11	11	88.1%
%Total NCRE	34.1%	37.7%	41.5%	21.7%

The analysis of this data shows that Chile is concentrating its efforts not only on the expansion of energy supply but also in increasing the share of Non-Conventional Renewable Energy (NCRE). In a two year period an increase of 21.7% of NCRE was registered. The share increase of solar energy should also be noted, which went from 223 MW in 2014 to 1,151 MW in 2016 (416%).

The installed capacity of energy production based on non-conventional renewable sources in Chile is 2,864 MW, with a further 2,583 MW under construction. The environmental assessment of an additional 18,024 MW has been approved and 6,853 MW are still under analysis. These projects include RE categories, with the exception of tidal and geothermal energy. Solar and wind energy have the greatest capacity of installation. Further details on the distribution of these projects and how they are divided by source is shown in Figure 14.

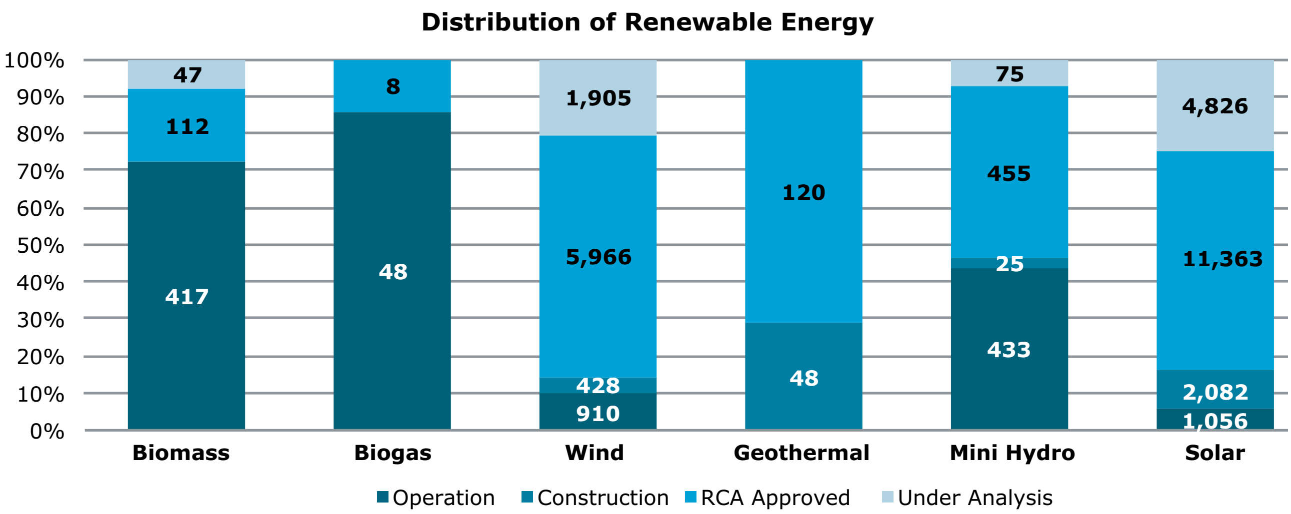

Figure 14 Distribution of NCRE Projects (Source: CNE, 2016)

In Chile, the industrial sector accounted for 15.6% of total secondary energy consumption[32] in 2014, equivalent to 6.6 Mtoe. The pulp and paper industry accounted for 35.47% of this amount, that is, 2.34 Mtoe[33]. Despite the industry's high energy consumption, a large part of this energy comes from biomass use, which in 2014 accounted for 67.6% of energy consumed by this sector. This biomass is the residue from extraction and processing of wood for the extraction of cellulose. It is mostly used in processes involving heat/steam production. The greatest opportunities in the industrial sector lie in the use of byproducts of productive activities, such as biogas and biomass.

The mining sector, one of the largest consumers of energy in Chile, is showing signs of progress in the use of NCRE in its installations. These mines are usually located in more isolated regions and use fossil fuels to generate energy. Of the total of energy consumed by the sector in 2014, diesel accounted for 41%, and electricity 56%[34,35]. The following are examples of NCRE progress in the sector: (i) the 110 MW solar plant at Cerro Dominador which will supply uninterrupted power to the Antofagasta mining complex, located in the Atacama desert, northern Chile; (ii) the El Arrayán wind power complex with 115 MW of installed capacity; (iii) the Chuquicamata mine[36], where a part of the energy used comes from the photovoltaic system installed therein.[37,38].

Energy Sector Government Agencies

Listed below are the main bodies and government agencies of the energy sector in Chile (the list is not exhaustive):

- **Ministry of Energy – ME[39]:** created in February 2010, it is a government body responsible for developing and coordinating plans, policies, and standards aimed at developing the country's energy sector.
- **National Centre for Innovation and Promotion of Renewable Energy – CIFES[40]:** Government body responsible for supporting the ME and the economic development agency (CORFO) in developing, implementing, and evaluating strategic projects in sustainable energy.
- **Superintendency of Electricity and Fuels – SEC[41]:** regulatory agency of the energy market. Its relationship with the federal government occurs through the Ministry of Energy.
- **Chilean Energy Efficiency Agency – AChEE[42]:** non-profit private law foundation whose mission is to promote, strengthen, and consolidate the efficient use of energy through the implementation of projects aimed at reducing energy consumption.

[32] Secondary energy is obtained via the transformation of a particular primary energy. For example: when crude oil (primary energy) is refined to obtain diesel oil, which is a secondary energy.
[33] BNE,2014
[34] Total energy consumed by the sector was 3.463 Mtoe.
[35] BNE, 2015
[36] Largest copper-producing mine in Chile, located in Antofagasta
[37] http://www.pv-magazine.com/services/press-releases/details/beitrag/solarmax-delivers-pv-inverters-for-the-largest-copper-mine-in-the-world_100015469/#axzz3DhIZKeb9
[38] http://www.nortonrosefulbright.com/knowledge/publications/134773/chile
[39] http://www.energia.gob.cl/
[40] http://cifes.gob.cl/
[41] http://www.sec.cl/
[42] http://www.acee.cl/

- **National Energy Commission – CNE[43]:** responsible for the analysis of prices, tariffs, and technical guidelines which energy generation, production, transmission, and distribution companies must follow.

Legislation

Listed below are the main legal frameworks and norms of the energy sector present in Chile (the list is not exhaustive):

- **Law 20,257, of 2008[44,45]:** General Electric Services Law, regarding the generation of electricity via non-conventional renewable energy sources. It requires that companies supplying energy prove that a quota determined by this law is generated based on NCRE, regardless of whether it is generated by the company itself or contracted from third parties. In 2010 this quota was 5% and will be valid until 2014. From 2015, the quota will increase annually by 0.5% until reaching 10% in 2024. This quota system will last 25 years (2010-2034).

- **Law 20,968 of 2013:** increased the limit established by Law 20,257 to 20%, and as such the following details regarding the signature of contracts must be observed: (a) for contracts signed from July 1st, 2013, the obligation will be 5% in 2013, increasing by 1% from 2014 until reaching 12% in 2020, and an increase of 1.5% from 2021 to reach 18% by 2024, and a 2% increase in the year 2025 to reach 20% in the same year; (b) For contracts signed between August 31st 2007 and before July 1st 2013, the obligation will be 5% for the years 2010 to 2014, increasing by 0.5% per year from 2015 and reaching 6% in 2016, and so on, to finally reach 10% in 2024.

- **Law 19,657 Concession for Geothermal Energy 2000[46]:** establishes a regulatory framework for prospection and exploration of geothermal energy, and its respective norms for concessions and contracts, in addition to the financing for geothermal energy exploration. It is the responsibility of the Ministry of Energy to control and regulate, including to manage auctions which take place every two to three years, and the tendering of geothermal energy.

- **Law 19,940 of 2004:** Regulates electric power transmission systems and introduces adjustments that refer to Law 20,257. It allows smaller power producers participation in the spot market and connection to the distribution network in order to promote private investment in the sector. The legislation also guarantees all small-scale producers (<9 MW) the rights to sell their energy on the local electricity market.

- **Law 20,018 of 2005:** also known as the "Lei Simples" or Simple Law, which allows energy producers, including NCRE, to sign long-term energy supply contracts with distribution companies.

- **Law 20,571 of 2014:** regulation on Distributed Generation (Net Metering), determining that NCRE electricity producers that send their surplus production to the system will receive credit in their electric energy account. The amount of this credit is equal to the electricity price charged per kwh to consumers.

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[43] http://www.cne.cl/quienes-somos/
[44] http://www.leychile.cl/Navegar?idLey=20257
[45] http://www.iea.org/policiesandmeasures/pams/chile/name-24577-en.php
[46] http://www.leychile.cl/Navegar?idNorma=150669

Financing Mechanisms

Financing options for RE projects in Chile are scarce and mainly offered by international organizations dedicated to the development of clean energy in the country, such as the BID, or CAF, which in Chile paid out US$ 173 million and US$ 5.13 million in 2014 respectively[47].

CORFO, the executive agency for public policies in the areas of entrepreneurship and innovation, has three lines of support focused on the financing of RE projects. These lines were discontinued after a restructuring of the organization which resulted in a reduction of CORFO's participation in the area. Since the lines were relevant to the development of RE in the region, they are mentioned below:

- **CORFO ERNC credit:** credit line channeled through investment banks for generation or transmission of wind, biomass, or small hydro energy projects. Up to 30% of the credit could be allocated to working capital required to commission the project. The beneficiary company must provide at least 15% of the total necessary investment from its own resources (CORFO 2008).
- **CORFO Environment Credit:** a credit line designed to implement or introduce preventive environmental technologies; reduce environmental pollution through preventive or corrective treatment of activities. A company could request up to 30% of the total funding to finance working capital. The beneficiary company must provide at least 15% of the total necessary investment from its own resources (CORFO 2008).
- **Pre-Investment Program for NCRE:** this was a pre-investment program in RE to finance part of the cost of studies of basic and detailed engineering of technologies (CORFO 2008).

As such, without the presence of specific financial mechanisms provided by the government, the possibilities of financing RE projects are reduced to generic financing tools and those of multilateral organizations committed to local development.

[47] (CEPAL, 2015)

Main Obstacles to the Progress of RE implementation

Figure 15 shows the obstacles which impede or hinder the development of projects for generating energy from non-conventional renewable sources in Chile, according to the methodological approach proposed by this study.

BD	Renewable resources database
CT	Technical training
CI	Cost of investment
ED	RE development strategy
F	Financing
IL	Infrastructure and Logistics
RA	Regulatory and Administrative
R	Regulation
RF	Financial Risk
S	Social
SC	Subsidy and competition with other sources
T	Technical

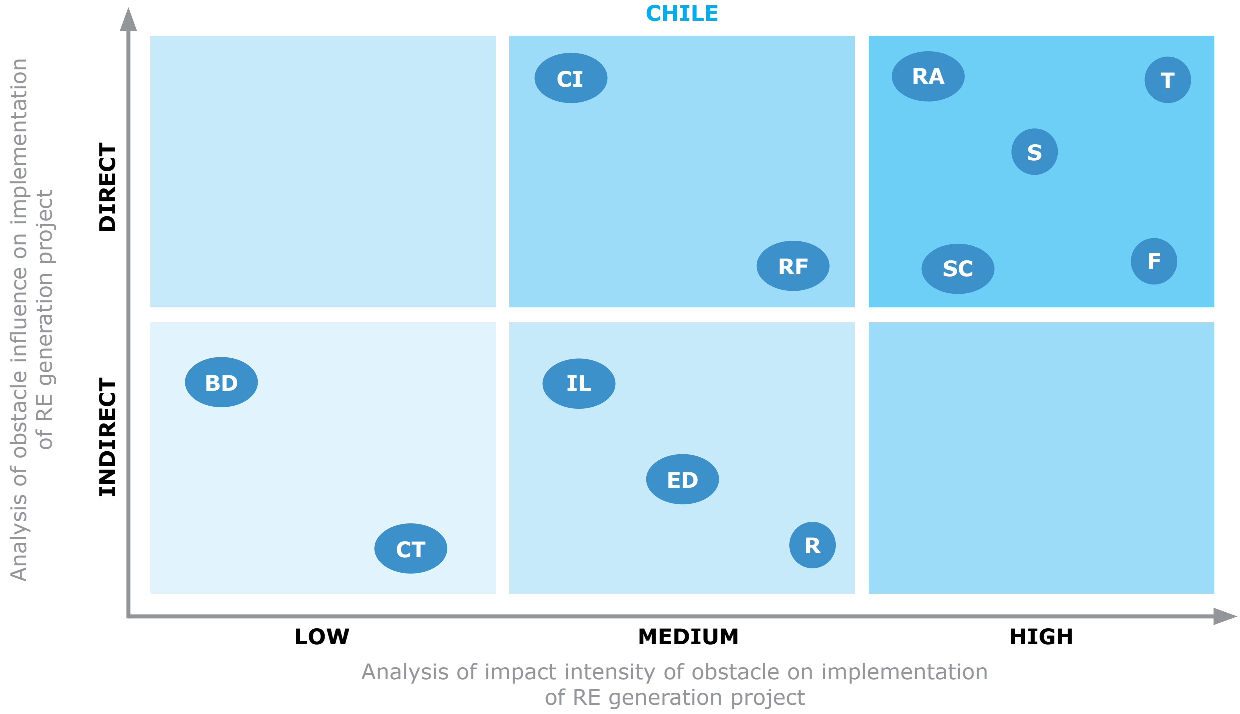

Figure 15 Matrix of obstacles in Chile (Source: own elaboration)

In Chile, administrative and regulatory obstacles were considered direct and high intensity, due to the high costs of transaction which RE impose on the entrepreneur. In this category there are also technical barriers, mainly due to the lack of norms relating to grid connection and the competition from other energy sources, mainly large scale hydroelectric projects. All these parameters result in difficulties for obtaining financing, mainly for small scale projects. In this quadrant there are also social obstacles, relating to the resistance of local communities to the implementation of RE projects in certain areas.

Of average intensity and direct impact are the high investment costs in acquiring equipment, as well as the associated financial risk of the projects. Classified as indirect obstacles are those related to legislation, because although it covers a large part of the sector (including a specific law for geothermal), it is not explicit about the objectives and criteria for connecting to the grid[48]. The same occurs with the development strategy. The obstacle linked to infrastructure is due to the remote location of the grid from potential resources, but was considered of medium intensity because of the possibility of being used only locally to supply energy, as is the case with the Atacama desert region where several mining companies are located.

In Chile, technical training of local labor and the mapping/updating of information on resources where considered obstacles of low intensity due to there already being non-conventional renewable energy projects in the country. As such, the main obstacles in Chile are related to economic aspects, mainly the difficulty in access to financing for the implementation of a RE project. The difficulties are even greater for small-scale RE projects.

COLOMBIA:

Colombia is a major exporter of oil and mineral fuels, which in 2014 accounted for 65.59% of exports. In the same year, GDP reached US$ 378 billion, a 4.38% increase on the previous year. Its composition is shown in the graph in Figure 16[49].

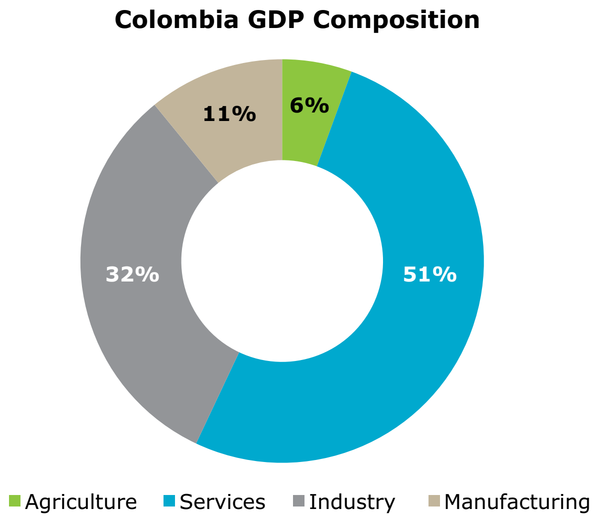

Figure 16 Composition of Colombia's GDP (Source: Own elaboration based on Global Edge data, 2016)

[48] Nasirov et al; 2015
[49] http://globaledge.msu.edu/countries/colombia/memo

Energy Context

Colombia has a wide range of energy resources, both renewable and conventional. Fossil fuels account for almost all primary energy produced. In 2014, this amount reached 95.25% (84.60% in 1990), of 136.34 Mtoe. The energy produced via hydroelectric plants represented only 3.14% of this total. Figure 17 shows production data for the years 2014 and 1990.

Primary energy demand in Colombia accounts for the consumption of only 23.89% (32.58 Mtoe) of total production, which conforms to the country's profile as an exporter of fossil resources. The export of coal, natural gas, and oil was 97.69 Mtoe in 2014, which corresponds to 71.65% of primary energy produced. Compared with 1990, demand has increased by 41%. On the other hand, production grew by 192% for the same period. Figure 18 shows a comparison between production and primary energy demand for the year 2014.

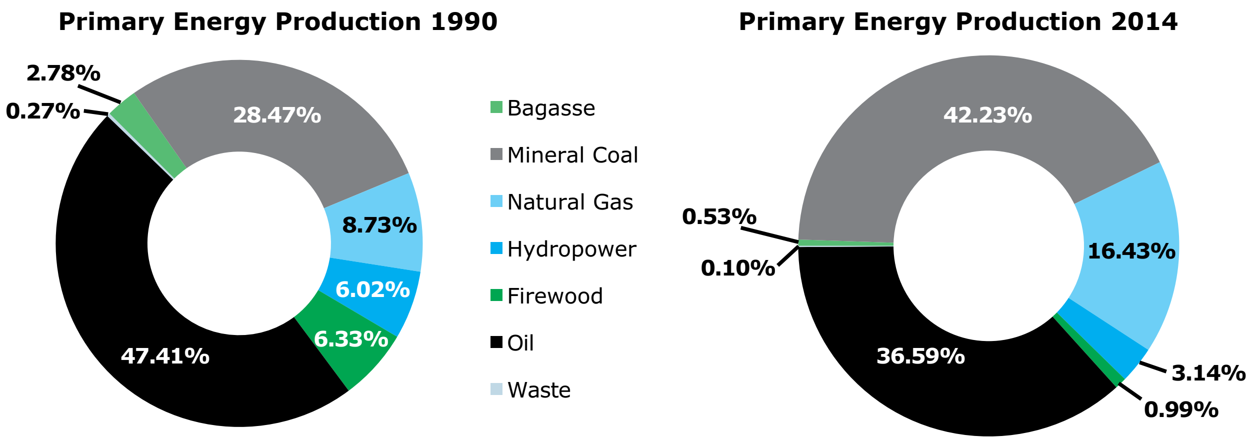

Figure 17 Comparison between PE production in the years 2014 and 1990 (Source: BECO, 2016)

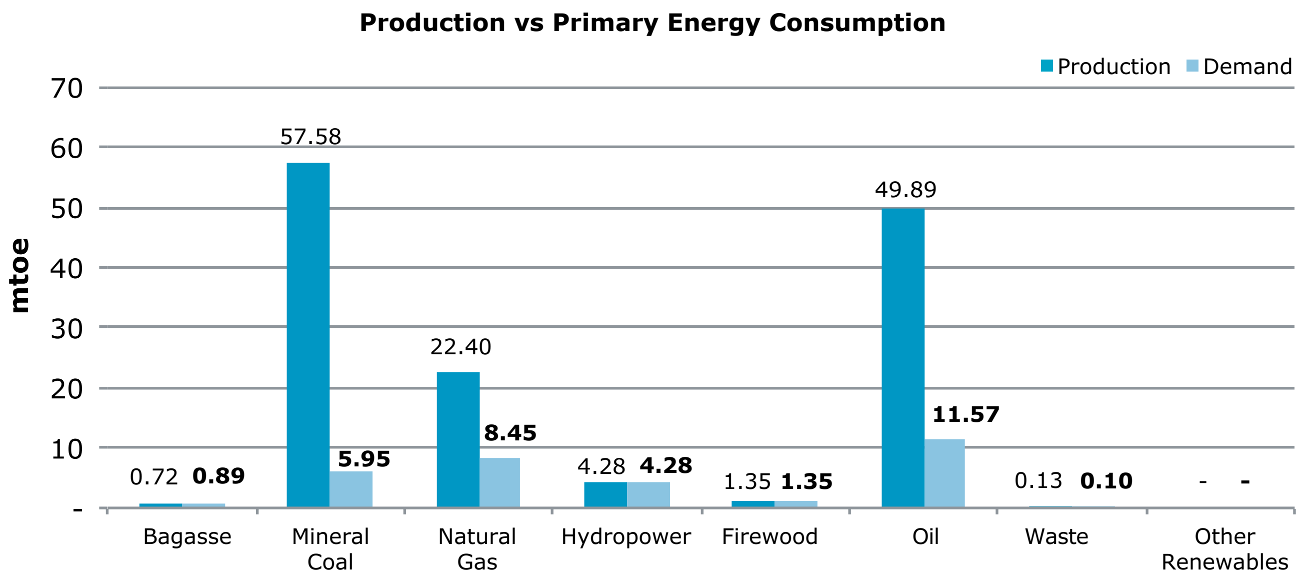

Figure 18 Production versus Primary Energy Demand in 2014 (values in Mtoe) (Source: BECO, 2016)

Mineral coal, whose production is mainly export-oriented, has a variety of applications within the national consumer market. Its main uses are for the transformation stage[50] with 64.68% of internal demand, and thermoelectric power generation and coke processes. Industrial consumption accounts for the remaining use, with highest consumption being recorded in the non-metallic mineral industry.

Additionally, the main uses of oil and natural gas are concentrated in the transport and industrial sectors. In the latter, the main use is for obtaining heat for processes. Natural gas, of which internal demand reached 8.45 Mtoe in 2014, also shows some diversification in its use. Like coal, it is used in thermoelectric generation (33.34%) and in the industrial sector, with the largest consumers being refineries. It also supplies the transport, residential, and public sectors as an energy component. Table 10 shows the main distribution figures of mineral coal and natural gas consumption for the year 2014.

CONSUMPTION PROFILE		
Mtoe Values	**CM**	**GN**
Internal Demand	**5.95**	**8.45**
Transformation	**3.85**	**2.82**
Thermal	1.34	2.82
Coke	2.51	-
Residential Consumption	**-**	**1.04**
Public Sector Consumption	**-**	**0.46**
Industrial Consumption	**2.10**	**2.46**
Food	0.44	0.17
Pulp and Paper	0.32	0.22
Non-metallic Minerals	0.92	0.59
Refineries	-	0,80
Others	0,42	0,68

Table 10 Energy Consumption Profile of Key Fossil Resources: Mineral Coal and Natural Gas (Source: BECO, 2016)

Internal demand for oil is almost entirely focused in the transformation sector, more precisely refineries. However, oil is also a strong export, with 80.64% of domestic production in 2014.

The food industry consumes the totality of sugarcane bagasse produced[51]. For 2014, bagasse consumption accounted for 2.72% of total demand. Firewood accounted for 1% of total primary energy and its consumption is exclusively residential. Hydroelectric plants make up a small portion of the country's primary energy, of 3.14%.

Figure 19 shows average growth rates of some development parameters in Colombia. Primary energy production grew, on average, by 5.54% in the period 1990-2014, even though it began a downward trend from 2003. International energy market fluctuations also contributed to this behavior, as Colombia is a large oil producer, and the volume of oil produced is directly related to the capacity of the external market to absorb it.

[50] By transformation we mean the input is transformed to obtain other products.
[51] ASOCANA, 2016
[52] http://www.asocana.org/modules/documentos/10392.aspx

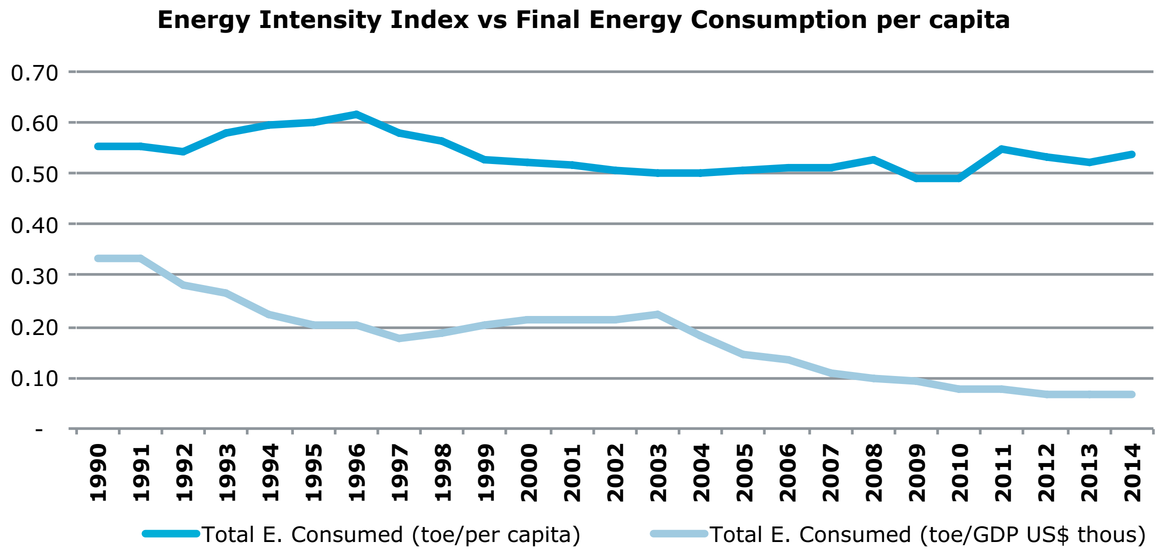

Figure 19 Energy Comparison (Sources: FMI, World Bank, IEA, BECO; 2016)

The total energy consumed per unit of GDP, in Colombia, is down from 2003, as energy consumption was partially stable in the period analyzed, while GDP grew. This was due to investment in energy efficiency. The creation of Colombian Energy Efficiency Council (CCEE)[53], in 2010, is evidence of the country's commitment to efficiency.

The Colombian energy matrix can be classified as hydrothermal, as 70 to 80% of electricity is produced via hydroelectric plants. In terms of installed capacity, the figure is 70.9%, while thermal power plants contribute 19.6%. Non-conventional renewable energies, such as biomass and wind energy, have a share of 0.06% and 0.11% respectively[54,55,56,]. Table 11 shows the composition of electricity production in the country, distributed by source type.

Table 11 Distribution of electric power production sources in Colombia (Source: UPME, 2016)

Generation of Electric Power		Source	Capacity (MW)	Share %
Thermal	Fossils	Liquid fuel	1,247.0	6.91%
		Fuel oil	299.0	1.66%
		Jet mix and natural gas	264.0	1.46%
		Kerosene (Jet)	46.0	0.25%
		Natural Gas	1,677.2	9.30%
		Charcoal	1,348.4	7.47%
	Renewable Sources	Bagasse	77.2	0.43%
		Biomass	10.0	0.06%
Wind		Wind	18.0	0.10%
Hydro		Water	13,055.5	72.36%

53 http://cceecol.org/
54 http://www.siel.gov.co/portals/0/generacion/2015/Seguimiento_Variables_Diciembre_2015.pdf
55 http://www.siel.gov.co/Inicio/Generaci%C3%B3n/Generaci%C3%B3n1/tabid/143/Default.aspx
56 http://www.upme.gov.co/Estudios/2015/Integracion_Energias_Renovables/INTEGRACION_ENERGIAS_RENOVANLES_WEB.pdf

In Colombia, non-conventional energy sources total 418.9 MW, distributed as follows: wind energy 18.42 MW, sugarcane bagasse 206 MW, and small hydroelectric plants 194.48 MW. Of the country's total installed capacity, these amounts correspond to 2.32%. Even so, the Colombian government is concentrating its efforts on studies, mapping, and legislation with the aim of promoting and facilitating the addition of these sources to the matrix.

To this end, the Energy Efficiency and Alternative Energy Information System (SI3EA)[58] was created, with the responsibility of elaborating various studies focusing on RE in Colombia, as for example, the Colombian Wind and Wind Energy Atlas, the Atlas of Residual Biomass Energy Potential in Colombia, and the study on the Integration of Non-Conventional Renewable Energies in Colombia, produced by the UPME. In 2010, the Program for Rational and Efficient Use of Energy and Non-Conventional Sources (PROURE)[59]was created, which sets a target of 6.5% of energy supplied to the grid to be from renewable sources by 2020, with 3.5% to be reached in 2015. It should be noted that this first stage of the target was not met.

In relation to estimates of non-conventional RE development in Colombia, wind power has a high potential in 6 regions of the country, in particular the north coast, as can be seen in Table 12.

Table 12 Colombian wind potential (Source: UPME, 2015)

Maximum wind capacity to be installed (MW)	
Region	**Power**
North Coast	20.000
Santanderes	5.000
Boyacá	1.000
Risaralda-Tolima	1.000
Huila	2.000
Cauca Valley	500
Total	**29.500**

Wind energy is particularly interesting for the energy sector due to its high availability in the territory. One of the main objectives of the implementation of this type of energy would be, apart from the diversification of the energy matrix, the gradual substitution of thermoelectric plants. In the Caribbean region there are many thermal plants which use natural gas and liquid fuels.

Colombia has an average radiation of 4.5kWh/m2/day, a figure which surpasses the global average of 3.9kWh/m2/d[60], favorable for solar photovoltaic energy. Table 13 shows the distribution of radiation values in some Colombian regions[61].

Table 13 Average irradiation values in the main Colombian regions (Source: UPME, 2015)

Average Irradiation in the Main Regions (kWh/m2/d)	
Region	**Power**
Guajira	6,0
Atlantic Coast	5,0
Orinóquia	4,5
Amazônia	4,2
Andean Region	4,5
Pacific Coast	3,5
Average	**4,5**

[58] http://www.si3ea.gov.co/si3ea/Home/Energ%C3%ADaEolica/tabid/75/language/en-US/Default.aspx
[59] https://www.minminas.gov.co/documents/10180/558752/Informe_Final_Consultoria_Plan_de_accion_Proure.pdf/e8cdf796-d7b1-4bb1-90b9-e756c7f48347
[60] UPME, 2015
[61] http://www.upme.gov.co/Docs/Atlas_Radiacion_Solar/1-Atlas_Radiacion_Solar.pdf

It is worth highlighting that Law 1715 of 2014 generated incentives for the installation of photovoltaic systems, favoring the possibility of commercialization of the surplus generated with the system and inserting a credit scheme for small-scale self-generation.

Energy from biomass is mostly used for the production of electric power and thermal power in co-generation systems. In Colombia, the main input used to this end is sugarcane bagasse, but there is also great energy potential from residue, bark, and seeds from traditional Colombian crops, as shown in Table 14.

Table 14 Energy Potential from Biomass (Source: UPME, 2015)

Estimate of Energy Potential from Traditional Crops		
Product	**Residue (kton)**	**Energy Potential (TJ)**
Palm	2,166.00	20,985.00
Sugarcane	15,927.00	121,575.00
Paneleira Cane	8,068.00	68,742.00
Coffee	5,855.00	56,925.00
Manioc	1,707.00	18,332.00
Rice	5,910.00	26,191.00
Banana	11,284.00	6,444.00
Plantain	19,689.00	11,242.00

Bodies and Energy Sector Government Agencies

The following are the Energy Sector Government Agencies in Colombia (the list is not exhaustive):

- **Ministry of Mines and Energy – MME[62]:** public entity of national character, responsible for the coordination and elaboration of energy policy and administration of non-renewable natural resources. It also coordinates the generation, transmission, distribution, and commercialization of electric power in the country, as well as developing alternative energy sources for the diversification of the matrix and energy security.

- **Mining and Energy Planning Unit – UPME[63]:** Special Administrative unit, of national order and technical character, linked to the MME, governed by Law 143 of 1994 and by Decree 1258 of 2013. Among its main objectives and functions are the integral planning of the mining energy sector, management of information regarding the mining and energy sectors, among others.

- **Energy and Gas Regulatory Commission – CREG[64]:** regulates the provision of public domestic electricity services, fuel gas, public services for liquid fuels; regulates monopolies. The CREG is also responsible for promoting competition between utilities, so that both monopoly and free competition operations are economically efficient.

- **National Council of Operation – CNO[65]:** body created by Law 143 of 1994 has the main purpose of determining the technical aspects which guarantee the operation of the national grid (SIN) in a safe, reliable, and economic way. It is responsible for the Operating Regulations. The CNO is formed

[62] https://www.minminas.gov.co/ministerio
[63] http://www.upme.gov.co/
[64] http://www.creg.gov.co/
[65] http://www.cno.org.co/content/quienes-somos

of a member of each of the power generating companies in Colombia, provided they have an installed capacity of between 1 and 5% of the national total.

- **Trade Advisory Committee – CAC[66]:** created by the CREG through Resolution 68 of 1999 for the purpose of assisting it in the review of commercial aspects of the Wholesale Energy Market.

- **Superintendency of Public Residential Services – Superservicios[67]:** technical body created by the Constitution of 1991 by determination of the President of the Republic. It is responsible for the inspection, supervision, and control of entities and companies providing energy and gas as public residential services

- **National Dispatch Center – CND[68]:** responsible for the planning, supervision, and control of the integrated operation of the grid (SIN). The CND must follow the Code of Operation and the Technical Agreements drawn up by the CNO.

- **XM Company of Market Experts[69]:** regulated by the CREG and dedicated to the operation of the grid (SIN) via the National Dispatch Center. It is also in charge of the administration of the wholesale energy market in Colombia, for both domestic and international energy transactions.

Legislation

The following are the main legal frameworks and norms of the energy sector in Colombia (the list is not exhaustive):

- **Law 1,715 – Year 2014[70]:** regulates the integration of NCRE into the national energy system. Its objectives are to promote the development and use of NCRE, mainly those of a renewable nature, in the national energy system, and to contribute to the reduction of greenhouse gas emissions (GHG) and increase the security of the energy supply. It determines the legal framework of these technologies, the necessary investment for promotion of NCRE and promotion of research and development of clean technologies for energy production.

- **Decree 2,143 – Year 2015[71]:** gives new definitions relating to production, invest-

[66] http://www.cac.org.co/quienes.htm
[67] http://www.superservicios.gov.co/Institucional
[68] http://www.xm.com.co/Pages/DescripciondelSistemaElectricoColombiano.aspx
[69] http://www.xm.com.co/Pages/QuienesSomos.aspx
[70] https://www.minminas.gov.co/documents/10180//23517//22602-11506.pdf
[71] https://www.minminas.gov.co/documents/10180//23517//36862-Decreto-2143-04Nov2015.pdf

ment, and new energy projects of NCRE, among others; defines the rules for special deductions from income tax, general requirements for access to incentives, maximum limits of special deductions, and other details and explanations related to the deductions. There are other details related to tariff exemptions and other taxes.

- **UPME Resolution 0281 – 2015[72]:** limits the maximum power of small-scale self-generation of energy generated through NCRE. The limit is 1 MW and corresponds to the installed capacity of the system.

- **CREG Resolution 024 – 2015[73]:** regulates the activity of large-scale self-generation of energy from NCRE in the grid (SIN), establishing parameters and conditions for connection to the SIN, sale of surplus from self-generators to the SIN, among other provisions.

- **Decree 1623 – 2015[74]:** modifies Decree 1073 of 2015[75] regarding policy guidelines for the expansion of energy service coverage in SIN and Non-Interconnected Zones (ZNI), among other provisions.

- **DECREE 2492 – 2014[76]:** establishes measures to be adopted through the implementation of mechanisms of response to demand, as well as guidelines which aim for efficient energy management by the CREG. It also establishes that plans for the expansion of electricity service coverage must be drawn up by the UPME, among other provisions.

- **Decree 2469 of 2014[77]:** establishes conditions for the delivery of surplus by self-generators, setting equal conditions for the participation of large-scale producers and self-generators in the main energy market, among other provisions.

- **UPME Resolution 143 of 2016[78]:** modifies Article 5 and adds annexes and articles to UPME Resolution 0520 of 2007, by which it establishes the registration of generation projects, among other provisions.

- **UPME Resolution 045 of 2016[79]:** establishes the requirements and procedures for the emission of certification and assessment of non-conventional renewable energy sources, with the aim of obtaining VAT exemption and other tariff issues.

[72] https://www.minminas.gov.co/documents/10180/18995913/res_281.pdf/6077cb6c-dabc-43fc-8403-cb1c5e832b37
[73] http://apolo.creg.gov.co/Publicac.nsf/1c09d18d2d5ffb5b05256eee00709c02/67513914c35d6b8c05257e2d007cf0b0/$FILE/Creg024-2015.pdf
[74] https://www.minminas.gov.co/documents/10180//23517//36632-Decreto-1623-11Ago2015.pdf
[75] Decree focused on the energy sector, in which a series of definitions pertaining to the sector are set forth, and attributions to regulatory bodies, among others. Available at: https://www.minminas.gov.co/documents/10180/170046/Decreto+%F2nico+Reglamentario+Sector+Minas+y+Energ%92a.pdf/8f19ed1d-16a0-4a09-8213-ae612e424392 https://www.minminas.gov.co/documents/10180/170046/Decreto+%F2nico+Reglamentario+Sector+Minas+y+Energ%92a.pdf/8f19ed1d-16a0-4a09-8213-ae612e424392
[76] https://www.minminas.gov.co/documents/10180//23517//36863-Decreto-2492-03Dic2014.pdf
[77] https://www.minminas.gov.co/documents/10180//23517//36864-Decreto-2469-02Dic2014.pdf
[78] http://www.siel.gov.co/siel/documentos/documentacion/Generacion/143_2016.pdf
[79] http://www1.upme.gov.co/sala-de-prensa/secciones-de-interes/resoluciones/res-045-febrero-2016

Financing Mechanisms

Table 15 shows the main national mechanisms which finance the implementation of RE projects in Colombia.

Table 15 Financial Mechanisms for RE in Colombia (Source: OLADE, 2011)

Organization	Name of Financial Mechanism	Description	Public/Private	Observations
Bancoldex - Colciencias	Bancoldex - Colciencias Fund	Partial Loan	Public	Research, Development, Innovation
Bancoldex	aProgresar Fund	Loan with incentives	Public	Acquisition of assets
Private Banks	Loan	Market Loans	Private	Construction
IPSE	FAZNI	Public Investment	Public	Construction
FOMIPYME	-	Financing technological development	Public	-

In addition to national financing mechanisms, international and multilateral organizations also collaborate towards the financing of projects aimed at sustainable development, including the implementation of RE energy projects, in Colombia. For example, the BID and CAF, which paid out US$ 5.8 million and US$ 50.2 million in Colombia, respectively[80].

Main Obstacles to the Progress of RE Implementation

Figure 20 shows the obstacles which impede or hinder the progress of energy generation projects from renewable sources in Colombia, according to the methodological approach of this study.

BD Renewable resources database
CT Technical training
CI Cost of investment
ED RE development strategy
F Financing
IL Infrastructure and Logistics
RA Regulatory and Administrative
R Regulation
RF Financial Risk
S Social
SC Subsidy and competition with other sources
T Technical

[80] CEPAL, 2015

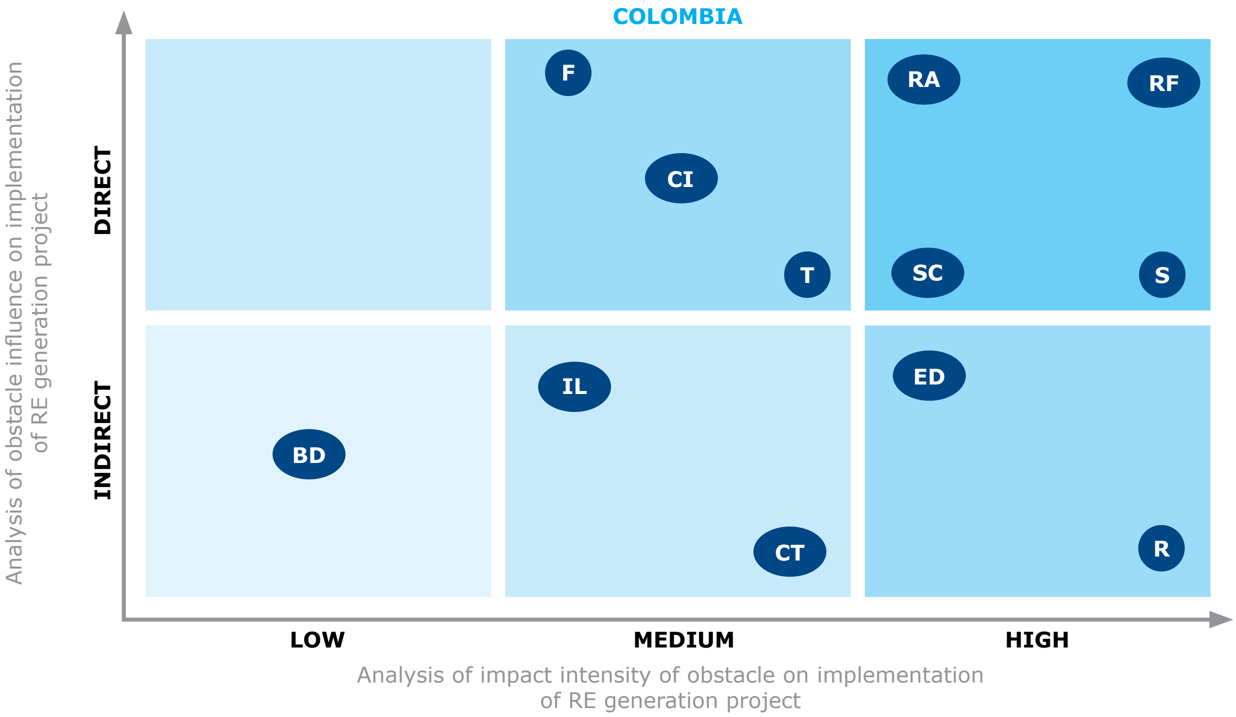

Figure 20 Matrix of obstacles in Colombia (Source: own elaboration)

Direct and high-intensity obstacles which hinder the development of non-conventional RE in Colombia are closely related to the bureaucracy in obtaining permits - which increase transaction costs - and the low price of conventional sources of energy, which leads to the economic unfeasibility of RE-related projects.

In addition, it should be highlighted that obstacles relating to the financial risk of projects are linked, mainly, to the lack of experience of agents in general with RE. There is a general and specific law for RE in Colombia, with various definitions, parameters, and rules. However, studies reviewed indicate dubious points in several aspects.

Within the category of direct obstacles of medium intensity, the difficulty in obtaining financing stands out. This is due to the perceived risks linked to RE projects. The cost of importing equipment is still high, which further impairs its procurement and financing.

Among indirect obstacles, the need for greater technical training of human resources for dealing with the various phases of RE projects is salient. Infrastructure for grid connection and mapped locations is also precarious, as is access to these sites.

Finally, there is a combination of factors which has lead to the slow development of RE in Colombia: low cost and relative abundance of conventional sources (fossils), a large share of hydroelectric projects, and a high cost of investment in the production of energy via non-conventional means. Added to this are the political and sociocultural difficulties in taking long-term action, as is the case with areas of high RE potential which are located in regions of indigenous communities protected by law, or located in areas where residents do not approve of RE facilities.

MEXICO:

Mexico's three largest export volumes for 2014 were from the industrial sector. Vehicles and parts accounted for 21.65%, and electric and industrial machinery reached 20.15% and 15.19% respectively, adding up to 57% of the total volume[81]. For this same year, GDP reached US$1.297 billion[82], up by 2.85% on the previous year. Figure 21 shows its composition[83].

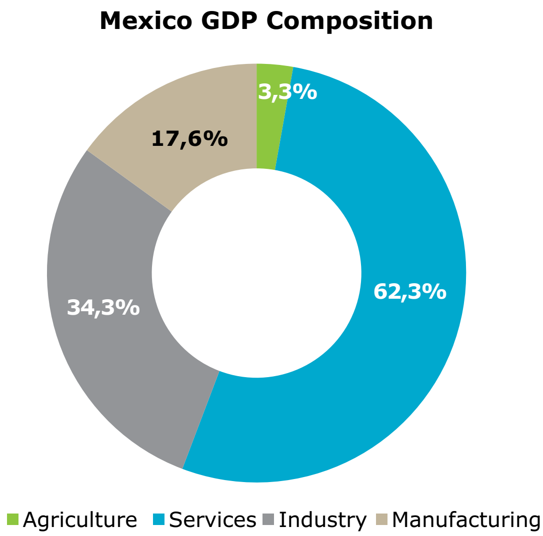

Figure 21 Composition of Mexico's GDP (Source: Own elaboration based on Global Edge data, 2016)

Energy Context

In 2014, Mexico produced a total of 133.66 Mtoe of primary energy, with 47.28% going to the foreign market, and the remainder going to the country's refineries to obtain derivatives, most of which is used as a secondary energy source.

Mexico is highly dependent on fossil fuels for the production of primary energy; Figure 22 shows the distribution of primary energy in Mexico in 1990 and 2014.

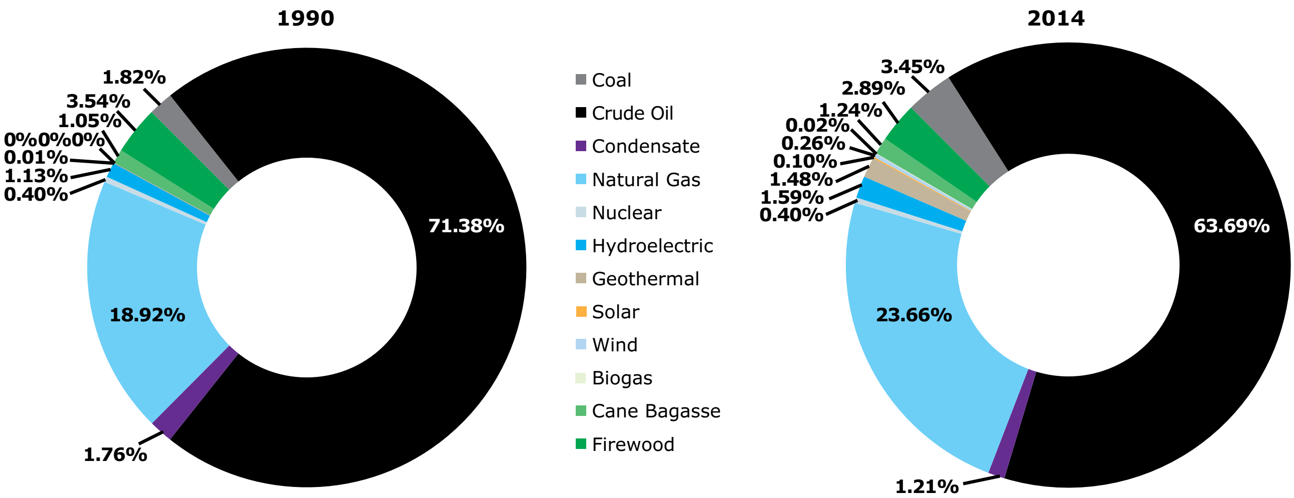

Figure 22 Distribution of Primary Energy Production in 1990 and 2014 (Source: Own elaboration with SIE[84] data, 2016)

[81] http://globaledge.msu.edu/countries/mexico/tradestats
[82] http://databank.worldbank.org/data/reports.aspx?source=2&country=&series=SP.POP.TOTL&period=http://data.worldbank.org/data-catalog/GDP-ranking-table
[83] http://globaledge.msu.edu/countries/mexico/economy
[84] http://sie.energia.gob.mx/ Sistema de Informação Energética

In 1990, hydrocarbons accounted for 93.88% of the total of primary energy produced in the country, while the remainder was split among renewable sources and nuclear, with a share of 5.73% and 0.40% respectively. In 2014, the same predominance of fossil fuels is evident, with 91.62%, while renewable sources and nuclear registered 7.56% and 0.39% respectively.

For the period under analysis, growth of total production of primary energy registered at 13%. Of fossil resources, coal grew by the most (114.4%), followed by natural gas (40.8%). Figure 23 shows the production profile versus primary energy demand for Mexico in 2014.

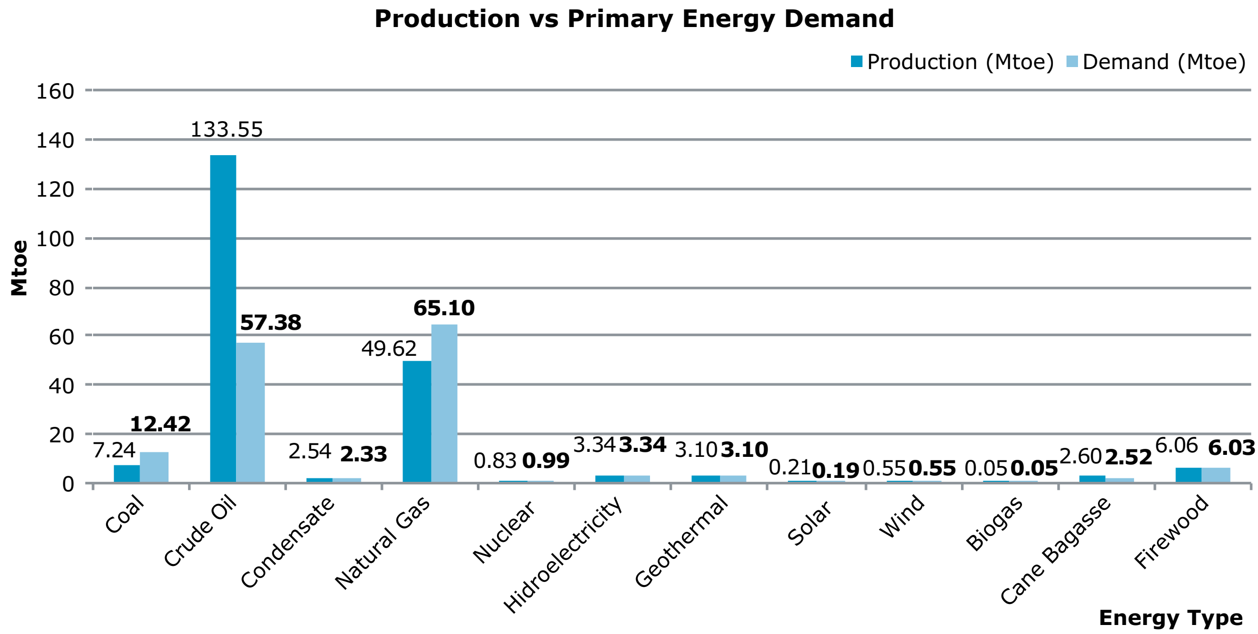

Figure 23 Production versus Primary Energy Demand (Source: Own elaboration with SIE[85] data, 2016)

The input with highest volume of production and a large portion exported is crude oil. Coal and natural gas are greatly used in the production of electricity. The same occurs with sugarcane bagasse, whose energy produced is destined to the industrial sector, mostly the sugar sector. The residential sector accounts for 100% of the consumption of firewood.

Coal is imported to meet domestic demand, even though its production has increased significantly in recent years. The production of electricity by means of thermals is the main destination of this input, representing 68.53%. Coal-fired thermoelectric plants have an installed capacity of 5,443.36 MW, representing 7.52% of the total installed capacity in the country, distributed among four plants[86]. All these plants are destined to producing electricity for commercial use. The other two main uses are focused on the industrial sector, with 31.26%, of which 16.26% is destined to the coke industry.

[85] http://sie.energia.gob.mx/ Sistema de Informação Energética
[86] One of these plants is mixed, using coal, fuel oil, and natural gas. Its installed capacity is only 65 MW, which represents 1.19% of the total installed capacity of coal-fired thermal plants. This plant belongs to the industrial sector.

Natural gas accounted for 23.76% (49.66 Mtoe) of the production of primary energy in Mexico in 2014. Total domestic supply was 67.64 Mtoe[87], of which 66.31% (44.85 Mtoe) went to the manufacturing sector, and another 11.10% was used/ consumed by the sector itself. Mexico has 170 natural gas-fueled thermoelectric plants, with a capacity of 30,118.85 MW (8.04% of total capacity), of which 37.26% (35 plants) belong to energy generating companies, 38.93% (22 plants) to independent energy producers, and the remainder distributed among the industrial sector.

There are other thermal plants which use natural gas and other fuels. These plants have a total capacity of 5,820 MW (43 plants and 8.04% of total capacity) and belong to energy generating companies, oil sector companies, and independent producers. These three sectors total 31 plants with 94% of capacity. The others belong to various industrial sectors.

There are currently 78 natural gas-fired thermal plants[88] under construction, which will increase installed capacity by 5,034 MW[89]. When these plants become operational, total installed capacity[90] will be 40,973.48 MW.

In the industrial sector, primary energy consumption of 2014 was 2.76 Mtoe, equivalent to only 1.31% of total primary energy produced, of which coal had the largest share, with 1.85 Mtoe. Of the others, sugarcane bagasse, with 0.94 Mtoe, was destined to the production of electricity and solar energy.

Table 16 shows the distribution of energy consumption by the industrial sector, including primary and secondary energy for 2014.

Table 16 Total Energy Consumption of the Main Industrial Sectors (Source: Own elaboration with SIE[91] data, 2016)

Sector Consumption Primary Energy (Mtoe)	Iron	Cement	Sugar	Petro-chemi-cals	Chemi-cal	Metals	Pulp and Paper	Glass	Other
Solar Energy	-	-	-	-	-	-	-	-	0.01
Sugarcane Bagasse	-	-	0.81	-	-	-	-	-	0.14
Coal	-	0.14	-	-	-	-	-	-	1.70
Coke	1.66	2.67	-	-	0.01	-	-	-	0.01
Oil and derivatives	0.07	0.03	0.03	0.01	0.16	0.36	0.07	0.04	2.06
Gas	2.86	0.13	-	2.35	1.87	0.16	0.74	1.26	5.03
Electricity	0.47	0.79	0.08	0.12	0.41	0.82	0.25	0.10	10.04
Other	0.00	-	0.02	0.00	0.06	-	0.00	-	
Total	**5.07**	**3.75**	**0.88**	**2.48**	**2.52**	**1.34**	**1.06**	**1.41**	**18.98**

87 About 18.23 Mtoe of NG comes from "other sources" according to the National Energy Balance, however these sources are not detailed.
88 Only one of these plants is a mixed plant with NG and Diesel, with a capacity of 37.86 MW
89 CRE, 2016
90 Including mixed plants
91 http://sie.energia.gob.mx/ Sistema de Informação Energética

Figure 24 shows the energy intensity indicators for Mexico, pertaining to consumption of primary energy and its relation to GDP and also evolution of final energy consumption per capita for the country. There is an improvement in energy consumption over the years, as a result of efforts towards energy efficiency not only in production processes but in the use of energy as a whole. The National Commission for the Efficient Use of Energy (Conuee[92]) was created in 2008 through the Law on Sustainable Energy Use, and its main objective is the promotion and regulation of actions aimed at improving energy efficiency in the country. Per capita energy consumption shows stable behavior.

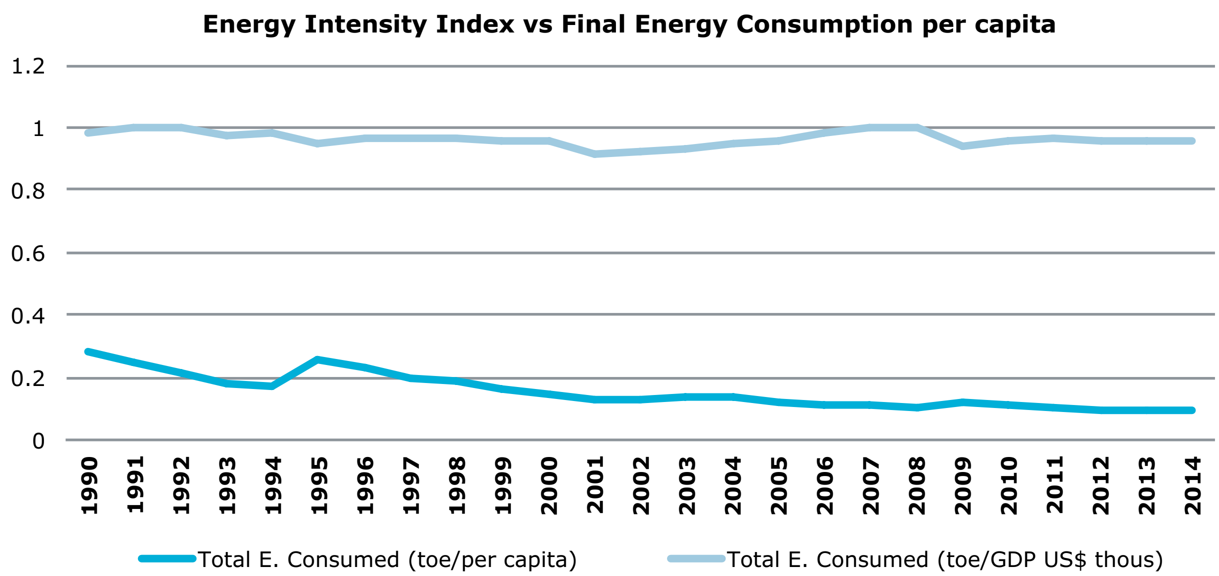

Figure 24 Comparison of PE production and total energy consumption (Sources: Own elaboration based on World Bank data, SENER; 2016)

Most of the available official information and statistics available on RE in Mexico are geared to the use of these sources for generation of electricity, with little industry-specific information. The total installed capacity of electricity generation in Mexico is 72.41 GW, with authorization from the regulator to produce up to 384,294 GWh/a, through a total of 753 plants in operation.

There are currently 193 (25.63%) plants destined to the production of electricity from renewable sources, including large-scale hydroelectric projects, which total an installed capacity of 16.67 GW. These plants have authorization from the regulating body to jointly produce 52,170 GWh/a. With this infrastructure, generation via renewables is capable or reaching 13.58% of the estimated and authorized total, representing 23.02% of all national installed capacity.

[92] https://www.gob.mx/conuee

For Mexico, large hydroelectric plants are also considered renewable sources and, unlike other countries, there are no non-conventional sources. All are deemed renewable and are treated alike by regulatory bodies. Large hydroelectric plants represent 16.62% (12.04 GW) of the national installed capacity with 33 facilities throughout the territory. If we look only at RE, large hydroelectric plants represent 72.23% of installed capacity. There are, however, other sources, as follows:

- **Wind:** after hydropower, wind power is the second largest source of renewable source of electricity production. In April 2016, installed capacity was 2,722 MW, distributed among 31 plants, of which 21 are located in Oxaca, the region with the highest concentration of winds in the country, and represent approximately 83.15% of all installed wind capacity.

- **Photovoltaic Solar:** This type of power is still underdeveloped in the country, accounting for only 0.16% of installed capacity of renewable energy (13 plants). The distribution of these plants is not as concentrated as with wind power, with the greatest concentrations being in: Baja California (3), Durango (5), Mexico State (2).

- **Hydroelectric plants of up to30MW:** small hydropower plants are still gaining popularity in the country. Currently there are 48 plants with an installed capacity of 442.71 MW, equivalent to 2.63% of the total capacity of renewables. Regions with the greatest number of plants are Jalisco and Michoácan, with 7 and 8 plants respectively.

- **Hydroelectric plants greater than 30MW:** large hydroelectric plants are already widespread and an established source in the country, and generate the largest volume of energy from renewables. In April 2016 there were a total of 31 stations with 11,930.1 MW of capacity, equivalent to 71.37% of RE and 16.47% of the total installed capacity of all sources (RE and conventional). Regions with the highest concentrations of these plants are: Sinaloa (5), Michoacán (5), and Jalisco (4).

- **Biomass:** there are two categories: biogas and sugarcane bagasse. The former is still in a phase of maturation and dissemination of the benefits of the technology, while the latter is widely used by the sugar sector. There are 16 biogas plants in operation, with 64.76 MW of installed and authorized capacity, while bagasse plants represent a capacity of 316.81 MW. Together these plants total 381.57 MW, equivalent to 2.32% of RE

- **Geothermal:** there are currently 5 plants which account for 186.09 MW of installed and authorized capacity, equivalent to 1.18% of RE.

[93] For this study, the two plants which use biogas and natural gas were not considered. They have a total installed and authorized generation capacity of 1.95 MW and both belong to the food sector. Their authorized generation capacity is 12.62 GWh/y.
[94] For this study, the plant that uses Diesel sugarcane bagasse. Its authorized capacity is 14.40 MW, with an authorized generation capacity of 46.66 GWh/y.
[95] One of these plants is joint geothermal and solar photovoltaic. Its authorized installation capacity is 52 MW and authorized generation capacity is 387 GWh/y. This plant belongs to the industrial sector.

Mexico aims to increase installed RE capacity: the target is for installed capacity of electricity generation via RE to reach 32.8%, with electricity generation from these sources to reach 24.9% by 2018. In addition, the advantages of Mexico investing in the development of RE are the following:

- **High level of solar incidence in at least 70% of the territory (average of 4.5kW/ day / m2);**
- **High wind intensity in specific areas;**
- **High geothermal potential, currently 4th place worldwide;**
- **Great potential for small hydropower facilities (<30MW);**
- **Good availability of agricultural waste.**

The National Renewable Energy Inventory (INERE) provides a survey of data regarding all renewable energy projects to be developed, in the following categories: under construction, construction to begin, and under review. The first two are classified as proven, and the latter as probable. The data from the Energy Regulation Commission (CRE) only takes into account the categories 'in operation', 'under construction', and 'construction to begin'. Therefore, for compiling the information on the future of renewable energy in Mexico presented in Table 17, regarding electric power, data was used as follows:

- **CRE: plants in operation, under construction[96], and construction to begin[97]. This choice is due to their data being more updated, from April 2016.**
- **INERE: plants under review.**

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[96] For biogas, mixed plants using Natural Gas were excluded from the analysis. The two plants have an authorized installation capacity of 86.49MW and an authorized generation capacity of 681.79GWh / y. The larger one is owned by the industrial sector and the lowest by the service sector.

[97] For biogas, the mixed plant with using Natural Gas was excluded from the analysis. Its authorized installation capacity is 30 MW and authorized generation capacity is 153.52 GWh/a.

Table 17 RE electricity generation projects under construction, beginning construction, and under review (Source: Own elaboration with SENER data, 2016; INERE, 2015)

RE Type		Capacity in MW	Generation (GWh/year)	Number of Plants
WIND	Under Construction	3,219.36	10,224.32	30
	Construction to begin	3,572.38	11,849.17	45
	Total Potential	6,791.74	22,073.49	75
	Overall Future Total	9,513.74	31,391.64	106
PHOTOVOLTAIC	Under Construction	3,028.00	6,327.44	127
	Construction to begin	5,622.89	13,108.74	165
	Total Potential	8,650.89	19,436.18	292
	Overall Future Total	8,766.49	19,692.60	305
HYDROELECTRIC (up to 30MW)	Under Construction	320.03	1,710.60	23
	Construction to begin	305.30	1,370.88	29
	Under Review	1,401.46	12,276.96	451
	Total Potential	2,026.79	15,358.44	503
	Overall Future Total	2,469.50	17,286.14	551
HYDROELECTRIC (>30MW)	Under Construction	476.10	1,287.60	5
	Construction to begin	39.46	147.00	1
	Under Review	1,227.30	10,750.88	18
	Total Potential	1,742.86	12,185.48	24
	Overall Future Total	13,672.96	47,436.65	55
BIOMASS	Under Construction (Biogas)	49.74	333.50	13
	Under Construction (Bagasse)	234.16	1,028.09	7
	Construction to begin (Biogas)	13.81	113.58	5
	Construction to begin (Bagasse)	-	-	0
	Under review (Biogas)	40.14	234.43	166
	Under review (Bagasse)	26.77	156.38	103
	Total Potential	364.62	1,865.98	294
	Overall Future Total	746.19	3,073.86	323
GEOTHERMAL	Under Construction	30,00	237,60	1
	Construction to begin	126,62	953,31	5
	Under Review (High Enthalpy)	60,00	473,43	2
	Under Review (Medium Enthalpy	412,90	3.257,56	44
	Under Review (Low Enthalpy)	1.273,80	1.049,60	211
	Total Potential	1.903,32	5.971,50	263
	Overall Future Total	2.089,41	12.551,71	268

According to information provided by the CRE regarding generation of electricity from renewable sources, the industrial sector, including the oil sector, has plants for generating their own electricity. Of the 31 wind plants in operation, 18 belong to the industrial sector, with an installed capacity of 1,884.35 MW, equivalent to 69.22%.

As for photovoltaic plants, the industrial sector is in possession of 5, with an installed capacity of 36.61%, equivalent to 31.67% of the total. Of the small hydroelectric plants, few belong to the industrial sector, with only 9 of these facilities representing 13.67% (60.54 MW) of total installed capacity. Only two large hydroelectric plants belong to the industrial sector, but their installed capacity exceeds the established limit of the small power plants by only 5 and 6 MW. Therefore, only 71 MW (0.6%) belongs to the industrial sector.

Of the biogas plants, only 5 belong to the industrial sector and correspond to 14.95 MW (23.09%). Sugarcane bagasse plants total 316.81% MW (100%), and of 13 plants, 10 belong to the sugar sector.

Agents of the Energy Sector

The following are the Energy Sector Government Agencies in Mexico (the list is not exhaustive):

- **Ministry of Energy – SENER[98]:** responsible for steering the country's energy policy and overseeing the public agencies which make up the electricity sector. It promotes the participation of private agents in terms of legislation. Also responsible for energy sector planning and setting its economic guidelines.

- **Energy Regulation Commission– CRE[99]:** regulatory body of the electricity sector, created by Decree in 1993 and operates autonomously. It ensures that supply and sale of electricity to public service users, and the generation, export, and import of energy (usually by private individuals), are done transparently and efficiently.

- **Federal Electricity Commission – CFE[100]:** created by Federal Law in 1937. Parastatal entity responsible for planning, generation, transmission, distribution, commercialization, and import of electricity. It operates the SEN, and has control of the transmission and distribution networks. It is also responsible for maintenance and expansion projects of electric infrastructure.

[98] http://www.gob.mx/sener/
[99] http://www.cre.gob.mx/
[100] http://www.cfe.gob.mx/

Legislation

In Mexico there is only a single general law that addresses the use of renewable energy and the financing opportunities for energy transition. The final version of this law was approved and published in the Official Gazette (DOF) on December 24th, 2015.

- **Law for the Use of Renewable Energy and the Financing of the Energy Transition[101]:**

- Regulates the use of renewable energy and clean technology for electricity generation to different ends, for provision of public electricity services, as well as establishing national strategy and instruments for financing the energy transition.

- The use of renewable sources and clean technology is of public benefit (utility) and will be carried within the national strategic framework for energy transition; various definitions concerning the energy sector are set forth; the powers of the Ministry of Energy and the Energy Regulation Commission are specified; it also establishes conditions for the sale of surplus energy to the market and the conditions and contract duration between the energy supplier and the energy producer using renewables.

- Determines that the National Strategy for Energy Transition and Sustainable Energy Use is a mechanism through which the Mexican State will drive policies, programs, actions and projects in order to achieve greater use of renewable energy and clean technologies, while also promoting energy sustainability and reducing dependence on hydrocarbons. The Fund for Energy Transition and Sustainable Use of Energy is created.

[101] http://www.diputados.gob.mx/LeyesBiblio/abro/laerfte/LAERFTE_abro.pdf

Financing Mechanisms

Table 18 shows the main financing mechanisms in Mexico for RE projects.

Table 18 Financial mechanisms for RE in Mexico (Source: OLADE, 2011)

Institution / product	Mechanism Type	Project Phase	Coverage	Interest Rate	Technology
BANOBRAS - Structuring of Projects	Syndicated Credit	Construction and Operation	National	Fixed or Variable	All RE Technology
NAFIN - Sustainable Projects Support Program	Syndicated Credit	Construction In 2014 NAFIN mobilized 210.3 million dollars, generated through concessional loans. All resources were earmarked for mitigation of climate change, and 93% 93% of renewable energy. In 2013 the amount added mobilized 574	National	Lower interest rates than market	RE technology associated with private energy production projects
FTL/BID / CFI	Credit	Construction	International	Dependent on project	Large-scale wind projects, small hydropower projects, solar and biomass projects. Commercial Demonstration of Renewable Energy Technologies
World Bank / CFI	Credit	Studies and Construction	International	Dependent on project	Renewable energy projects promoted by the private sector, for profit.
FONADIN/ BA NOBRAS	Subordinated or convertible credit	Construction and Operation	National	Interbank balance added to a margin determined by a financial institution.	All associated with infrastructure projects or public services with some form of private participation.

In addition there are some international funds and multilateral organizations in Mexico with financial resources for the development and promotion of RE in the region. These include the BID and CAF, which disbursed a total of US$ 288.4 million in 2014 and US$ 20.20 million in 2013, respectively[102].

[102] CEPAL, 2015

Main Obstacles to the Progress of RE Imprementation

Figure 25 shows the obstacles which impede or hinder the progress of projects for the generation of renewable energy in Mexico, using the methodological approach put forth by this study.

BD Renewable resources database
CT Technical training
CI Cost of investment
ED RE development strategy
F Financing
IL Infrastructure and Logistics
RA Regulatory and Administrative
R Regulation
RF Financial Risk
S Social
SC Subsidy and competition with other sources
T Technical

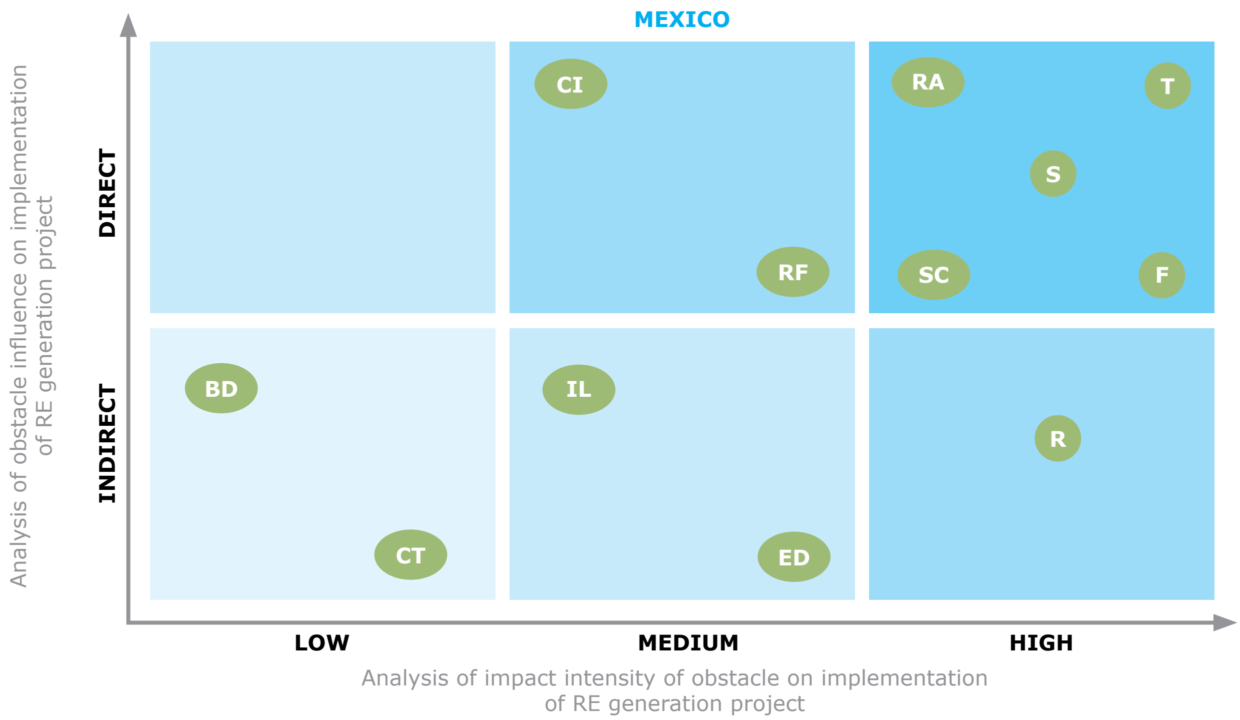

Figure 25 Matrix of obstacles for Mexico (Source: own elaboration)

Of the obstacles classified as direct and high-intensity, regulation and administration are the most prominent, given the various procedures and agencies that need to approve investments in RE. Projects transit, on average, through ten government agencies.

There is, additionally, a general lack of knowledge of the correct sequence to be followed for submitting projects to public agencies: the information available is insufficient, and the concentration of agencies in Mexico City increases investment costs due to the constant and necessary journeys to be made. Lastly, there is an extensive processing time and deadlines can take an average of 410 to 530 days[103].

[103] Molina, 2014

Furthermore, Mexico is rich in fossil resources and subsidizes the use of conventional energy resources. These two factors have an impact on the economic viability of RE projects and, consequently, their financing.

In the technical aspect, apart from intermittence, there are difficulties in connecting to the grid. Current legislation, despite being very specific and exclusively addressing renewables, is not considered transparent and clear in several aspects. In addition, the main obstacle for the development of renewable energy in Mexico has its root in legislation, given that the very way it was developed forces the CFE, which controls most of the generation in the country and is state-controlled, to invest in increasing generating capacity only in economically profitable and low-cost sources. Current legislation prevents CFE from investing in renewables by law, and is thus required to invest in cheaper sources. Consequently, the possibility of government investment in the generation of renewable energy is remote, as these sources have higher costs in the country[104].

Some communities have organized resistance to the progress of RE, mostly those protected by legislation or those near tourist areas, and as such were considered high-intensity obstacles. The high cost of investment in RE projects should also be noted. As there is already a history of projects related to RE in Mexico and a mapping of regions prone to this type of power generation, 'technical training' and 'database of renewable resources' were considered low-intensity obstacles.

Despite there being a specific SENER plan for the development of renewables, there are still challenges facing its implementation. The creation of the National Renewable Energy Inventory (INERE) was an important step in overcoming these challenges, and which facilitated the dissemination of knowledge of proven potentials for these energy sources.

There is still a lack of trained human resources with technical knowledge for both power analysis and system installation and maintenance. Lack of resources is also a factor compromising the development of national technology.

It is important to emphasize that of the countries analyzed in this study, Mexico is the only one with robust infrastructure for the generation of electricity from biogas, as well as studies of its related potentials. However, the points of biogas generation (solid urban waste and waste water) are, normally municipal property, which makes managing the process difficult. Added to this is the fact that the specific regulatory standards[105] for this purpose do not address the issue of methane recovery.

[104] Lokey (2008) and Alemán-Nava et al (2014)
[105] NOM-083-SEMARNAT-2003 and General Law for the Prevention and Integral Management of Waste

PERU:

In 2014, iron ore was the biggest export, reaching 27.45%, followed by precious stones and metals, with 15.81%. The third largest export was oil and fuel oils with 12.36%. These three products jointly represent 55.62% of Peruvian exports[106]. For this same year, GDP reached US$ 202.59 billion[107], up 4.15% on the previous year. Its composition is shown in Figure 26[108].

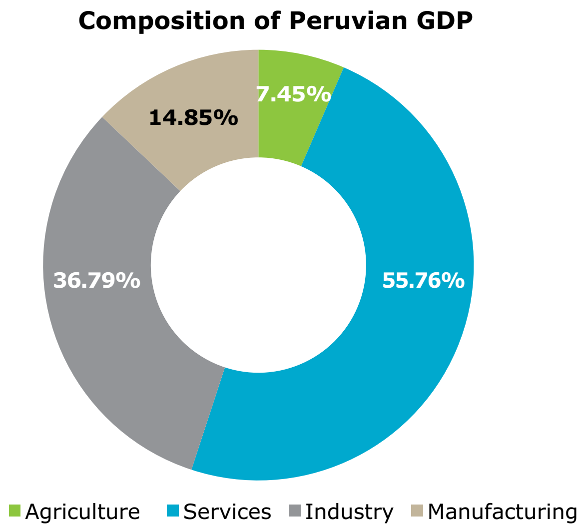

Figure 26 Composition of Peruvian GDP in 2014 (Source: Own elaboration based on Global Edge data, 2016)

Energy Context

Peru has one of the largest private reserves of natural gas in South America. Natural gas therefore predominates in the production of primary energy. Figure 27 shows the country's primary energy production profile.

In 2014, 25.87 Mtoe of primary energy was produced, while domestic consumption was 29.85 Mtoe. The difference is made up for with oil and mineral coal imports. Domestic oil production was 3.50 Mtoes, which supplied 30.51% of internal demand. Coal imports (0.37 Mtoe) supplied 47.30% of internal demand (0.78 Mtoe).

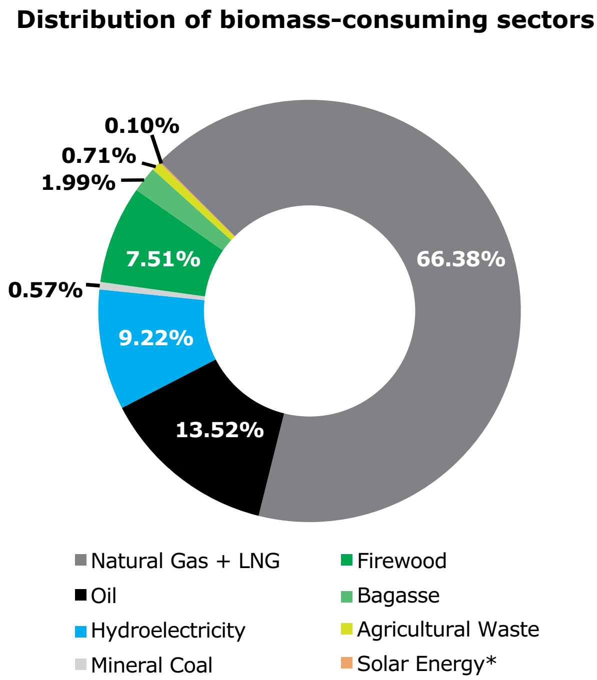

Figure 27 Distribution of Primary Energy Production in 2014 (Source: Ministry of Energy and Mines[109], 2015)

[106] http://globaledge.msu.edu/countries/peru/tradestats
[107] http://databank.worldbank.org/data/reports.aspx?source=2&country=&series=SP.POP.TOTL&period= http://data.worldbank.org/data-catalog/GDP-ranking-table
[108] http://globaledge.msu.edu/countries/peru/economy
[109] https://www.osinergmin.gob.pe/seccion/centro_documental/hidrocarburos/Publicaciones/BALANCE%20DE%20ENERG%C3%8DA%20EN%20EL%20PERU%202014.pdf

Figure 28 shows the relationship between primary energy production and how much of this energy, by source, is consumed internally in the country. Firewood is used in homes to obtain heat, although a portion is also used in coal mines. In 2014, for example, this amount corresponded to 5.19% of the total volume produced.

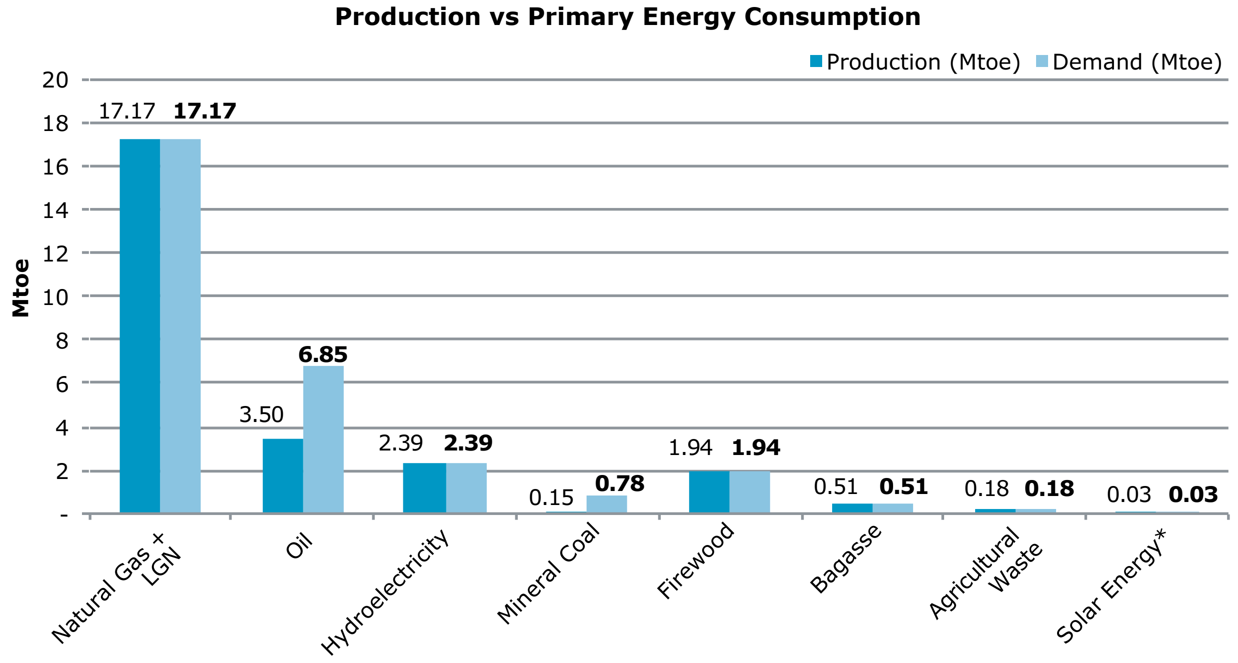

Figure 28 Primary Energy produced versus Internal Consumption of Primary Energy (Source: Own elaboration based on data from the Ministry of Energy and Mines)

Table 19 shows how primary energy consumption produced in the country is distributed. Most of the domestic oil supply is destined for refineries, to be used for obtaining secondary energy and non-energy derivatives.

Natural gas is processed in its entirety in plants within the country, a portion of which goes towards the production of electricity (through thermoelectric plants) and also to the production of liquefied natural gas (LNG), which goes to the foreign market.

Distribution of Primary Energy (Mtoe)		
Application	**Value**	**%**
Refinery	6.84	25.21%
Gas Plants	17.15	63.21%
Power Stations	3.04	11.20%
Hydro Power	2.38	8.78%
Bagasse	0.42	1.53%
Mineral Coal	0.20	0.74%
Solar	0.02	0.06%
Wind	0.02	0.08%
Coke	-	-
Mineral Coal	-	-
Mining	0.10	
Firewood	0.10	0.37%
Total Renewable	**2.94**	**10.83%**
Total Fossil	**24.20**	**89.17%**
General Total	**27.14**	

Table 19 Distribution of Primary Energy Application (Source: National Energy Balance, 2015)

According to the analysis of the data presented in Tables 20 and 21, around 48.66% of the electricity produced in Peru is obtained by means of thermoelectric generation, while 97.90% is obtained by thermals driven by natural gas. Hydropower accounted for 50.25% of national electricity production for 2014. Solar and wind energy combined reached only 1.05% for that year.

Figure 29 shows the IIE indicator, which relates energy consumption to the country's GDP and also the evolution of final energy consumption per capita. IIE shows a downward trend in Peru, as

Table 20 Electricity Generation in 2014 by type (Source: COES, 2015)

Electric Power Production		
Type	**Energy Produced (GWh)**	**Share (%)**
Hydroelectric	21,002.91	50.25%
Thermoelectric	20,337.37	48.66%
Solar	199.30	0.48%
Wind	256.31	0.61%
Total	**41,795.89**	

Table 21 Electricity generation via thermoelectric plants (Source: COES, 2015)

Thermoelectric Generation		
Fuel Type	**Energy (GWh)**	**Share (%)**
Liquids	87.7	0.43%
Natural Gas	19910	97.90%
Mineral Coal	163.2	0.80%
Cane Bagasse	146.1	0.72%
Biogas	30.3	0.15%

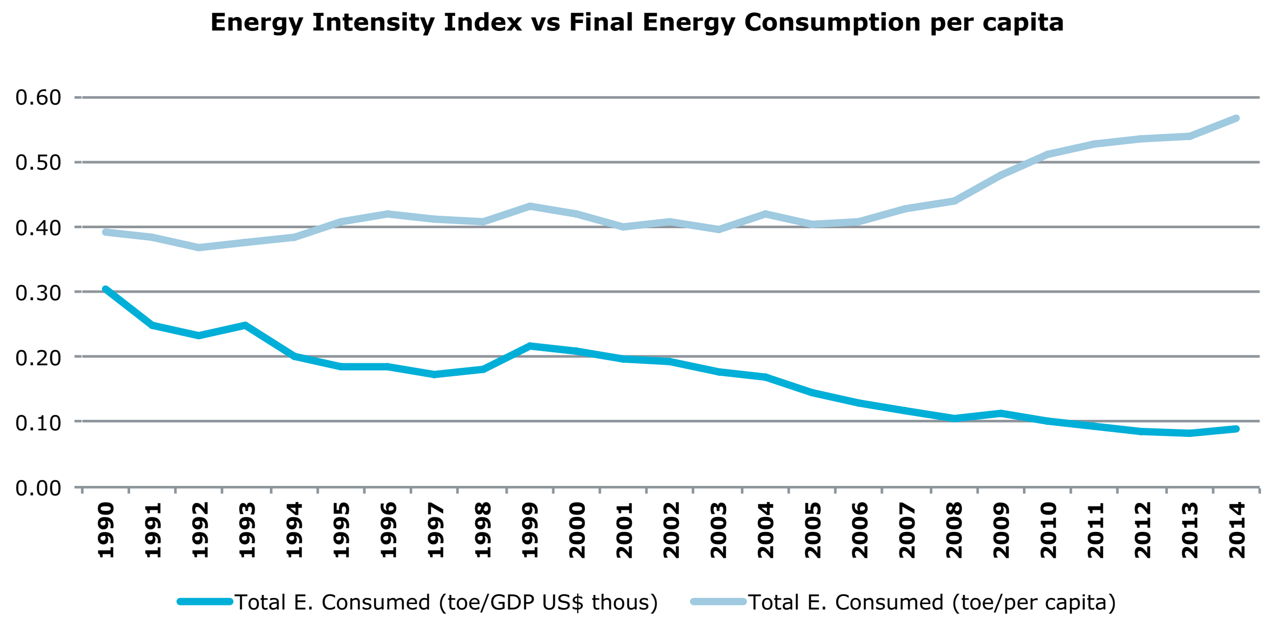

Figure 29 Comparison of energy indicators in Peru (Sources: World Bank, 2016, IEA, 2016)

a result of the implementation of energy efficiency processes as a whole. The point at which the fall occurs, continuing to drop fairly consistently, is also the moment the country approves Law N 27,345[110] - Law of Promotion of the Efficient Use of Energy, showing the country's efforts to apply and promote the concept of energy efficiency.

Per capita energy consumption shows growth, indicating that the country, during the period analyzed, provided greater access to energy at the same time as the purchasing power of the population improved, consuming forms of energy, both electric and for transportation, on a larger scale.

The main source of energy in Peru is from hydroelectric power plants, mainly those greater than 30 MW. Due to its relative abundance of water resources and one of the largest reserves of natural gas in Latin America, it has not sought to diversify its energy matrix. Consequently, there is low exploitation of these sources in the production of local energy. There are five solar plants in the country, for which 2014 production was 199.3 GWh, equivalent to only 5% of the total electricity produced in the country[111].

There are three wind power plants in Peru, and a total of 73 wind turbines installed, which in 2014 produced 25,630 GWh, the equivalent to only 0.61% of the total produced[112]. Figure 30 shows the percentage distribution of the share of renewable sources, including hydropower, in the production of energy for 2014.

The development potential for RE in Peru is concentrated in wind, solar, and photovoltaic sources. The estimated wind potential in Peru was 22,000MW and 60 concessions were approved for studies aimed at the development of wind farms, a good number of which are located on the Peruvian coast[114].

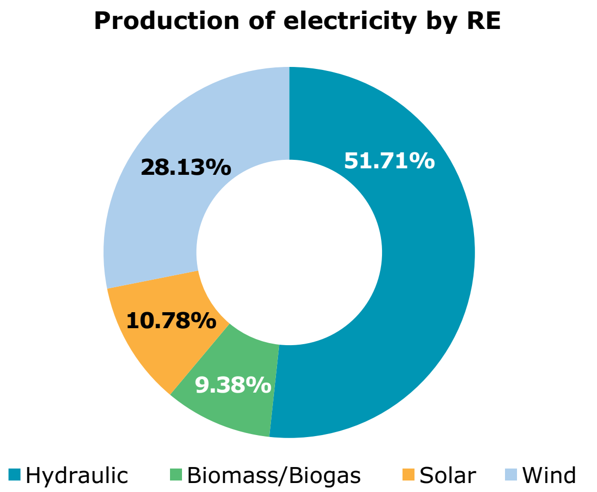

Figure 30 Distribution, by source, of electricity production through renewables (Source: Ministry of Energy and Mines 2015[113])

Table 22 shows the estimated potential for each type of renewable energy and also how much of this energy is currently installed.

Table 22 Potential of Renewable Energies (Source: Fullbright Norton Rose, 2016)

Resource / Source	Assessed Potential (MW)	Installed Capacity (MW)
Hydroelectric	70,000	3,118
Wind	22,000	142
Solar	Not assessed	80
Biomass	450	27.4
Geothermal	3,000	-

110 http://www.minem.gob.pe/minem/archivos/file/Electricidad/legislacion/002subsectorelectricidad/Ley27345.PDF
111 e 112 COES, 2016
113 http://www.stilarenergy.com/magazine/archivos_magazine/Evolucion_indicadores_EE_1995_2015.pdf
114 http://library.fes.de/pdf-files/bueros/peru/07881.pdf

Agents of the Energy Sector

The following are the main bodies and agents of the energy sector in Peru (the list is not exhaustive):

- **Ministry of Energy and Mines – Minem[115]:** Main body of the energy and mining sector and an integral part of the executive branch. Responsible for policies of national scope related to the sustainable development of the sector, ensuring harmony with national policy. Among its main attributions are the elaboration of the country's energy mining inventory; to formulate and approve Reference Plans, Sector Development Plans, and Strategic Sector Plans, within its competence; to be the competent environmental authority with regards to energy mining activities, among others.

- **Supervisory Body for Investments in Energy and Mines - OSINERGMIN[116]:** Created by Law 26,734 in 1996 as a public institution in charge of regulating and supervising companies belonging to the electric, hydrocarbon and mining sector, ensuring compliance with legal provisions within their activities. Responsible for establishing tariffs and compensation; Oversees compliance with regulations established by MINEM. It has functional, technical, administrative, economic and financial autonomy. It also has the autonomy to complement regulation, if necessary.

- **Committee for Economic Operation of the System – COES[117]:** private entity, non-profit and subject to public law. Formed by all SEIN agents (producers, transmitters, distributors and free users). Its decisions must be followed by all agents. Responsible for the operation and coordination of the SEIN always aiming for minimum cost, security of the system and best use of energy resources. It is also responsible for the planning and development of energy transmission activity; manages the short-term market.

Legislation

The following are the main legal norms and frameworks of the energy sector in Peru (the list is not exhaustive):

- **Legislative Decree 1,002 of 2008, updated on September 13, 2010[118]:** promotes Investment for Electricity Generation with the Use of Renewable Energies, with the main objective of guaranteeing an increase of the electric power supply through renewable sources, thus meeting the country's growing demand.

- **Supreme Decree N 012-2011 EM[119]:** also puts forth definitions within the scope of RE, establishing requisites and procedures for the elaboration of the Energy Auction, including RE. It also presents the mechanisms to be used in the composition of electricity tariffs coming from RE, among other provisions.

[115] http://www.minem.gob.pe/minem/archivos/file/Electricidad/legislacion/002subsectorelectricidad/Ley27345.PDF
[116] e [117] COES, 2016
[118] http://www.stilarenergy.com/magazine/archivos_magazine/Evolucion_indicadores_EE_1995_2015.pdf
[119] http://library.fes.de/pdf-files/bueros/peru/07881.pdf

- **Other Decrees which address Renewable Energies[120]:**

- **Supreme Decree 031-2012 EM:** makes amendments to Supreme Decrees N 012-2011-EM and N 009-93-EM relative to the regulatory framework of the RER hydraulic energy generation concessions.

- **Supreme Decree N 020-2013-EM:** approves the regulation for the promotion of investments from isolated areas to the network.

- **Emergency Decree 019-2008:** declares that it is of national interest to implement and use the "Passive system of indirect solar energy capture" alternative heating technology called the Trombe wall.

- **Supreme Decree N056-2009-EM:** adjusts the competence of State Governments for the authorization of definitive generation concessions through the RERs.

- **Law N 26848:** law on Geothermal Resources. Establishes parameters and rules for operation.

- **Supreme Decree N019-2010-EM:** approves the new regulation of Law No. 26,848 on Geothermal Resources.

- **Supreme Decree N 024-2013-EM:** modifies the Regulation of the Law of Promotion of Investments for Generation of Electricity through Renewable Energies and Regulation of the Law of Electric Concessions.

Financing Mechanisms

The RE market in Peru is growing and in demand of financial resources for its development. Some national institutions allocate funds to finance projects in different phases. There are also international institutions that operate in the country financing projects with both public and private sectors.

Table 23 shows national financing mechanisms.

In addition, there are multilateral and international organizations present in Peru that assist in the financing of RE projects. Among them are the BID and CAF, which allocated US$ 883 million and US$ 471 million to these ends in 2014, respectively[121].

Table 23 National financial mechanisms in Peru (Source: OLADE, 2011)

Organization	Program Name	Public/Private Mechanism	Scope	Project Phase	Interest Rate
COFIDE	Bio-business	Public	National	All phases	Variable
INTERBANK	Project Finance	Private	National	Construction and Operation	Fixed
BCP	Capital Markets Medium Term Loan	Private	National	Construction and Operation	Variable

[120] http://www.minem.gob.pe/minem/archivos/file/Electricidad/legislacion/002subsectorelectricidad/Ley27345.PDF
[121] CEPAL, 2015

Main Obstacles to the Progress of RE Implementation

Figure 31 shows the obstacles which impede or hinder the progress of projects for energy generation from renewable sources in Peru, according to the methodological approach proposed in this study.

BD Renewable resources database
CT Technical training
CI Cost of investment
ED RE development strategy
F Financing
IL Infrastructure and Logistics
RA Regulatory and Administrative
R Regulation
RF Financial Risk
S Social
SC Subsidy and competition with other sources
T Technical

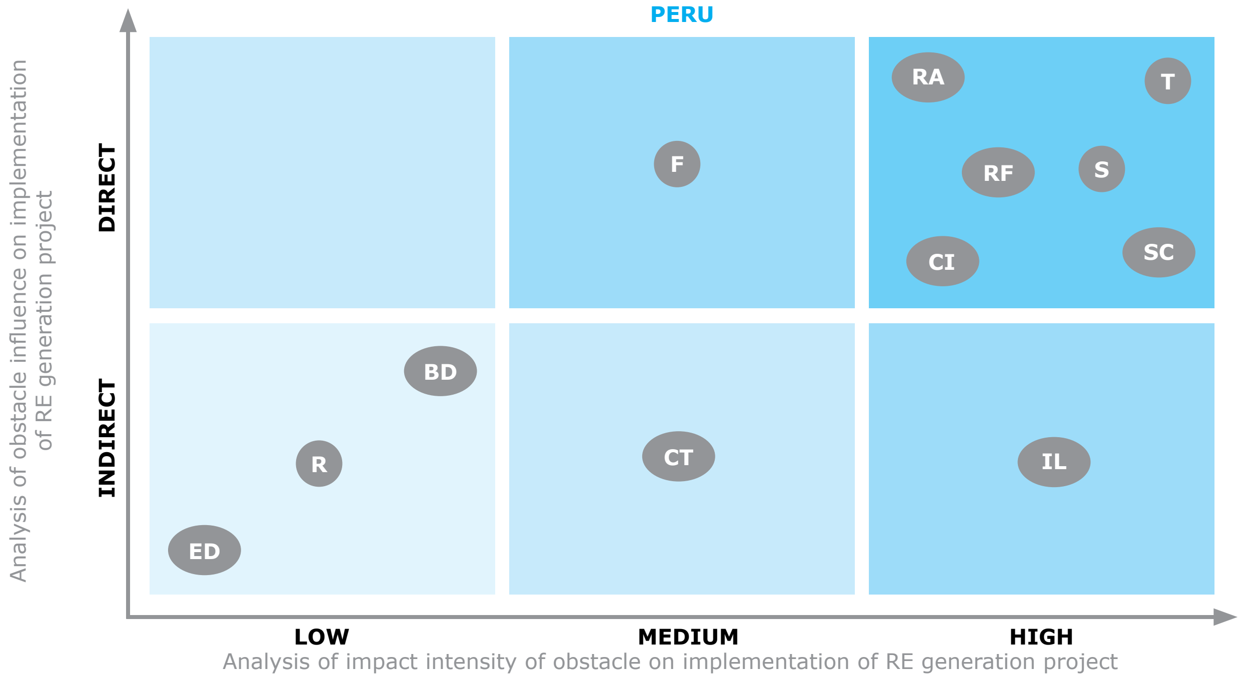

Figure 31 Matrix of obstacles in Peru (Source: own elaboration)

In Peru, there is a high concentration of high-intensity direct obstacles, due to the bureaucracy involved in obtaining licenses and environmental and installation permits for renewable energy projects.

As with the other countries in this study, competition with fossil resources is high, and because there are large concentrations of natural gas in the country, the economic viability of natural gas projects tends to be higher. Investment costs (acquisition of equipment and parts) are also high. There is also a lack of technical standards for connecting RE to the grid. The absence of infrastructure affects the connection of energy to the grid. Renewables with the greatest potential lie in the Amazon and Andean Region. Both regions have a lack of infrastructure, both in terms of connection to the grid and access to the site[122].

However, Peru's regulations for renewables are comprehensive, objective and transparent, with only a few technical specifications missing. The same occurs with mapping of information of the areas and their respective powers, as well as the RE development strategy.

One of the main obstacles to the definitive entry of renewable energy into the Peruvian energy market pertains to the low energy prices practiced in the country, as well as the need for greater investment in the training of human resources for the development of a national technical staff capable of managing all the project stages of the installation of a renewable facility.

[122] Norton, 2016

Comparative Analysis

The purpose of this chapter is to present the context of RE in the industrial sectors of the countries analyzed and the obstacles to its progress on a large scale. Different perspectives were applied in the comparative analysis of the data: regarding the presence of RE in the country's energy matrix, applied energy tariffs, and obstacles to the progress of RE.

Another perspective of analysis is the share of renewable energy sources in the economy, including large hydroelectric plants, in the countries' energy matrix. Two aspects were taken into account: (i) the share of renewable sources in the total primary energy available (Figure 32); and (ii) the share of renewable energy in the production of electricity (Figure 33).

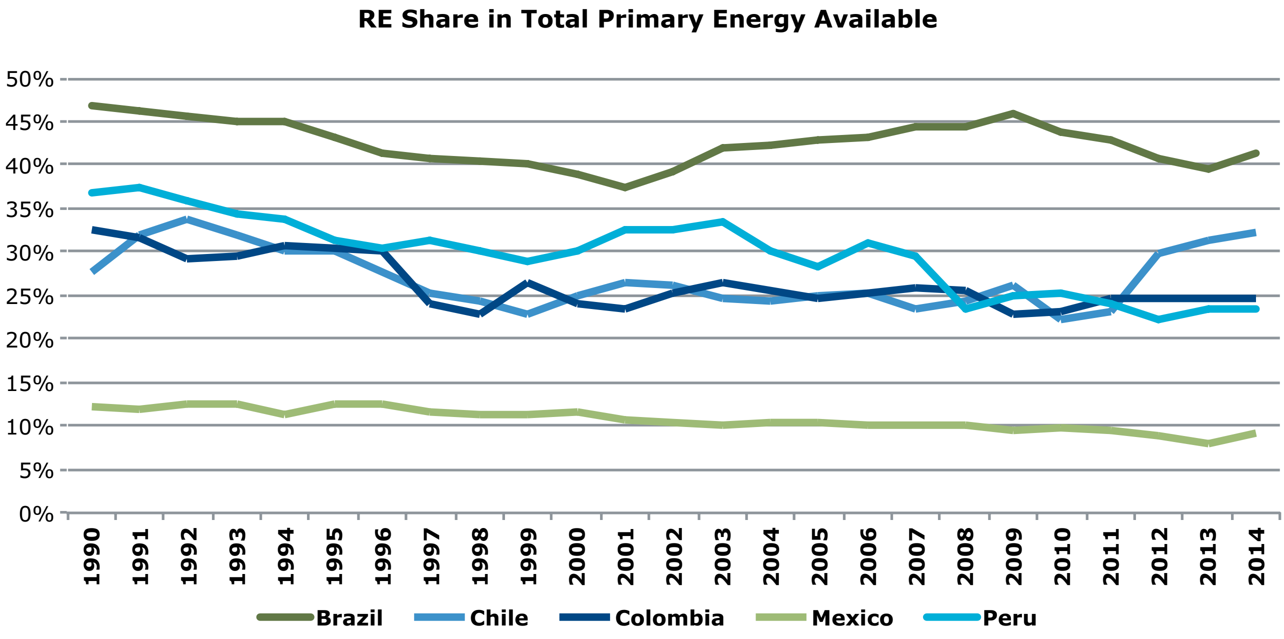

Figure 32 Comparative analysis of percentage share of renewable energy in total primary energy available (Source: own elaboration with EIA data, 2016)

Figure 32 shows that, of the countries analyzed, Brazil has the largest share of renewable energy sources in total primary energy available. Brazil reached figures close to 50% at peak times, as in the years 1990 and 2009. These variations in Brazil's data are also explained by the variation of the country's hydrological regime, which directly affects the levels of the reservoirs of the hydroelectric plants. The same occurs with the other countries analyzed. Mexico is the country with the lowest share of RE in the production of electricity.

It is worth noticing that Brazil has abundant water resources. However, due to its vast territory it suffers losses in the distribution of energy as the greater hydroelectric potential is located far major centers of consumption.

The industrial sectors of the countries studied have an average consumption of 28.6% of the total energy consumed, with electricity being the most consumed form. Figure 33 shows RE share in the electricity production of the countries analyzed.

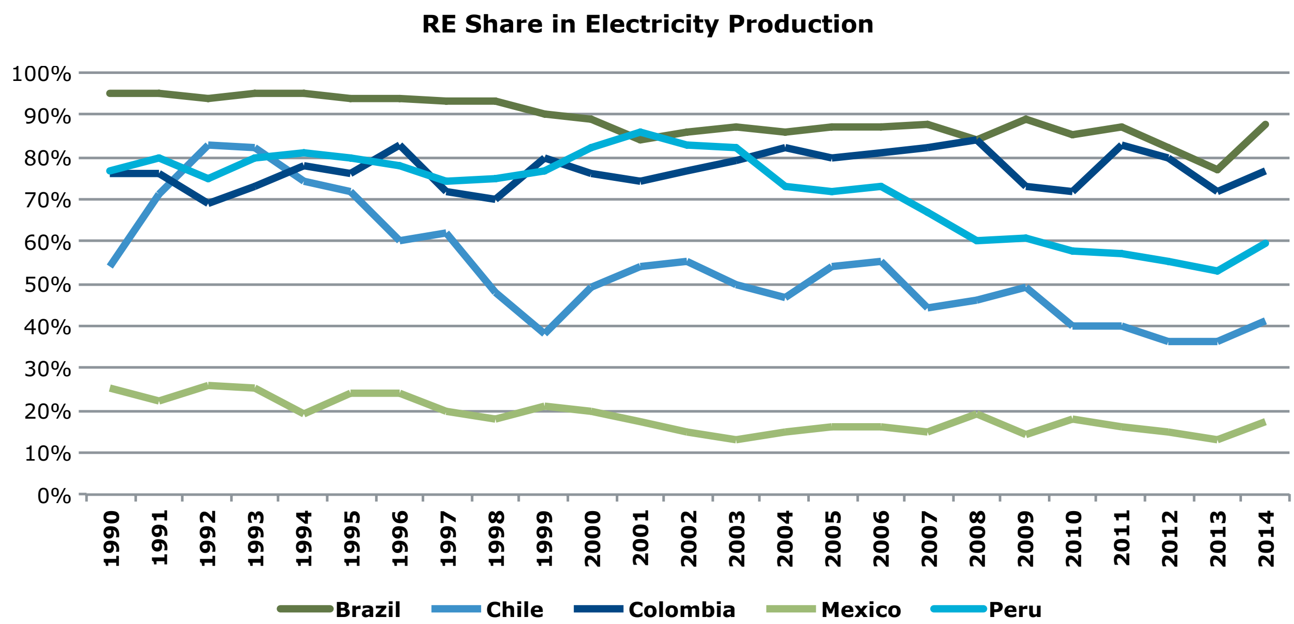

Figure 33 Percentage share of RE in electricity production of countries (Source: own elaboration, with IEA data, 2016)

As with other energy sources, RE is subject to variations in climate, soil, geographic aspects and the country's economic situation. The latter, for example, can be seen with biomass, which is commonly linked to crop residues. In times of economic crisis there is less planting and therefore less waste to be converted into energy. In the analyzed countries, the predominant source for the production of RE is water, a source subject to the hydrological regime.

There is evidence that efforts are being made in all the countries analyzed to increase the share of renewables in their energy matrix. In this respect, large hydroelectric plants were not the main focus of interest. In general, legislation, government programs, and financial mechanisms are under analysis or have already been created to encourage the generation of electricity through sources such as solar, wind, geothermal, small hydropower plants (up to 30MW) and biomass. There are also indications that increasing the share of renewable energy will not only happen in the industrial sector. The countries are seeking to diversify their matrices, encouraging alternative sources through small, medium and large producers to supply the grid.

From the perspective of energy use by the industrial sector, it is worth highlighting a study carried out by the International Energy Agency. This study identified national energy production through renewable sources and its specific consumption by the industrial sector. From this analysis it was possible to stratify data for biomass and biofuels, which are presented in Table 24. Figure 34 shows the percentage distribution of how much of this type of renewable energy was consumed by the industry.

Table 24 Production of biomass and biofuel in ktoe (Source: IEA, 2016)

Year	Brazil	Chile	Colombia	Mexico	Peru
2000	45,747	4,720	3,430	8,939	2,234
2001	48,015	4,716	3,276	8,632	2,260
2002	52,209	4,781	3,445	8,507	2,264
2003	58,382	4,539	3,683	8,546	2,244
2004	61,720	4,773	3,208	8,601	2,331
2005	64,187	4,829	3,244	8,883	2,270
2006	68,417	4,954	3,510	8,675	2,363
2007	74,777	5,192	3,485	8,689	2,561
2008	80,586	5,324	3,536	8,536	1,878
2009	76,889	5,512	3,523	7,978	2,465
2010	83,344	4,902	3,781	8,116	3,042
2011	78,405	5,911	3,513	7,976	2,947
2012	79,629	9,383	3,677	8,362	2,681
2013	82,710	10,247	3,692	8,953	2,616
2014	84,315	7,380	3,717	8,738	2,638

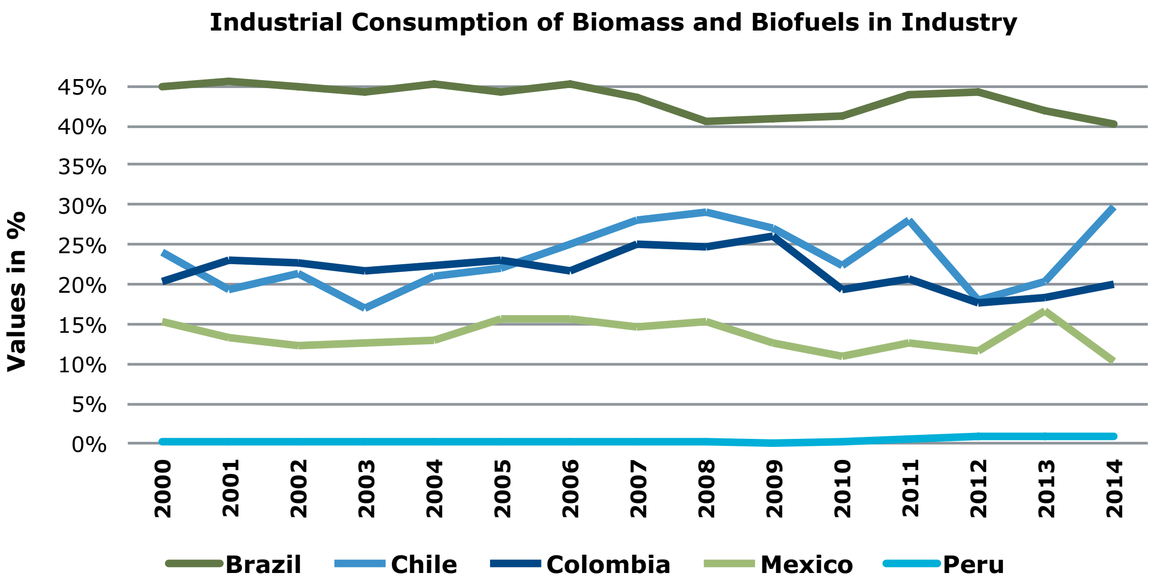

Figure 34 Percentage distribution of biomass and biofuels consumption (Source: EIA, 2016)

Additionally, for Mexico it was possible to identify how much wind and/or solar power was destined for industry, as shown in Table 25.

Table 25 Total production and industrial consumption of renewable energy - wind, solar in ktoe in Mexico (Source: IEA, 2016)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Prod.	45.7	54.4	60.5	69.0	76.6	86.9	100.2	132.1	102.8	149.3	225.2	280.5	476.6	541.8	764.2
Industrial Cons.	2.0	2.4	2.7	3.1	3.5	3.9	4.4	5.1	3.6	4.4	5.2	6.3	8.0	9.1	9.9

Energy tariffs

Table 26 shows average figures in 2014 for electricity in the countries studied, in some sectors.

Table 26 Average energy prices in countries in Latin America (Source: Climate Scope, 2015)

Comparative Figures Energy Prices in 2014 (US $ / MWh)						
Type / Country	**Chile**[123]	**Colombia**[124]	**Mexico**[125]	**Peru**[126]	**Brazil**[127]	**World**
Residential	176.00	161.07	90.11	150.00	130.08	119.86
Commercial	108.00	154.78	228.26	117.00	124.87	162.95
Industrial	135,00	121,74	121,51	78,00	106,18	123,83

It can be seen that Chile has the highest energy price of the 5 countries, as well as being the only price above the global average. Colombia and Mexico's figures are closer to the world average, and respectively have the second and third-highest energy prices. Brazil's average for the industrial sector is below the world average. Finally, it is estimated that the lowest cost is in Peru, with a figure close to half that of the world average.

While low energy tariffs for the industrial sector are important both for maintaining and accelerating the growth of the productive sector, they also end up hampering the entry of energy produced through non-conventional renewable sources.

[123] www.climatescope.org/en/country/chile/#/details
[124] www.climatescope.org/en/country/colombia/#/details
[125] www.climatescope.org/en/country/méxico/#/details
[126] www.climatescope.org/en/country/peru/#/details
[127] www.climatescope.org/en/country/brazil/#/details

Obstacles to the Progress of RE

It can be said, in theory, that there are common obstacles to the progress of RE, especially in developing countries. As a contribution to this debate, this study sought to compare, through its own methodological approach, the obstacles that potentially prevent or hinder the large-scale development of RE projects in the countries analyzed.

Generally speaking, the obstacles encountered for the expansion of renewable energies in the energy matrix of the countries concerned are very similar, in some cases changing the intensity with which they occur. Figure 35 presents a comparison between the obstacles identified and indicates their intensity for each of the countries and whether the influence on the decision to implement an RE project is direct or indirect:

BD Renewable resources database
CT Technical training
CI Cost of investment
ED RE development strategy
F Financing
IL Infrastructure and Logistics
RA Regulatory and Administrative
R Regulation
RF Financial Risk
S Social
SC Subsidy and competition with other sources
T Technical

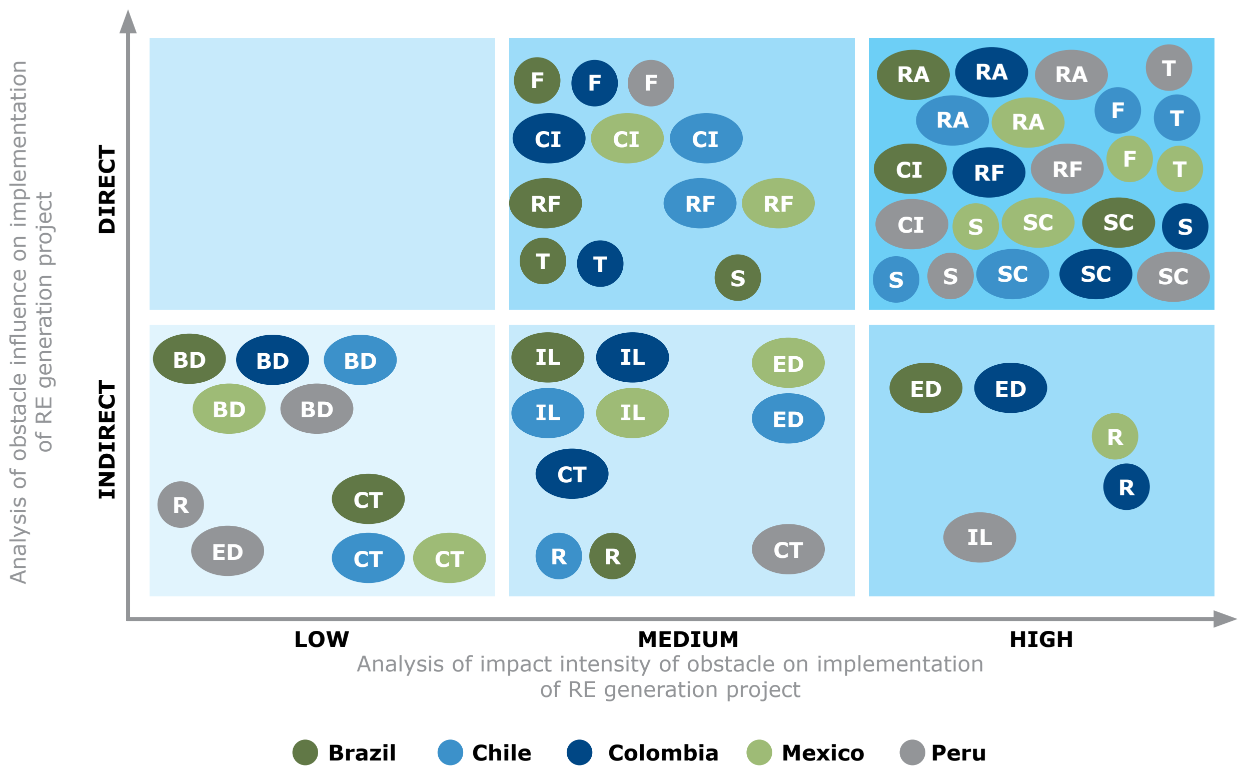

Figure 35 Obstacle matrix for comparative analysis Brazil, Colombia, Chile, Mexico and Peru (Source: own elaboration)

The comparative analysis of the main obstacles observed in the analyzed countries indicates:

- "Regulatory and administrative barriers" are present in all the countries analyzed, and are a direct influence with a high degree of intensity. The bureaucracy to which RE projects must be submitted so they may obtain their due licenses and authorizations should be noted. Too often, the exact processes required for RE projects to be efficiently approved by government bodies and agencies are not clear.

- Obstacles related to "subsidies and competition with other energy sources" also constitute direct and high-intensity barriers in all countries. Subsidies, especially for conventional energy sources, make it difficult to introduce RE generation projects in all the countries analyzed. They are quite present in Brazil and Chile, which have a large portion of their energy supplied by large hydroelectric plants, which in Brazil are also considered renewable. Even indirect competition with large-scale hydroelectric plants makes it difficult for other renewable sources to enter.

- The "Social" obstacle is also significant in all the countries analyzed, as it interferes with or delays the implementation of RE projects through resistance from local communities. In Colombia, Chile, Mexico, and Peru this obstacle's influence is high due to a combination of protected communities and protected areas which coincide with areas of potential for renewables. Along these lines Chile also has the issue of competition for the use of the areas, as renewable potential is sometimes located in mining areas, while in Colombia and Mexico renewable potential is also in tourist areas, which creates resistance from local communities, who fear that the installations may be an 'eyesore' and thus affect tourist activity.

- The "Financing" obstacle also interferes directly in all countries analyzed, but with different degrees of intensity. All countries receive international resources for the development of RE projects, but are subject to a number of standards for approval. In Brazil, for example, there are already significant national mechanisms that encourage the advancement of RE in the country, therefore being considered an obstacle with an influence of medium intensity. The same is true of Colombia and Peru.

- Among the indirect high-intensity obstacles is the "Renewables Development Strategy" that is present in Brazil and Colombia. Although a strategy for development of renewables has been drawn up in these countries, and there are government plans to go ahead with them, they have yet to be fully implemented.

- As for the "Regulation" obstacle, Mexico and Colombia share a certain similarity, as they have a general law on renewables with definitions and requirements, as well as an incentive plan. However, these do not cover all necessary aspects, causing doubts for entrepreneurs and financiers. Brazil and Chile also share similarities with regards to the "Regulation" obstacle, since there are a relative number of decrees and norms, but these are scattered and do not cover all forms of renewables. In the case of Chile, there are missing parameters required for clarification in relation to grid connection.

- Peru stands out in the "Regulation" and "Renewables Development Strategy" categories. The former is considered to be the most complete and objective, while the latter presents clear points on which path the country will take to include renewables in its matrix.

Conclusion

The industrial sector uses renewable energy directly and indirectly. The indirect form is through the consumption of electricity via the grid, that is, when it is also fed with electricity generated from renewable sources. When this form of consumption occurs, determining of how much of the energy consumed by the industry has come from renewable resources would require a complex calculation which at the same time would have no guarantee of being accurate.

The direct form occurs when the industry uses the renewable resource to generate its own energy, be it in the form of electricity or heat, which are the most common. In this case, most of the renewable resource used is biomass, which is often a waste product specific to the industrial process itself, as with the sugar and alcohol, and paper and pulp industries.

Energy generated from renewable sources is intermittent in its production, which is a disadvantage compared to more traditional sources. Thus, one of the ways to encourage its use by the industrial sector would be to use it as a complementary form of energy supply, especially for companies that are located in areas further away from the grid. An example is the mining industry in Chile, which owns the majority of the extraction and processing units located in the Atacama region. As in this region the industry has practically no access to the grid, it generates thermoelectric energy for its own consumption (energy with higher GHG emissions than renewable energy). In this case, renewables such as solar and wind could be complementary sources of energy, and as their supply is expanded and the technology fully mastered, thermoelectric generation would become the complementary source.

Another relevant aspect is the accumulation of knowledge resulting from the large-scale adoption of RE projects, generating a virtuous cycle: as more projects are completed, more information is recorded for the analysis of investments and risks and the greater the qualified technical staff for this type of project. It is also important to keep information on energy potentials always up to date, which would help the progress of this agenda in all the countries analyzed.

In addition, it is essential to reduce the administrative difficulties and bureaucracy involved in RE generation projects in all the countries analyzed. It is important to emphasize that reducing these difficulties does not mean reducing socio-environmental requirements, but making the process of obtaining licenses and approvals as efficient as possible, reducing transaction costs while respecting those social and environmental requirements.

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